CHAPTER IV

Risk Assessment and Vulnerability Assessment

Assessing risks is the second step in the four-step mitigation plan process. The risk assessment step has four parts: identify hazards, profile hazard events, inventory assets and estimate losses (Figure 1). Conducting a risk assessment is a way of asking and answering "what if…" questions. For instance, what if the Territory receives several days of heavy rain?

The risk assessment answers questions regarding history, probability and impact. These answers are then used in the third step of mitigation planning, developing a mitigation plan. They provide essential data to determine mitigation strategies and to define specific prioritized mitigation projects.
The development of a comprehensive natural hazard risk and vulnerability assessment is necessary to gain an understanding of the risks of natural disasters to the people of American Samoa. The Project Team, in collaboration with American Samoa Government (ASG) representatives, examined the vulnerability of current and future populations and structures (including critical facilities and infrastructure) to various natural hazards. The risk assessment provides a compilation of information and available data sets to American Samoa government officials for comprehensive planning purposes to save lives and reduce property losses in future disasters.

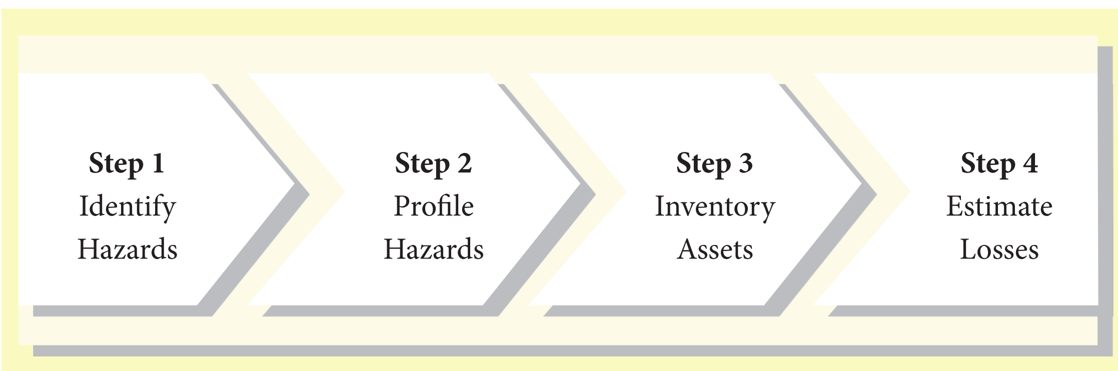

Figure 1 Risk Assessment Process

The risk assessment is formatted to meet the Federal Emergency Management Agency's state-level hazard mitigation planning regulations as found in C.F.R. 44 201. FEMA requires American Samoa to profile each possible natural hazard event, to assess vulnerability and estimate potential losses by jurisdiction. Using data compiled on historical natural hazard events between approximately 1960 and 2014, the risk assessment discusses thirteen main natural hazards as follows: climate change (including sea level rise), coastal erosion, drought, earthquake, flood, high surf, landslide, lightning, soil hazards (including sinkholes, subsidence and expansion) tropical cyclones (including storm surge and high wind storms), tsunamis, volcano (including vog), wildfire and one man-made hazard, hazardous materials. Storm surge is treated as an associated hazard to tropical cyclones. New hazards for the 2015 update are coastal erosion, high surf, lightning strike, and soil hazards. Hazards profiles, including a description of the hazard, historical occurrences, extent (or magnitude), location and vulnerability, beginning on page 64 with the climate change hazard. Hazard profiles are presented in alphabetical order.

Extensive information regarding the history, economy, population and islands that make up American Samoa can be found in Chapter 2. Major areas of population include the villages of Tafuna, Nu'uuli, Pago Pago, Iliili, and Pavaiai. It is advisable to review Chapter 2 prior to reading the Risk Assessment to best understand the layout and villages of the Territory.

GIS Date for Buildings

Data was requested and collected through American Samoa agencies, federal agencies, state sources, non-profits, and Internet sources. Baseline building and critical data is as follows:

- Tutuila/Aunu'u Buildings: 2010 dataset. This dataset incudes includes 16,351 structures. There is no associated building value information. However, 94 of these structures were listed as demolished or destroyed as a result of the tsunami. These structures were not included in the hazard zones estimates.
    - o Tutuila/Aunu'u Critical Facilities: 2007 dataset. The 2007 dataset includes type, name, and value estimation. New critical facility information was requested. Although a new critical facility layer was not available, new information was added to the list through the planning process. This included 2 fire stations, a hospital in eastern Tutuila, and the new court building. However, values were not provided for the new facilities. This brings the total up to 240 critical facility structures. In addition, several additional holdings were mentioned and also included separated including ASTCA infrastructure, tsunami sirens, and safe zones. In appendix D, the complete list of critical facilities is available included which critical facilities are new for the 2015 plan update.
- Ta'u Buildings: 2003 data set. Limited information on type was provided and no building values were provided.
    - o Ta'u Critical Facilities: 2003 dataset. Name and type was provided. No building values were provided. However, some of the new critical facility data (primarily tsunami sirens) are available for the Manu'a Islands.
- Ofu-Olosega Buildings: 2011 dataset. No information on type, name or building value was provided.
    - o Ofu-Olosega Critical Facilities: no data provided. However, some of the new data (primarily tsunami sirens) are available for the Manu'a Islands.
- Swains Island: No information was provided on buildings. Only 17 people live on the island according to the 2010 U.S. Census.
- Rose Atoll: Uninhabited

Hazard Identification

Hazard identification is the process of identifying the kinds of natural hazards that can affect the mitigation plan study area – in this instance the Territory of American Samoa. For the purpose of this plan, five hazards were added to the list from 2011. These are sea level rise (combined with climate change), lightning strike, coastal erosion, high surf and soil hazards (expansion, subsidence and sinkhole). In all, fourteen hazards were studied: they are climate change (including sea level rise), coastal erosion, drought, earthquake, flood, hazardous materials, high surf, landslides, lightning strike, soil hazards (including expansion, subsidence and sinkholes), tropical cyclones, tsunami, volcano and wildfire. Table 1 indicates each hazard studied and the justification for inclusion in the mitigation plan.

Table 1 Hazards Included in the Plan

Hazard	Justification for Inclusion
Climate Change (sea level rise)	Climate Change directly impacts American Samoa by increasing the impacts of hazard events such as flooding, drought and tsunamis. In addition, climate change may be a possible cause of sea level rise. Sea level rise will threaten areas further inland with flooding.
Coastal Erosion	Much of the development is located in the relatively narrow coastal plain making this a hazard of major concern. The reef flat, which extends up to 200 feet on the south shore of Tutuila, provides some shoreline protection, although steep volcanic cliffs generally characterize the north shore coasts. Shoreline analysis identified about 10 percent of critical facilities within critical erosion areas, potentially many of these structures at risk to future erosion.[1]
Drought	Drought occurs in American Samoa and has resulted in economic impacts and water shortages. There is evidence that severe drought events may follow a strong El Niño period. Drought can result in water shortage and impact economic activities on the island.
Earthquake	The primary earthquake source for American Samoa is the northernmost section of the Tonga Trench (or Tonga-Kermadec Trench), more than 100 miles southwest of the Samoan island chain. The Tonga Trench is a seafloor geographic and tectonic feature created by the collision of the Pacific Plate that subducts westward beneath the Australian Plate. The Pacific-Australian subduction zone is considered an area of high seismic activity, and the collision of these two plates is a source of large but distant earthquakes felt in American Samoa. Earthquakes over 7.0M have been recorded. Further, earthquakes can be a precursor for a tsunami.
Flood	Flooding is a regular occurrence in American Samoa due to rainfall, thunderstorm rain, tropical cyclones, and tsunami. Several disaster declarations resulted from flood impacts. Flood has resulted in substantial damages and often is a precursor for landslides.
Hazardous Materials	American Samoa stores extensive hazardous materials on island. Further, many extremely dangerous (and illegal) hazardous materials, such as fertilizer, are being imported. Often times, the most dangerous hazardous materials are being abandoned or not stored properly, creating a safety and health issue to nearby dwellings and to the environment.[2]
High Surf	This hazard has resulted in road damage and debris, and it may impact economic activity.
Landslides	Previous landslides have resulted in substantial damage and even death on island. Given the natural topography and history of landslides on Tutuila, future landslides are a certain occurrence. Landslides are less frequent on the Manu'a islands but still possible given the steep slope in some areas.
Lightning Strike	Lightning strikes are not frequent occurrences but have reportedly caused a death, an injury and electronic damage in American Samoa. Future events can result in death, injury, power outage, wildfire or structure fires.

1 Section 309 Assessment and Strategy for the American Samoa Coastal Management Program. (2011). American Samoa Coastal Management Program. Retrieved August 8, 2014 from http://coastalmanagement.noaa.gov/mystate/docs/as3092011.pdf, p. 20

2 Only natural hazards are required in the hazard mitigation plan. However, given the concern and potential impact by a natural hazard, hazardous materials on the island are discussed.

Hazard	Justification for Inclusion
Soil Hazards (including expansion, subsidence and sinkholes)	These are low probability hazards. They were included because they are possible on the islands, particularly subsidence. Each of these hazards may result in property damage
Tropical Cyclones and High Wind Storms	All the major tropical cyclones affecting American Samoa during the past 50+ years have been classified between Categories 1 and 3 on the Saffir-Simpson Hurricane Scale. Historical records give no indication of any Category 4 or 5 hurricanes impacting this area though it is possible. It appears that due to the relatively close proximity to the equator, 840 miles south of the 0 degree latitude line, the most intense tropical cyclones in the vicinity of American Samoa are rare. However, even less severe storms can wreak havoc on the islands including death and damage due to flooding, high wind, and high surf.
Tsunami	The entire coastline of American Samoa is at risk to tsunamis. Wave heights along the shoreline would be directly related to the energy of the wave and direction in which it was generated. The pocket coves and bays of the island are at higher risk of damage due to shallow bathymetry and the amplifying effect of the wave energy as it nears the shore. Tsunamis range from relatively weak, just generating larger than normal waves, to catastrophic, similar to the 2009 tsunami event that severely impacted the territory.
Volcano	American Samoa formed as a result of volcanic activity over a hot spot in the Pacific Plate. Tectonic uplifts and volcanic activity during the early formation period of the islands have led to steep inclines and sharp cliffs being the dominant geographical features of the main islands. The most recent volcanic eruptions were in 1866 and an active hotspot remains. In addition, volcanoes are active on the neighboring islands of Samoa in Apia. An associated hazard to volcano and possible impact to American Samoa is vog, a type of air pollution. It is the haze caused by a combination of volcanic activity and weather which becomes thicker or lighter depending upon the amount of emissions from the volcano, the direction and amount of wind, and other weather conditions. Other respiratory illnesses may also rise during a volcano eruption.
Wildfire	Wildfire is possible and does occur in American Samoa. However, the fires are rarely large enough to cause significant damage. A fire suppression plan does exist for the islands.

Hazard information collection and assessment was conducted for all hazards under consideration. Information sources used in the risk and vulnerability assessment included hazard mitigation plans, reports and studies conducted in the region, Internet resources, local newspapers, and personal interviews conducted with government agency representatives, professional experts, and residents of American Samoa. These sources are referenced in theAppendices.

In addition, reviewing previous disaster declarations provides insight to known hazards that impact the islands. Table 2 shows a list of FEMA declared disasters since 1966.

Table 2 FEMA Declared Disasters [3]

Year	Date	Disaster Types	Disaster Number
2014	09/10	Severe Storms, Flooding and Landslides	4192
2009	09/29	Earthquake, Tsunami and Flooding	1859
2005	02/18	Tropical Cyclone Olaf, including high winds, high surf, and heavy rainfall	1582
2004	01/13	High winds, high surf and heavy rainfall associated with Tropical Cyclone Heta	1506
2003	06/06	Heavy rainfall, flooding, landslides, and mudslides	1473
1991	12/13	Hurricane Val	927
1990	02/09	Hurricane Ofa	855
1987	01/24	Hurricane Tusi	785
1981	03/24	Typhoon Esau	637
1979	11/09	Flooding, mudslides, landslides	610
1974	09/30	Drought	449
1966	02/10	Typhoon, high tides	213

Hazard Profiles

Each hazard mentioned above is profiled separately to describe the hazard and potential impacts on the islands of American Samoa. The islands of Tutuila, Ofu-Olosega, and Ta'u are included. Where data exists, additional information on location (such as district, county, or village) will also be included. The profile for each hazard includes:

- **Description:** A scientific explanation of the hazard including potential magnitude (or severity) and impacts;
- **Location:** Geographical extent of the hazard;
- **Previous occurrences:** The number of previous impacts from the hazard on American Samoa in the past;
- **Extent** (or magnitude): The severity of the hazard in the past and potentially severity in the future. Measures may include wind speed, wave height, or property damage, for example;
- **Probability of future events:** The likelihood of future events impacting the islands. Given that an exact probability is often difficult to quantify, this characteristic is categorized into ranges to be used in hazard profiles:
    - o Unlikely: Less than 1% annual probability
    - o Possible: Between 1% and 10% annual probability
    - o Likely: Between 10+% and 90% annual probability
    - o Highly Likely: Greater than 90% annual probability
- **Vulnerability Assessment:** The vulnerability assessment will address conditions that may increase or decrease vulnerability such as topography, soil type, land use, and development trends will also be included.
- **Potential Losses:** Estimated losses will be calculated using available data and resources. Methods utilized include GIS analysis and hazard modeling where tools are available. Information such as number of structures at risk and critical facilities at risk will be analyzed.

3 Disaster State (2014). Federal Emergency Management Agency. Retrieved February 28, 2014 from http://www.fema.gov/news/disasters_state.fema?id=60

It is recognized that American Samoa traditionally refers to areas of the islands as villages and districts (East District, West District, and Manu'a District), as opposed to county geographies. However, the best available data for mapping and analysis boundaries was U.S. 2010 Census data, so the county geography was utilized. It is also recognized that the 2010 Census data did not include FoFo County, which is included as part of Lealatua County in this version of the plan (including the Village of Leone). Future revisions of this plan should move towards aligning the traditional American Samoan areas of reference with the best available data.

Priority Risk Index (PRI) Index

The prioritization and categorization of identified hazards for American Samoa is based principally on the Priority Risk Index (PRI), a tool used to measure the degree of risk for identified hazards in a particular planning area. The PRI was used to assist the American Samoa Hazard Mitigation Planning Council in gaining consensus on the identification of those hazards that pose the most significant threat to the islands based on a variety of factors including location extent, impact, probability, warning time, and duration. The PRI results are presented below. Combined with the inventory of ASG assets and critical facilities, the hazard profiles generated through the use of the PRI allows for the prioritization of hazard

The PRI results provide a numerical value for each hazard that allows hazards to be ranked against one another (the higher the PRI value, the greater the hazard risk). PRI values are obtained by assigning varying degrees of risk to five categories for each hazard (probability, impact, spatial extent, warning time and duration). Each degree of risk has been assigned a value (1 to 4) and an agreed upon weighting factor.

