Natural Hazard Risk and Vulnerability Assessment and Mitigation Plan for The Territory of American Samoa, 2003

J. Buika[a], S. Goosby[a], S. Mielbrecht[a], R. Rebold[a], U. Glick[a], G. James[a], A. Chatman[a], Dr. M. Hamnett[b], C. Anderson[b], E. Yamashita[b], T. F. Vaiagae, Ph.D.[c], and E. Stevens[c]

[a] Pacific Disaster Center, 590 Lipoa Parkway, Suite 259, Kihei, HI 96753, USA (jbuika@pdc.org),
[b] Social Science Research Institute, College of Social Science, 2424 Maile Way, Ste. 719, Honolulu, HI 96822, [c] Territorial Emergency Management Coordinating Office, Office of the Governor, P. O. Box 997755, Pago Pago, American Samoa 96799

Abstract – Partnering with the University of Hawaii, as well as government and industry decision makers, The Pacific Disaster Center, Hawaii, completed a Natural Hazards Risk and Vulnerability Assessment for the Territory of American Samoa. For the first time, remote sensing data was incorporated into a Geographic Information System (GIS) to understand vulnerability of critical facilities to six dominant natural hazard threats. Using this risk assessment, the American Samoa Hazard Mitigation Council has been able to identity and prioritize mitigation actions for critical facilities as part of an *American Samoa Natural Hazards Mitigation Plan*. The success of the risk and vulnerability assessment and mitigation plan is discussed in terms of resources, advocacy, education and a recent disaster event.

Keywords: Natural Hazards, Mitigation, Planning, Risk and Vulnerability Assessment, GIS, Remote Sensing, Earthquakes Flood, Landslide, Tsunami, Tropical Storms, American Samoa

1. INTRODUCTION

Working with the American Samoa Government, the Pacific Disaster Center, Maui, Hawaii, facilitated the development of the 2003 *American Samoa Natural Hazard Mitigation Plan*. During Phase I of this effort, the Pacific Disaster Center and University of Hawaii project team (Project Team), in collaboration with American Samoa Government representatives, developed a comprehensive Natural Hazard Risk and Vulnerability Assessment to gain an understanding of the risks of natural hazards to the people of American Samoa. The Project Team developed the American Samoa Mitigation Plan as Phase II of the project. The planning process required the active participation of the American Samoa Government to identify, assess, and select mitigation measures and to prioritize mitigation projects vulnerable critical facilities in order to reduce the risk of future disaster impacts.

Accomplishments of the planning project include Hazard Mitigation Council leadership, American Samoa Government agency support and commitment, public participation, hazard and loss estimation research, GIS mapping of critical facilities and hazards, and analysis of mitigation issues through the focus group planning process.

This effort will culminate in increased build mitigation-planning capacity in American Samoa through a collaborative effort involving the American Samoa Hazard Mitigation Council, staff from the Territorial Emergency Management Coordinating Office, and other American Samoa Government agencies. Funding for the project was provided through the American Samoa Government, supported by a Federal Emergency Management Agency (FEMA) Pre-disaster Mitigation Planning Grant. The Pacific Disaster Center, University of Hawaii, and American Samoa Government contributed significant in-kind labor matches.

2. RISK AND VULNERABILITY ASSESSMENT METHODOLOGY

The Project Team examined the vulnerability of critical infrastructure and economic assets to natural hazards, including tropical cyclone, earthquake, flood, landslide, tsunami, and drought. The Federal Emergency Management Agency offers detailed guidance documents, which served as the basis for project completion (FEMA 386-1, 386-2, and 386-3), including *Gaining Local Support for the Mitigation Plan, Understanding Your Risks and Vulnerabilities to Natural Hazards, and Developing the Mitigation Plan*, respectively. For the assessment presentation, remotely sensed imagery was combined with other hazard and infrastructure data sets in an ArcView GIS format. The Risk and Vulnerability Assessment provides a compilation of available historical hazard data research in tables and value-added mapping and analysis to American Samoa government officials for comprehensive planning purposes to save lives and reduce property losses in future natural disasters.

3. APPLICATION OF GEOGRAPHIC INFORMATION SYSTEMS AND REMOTE SENSING IN HAZARD ANALYSIS

GIS and remote sensing software and a variety of spatial data were used together to process and present appropriate data sets supporting the risk and vulnerability assessment as the basis for the mitigation plan. A combination of the ESRI GIS software suite of applications together with ENVI/IDL, ERDAS/Imagine, and ER Mapper remote sensing software were used. Common to GIS projects in many Pacific island nations, the Project Team ssues of local datums and spatial alignment often hinder spatial data of American Samoa was a partial exception. The Project Team was able to build on the excellent work already undertaken by American Samoa GIS User Group which included federal agencies as well as the American Samoa Power Authority and Department of Commerce.

Just previous to the onset of the project, NOAA had ortho-rectified two image scenes: a 1-meter panchromatic Ikonos product and a 4-meter multispectral Ikonos product using independently gathered GPS points as ground control. These two 2001 Ikonos scenes became the keystone spatial data sets for all of the data processed on the main island of Tutuila. In addition to their use in the spatial alignment of diverse sets of hazard data, the Ikonos images were used in the manual feature extraction and the manual validation of other data sets. The physical location and configuration of critical facilities were identified and validated in this manner following the development of the list of critical facilities by the American Samoa Hazard Mitigation Council.

For some visualizations of hazard and critical facility data, NOAA 1994 aerial photography of 1-foot to 1-meter resolution was used. These photos had been purchased from NOAA/NOS and then scanned at 800 DPI and rectified against the Ikonos and the Digital Raster Graphics using ERMapper. When these photos were used, their 1994 content was judged for progress/change against the more modern 2001 Ikonos.

These raster data sets were used in conjunction with the USGS 10-meter DEM to visualize land cover and slope and to form a backdrop against which to identify and map areas in American Samoa that are at risk from earthquakes, riverine flooding, landslides, and coastal flooding due to storm surge and tsunamis. In most cases, the hazards are classified into high-, medium-, and low- risk areas. GIS was also used to locate critical facilities, such as hospitals and government buildings, that are in the hazard risk areas to help determine the vulnerability of these structures to a profile of natural hazards. Calculations performed with the GIS software allowed analysts to estimate the cost of replacing any of the critical facility buildings that may be impacted or destroyed in a disaster.

Spatial data of structures deemed to be "critical facilities" was derived from a vector file of building footprints taken from the United States Geological Survey (USGS) Digital Raster Graphics of Tutuila. It was updated for more recent construction and assigned attributes, such as structure name, cost, and contact persons, with inputs from the American Samoa Mitigation Council. In addition, an "all-hazard" composite summary map was developed using GIS, representing the intersection of multiple hazard layers depicting moderate and high risk. Figure 1 is an example of the multi-hazard risk map for the LBJ Hospital critical facility footprint located near the high-hazard flood zone and the high-hazard landslide zone. Areas where these two mapped hazards intersect are indicated in red.

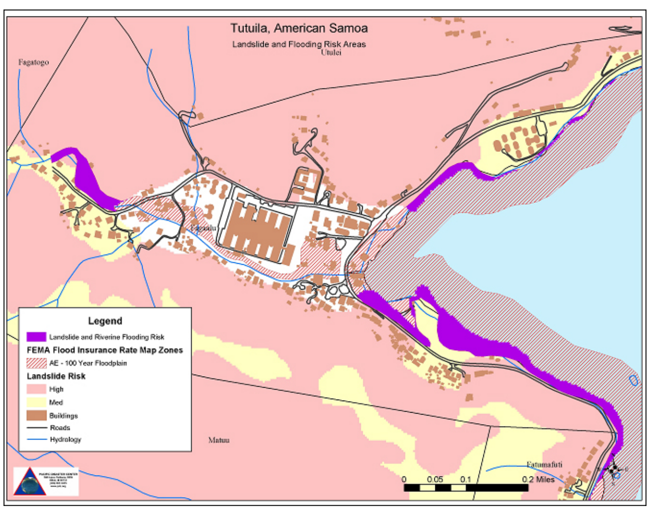

Figure 1: Composite high-hazard map risk map indicating intersection of flood and landslide hazards in red. Large building footprint is the LBJ hospital located in or near the pink-hachure flood-hazard zone and the pink landslide hazard zone.