To calculate the PRI value for a given hazard, the assigned risk value for each category is multiplied by the weighting factor. The sum of all five categories equals the final PRI value, as demonstrated in the example equation below:

PRI VALUE = (PROBABILITY x .30) + (IMPACT x .30) + (SPATIAL EXTENT x .20) +
(WARNING TIME x .10) + (DURATION x .10)

According to the weighting scheme applied for American Samoa, the highest possible PRI value is 4.0. Table 3 shows the weighting schemes for each category. By determining a value for each hazard that can be relatively compared to other hazards threatening the planning area, hazards can be ranked with greater ease. Many of the PRI categories are described within the hazard profiles. The final PRI results, including the calculated values for each hazard in American Samoa, are found at the end of this section in the "Summary of Hazard Risk," beginning on page 205.

Table 3 Priority Risk Index Criteria for American Samoa Hazard Mitigation Plan

PRI Category	DEGREE OF RISK			Assigned Weighting Factor
	Level	**Criteria**	**Index Valu**	
Probability	Unlikely	Less than 1% annual probability	1	30%
	Possible	Between 1 and 10% annual probability	2	
	Likely	Between 10 and 90% annual probability	3	
	Highly Likely	90%+ annual probability	4	
Impact	Minor	Only minor property damage and minimal disruption to government functions and services. No shutdown of critical facilities.	1	30%
	Limited	Minor injuries are possible. More than 10% of buildings damaged or destroyed. Temporary shutdown of critical facilities (less than one week).	2	
	Critical	Multiple deaths/injuries possible. More than 25% of buildings damaged or destroyed. Complete shutdown of critical facilities for more than one week.	3	
	Catastrophic	High number of deaths/injuries possible. More than 50% of buildings damaged or destroyed. Complete shutdown of critical facilities for 30 days or more.	4	
Spatial Extent	Negligible	Limited to one specific area	1	20%
	Small	Small areas affected	2	
	Moderate	Large areas affected / multiple campuses affected	3	
	Large	All areas affected / all campuses affected	4	
Warning Time	More than 24hrs	Self-explanatory	1	10%
	12 to 24 hours	Self-explanatory	2	
	6 to 12 hours	Self-explanatory	3	
	Less than 6 hours	Self-explanatory	4	
Duration	Less than 6 hours	Self-explanatory	1	10%
	Less than 24 hours	Self-explanatory	2	
	Less than one week	Self-explanatory	3	
	More than one week	Self-explanatory	4	

Climate Change

Description

Climate change was added to the list of hazards warranting study in 2008 because it directly impacts American Samoa by potentially increasing flooding or increasing drought to the islands. It was expanded in the 2015 update to include sea level rise.

Climate change is defined by the U.S. Environmental Protection Agency (EPA) as "any significant change in the measures of climate lasting for an extended period of time. In other words, climate change includes major changes in temperature, precipitation, or wind patterns, among others, that occur over several decades or longer."[4]

The exact cause of climate change is still being researched. There are thought to be several contributing factors or potential causes including: orbital variations (changes to the amount and location of sunlight reaching the earth's surface); solar output (the amount of energy from the sun input to earth); magnetic field strength (evidence that an increased magnetic field leads to increased rain fall, particularly in the tropics), volcanism (eruptions release gas into the air that may raise the global temperature or particles that may decrease it); plate tectonics (impacts ocean circulation causes ocean temperature to rise or fall); and human causes (primarily conducting activities that release large amounts of carbon dioxide and other greenhouse gases into the atmosphere; these gases trap energy in the earth's atmosphere, causing the temperature rise).

Typically the impacts of climate change are slow-onset, meaning they occur gradually over time. Climate change is assumed to be a contributing factor for weather patterns and rising sea levels, which carry subsequent impact. Two major weather patterns impacting American Samoa are El Niño and La Niña. In addition, sea level rise, an associated hazard, is described below.

Description of El Niño

El Niño is characterized by unusually warm ocean temperatures in the equatorial Pacific. El Niño is a disruption of the ocean-atmosphere system in the Tropical Pacific having important consequences for weather and climate around the globe. It may cause increases in sea level, increased flooding, and changes in natural resources available to American Samoa.[5]

El Niño is normally accompanied by a change in atmospheric circulation (the location of the jet stream) called the Southern Oscillation. Together, the ENSO (El Niño-Southern Oscillation) phenomenon is one of the main sources of inter-annual variability in weather and climate around the world. El Niño events tend to alternate about every three to seven years. However, the time from one event to the next can vary from one to ten years. The event typically lasts between twelve and eighteen months. El Niño is forecasted to develop during the 2014 season, after a four year absence.

4 Glossary of Climate Change Terms. (2013). U.S. Environmental Protection Agency. Retrieved August 8, 2014 from http://www.epa.gov/climatechange/glossary.html#C

5 National Assessment: Overview Islands. U.S. Global Change Research Program. Retrieved August 8. 2014 from http://www.usgcrp.gov/usgcrp/Library/nationalassessment/overviewislands.htm

Description of La Niña [6]

La Niña is characterized by unusually cold ocean temperatures in the equatorial Pacific. Typically, a La Niña is preceded by a buildup of cooler-than-normal subsurface waters in the tropical Pacific. Eastward-moving atmospheric and oceanic waves help bring the cold water to the surface through a complex series of events still being studied. In time, the easterly trade winds strengthen, cold upwelling off Peru and Ecuador intensifies, and sea-surface temperatures (SSTs) drop below normal. During the 1988- 89 El Niño, SSTs fell to as much as 4 degrees Celsius (7 degrees Fahrenheit) below normal. Both La Niña and El Niña tend to peak during the Northern Hemisphere winter. The interval between La Niña events is about two to seven years and it may follow a La Niña event (but not always). La Niña conditions typically last approximately 9-12 months. Some episodes may persist for as long as two years. La Niña conditions may increase the intensity of hurricanes, cause drought, or limit natural resources available in American Samoa.[7]

Description of Sea Level Rise

Sea level rise is generally defined as the mean rise in sea level. It is a slow-onset hazard; meaning that it occurs gradually and its impacts may not be felt immediately. Sea level rise is caused by two main factors: warming oceans (the tendency of warm water to take up more space than cooler water) and melting glaciers resulting in a greater amount of water in the oceans. Further, according to NOAA, "ocean warming contributes to global mean sea level rise by reducing the density of seawater, thus increasing its volume."[8] The increased volume of water results in more land being inundated by water. Regardless of the cause, rising oceans means that greater areas of coastal shorelines can be inundated by water. Research affirms that global sea level is rising, but is not conclusive on the extent to which it will impact specific areas.

A 2007 Intergovernmental Panel on Climate Change (IPCC) found that global sea level rose by approximately seven inches during the 20th century.[9] Sea level rise is occurring globally but not in a uniform manner. Some areas are experiencing a faster rise in water levels than other areas. In areas where the land is sinking (subsidence) sea level rise conditions may be higher, for example. Low-lying coastal areas are particularly vulnerable. This is a particular concern in American Samoa since a large portion of the population resides near coastal areas. In neighboring Samoa, nearly one in four homes are below four meters elevation according to Swiss Re. similar conditions are likely in American Samoa though this could not be verified.[10])

The potential impacts of sea level rise in American Samoa are pronounced. It may exacerbate the effects of hazard events such as coastal flooding, a tsunami or a hurricane. When these hazards are combined with sea level rise, more water will inundate the land further inland. Salinization, when salt water encroaches into fresh groundwater aquifers, is also a concern. This may contaminate drinking water supplies. Shoreline erosion and loss of developable land are also potential impacts of sea level rise in American Samoa. Environmental impacts from sea level include loss of mangroves, which help to protect the shoreline and filter unwanted pollutants from the water and coral dye-offs.

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6 La Niña FAQ. (1998). National Oceanic and Atmospheric Administration. Retrieved August 8, 2014 from http://www.elnino.noaa.gov/lanina_new_faq.html

7 Suplee, Curt. "El Niño/La Niña: Nature's Vicious Cycle." National Geographic. Retrieved August 8, 2014 from http://www.nationalgeographic.com/elnino/mainpage3.html

8 Johnson, G.C., and S.E. Wijffels. (2011). Ocean density change contributions to sea level rise. Oceanography 24(2):112–121, doi:10.5670/oceanog.2011.31f Retrieved April 2, 2014 from: http://oceans.pmel.noaa.gov/Papers/gcj_3x.pdf

9 Climate Impacts on Coastal Areas. (2014). U.S. Environmnetal Protection Agency. Retrieved August 8, 2014 from http://www.epa.gov/climatechange/impacts-adaptation/coasts.html#adapt

10 Samoa, South Pacific: Facing the risks of rising sea levels. (2014). Swiss Re. Retrieved August 8, 2014 from http://www.swissre.com/rethinking/climate_and_natural_disaster_risk/Samoa_South_Pacific_Facing_the_risks_of_rising_sea_levels.html

Several Pacific island states are threatened with total disappearance due to sea level rise. New York Times author Jonathan Adams wrote an article titled "Rising Sea Levels Threaten Small Pacific Island Nations" on May 3, 2007.[11] He states in his article:

> Dire climate change predictions may seem like science fiction in many parts of the world. But in the tiny, sea-swept Pacific nation of Tuvalu, the crisis has already arrived. Tuvalu consists of nine low-lying atolls totaling just 26 square kilometers, or 10 square miles, and
>
> in the past few years the "king tides" that peak in February have been rising higher than ever. Waves have washed over the island's main roads; coconut trees stand partly submerged; and small patches of cropland have been rendered unusable because of encroaching saltwater. The government and many experts already assume the worst: Sometime in the next 50 years, if rising sea-level predictions prove accurate, the entire 11,800-strong population will have to be evacuated. The ocean could swallow Tuvalu whole, making it the first country to be wiped off the map by global warming.

In addition, two uninhabited islands in the Kiribati chain (roughly between Hawaii and American Samoa) have already disappeared due to sea level rise. The people of Funafti in Tuvalu and on Kiribati Island are lobbying to find new homes; salt-water intrusion has made groundwater undrinkable, and these islands are suffering increasing impacts from hurricanes and heavy seas.

In neighboring independent Western Samoa, some villagers of Saoluafata have noticed that their coastline has retreated by as much as 50 meters in the last decade. Many of these people have had to move further inland as a result.

Location

Climate change is a global phenomenon that is impacting the world. In American Samoa, impacts due to new or more severe weather patterns will cover the entire planning area. Coastal areas are at greatest risk and will be impacted by more severe and more frequent flooding. However, its secondary impacts, such as more frequent and stronger storms, increased flooding and potential contamination of drinking water may impact the entire American Samoa island chain.

NOAA has created a hypothetical sea level rise viewer, the Digital Coast, which can be used at: http://csc.noaa.gov/slr/viewer/. Static maps from the Digital Coast are below; they show water encroachment due to hypothetical sea level rise scenarios at the 1 foot, 3 foot and 6 foot levels for Tutuila, Aunu'u and Manu'a Islands. However, given subtle changes, the maps are most practical when using the digital viewer. The figures are presented as follows:

- Figure 2 Tutuila Island Hypothetical Sea Level Rise Areas
- Figure 3 Pago Pago (Tutuila Island) Hypothetical Sea Level Rise Areas
- Figure 4 Tafuna Plain East (Tutuila Island) Hypothetical Sea Level Rise Areas
- Figure 5 Tafuna Plain West (Tutuila Island) Hypothetical Sea Level Rise Areas
- Figure 6 Ofu and Olosega Islands (Manu'a Group) Hypothetical Sea Level Rise Areas
- Figure 7 Ta'u Island (Manu'a Group) Hypothetical Sea Level Rise Areas

11 Adams, Jonathan. (2007). "Rising Sea Levels Threaten Small Pacific Island Nations". New York Times. Retrieved August 8, 2014 from http://www.nytimes.com/2007/05/03/world/asia/03iht-pacific.2.5548184.html?pagewanted=all

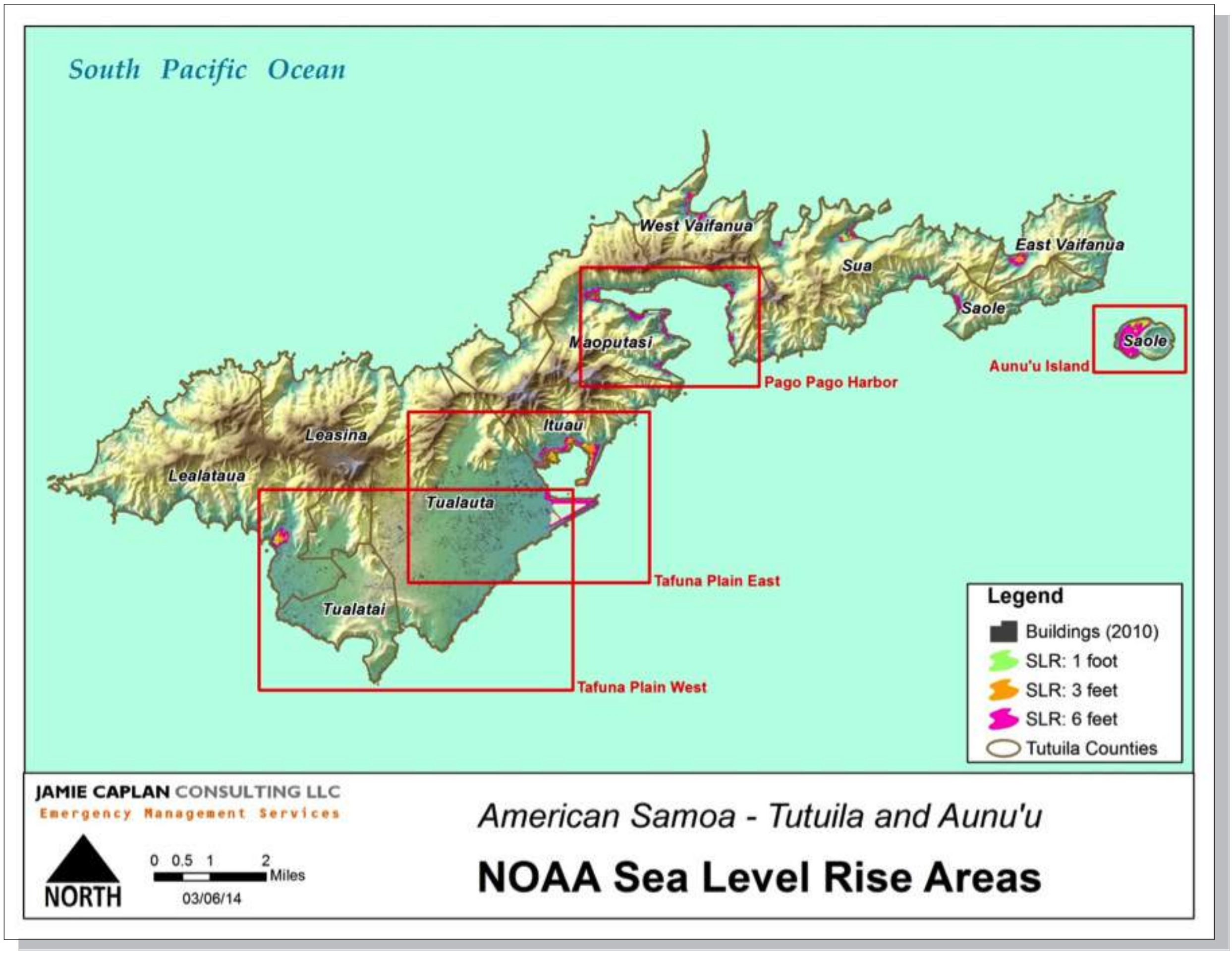

Figure 2 Tutuila Island Hypothetical Sea Level Rise Areas

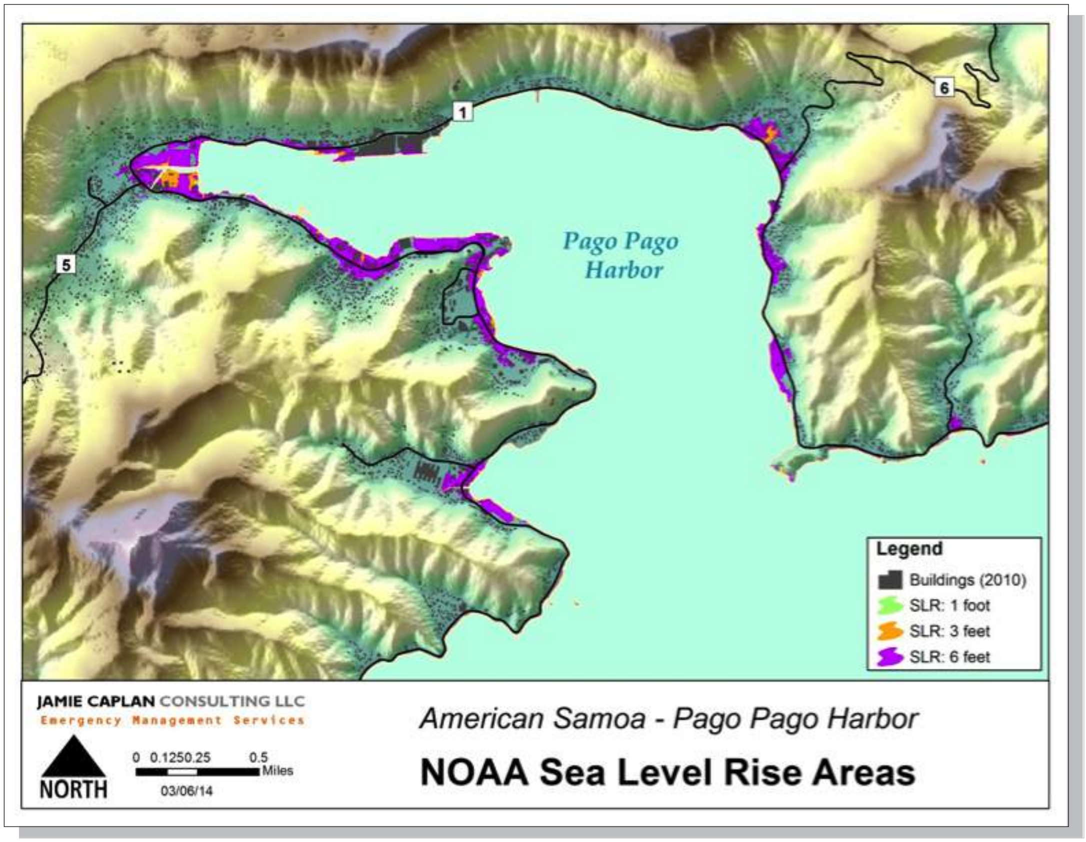

Figure 3 Pago Pago (Tutuila Island) Hypothetical Sea Level Rise Areas

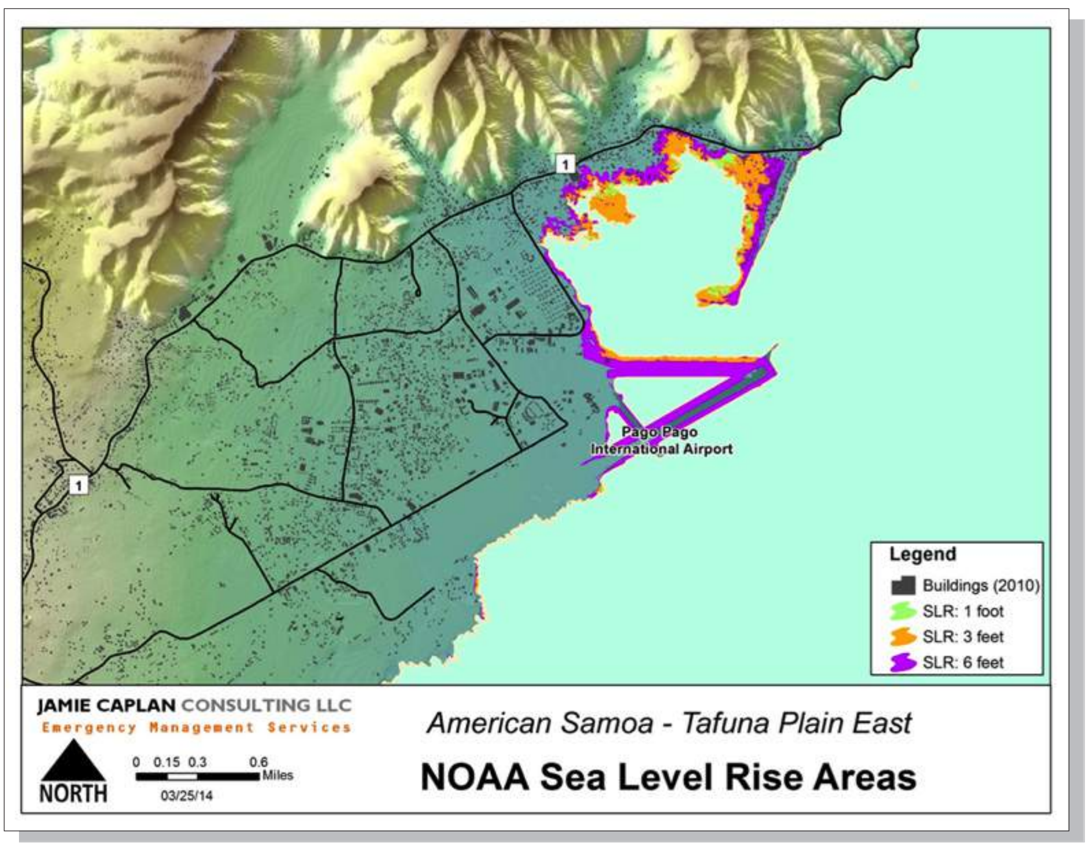

Figure 4 Tafuna Plain East (Tutuila Island) Hypothetical Sea Level Rise Areas

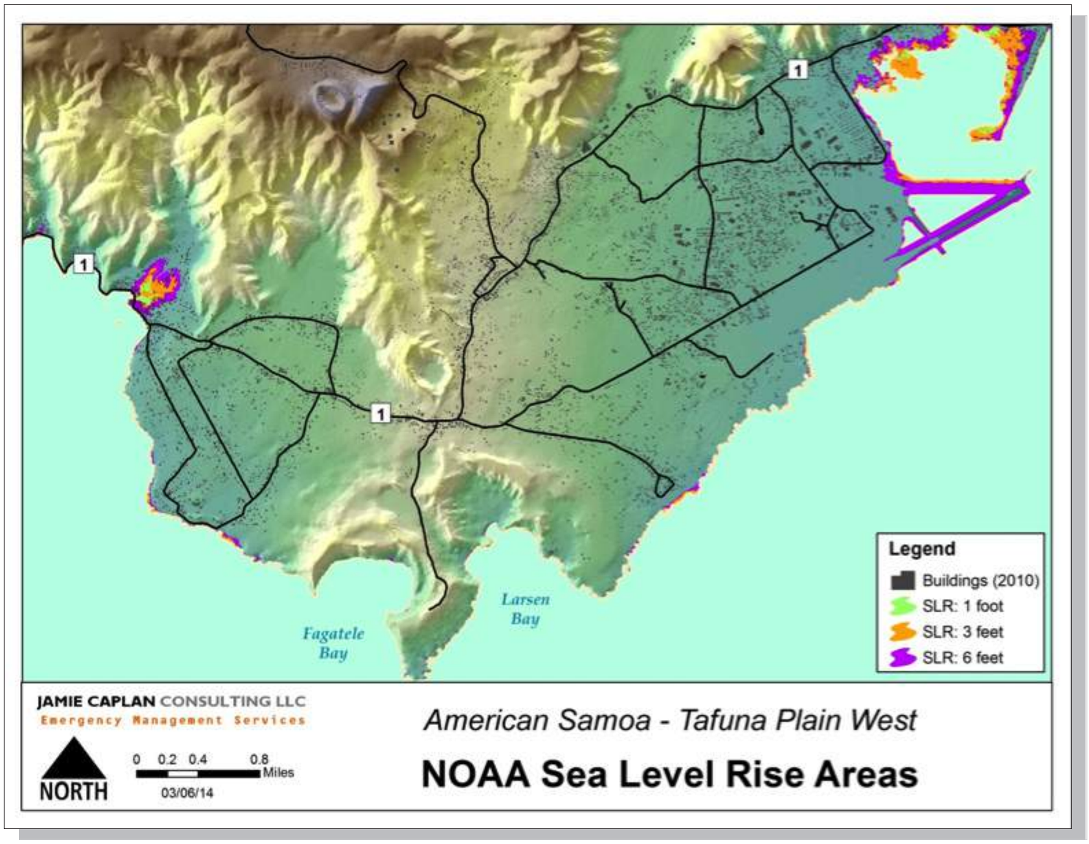

Figure 5 Tafuna Plain West (Tutuila Island) Hypothetical Sea Level Rise Areas

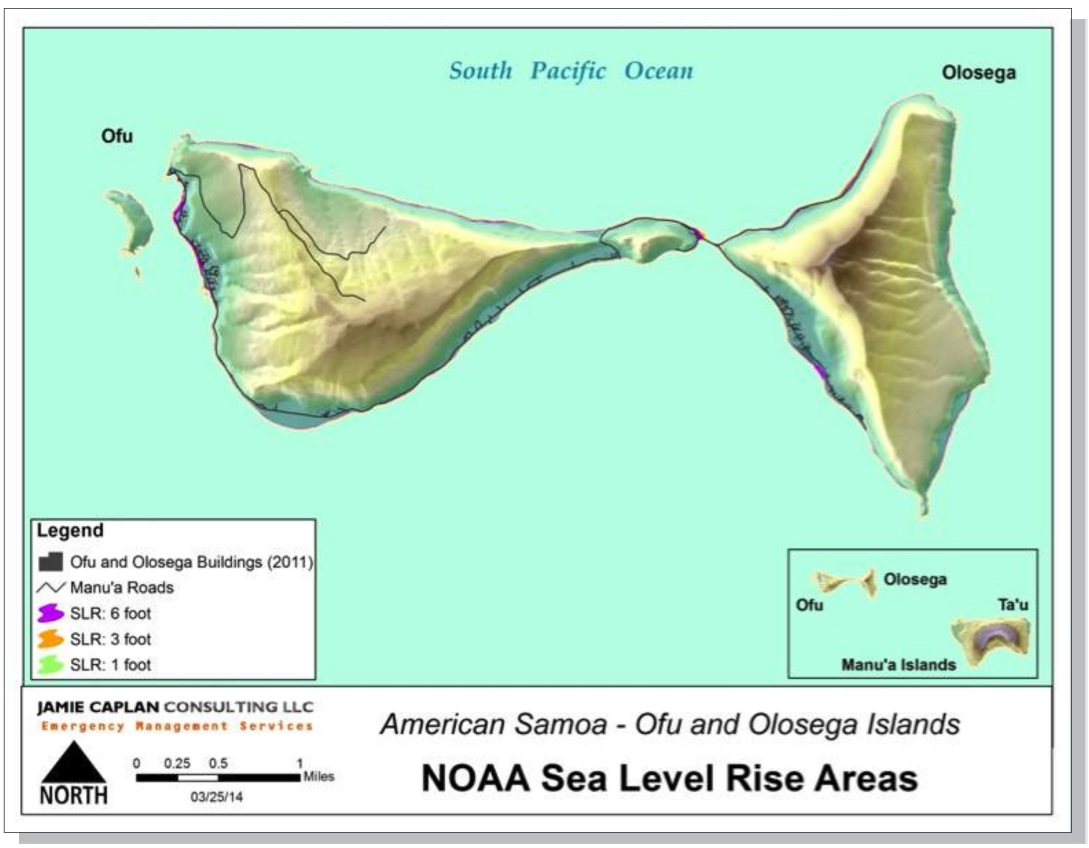

Figure 6 Ofu and Olosega Islands (Manu'a Group) Hypothetical Sea Level Rise Areas

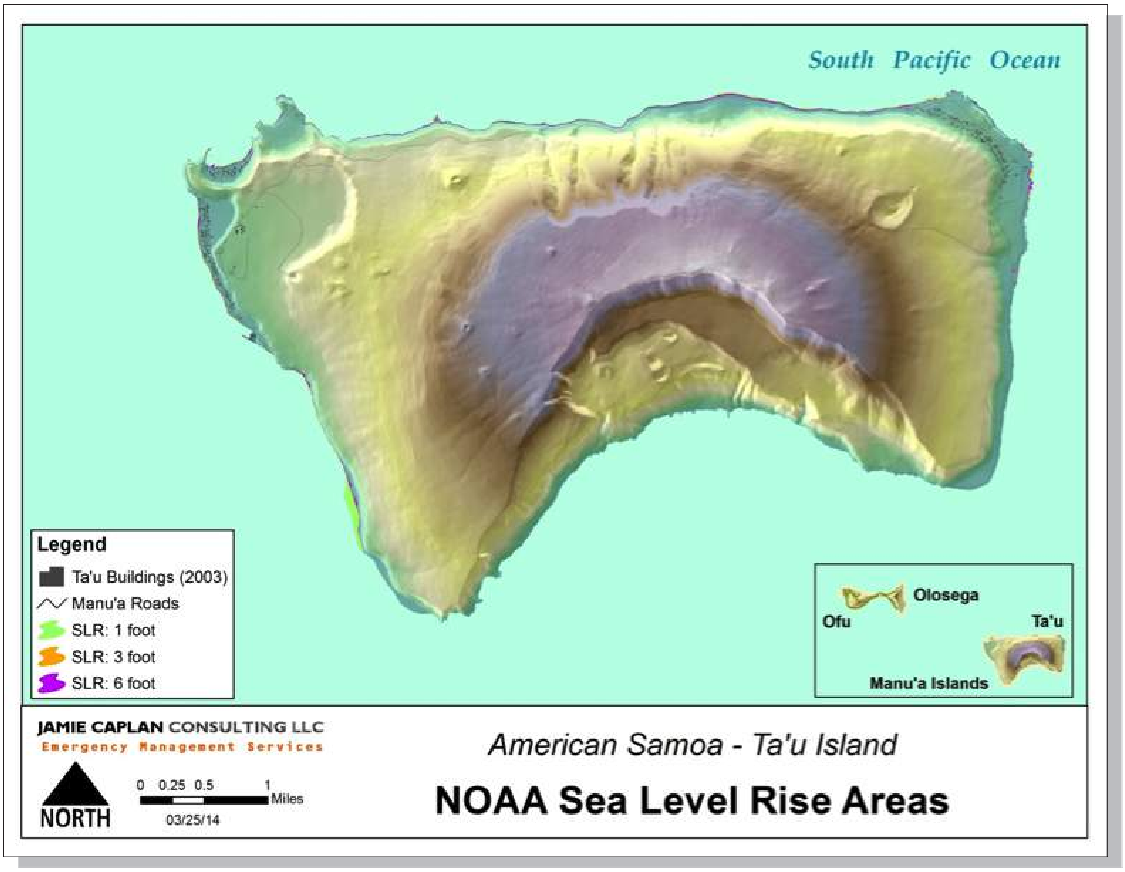

Figure 7 Ta'u Island (Manu'a Group) Hypothetical Sea Level Rise Areas

Previous Occurences

Given that climate change is a relatively new phenomenon, limited data exists. However, the United States Geological Survey (USGS), National Ocean and Atmospheric Administration (NOAA), National Integrated Drought Information System (NIDIS) and ENSO cycle trends provide evidence of climate change in American Samoa.