The following natural hazards were considered in the study; their data status and spatial data use are discussed below:

- **Drought** (an island-wide issue) – Historical information depicting spatial data could not be located for this hazard although it has been an island-wide phenomena. Anecdotal non-spatial data could be found to exist on crop damage and potable water deliveries to remote villages.

- **Earthquake** (geology, soils) - Spatial data that portrayed areas of increased earthquake damage risk were derived from the merging the composite soils type data derived from the United States Department of Agriculture (USDA) report: *Soil Survey of American Samoa,* 1984. Areas of bedrock were rated as lower risk to earthquake ground shaking effects. Figure 2 represents a first-level differentiation of earthquake hazard areas developed by segregating bedrock from all other soil types. Other soil types are shown in red. Figure 3 plots critical facilities versus potential earthquake ground shaking map.

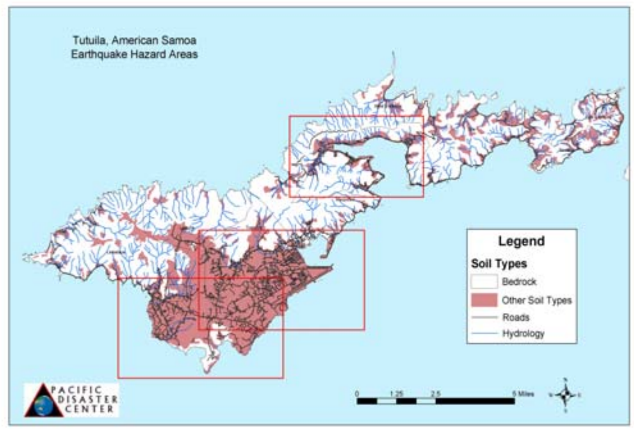

Figure 2: Tutuila, American Samoa earthquake hazard. Higher probable ground shaking is represented in red as a composite of other soil types. Bedrock is shown in white and represents less shaking hazard. Map derived from USDA, *Soil Survey of American Samoa,* 1984.

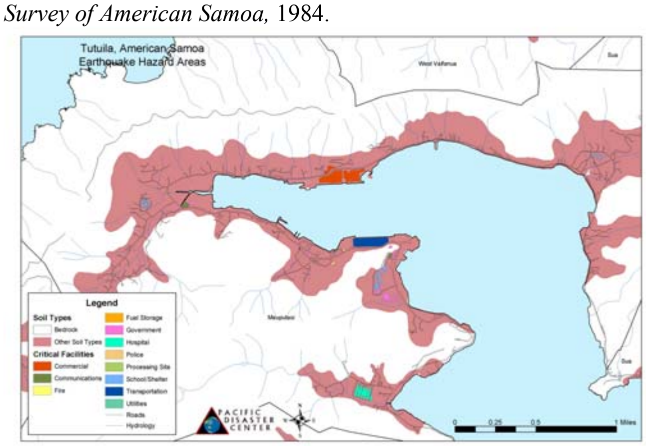

Figure 3: Critical facilities locations versus potential earthquake shaking map. Earthquake hazard map of Pago Pago Harbor area shows potential increased ground shaking (red). Map derived from USDA, *Soil Survey of American Samoa* 1984.

- **Floods** (Flood Insurance Rate Maps (FIRMs), riverine flooding) - Spatial data derived from digitizing the paper FEMA Flood Insurance Rate Maps was used to identify flood prone riverine areas. To improve spatial control, these vector files were also spatially adjusted (rubbersheeted) to the National Oceanic and Atmospheric Administration (NOAA) orthorectified Ikonos imagery of Tutuila (figure 4).