The USGS conducted an assessment on sea level rise. Its data indicated a rate of sea level rise of 1.48 millimeters per year, which is equivalent to 0.49 feet in 100 years.[12] It found that the National Park of American Samoa falls within the very low vulnerability category based on the water elevation alone. However, a more detailed assessment by USGS, called the Coastal Vulnerability Index (CVI), shows varied risk along the shoreline of the National Park of American Samoa. The CVI combines wave, tide, and sea level rise estimates to provide insight into the relative potential of coastal change due to future sea level rise. Areas of vulnerability as a result of the CVI are shown in the vulnerability assessment.

12 Physical Process Variables: Coastal Vulnerability Assessment of National Park of American Samoa to Sea-Level Rise. (2005). USGS Science for a Changing World. Retrieved August 8, 2014 from http://pubs.usgs.gov/of/2005/1055/html/ppvariables.htm

NOAA has collected sea level rise data at the Pago Pago station since 1948. Data indicates that mean sea level is rising. NOAA estimates a trend of 2.07 millimeters per year (beginning in 1948), which is equivalent to 0.68 feet (0.21 meters) in 100 years.[13] A sharp increase was observed after 2010 perhaps due to the strong La Niña in 2010-2011. The rise has since declined but is still above the mean sea level rising trend line as shown in Figure 8.

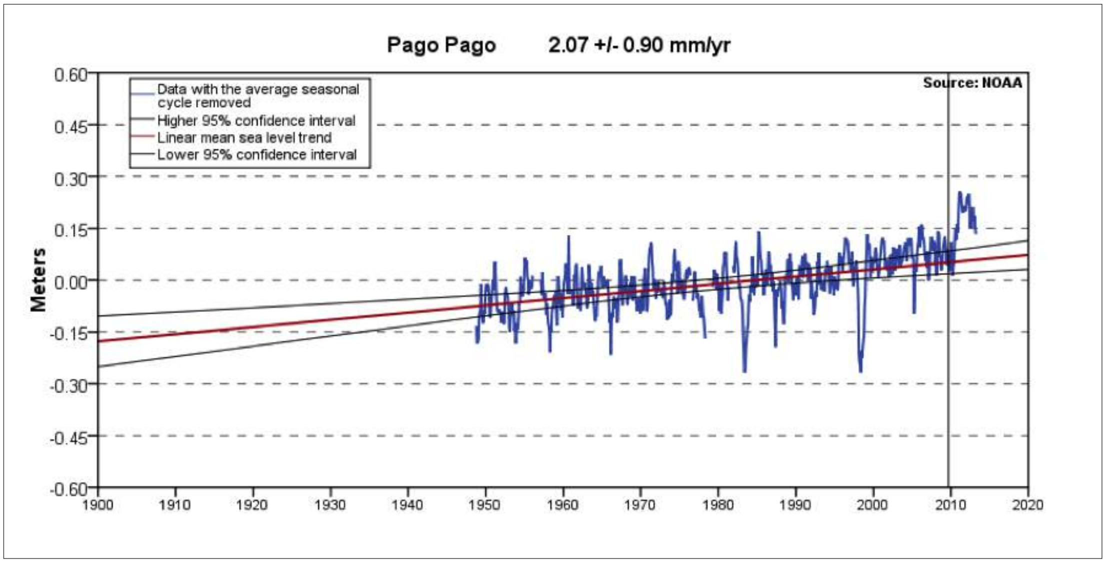

Figure 8 NOAA Annual Sea Level Rise Records

NIDIS began reporting sea level rise information in the Pacific Region, including American Samoa, in 2013. This does not show a complete assessment but may be a useful tool moving forward with mitigation plan updates. Available information from NIDIS is provided in Table 4 below.[14]

Table 4 NIDIS Sea Level Rise Information

Year	Quarter	American Samoa Reports
2013	1	Currently, all stations are 2 - 6 inches higher than normal.
2013	2	Information not available
2013	3	The monthly mean sea level in the 3rd quarter continued to show higher anomalies in most of the USAPI stations; all stations were 4 - 8 inches higher than normal. Persistently higher than average mean sea level continues to be observed across FSM and American Samoa. No significant impacts were noted
2013	4	The monthly mean sea level in the 4th quarter continued to show higher anomalies in most of the USAPI stations; all stations were 4 - 6 inches higher than normal.
2014	1	No significant impacts were reported this quarter for American Samoa.

As noted above, research is still emerging on the sea level rise hazard since it is relatively new. Although the information presented above from USGS, NOAA, and NIDIS differ in their estimated value, they all show a rising trend in mean sea level in American Samoa. In addition, climate change may also be linked to the El Niño and La Niña weather events.

13 Mean Sea Level Trend. NOAA Tides and Currents. Retrieved August 8, 2014 from http://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=1770000

14 Climate Impacts and Outlooks. (2013). Hawaii and U.S. Pacific Island Regions. Retrieved August 8, 2014 from http://www.drought.gov/media/pgfiles/Pacific%20Region%20Q2%202013%20Climate%20Impacts%20and%20Outlook.pdf

El Niño

Sea level in American Samoa did not vary significantly from July, August, and September to October, November and December during the strong and moderate El Niño years.[15] The strong years (increase in temperatures over 1.5 degrees for at least 3 months) are: 1957, 1965, 1972, 1982, 1997, and 2009. The moderate years (temperature increase of 1-1.4 degrees for at least 3 months) are: 1951, 1963, 1968, 1986, 1987, 1991, 1994, 2002, and 2009. During July, August and September, these reverse and strong trade winds cause water to pile up in South America. As a result, the sea level in South Pacific Islands (e.g., American Samoa) remains unchanged. By January, February and March, the westerly winds strengthen and move to the center to south central region.

Due to the shift of trade winds, American Samoa experiences a sea level drop with a time lag of 3-6 months. Previous El Niño events in American Samoa have led to precipitation averages about 10 percent above normal.[16] During years that follow a strong El Niño, American Samoa typically experiences a period of prolonged dryness.

La Niña

Nearly all El Niño events are associated with a persistently negative (Southern Oscillation Index) SOI near -1.0 or lower. During La Niña, the SOI is persistently positive, near +1.0 or higher. Previous events have led to precipitation amounts that average close to 10 percent below normal. La Niña events are more likely to cause a decrease in sea levels. The strong 2010-2011 season caused a mean sea level drop of 5 millimeters.[17] Strong events (decrease in temperate over 1.5 degrees for over 3 months) were 1973, 1975, 1988, 1999, and 2010. Moderate years were 1955, 1970, 1998, and 2007.

Records from 1900 to 2014 indicate 32 El Niño events and 23 La Niña events as shown in Table 5 below.

Table 5 Previous El Niño and La Niña Years [18]

El Niño	La Niña
1900-1901	--
1902-1903	1903-1904
1905-1906	1906-1907
--	1908-1909
1911-1912	--
1914-1915	1916-1917
1918-1919	1920-1921
1923-1924	1924-1925
1925-1926	1928-1929
1930-1931	1931-1932
1932-1933	1938-1939
1940-1941	--
1941-1942	1942-1943

15 i) Weier, John. (2010). "Reverberations of the Pacific Warm Pool". Intute. Retrieved August 8, 2014 from http://www.intute.ac.uk/sciences/worldguide/html/805_articles.html
ii) Special Section: ENSO and Sea-Leavel Variability: Physical Mechanism. (2004). Pacific ENSO Update: Vol. 10, No. 4. Retrieved August 8, 2014 from http://www.soest.hawaii.edu/MET/Enso/peu/2004_4th/special_section.htm
iii) El Niño theme page. Retrieved August 8, 2014 from http://www.pmel.noaa.gov/tao/elnino/nino-home.html#

16 Rainfall Variations During ENSO. NOAA National Weather Service. Retrieved August 8, 2014 from http://www.prh.noaa.gov/peac/rain/am_samoa.php

17 La Niña caused global sea level drop. (2012). Phys Org. Retrieved August 8, 2014 from http://phys.org/news/2012-10-la-nina-global-sea.html

18 El Niño and La Niña. (2014). Storm Fax. Retrieved August 8, 2014 from http://www.stormfax.com/elnino.htm

El Niño	La Niña
1946-1947	1949-1950
1951-1952	--
1953-1954	1954-1955
1957-1958	--
1963-1964	1964-1965
1965-1966	--
1969-1970	1970-1971
1972-1973	1973-1974
--	1975-1976
1976-1977	--
1977-1978	--
1982-1983	--
1986-1987	1988-1989
1991-1992	--
1992-1993	--
1994-1995	1995-1996
1997-1998	1998-1999
--	2000-2001
2002-2003	--
2004-2005	--
--	Early 2006
2006-2007	--
--	2007-2008
2009	--
--	Late 2010 - early 2011

Extent

Extent of climate change can be measured in terms of level of sea level rise change per year. USGS and NOAA sources indicate between 1.48 and 2.07 millimeters (0.06 – 0.08 inches) per year, respectively. In addition, 2 out of 4 NIDIS reports in 2013 reported an increase in mean sea level rise at 2 to 6 inches above normal. Lastly, climate change extent can be measured in terms of strong El Niño or La Niña events, which occur when temperatures are 1.5 degrees higher or lower for three consecutive months, respectively.

Probability of Future Events

El Niño and La Niña typically occur about every 2 to 7 years. Sea level changes are occurring annually. The mean trend is increasing though in some years sea level in American Samoa has decreased. Based on information from the USGS and NOAA, sea level rise is estimated to be between 1.48 and 2.07 millimeters per year, respectively as measured over time. This is an estimated average of 0.59 feet (about 6 inches) per 100 years. An accurate statistical probably is difficult to quantify for climate change but can be quantified as likely, occurring between 10% and 90% annually.

Vulnerability Assessment

The American Samoa Government passed an executive order in 2007 to address climate change. Executive Order (EO) 0101A-2007 notes several impacts of climate change to American Samoa[19]:

- A loss of landmass and shoreline from an increase in sea level;
- An increase in food costs and dependence upon off-island food sources because of a projected decreases in local agricultural production due to the increase in temperature, loss of land mass and higher rate of pest infestation;
- Potential need for the relocation of the our population and the resulting loss of spiritual connection to the land our families have occupied for centuries;
- Coral reef loss due to increases in water temperature and depth; and
- An increase in mortality and economic losses from an increase in the number and strength of tropical storms and lack of reef protection.

In addition, the EO outlines several strategies to reduce the impact through direct actions. These include transitioning to hybrid vehicles to be purchased, using incandescent light bulbs, installing vapor recovery nozzles at fuel stations, purchasing energy star appliances, and banning importation of high phosphorous (11%+) detergents.

Impacts from climate changes are also anticipated in terms of greater severity and occurrence as follows:

- Greater severity:
    - o As water moves further inland due to sea level rise, more structures are at risk to flooding and impacts.
    - o Stakeholders describe rain events as much heavier in recent years.
- Increased hazard occurrence:
    - o Meetings with stakeholders indicated that hazards are occurring more frequently such as drought, tsunami, and cyclones.
    - o In addition, stakeholders noted a change in rain events. Previous rain events would cover the entire island. Now it is common for a rain event to occur in small areas.

In addition, the USGS indicates areas of vulnerability via the Relative Coastal Vulnerability Assessment shown in Figure 9. It is specific to areas around the American Samoa National Park. The Coastal Vulnerability Index provides insight into the relative potential of coastal change due to future sea-level rise. The maps can be viewed as an indication of where physical changes are most likely to occur as sea level rises.

19 Executive Order No.010A. (2007). Office of the Governor: Pago Pago, American Samoa. Retrieved August 8, 2014 from http://www.epa.as.gov/sites/default/files/documents/climate_change/2007climatechangeeo.pdf

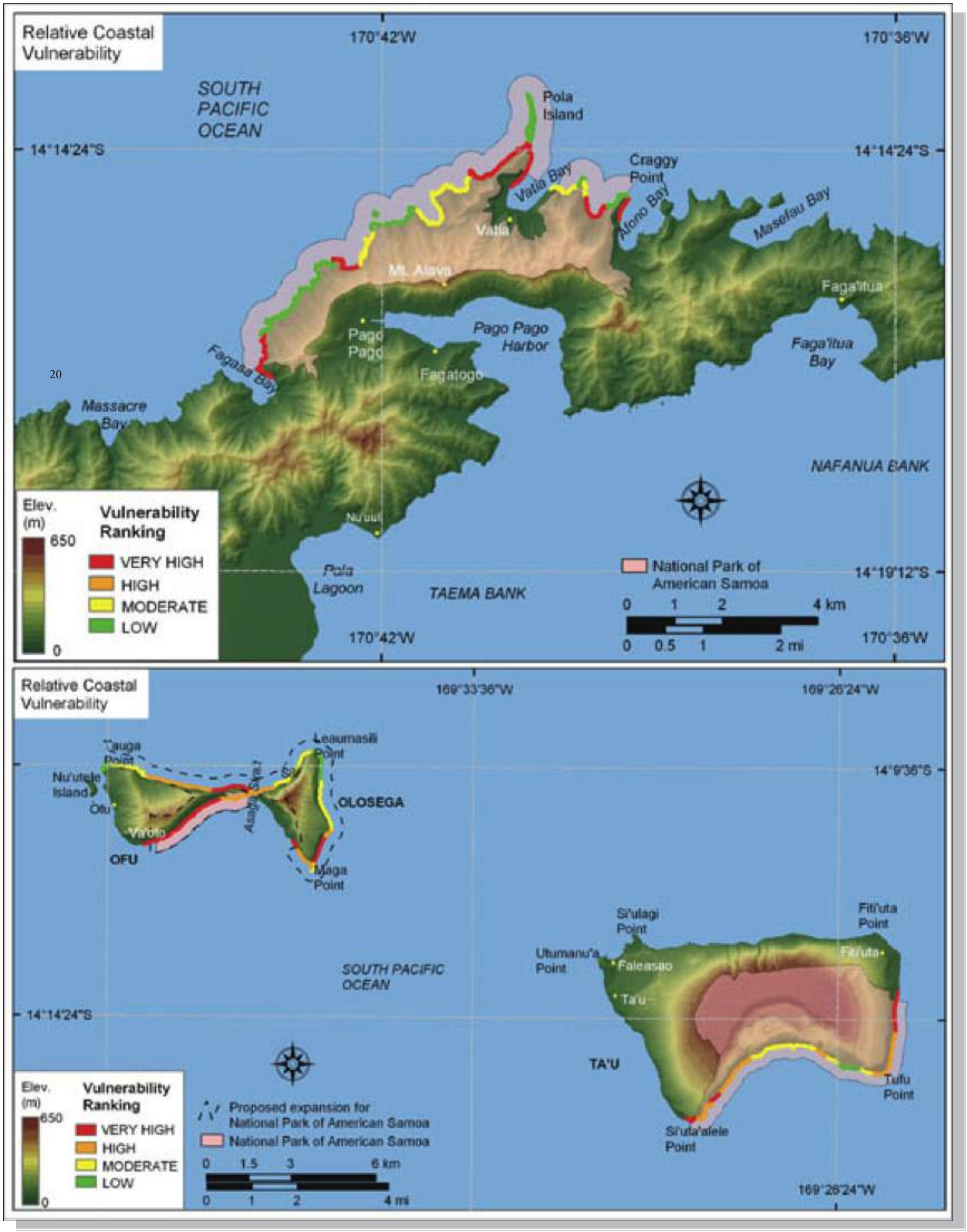

Figure 9 NOAA CVI Future Sea Level Rise Vulnerability [20]

20 Pendleton, Elizabeth, Robert Thieler, and Jeffress Williams. (2005). "Relative Coastal Vulnerability Assessment of National Park of AMerican Samoa (NPSA) to Sea-Level Rise. Retrieved August 8, 2014 from http://woodshole.er.usgs.gov/project-pages/nps-cvi/parks/npsa.htm

Potential Losses

There is an inherent risk of building in or near floodplains. Continued flooding is likely and sea level rise will flood areas further inland. In order to better define risk in American Samoa, areas of hypothetical sea level rise (SLR) data were also investigated using GIS intersect analysis to determine the number and type of building at risk to sea level rise. This analysis was also used for critical facilities. Sea Level Rise areas of 1-foot and 3-feet were used with data provided by NOAA. The results are summarized in Table 6 below.

Table 6 Buildings Potentially At Risk to Sea Level Rise

Country (District)	Total Number of Buildings	Total Number of Buildings in the 1-foot SI.R area	Type	Total of Buildings in the 3-feet SLR area	Type
TUTUILA ISLAND					
East Vaifanua (East District)	497	0	--	6	6 residential
Ituau (East District)	1,075	3	1 commercial	61	1,402
Lealataua (East District)	2,026	3	3 residential	36	36 residential
Leasina (West District)	474	0	--	0	--
Maoputasi (East District)	2,246	0	--	0	--
Saole (East District)	543	0	--	2	2 residential
Sua (East District)	938	0	-	0	--
Tualatai (West District)	903	0	--	0	--
Tualata (West District)	7,441	0	--	1	1 residential
West Vaifanua (East District)	172	0	--	5	5 residential
Tutuila Island Total	16,315	16	--	141	--
AUNU'U ISLAND					
Saole (East District)	179	0	--	0	--
Aunu'u Island Total	179	0	--	0	--
MANU'A ISLANDS					
TA'U					
Faleasao (Manu'a District)	18	0	--	0	--
Fitiuta (Manu'a District)	180	0	--	0	--
Tau (Manu'a District)	208	0	--	1	1 fale
Ta'u Island Total	469	0	--	1	--

OFU ISLAND					
Ofu (Manu'a District)	133	1	unknown	2	unknown
Ofu Island Total	133	1	--	2	--
OLOSEGA ISLAND					
Olosega (Manu'a District)	101	--	--	--	--
Olosega Island Total	101	--	--	--	--
TOTAL	**17,018**	**16**	**--**	**141**	**--**

The analysis indicates that Maoputasi County has the greatest number of buildings at risk to sea level rise. The county is densely developed along the coast and Pago Pago resides here, adding to the vulnerability.
A critical facility analysis was also performed using available data. The results indicated that one critical facility, the KKHJ Radio Station, is potentially in the 1-foot SLR risk area in Tutuila. In addition, five critical facilities were reported as in the 3-feet SLR area in Tutuila: Masefau Elementary School (3 structures valued at a combined $675,000), District Court Building ($54,000) and the KKHJ Radio Station. These structures have an approximate combined value of $730,000. No critical facilities were determined to be in the 1-foot or 3-feet SRL area in Ta'u. These structures are highlighted in Table 7, Figure 10, and Figure 11. In addition, assembly areas, safe zones, tsunami sirens, and ASTCA communication infrastructure were analyzed for vulnerability. The results are reported below.

Table 7 Number of Critical Facilities (CFs) in the SLR Hazard Area

Location	Total Number of Buildings	Total Number of CF in the 1-foot SLR area	Value	Total Number of Buildings in the 3-feet SLR area	Value
Tutuila Island CFs	240	1	N/A	5	$730,000
Ta'u Island CFs	42	0	--	0	--

- Assembly areas
  - No assembly areas were found to intersect the 1-foot or 3-feet SLR areas.

- Safe Zones
  - All four safe zone areas in Tutuila intersect with the 1-foot and 3-feet SLR areas.

- Tsunami Sirens
  - Two sirens were located in the 3 -feet SRL area: number 4 (Maoputasi County) and number 19 (Sua County). These structures, mostly new and made of metal, are largely fortified from flood. However, frequent flooding may compromise their foundation.

- ASTCA Infrastructure
  - No ASTCA infrastructure was found to be located in the SLR areas.

A complete listing of critical facilities and associated information (such as assembly areas, safe zones, and tsunami sirens) can be found in Appendix D.

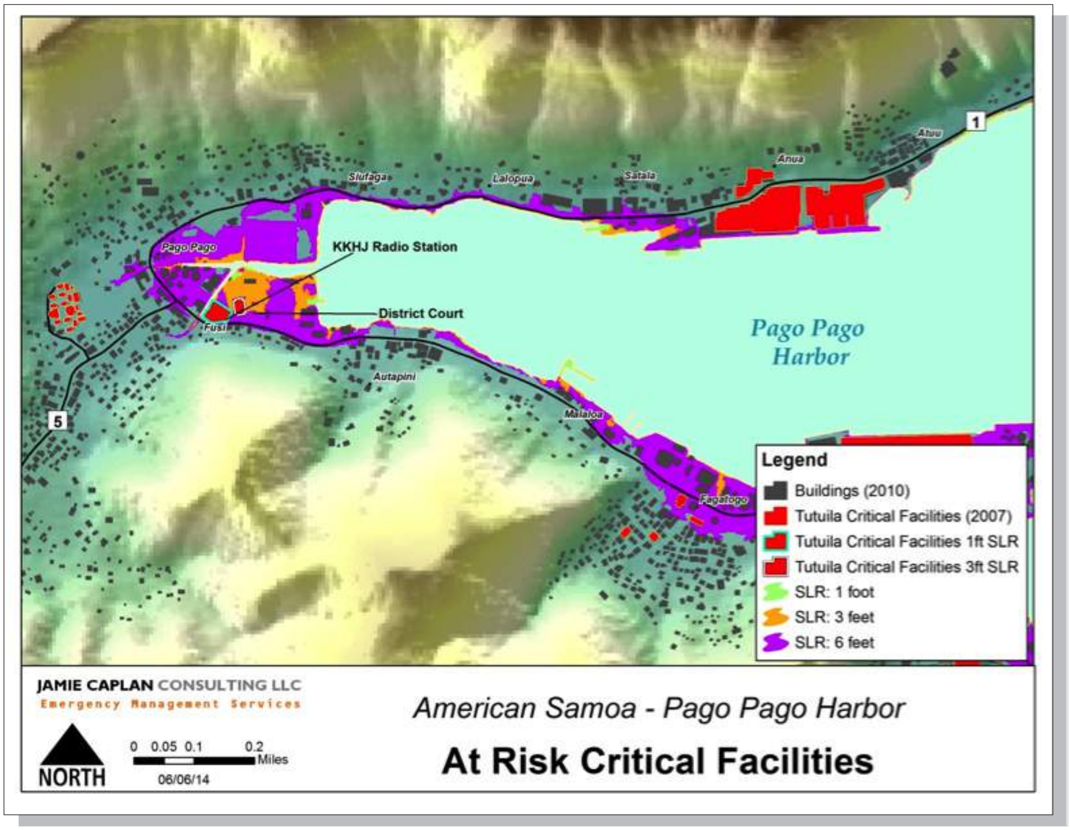

Figure 10 Critical Facilities Potentially at Risk to Sea Level Rise (Greater Pago Pago)

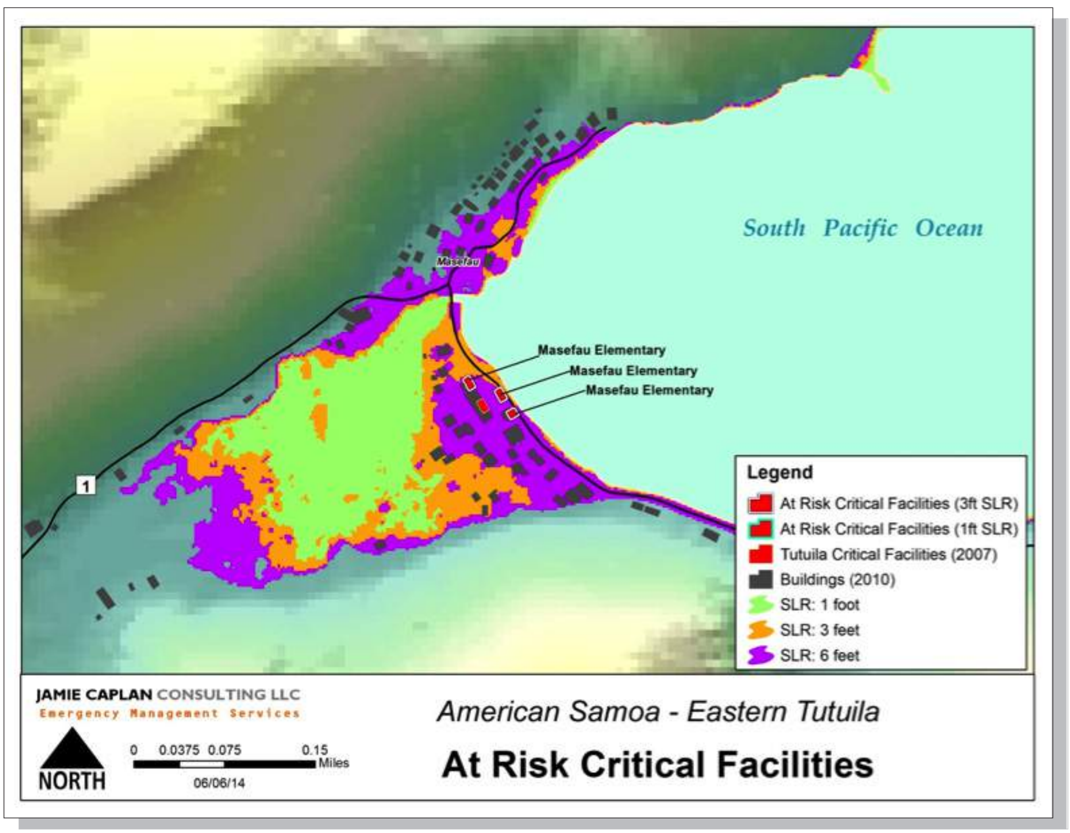

Figure 11 Critical Facilities Potentially At Risk to Sea Level Rise (Eastern Tutuila)

Coastal Erosion

Description

According to the USGS, erosion is the process whereby materials of the earth's crust are loosened, dissolved, or worn away and simultaneously moved from one place to another. Waves, wind and currents all work to erode coastlines. Further, erosion can be exacerbated by human activity such as development that may cause premature degradation of shoreline, disruption of vegetative materials holding the soils in place, or excessive runoff, which washes the shore away. This is evident in American Samoa, which does not have many wide beaches. Opposite to erosion, a natural accretion process occurs, when deposits of sediment are added to the shoreline. When the erosion process exceeds the accretion process, beaches shrink horizontally. Given these two competing processes, the amount of erosion varies over time.

Coastal erosion is a slow onset hazard, meaning that very small changes occur over time and impacts may not be felt immediately. In other words, erosion today may not be creating any damages to structures. However, as erosion becomes severe enough to impact properties, it may be too late to mitigate the issue.

Often, however, mitigation measures can be put in place to lessen the impact and speed of erosion. For example, an interlocking concrete system known as "Samoa Stone" was used in the village of Vatia on the northern coast of Tutuila. The interlocking mechanism makes it very stable against wave action. In addition, coral reef serves as a natural barrier to erosion by softening the intensity of wave actions and run-up. American Samoa's Crown-of-thorns starfish (COTS) outbreaks, hurricanes, and mass coral bleaching episodes had caused declines in hard coral cover, but coral reefs now show good recovery.

Figure 12 Samoa Stone in Vatia [21]

21 Photo by Rommel S. Dorado. Google Maps Imagery.

Shoreline erosion is of particular concern in American Samoa and has been since at least since World War II. There is limited flat land, and most of that is in the form of narrow coastal plains at the base of steep mountains. As a result, almost all villages are built along the coast, close to, or impinging upon, the shoreline. While this is common throughout the islands, Figure 13 below shows imagery of Vatia Village along the coast. The connecting roads parallel the shoreline, often at the seaward edge of the backshore berm.