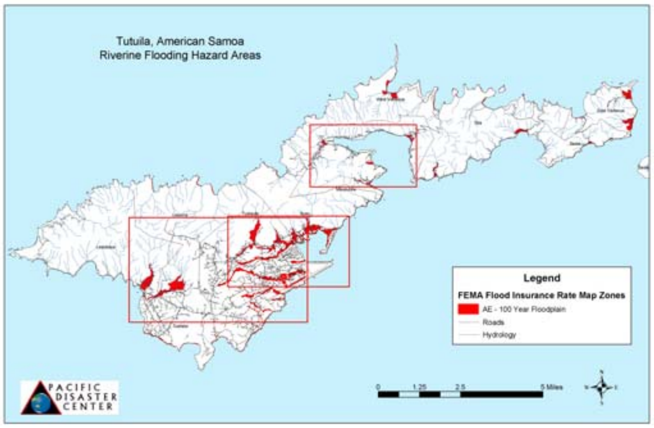

Figure 4: Riverine flood hazard areas, Tutuila. FEMA flood zone AE indicated in red.

- **Landslides** (landslide hazard map) - Spatial data derived from digitizing paper maps associated with the 1990 Landslide Hazard Mitigation Study, completed by the USDA/NRCS (formerly SCS, Soil Conservation Service), were used to identify areas at high-, medium-, and low-risk to landslides (Figure 5). Recent (1979 to the present) slide occurrences were also mapped.

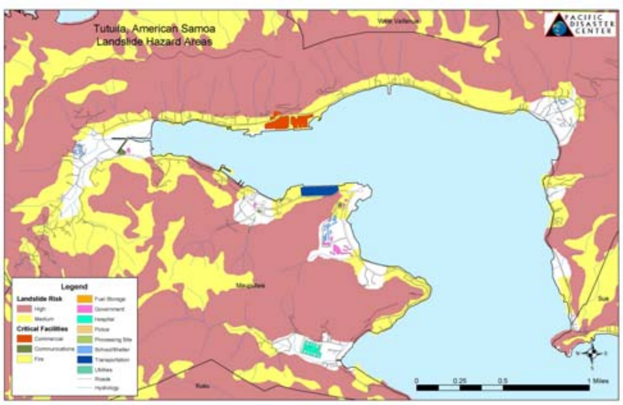

Figure 5: Landslide risk for critical facilities – Pago Pago Harbor area, Tutuila. High-risk areas are marked in red and medium risk in yellow. Derived from USDA, *Landslide Mitigation Study*, 1990.

- **Tropical Cyclone** (FIRMs, storm surge) - Spatial data derived from digitizing paper FEMA Flood Insurance Rate Maps was used to identify coastal areas prone to cyclone-generated storm surge. Analysis of concurrence of tropical cyclones with El Niño events, shows a moderate-to-strong correlation (Figure 6). The Project Team derived historical hurricane tracks from the Pacific Disaster Center's online *Asia Pacific Natural Hazards and Vulnerabilities Atlas* to display and understand history and frequency of tropical cyclones (www.pdc.org) (Figure 7).

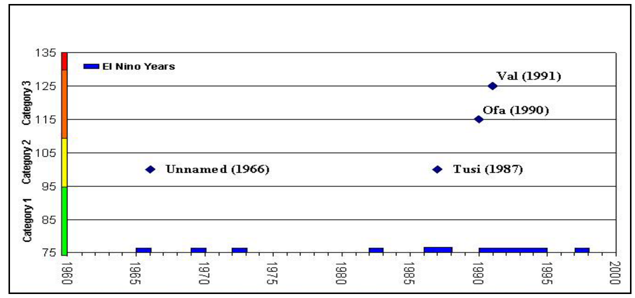

Figure 6: Tropical cyclone concurrence with El Niño events. El Niño episodes are indicated by blue horizontal bars. Hurricane names are plotted according to recorded sustained wind speeds per hurricane categories 1-3. Data derived from the Pacific Disaster Center's *Asia Pacific Natural Hazards and Vulnerabilities Atlas*.