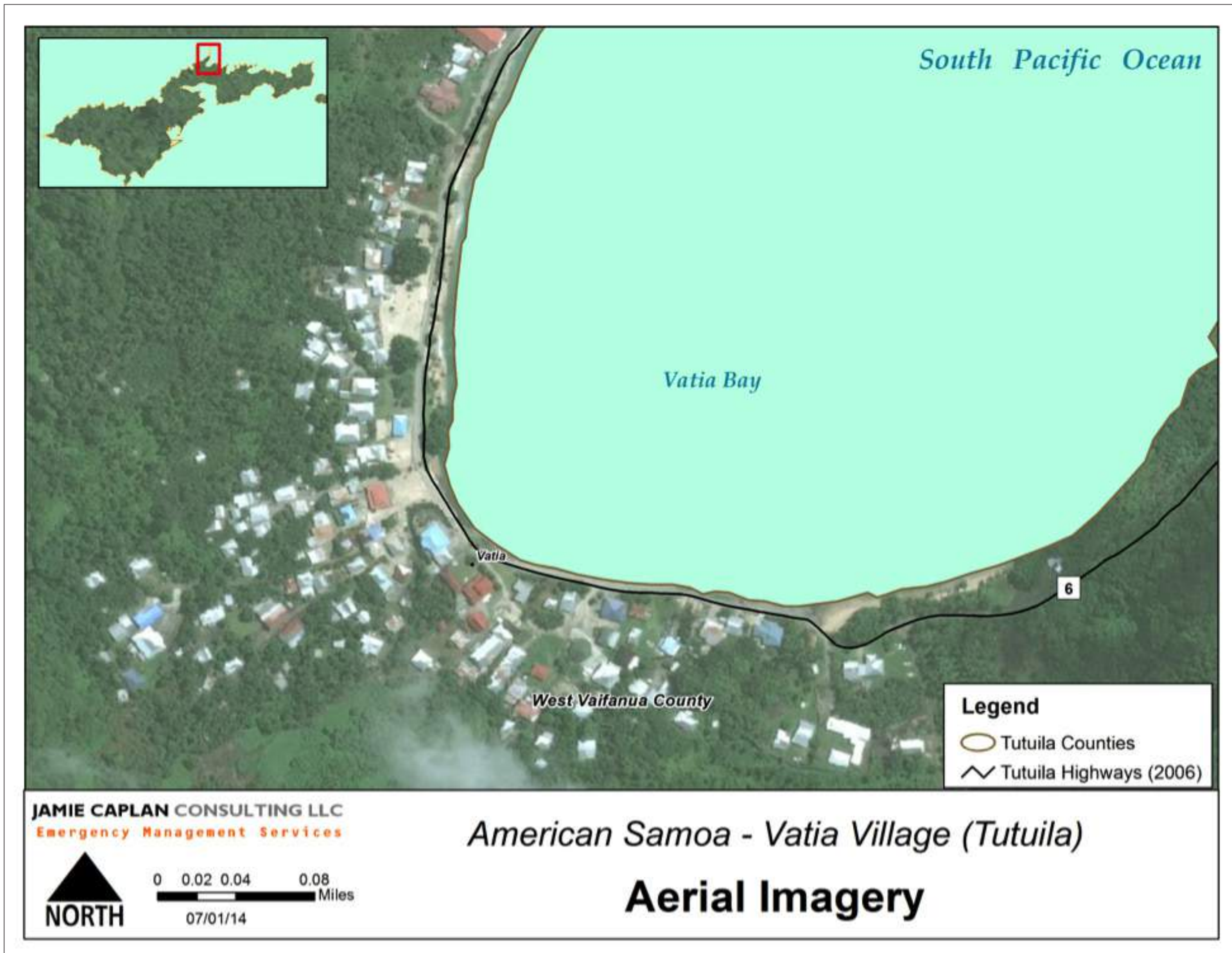

Figure 13 Typical Building Proximity to the Coast (Vatia Village)

Until recently, limited regulatory practices were in place to control sediment and erosion. In 2011, "The American Samoa Erosion and Sediment Control Field Guide was developed for contractors and site inspectors." A consultant prepared it for the American Samoa Environmental Protection Agency (ASEPA) and the American Samoa Coastal Zone Management Program. This guide ensures compliance with the USEPA National Pollutant Discharge Eliminations System (under the Clean Water Act), the American Samoa Water Quality Standards (ASAC 24.02), and the American Samoa Coastal Management Program (ASAC 26.02). This guidance helps to limit erosion from man-made causes.

Location

There are approximately 120 miles of shorelines across the 7 islands of American Samoa. All coastal areas in American Samoa are subject to coastal erosion. Although erosion is a natural process, severe weather events, such as storm surge and hurricanes, as well as human development, may exacerbate the process.

In 2004, the Coastal Engineers of the U.S. Army Corp of Engineers, Honolulu District, conducted a shoreline study for Tutuila and Aunu'u Islands. It classified American Samoa shorelines into several erosion and shoreline protection categories:

Shoreline Erosion Status

- Critical: Highly susceptible to erosion
- Potentially Critical: Moderately susceptible to erosion
- Non-critical: Low susceptibility to erosion

Shoreline Protection Type

- Engineered: Professionally installed seawall or other manmade protection
- Marginal: Slight modification but not professionally constructed
- None: No protection

Table 8 below indicates the amount of critical areas in American Samoa on Tutuila and Aunu'u Islands. The following maps (Figure 14 through Figure 17) show shoreline erosion and protection areas. Unfortunately this data was not available for the Manu'a Group or atolls. The shorelines with the greatest need of protection would be the Critical (red) and Potentially Critical (orange) with no protection (white). As noted above, it is common for development to be in very close proximity to the shorelines (as depicted in Figure 13 on page 29). This makes areas of critical shoreline of particular concern. In many cases, development is just a few meters from the coast. Therefore, minimal erosion could lead to great losses for coastal villages in American Samoa.

Table 8 Amount of Critical Shoreline on Tutuila and Aunu'u Islands

County	Approx. Measured Shoreline (miles)[22]	Critical Shoreline (miles)	Percent Critical Shoreline
TUTUILA ISLAND			
East Vaifanua (East District)	3.39	0.20	6%
Ituau (East District)	3.42	0.78	23%
Lealataua (West District)	5.69	0.92	16%
Leasina (West District)	N/A	N/A	N/A
Maoputasi (East District)	7.42	0.65	9%
Saole* (East District)	4.40	0.63	14%
Sua (East District)	6.70	1.99	30%
Tualatai (West District)	1.29	0.11	9%
Tualata** (West District)	1.35	0	0%
West Vaifanua (East District)	1.40	0.19	14%
TOTAL	**31.23**	**8.94**	**29%**

**No areas of critical shoreline reported in Aunu'u*

***Tualauta County includes the area around the Pago Pago Airport, which is an area of non-critical erosion status.*

22 Total shoreline value was not available. The total shoreline was not measured for each county in the USACE study.

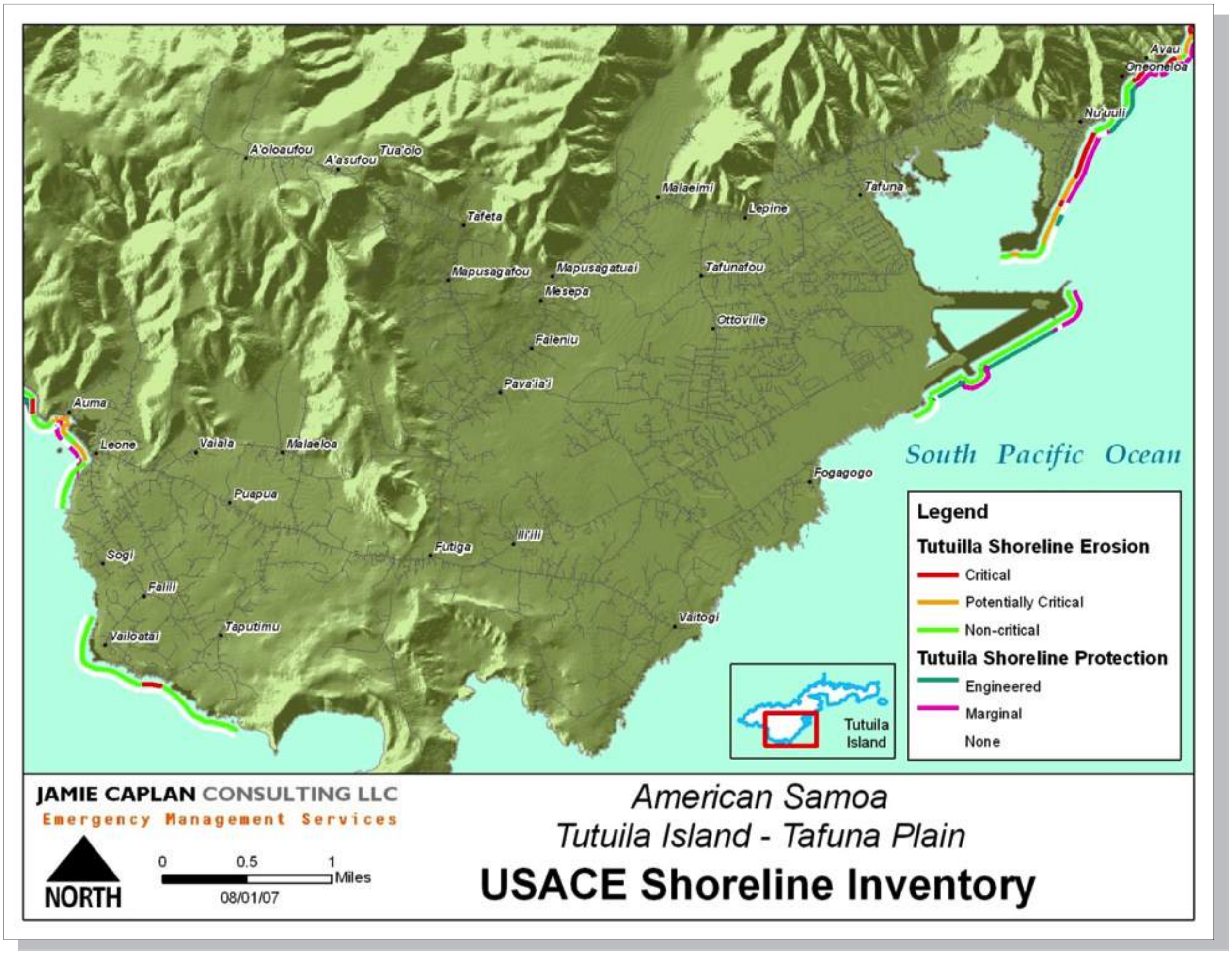

Figure 14 Tutuila Island – Tafuna Plain, USACE Shoreline Inventory

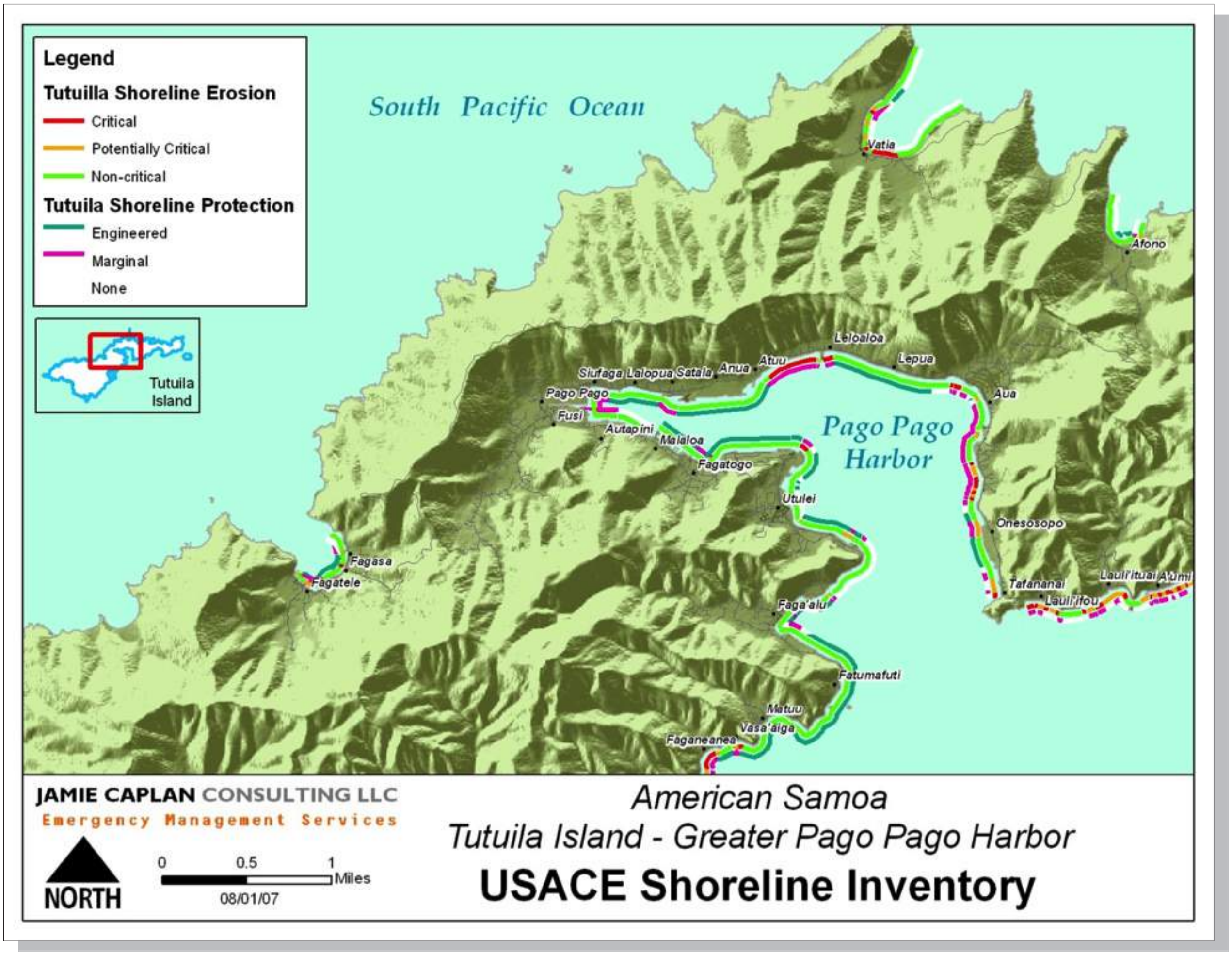

Figure 15 Tutuila Island – Greater Pago Pago Harbor, USACE Shoreline Inventory

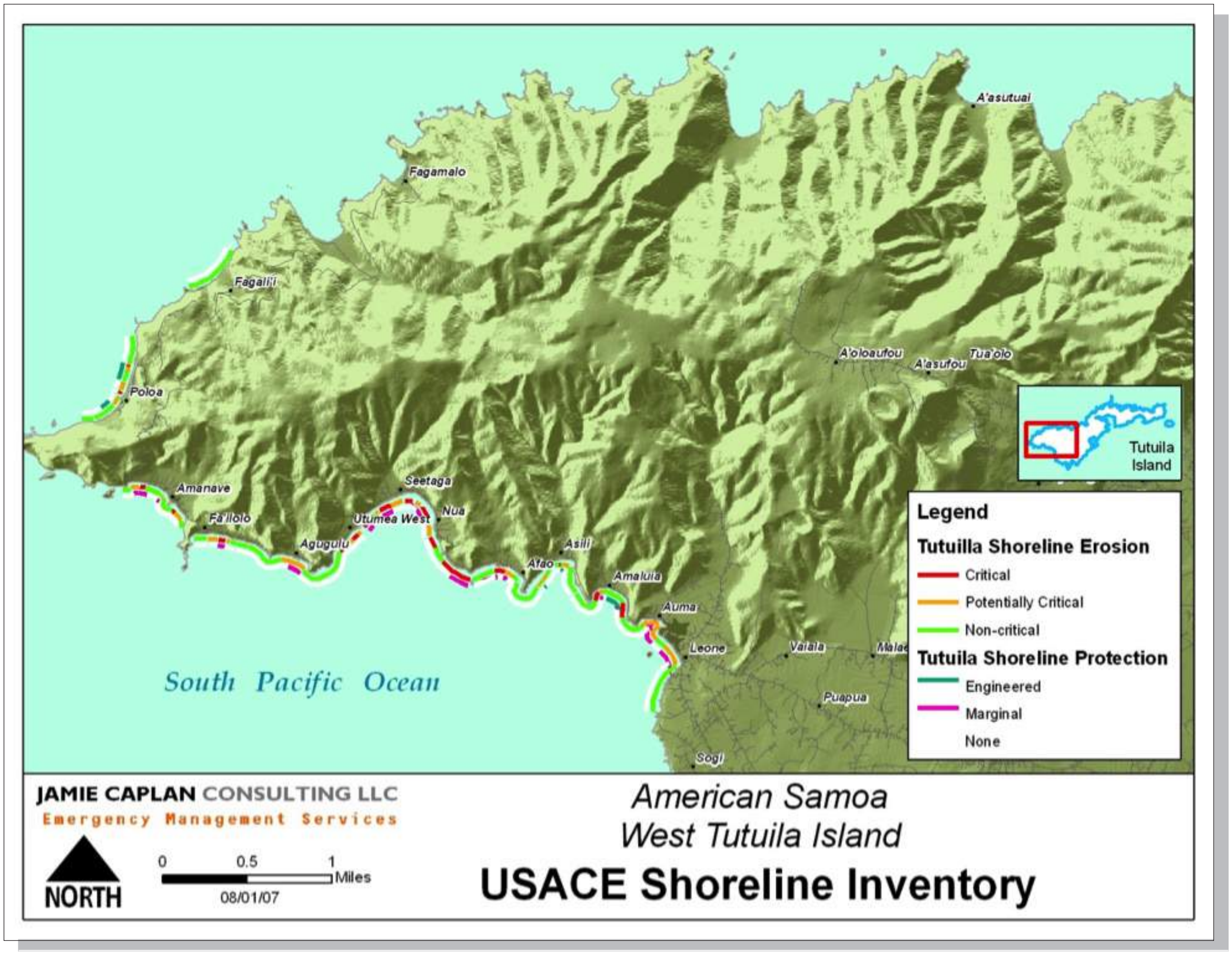

Figure 16 West Tutuila Island, USACE Shoreline Inventory

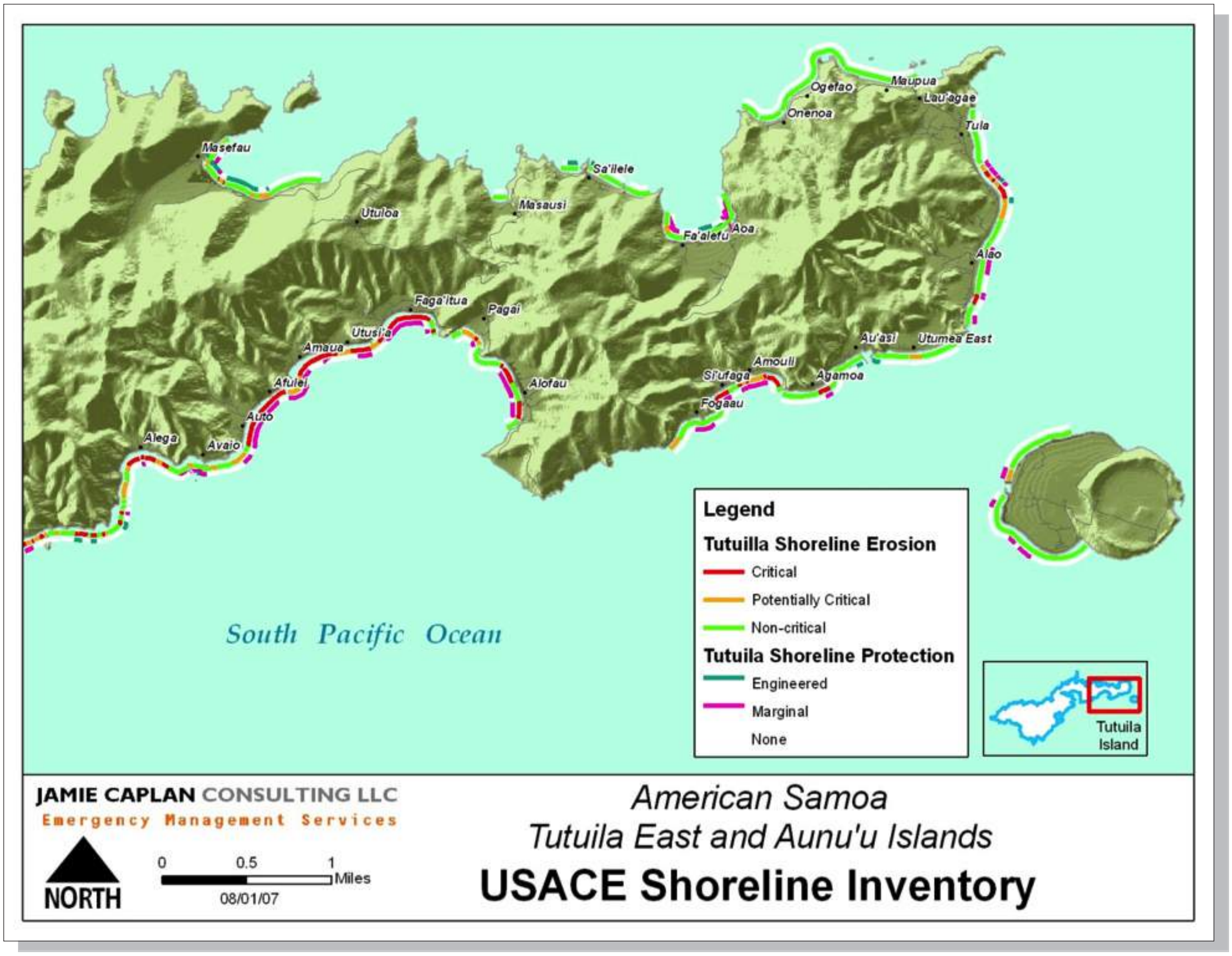

Figure 17 Tutuila East and Aunu'u Island, USACE Shoreline Inventory

Previous Occurences
NOAA's National Climatic Data Center reported one erosion event in May 2000: A high surf event combined with high tide led to beach erosion in low lying areas along the main road. Washed up debris, sand and rocks resulted in roadblocks. Estimated damage was $100,000.

In addition, the 2009 tsunami caused extension erosion damage. Information was gathered from the Geer Association.[23] Figure 18 below shows wave induced bluff erosion from the Tsunami in Aufaga. Beach erosion and sediment displacement were observed in Alao, Poloa, Amanave, Asili, and Leone. Along with the erosion from the tsunami, also came the uprooting of vegetation. Vegetation helps to stabilize the coast, so loss of vegetation can further exacerbate erosion.

Despite just one found reported event, Coastal erosion in American Samoa is a regular occurrence given the volcanic composition of the island. Coastal erosion is a slow onset hazard, meaning that very small changes over time may eventually result in large problems.

Figure 18 Bluff Erosion in American Samoa

Extent
Using the USACE study and terminology, critical areas (those highly susceptible to erosion) can be used to represent greatest extent. Such areas are currently present including at least nine miles on Tutuila Island. The entire shoreline could be subject to this status of erosion. Erosion does occur gradually and varies over time. Erosion put all current and future structures along the coast at risk to falling into the ocean. In addition, the beaches themselves are at risk to decreasing in horizontal area, reducing the width of the beach (sandy or rocky areas separating the water from inland areas).

23 Geo-Hazards. (2009). Geotechnical Extreme Events Reconnaissance. Retrieved August 8, 2014 from http://www.geerassociation.org/GEER_Post%20EQ%20Reports/American%20Samoa_2009/AmSamoa09_Ch05.html

Probability of Future Events

Given the limited reported erosion occurrences, a numerical statistical probability is difficult to calculate. However, the volcanic composition of the island and location in the South Pacific Ocean make regular and future erosion a certain occurrence. Therefore, the future probability was indicated as highly likely, greater than 90 percent annual probability.

Vulnerability Assessment

As erosion continues along the shoreline, impacts to structures and beaches can be expected.
Figure 19 below shows an actual example of coastal erosion in American Samoa (photo taken on 2014 site visit; structure likely impacted by tsunami).

Figure 19 Severely Eroded Shoreline in the Village of Leone (Tutuila Island)

Potential Losses

Areas of critical erosion were analyzed to determine the vulnerability of existing structures using GIS intersect analysis to determine the number and type of building at risk to erosion. Initially, no buildings or critical facilities or associated structures were found to be in an area of critical erosion. This is because the data only portrays critical areas along a narrow shoreline. In order to demonstrate buildings of greatest risk, a 0.1 mile buffer was applied to critical shorelines. As a result, the areas in the buffer zone can be considered most at risk to erosion. However, it should be noted that other areas at risk to erosion and may be experiencing erosion as shown by potentially critical areas in the maps above. Further, other areas, such as Leone (figure 19) may be experiencing coastal erosion due to recent coastal storms.[24]

Continued erosion and associated sea level rise are likely to threaten many buildings along the coastline.
A GIS intersect analysis was used to determine the number and types of buildings most at risk to coastal erosion. The results are summarized in Table 9.

24 The USACE Erosion data is current as as 2004. This was the best and most current data available for the planning area.

Table 9 Buildings Potentially At Risk to Coastal Erosion

County (District)	Total Number of Buildings	Total Number of Buildings in Critical Erosion Areas	Percent of Buildings at risk	Type
TUTUILA ISLAND				
East Vaifanua (East District)	497	31	6%	31 residential
Ituau (East District)	1,075	125	12%	1 business 1 commercial 123 residential
Lealataua (West District)	2,026	297	15%	4 church 293 residential
Leasina (West District)	474	0	--	--
Maoputasi (East District)	2,246	154	7%	1 Tedi 2 commercial 5 government 146 residential
Saole* (East District)	364	130	24%	1 business 129 residential
Sua (East District)	938	285	30%	2 business 2 commercial 4 church 15 residential
Tualatai (West District)	903	2	0%	2 residential
Tualata (West District)	7,441	0	--	--
West Vaifanua (East District)	172	87	51%	87 residential
TOTAL	**16,136**	**1,111**	**7&**	--

**All at risk buildings located on Tutuila Island. There are no areas of critical erosion identified on Aunu'u Island (Saole County). There is no data available for the Manu'a District.*

The analysis indicates Sua County has the highest percentage of buildings at risk. Sua is located in eastern Tutuila and has coastline on the north and south coastlines of the island. Given the exposure to the ocean on both sides, it is understandable why there is a high risk to coastal erosion. The analysis also indicates that Lealataua, Sua and Saole have the highest number of buildings at risk. All of these counties have significant shoreline and development along them.

A critical facility analysis was also performed using available data. The results indicated 25 critical facilities were located in the areas most at risk to coastal erosion. These structures have an approximate combined value of $13.7 million. These structures are highlighted in Table 10 and Figure 20. In addition, assembly areas, safe zones, tsunami sirens, and ASTCA communication infrastructure were analyzed for vulnerability. The results are reported below.

Table 10 Number of Critical Facilities (CFs) at Risk to Coastal Erosion

Location	Total Number of CFs	Total Number of CFs Most at Risk Coastal Erosion	Value
Tutuila Island CFs	240	25	$13,724,000
Ta'u Island CFs	42	N/A	--

Assembly areas

- Five assembly areas were found to intersect the areas at greatest risk to coastal erosion.

Safe Zones

- No safe zone areas in Tutuila intersect with the areas at greatest risk to coastal erosion.

Tsunami Sirens

- Fifteen sirens were found to intersect the areas at greatest risk to coastal erosion. These structures, mostly new and made of metal, are largely fortified from flood. However, frequent flooding may compromise their foundation.

ASTCA Infrastructure

- Five ASTCA infrastructure sites were found to be located in the areas at greatest risk to coastal erosion.

In addition to analyzed structures, there are several World War II Pill Boxes along the shorelines. There was no associated GIS data for their location, however. They are made of concrete so are somewhat resistant to erosion forces but often seem to have shifted from their original placement. Since many are several feet into the water and appear to be shifting due to erosion, these structures should be considered at risk to future erosion impacts.

A complete listing of critical facilities and associated information (such as assembly areas, safe zones, and tsunami sirens) can be found in Appendix D.

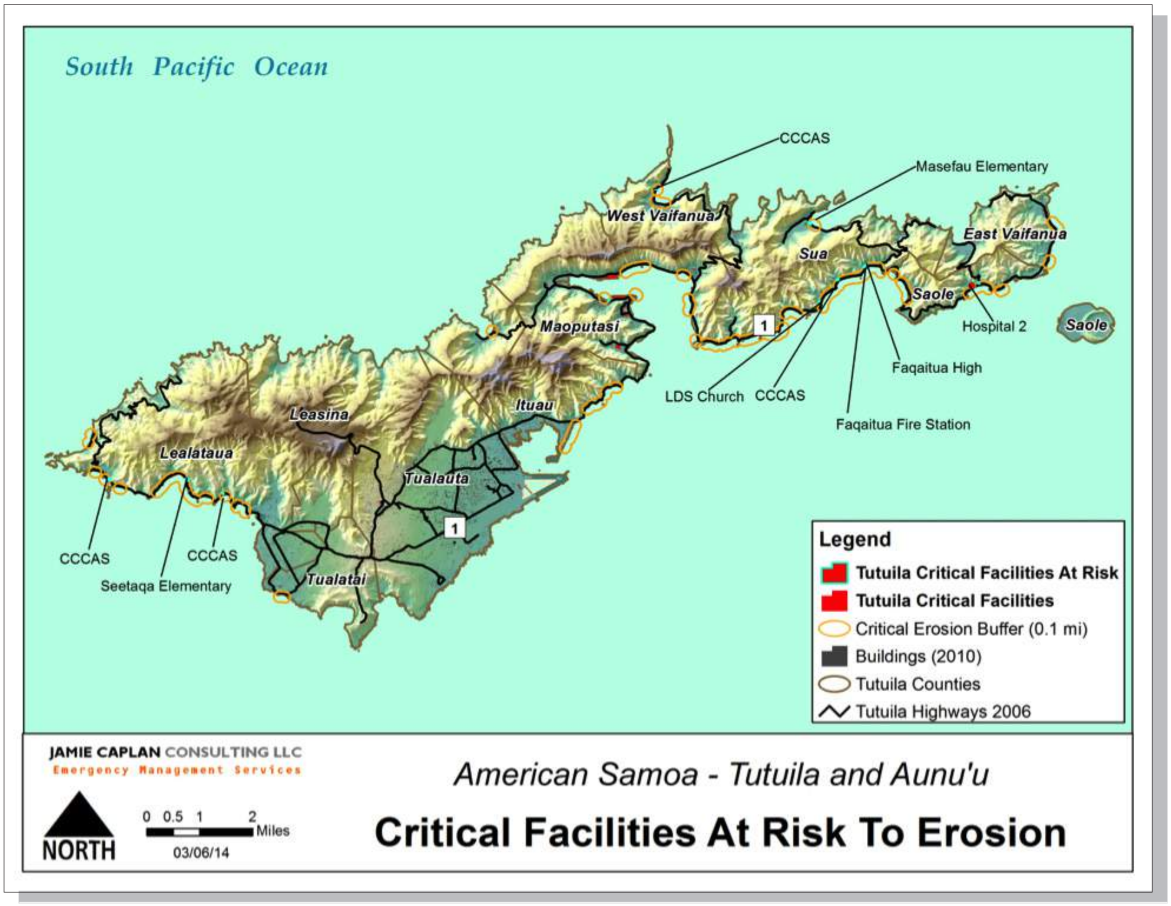

Figure 20 Critical Facilities at Greatest Risk to Coastal Erosion

Drought

Description

Although sometimes considered a rare and random event, drought is a normal, recurrent feature of climate. Drought is a temporary aberration and differs from aridity, as the latter is restricted to low rainfall regions and is a permanent feature of climate. Other climatic factors such as high temperatures, high wind, and low relative humidity are often associated with drought in many regions, including the Pacific Basin. Drought occurs in virtually all-climatic zones, varying significantly from one region to another, and can be defined according to meteorological, hydrological, or agricultural criteria. Drought is typically categorized in three types as shown in Table 11 below:

Table 11 Drought Types

Drought Type	Description
Meteorological Drought	Meteorological drought is usually based on long-term precipitation departures from normal, but there is no consensus regarding the threshold of the deficit or the minimum duration of the lack of precipitation that makes a dry spell an official drought.
Hydrological Drought	Hydrological drought refers to deficiencies in surface and subsurface water supplies. It is measured as stream flow, and as lake, reservoir, and ground water levels.
Agricultural Drought	Agricultural drought occurs when there is insufficient soil moisture to meet the needs of a particular crop at a particular time. A deficit of rainfall over cropped areas during critical periods of the growth cycle can result in destroyed or underdeveloped crops with greatly depleted yields. Agricultural drought is typically evident after meteorological drought but before a hydrological drought.