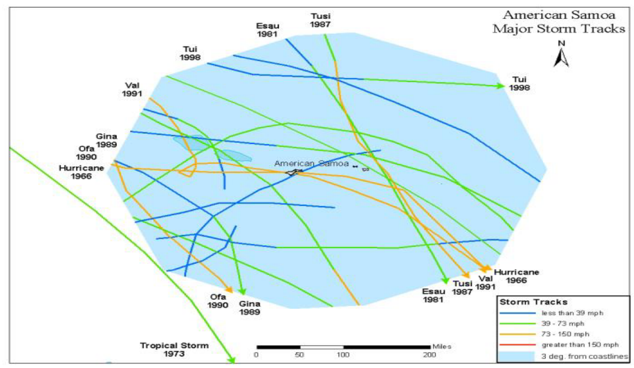

Figure 7: Historical storm tracks affecting American Samoa.

- **Tsunami** (FIRMs tsunami run-up) - Spatial data derived from digitizing paper FEMA Flood Insurance Rate Maps was used to identify coastal areas that would be at risk for tsunami run-up. To improve spatial control, these vector files were also rubbersheeted to NOAA orthorectified Ikonos imagery of Tutuila (Figure 8) . The GIS analysis for Pago Pago Harbor and surrounding area identifies a significant number of critical facilities that lie within the velocity wave hazard area, including the fire station, communications, government buildings, and transportation buildings.

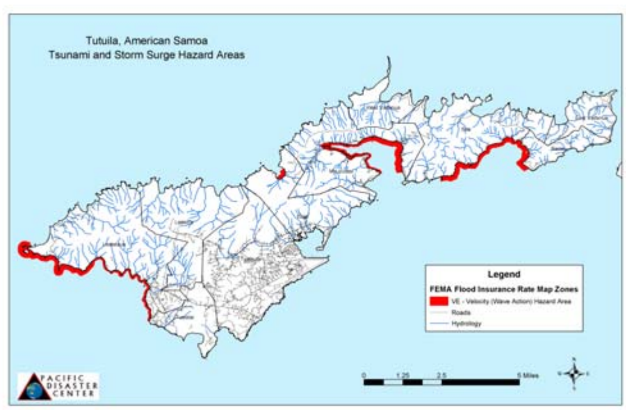

Figure 8: Estimated tsunami inundations and storm surge zones. Wave velocity hazard areas for the Island of Tutuila were identified using FEMA Flood Insurance Rate Maps VE zones.

4. MITIGATION PLANNING PROCESS

The American Samoa Hazard Mitigation Council served as a steering committee for the mitigation planning process. Planning efforts included a series of workshops and focus group meetings to identify, evaluate, and reach a consensus on mitigation efforts to reduce future disasters impacts in American Samoa. Fifteen American Samoa Hazard Mitigation Council meetings and Project Team investigations were held between January and September 2003 for the purposes of project kickoff and advocacy, data gathering and interviews, hazards and critical facilities review, mitigation planning focus groups, mitigation project identification and scoping, development of the mitigation plan, identification and prioritization of mitigation projects, and public education.

5. FACTORS LEADING TO A SUCCESSFUL MITIGATION PLANNING PROCESS

Mitigation planning and successful mitigation project implementation is a complex process involving many activities and public interactions over an extended period of time. Four combined factors helped move the American Samoa mitigation planning process forward to a position of long-term sustainability. These factors are resources, advocacy, education, and disasters.

Resources: Project resources combined both adequate financial funding and adequate personnel involvement and organization at all stages of the plan development. As part of recent U. S. Federal legislation, the *Disaster Mitigation Act of 2000*, adequate project funds were available to identify and hire an experienced Project Team in mitigation planning. This included involvement of more than 10 hazard, planning, and GIS personnel from the Pacific Disaster Center and the University of Hawaii. The American Samoa GIS User Group personnel representing five American Samoa Government agencies shared available data with the Project Team to develop natural hazard data layers required for planning purposes. Subject experts representing the American Samoa Power Authority, Territorial Emergency Management Coordinating Office, Department of Public Works, and Department of Commerce Coastal Zone Management Group (funded by the NOAA Pacific Services Center), provided scientific, technical, and engineering continuity for the project. A key component for project success was the involvement of a qualified local civil engineer to collect and analyze technical data. Federal funding incentives for mitigation projects have also driven the planning process. Moreover, the project built on a record of mitigation successes in American Samoa during the past decade.

Advocacy: As a testament to the efforts of all the stakeholders involved in the mitigation planning process, the strengths and accomplishments of the plan development process have been numerous. The American Samoa Government has endorsed the *American Samoa Hazard Mitigation Plan* with an Executive Order signed by the Governor. The Governor, Lt. Governor, Director of the Territorial Emergency Management Coordinating Office (TEMCO), the TEMCO staff, and the Hazard Mitigation Council have provided strong leadership and advocacy throughout the Territory, ensuring a continuous mitigation planning process. The American Samoa GIS User Group has been involved throughout the data collection process and will benefit from the natural hazards and inventory databases. Four Hazard Mitigation Council subcommittees discussed mitigation issues in focus group settings.

Education: The hazard mitigation planning process continues through education of many stakeholders. It has been extensively publicized and documented through radio, television, and newsprint, both in English and Samoan. The American Samoa GIS User Group has embraced students at the American Samoa Community College, which teaches GIS and GPS skills. Follow up risk and mitigation education activities will involve legislators, villages, and schools.

Disasters: Disasters provide critical educational and motivational windows of opportunity for policy makers and the pubic to understand and reinforce the importance of long-term mitigation planning and to take mitigation action. In May 2003, coinciding with the completion of the Risk and Vulnerability Assessment, American Samoa experienced historic flash flooding caused by rainstorms that dumped 10 to 15 inches of rain within a three-hour time period, accompanied by more than 20 documented landslides, which killed five people. Figure 9 shows representative damage to the flooded hospital critical facility affected by the May 2003 flood disaster. Figure 1 locates this same hospital critical facility in flood and landslide high-hazard zones.

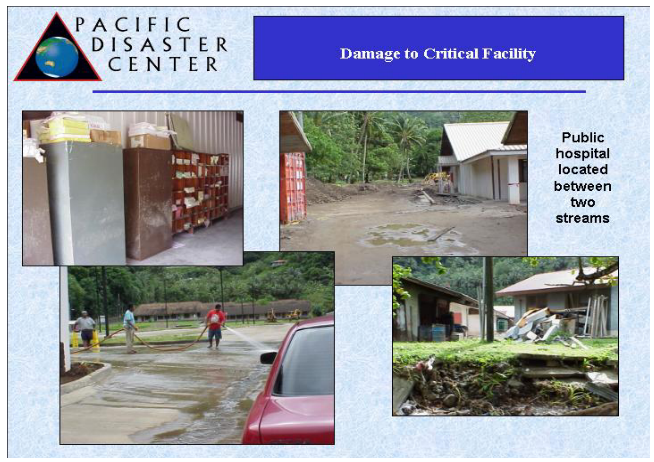

Figure 9: The LBJ Hospital in Tutuila, American Samoa suffered flood damage as a result of the May 2003 floods.

6. ACKNOWLEDGEMENTS

The authors wish to thank the American Samoa Government for permission to publish this paper. The Pacific Disaster Center (PDC) (www.pdc.org) is a public-private partnership sponsored by the PDC Program Office (ASD/NII). The content of the information does not necessarily reflect the position or policy of the U. S. Government and no official Government endorsement should be inferred. Since 2001, the East-West Center has been the managing partner of the Pacific Disaster Center.

7. REFERENCES

1. Disaster Mitigation Act of 2000, as required by Section 322 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act promulgated through Public Law 106-390.
2. FEMA*, Getting Started –Building Support for Mitigation Planning,* FEMA 386-1, 2002.
3. FEMA*, Understanding Your Risks – Identifying Hazards and Estimating Losses,* FEMA 386-2, 2001.
4. FEMA*, Developing the Mitigation Plan,* FEMA 386-3, 2003.
5. Pacific Disaster Center, *Asia Pacific Natural Hazards and Vulnerabilities Atlas,* www.pdc.org, 2003.
6. U. S. Dept. of Agriculture, *Landslide Mitigation Study*, 1990.
7. U. S. Department of Agriculture USDA/NRCS (formerly SCS, Soil Conservation Service), *Soil Survey of American Samoa,* 1984.