Drought should not be viewed as merely a physical phenomenon or natural event. Its impacts on society result from the interplay between a natural event and the demand people place on water supply. Recent droughts in both developing and developed countries, and the resulting economic and environmental impacts and personal hardships, have underscored the vulnerability of all societies to this “natural” hazard. Human activities often exacerbate the impact of drought. For example, water use can deplete ground water supply.

According to NOAA, precipitation totals below eight inches of the normal median amount are considered a critical threshold in the Pacific Islands.[25] The U.S. Drought Monitor, also records drought in the U.S. and categorizes drought into five categories as shown in Table 12. Although the U.S. Drought Monitor does not monitor drought in American Samoa, the descriptions of severity are a good measure in which to relate drought events throughout the world.

25 National Drought. (2014). National Climatic Data Center: Issue 14. Retrieved August 8, 2014 from https://www.ncdc.noaa.gov/sotc/drought/2014/1#det-reg-pacis

D0	Abnormally Dry	Going into drought: short-term dryness slowing planting, growth of crops or pastures. Coming out of drought: some lingering water deficits; pastures or crops not fully recovered
D1	Moderate Drought	Some damage to crops, pastures; streams, reservoirs, or wells low, some water shortages developing or imminent; voluntary water-use restrictions requested
D2	Severe Drought	Crop or pasture losses likely; water shortages common; water restrictions imposed
D3	Extreme Drought	Major crop/pasture losses; widespread water shortages or restrictions
D4	Exceptional Drought	Exceptional and widespread crop/pasture losses; shortages of water in reservoirs, streams, and wells creating water emergencies

Table 12 Five dought categatories categorized by U.S. Drought Monitor

Location
A drought is a regional event that is not confined to geographic or political boundaries; it can affect several areas at once. However, it can range in severity across those areas. All of American Samoa is at risk to drought occurrence.

Previous Occurences
In order to understand the conditions of past drought, it can be helpful to understand the normal precipitation received each year. American Samoa is a tropical rain forest climate and typically receives over 120 inches of rainfall annually. NOAA reports the following as normal monthly precipitation levels as shown in Figure 21.

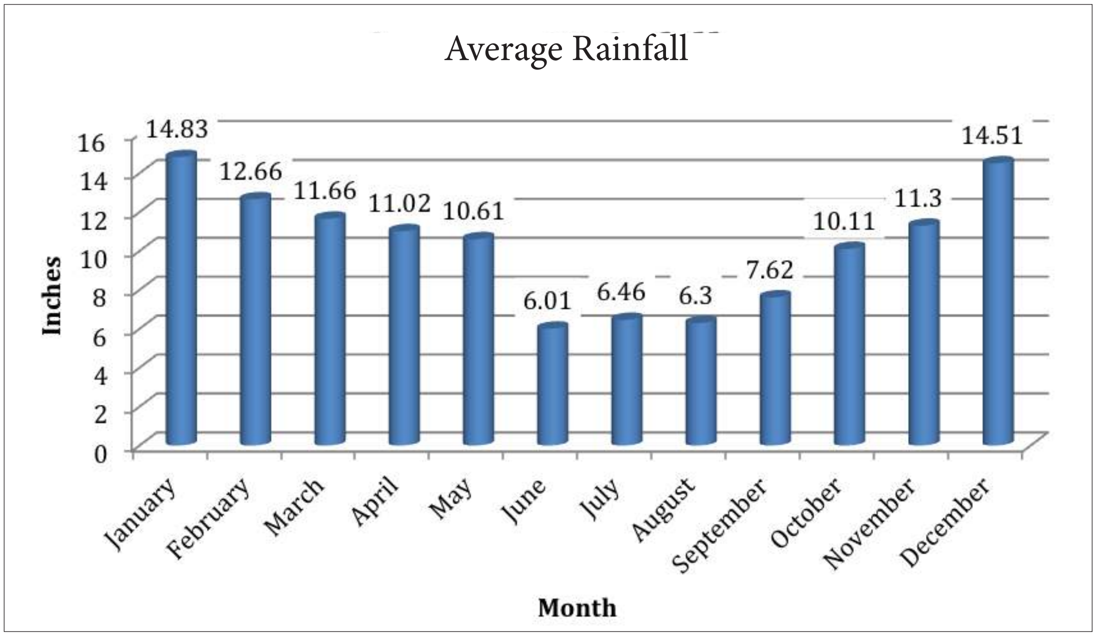

Figure 21 Average Rainfall in American Samoa (NOAA, Pago Pago Station)

Average monthly rainfall amounts of less than three inches per month for three consecutive months are indicative of potential drought in American Samoa, as was the case in 1974 and 1983. [26] The 1998 drought was declared after nine consecutive months of less than half the average monthly rainfall. The effects of drought tend to be long lasting throughout the Territory, as impact on agricultural crops is often devastating, and recovery time can be one or more growing seasons in length. Extended drought periods also present a fire hazard. Table 13 below shows a summary of significant droughts.

The USGS has indicated that as long as the Territory receives steady rainfall, at least 16 million gallons of water seeps into the fresh water zone per day. In 1998, water usage per day averaged about 8 million gallons, with 2 million gallons utilized by the local canneries, 2 million gallons for residential use, 1 million gallons to other businesses, and 1 million lost through leaks.[27] The old underground pipes of Pago Pago and Fagatogo areas were notorious for leaks before recent mitigation efforts.

Table 13 Summary of significant doughts

Event Type, Date	Location	Severity	Impacts
Drought, 1974 - 1975	All Islands	Significant impact.	Dried up underground water sources. Sediment made water undrinkable. Vegetation dried up, many crops damaged, causing food shortages. Drought broke with several days of heavy rainfall that caused devastating landslides. Water rationing, closure of schools, curtailment of fish cannery operations, reduction of work hours for government employees. Territory-wide recession.
Drought, 1983 - 1984	All Islands	Greatest impact.	Water rationing, school closure for 1 week. Cannery closed for 6 months, concurrent with renovations. Reduction of work hours for government employees. Territory-wide recession.
Drought, 1998	All Islands	Most severe, but less impacts due to improved capacity.	Wells in Tualauta District started to taste salty as groundwater levels were depleted. Only 10.11 inches of rain recorded by the weather bureau at Tutuila's airport from April to August. Several wells and rivers dried up, the Aunu'u natural spring evaporated, and the catchment area at Malaeloa completely dried up.
Drought, September 2011	All Islands	3 consecutive months of less than normal rainfall (between 26% 60%)	This event was less severe than previous occurrences and was quenched by rainfall the following month. However, it did prompt a U.S. Coast Guard/New Zealand team to send a ship with a desalination plant on board.

Drought Event (1974-1975)

According to some sources, the 1974 drought was considered the most devastating in American Samoa during the past 50 years with major impacts to the islands resulting in water rationing, and closure of schools.[28] Four to five months without rain during the Territory's usually drier wintertime depleted underground water sources.

26 "American Samoa Governor Declares State of Emergency." (1998). The Samoa News.
27 "Water Department Officials Take Water Conservation to the Schools." (1998). The Samoa News.
28 Ibid.

From April to August, only 24.28 inches of rainfall was recorded at the airport weather station in Tutuila. Above ground water was unavailable, and sediment in ground water sources made water undrinkable in places. Vegetation dried up throughout the island, and many crops were damaged. Vegetable crops failed. Taro and banana, staples in the local diet, were drastically impacted, causing food shortages. Impacts were felt even after rainfall returned. Taro fields had to be replanted, and it was eight months before the crop was harvestable. Bananas were quicker to come back. The drought finally broke with several days of heavy rainfall that caused devastating landslides.

Drought Event (1983-1984)

According to the National Weather Service office on Tutuila, the 1983 drought lasted for 6 months, with major impacts on the Territory, causing water rationing and closure of schools for 1 week. One cannery closed for 6 months, coincident with renovations. American Samoa's Governor arranged for Department of the Interior funds to support employees during this time. Both the 1974 and 1983 droughts resulted in the curtailment of fish cannery operations, reduction of work hours for government employees, and a general territorial-wide recession.[29]

Drought Event (1998)

A Samoa News article dated September 17, 1998 quoted the Executive Director of American Samoa Power Authority (ASPA), saying that the 1998 drought was "the worst one American Samoa has ever experienced."[30] ASPA is in charge of water operations in the territory. Wells in Tualauta District started to taste salty from the lack of rain as groundwater levels were depleted. Only 10.11 inches of rain were recorded by the weather bureau at Tutuila's airport from April to August. The previous record low rainfall for the same 5-month period was 18.52 inches in 1983. In contrast, another major drought year in 1974 recorded 24.28 inches during the same 5-month time period. Public response to the lack of rainfall in terms of subsequent reduced consumption on the part of the general public and the tuna canneries was particularly helpful. In another Samoa News article dated May 18, 1998, the acting Governor initiated a Water Conservation Campaign, urging ASG employees to "exercise the utmost discretion in the use of our public water resources."[31] Less than an inch of rain had been recorded in the first 3 weeks of the month of May. American Samoa received $267,000 from U.S. Office of Insular Affairs in drought mitigation funds during this drought, much of which went to the outer islands.

The NOAA Weather Service in Tafuna reported that September through December of 1997 received 50% less rainfall than the same 4-month period in 1996, and that January through April 1998 rainfall had decreased by almost 60% compared to the same period in 1997.[32] The month of May 1998 received less than 2 inches compared to 10 inches the previous year.

After an announcement of a possible drought in May 1998, ASPA launched a massive conservation campaign which included educational talks, visiting families with water consumption over 50,000 gallons, and repair of leaky pipes. ASPA noted that several wells and rivers had dried up, the Aunu'u natural spring had evaporated into nothing, and the catchment area at Malaeloa was completely dried up and more water outlets were predicted to follow suit.

29 "American Samoa Governor Declares State of Emergency." (1998). The Samoa News.
30 "ASPA Director Says This is American Samoa's Worst Drought." (1998). The Samoa News.
31 "Drought Conditions Remain in American Samoa." (1998). The Samoa News.
32 Ibid.

By early June, Governor Tauese Sunia declared American Samoa in a Territory of Emergency, charging ASPA with the responsibility to continue conservation efforts, and to take additional actions to: procure water production equipment, inventory all water systems, extend transmission and distribution lines to residents not served by the ASG water system, and build new water storage facilities.

By August, water losses had been reduced by 21 percent, largely through a water-recycling project at the tuna canneries and the massive campaign to locate and repair leaks in the water delivery piping system, made possible through mitigation funding.

In October, American Samoa's drinking water sources remained in critical condition, and federal assistance legislation was in progress to purchase water purification equipment. Even with the return of regular rainfall, it takes years for the Territory to replenish its aquifer.

While certainly the most severe drought experienced in American Samoa over the period discussed in this assessment, the 1998 drought did not have the greatest impact due to the islands' increased capacity to manage this type of event. Mitigation measures such as repair of leaking pipes, an increase in the number of ground wells, and greater catchment and reservoir capacity were implemented with good results. American Samoa now has a reserve capacity of 800,000 to 1 million gallons per day. Water loss due to leaky pipes is now a mere 18 to 20%. While "normal" usage stands at 8 million gallons per day, this usage can be successfully reduced to 5 million gallons during periods of drought.

The March 1998 Pacific ENSO Update, a bulletin issued by the Pacific El Niño-Southern Oscillation Applications Center, called the 1997/98 El Niño event "the most intense on record." [33] American Samoa was not the only Pacific island to experience very dry conditions that year. Record droughts had been forecasted for Guam, CNMI, Micronesia, the Marshall Islands, and Palau as well.

American Samoa lies in a region between the most extreme influences of the El Niño/Southern Oscillation (ENSO) cycle on rainfall in the Pacific. ENSO is an oceanic and atmospheric phenomenon typified by increased sea-surface temperatures and lower than normal atmospheric pressure in the eastern Pacific and the high negative values of the Southern Oscillation Index. Warm events generally cause wet conditions to occur north and east of the islands, and dry conditions to the south and west, with a somewhat variable impact on rainfall in American Samoa. Nevertheless, American Samoa's normally abundant rainfall can be affected by El Niño conditions, as the 1974, 1983, and 1998 droughts illustrated. The National Drought Mitigation Center website offers a detailed description of the ENSO cycle and its relationship to drought in Understanding ENSO and Forecasting Drought, http://www.drought.unl.edu/whatis/elNiño.htm.

Figure 22 compares annual rainfall amounts for the village of Pago Pago over a 30-year period, from 1970 to 2000, collected by NOAA's Tafuna Weather Station,[34] and identifies American Samoa's significant drought events. The various phases of the ENSO cycle were also identified that suggest a tendency for the Territory to experience prolonged dry periods in the years following intense El Niño events.

33 Update to Newsletter Issued 1st Quarter 1998: Pacific ENSO Update – Special Bulletin. (1998). University of Guam Water and Energy Research Institute, Pacific El Niño-Southern Oscillation Applications Center. National Oceanic and Atmospheric Administration Office of Global Programs: Vol. 4 No. 1.

34 National Oceanic and Atmospheric Administration, Local Climatological Data Annual Summary with Comparative Data. (1985). NOAA Tafuna Weather Station.

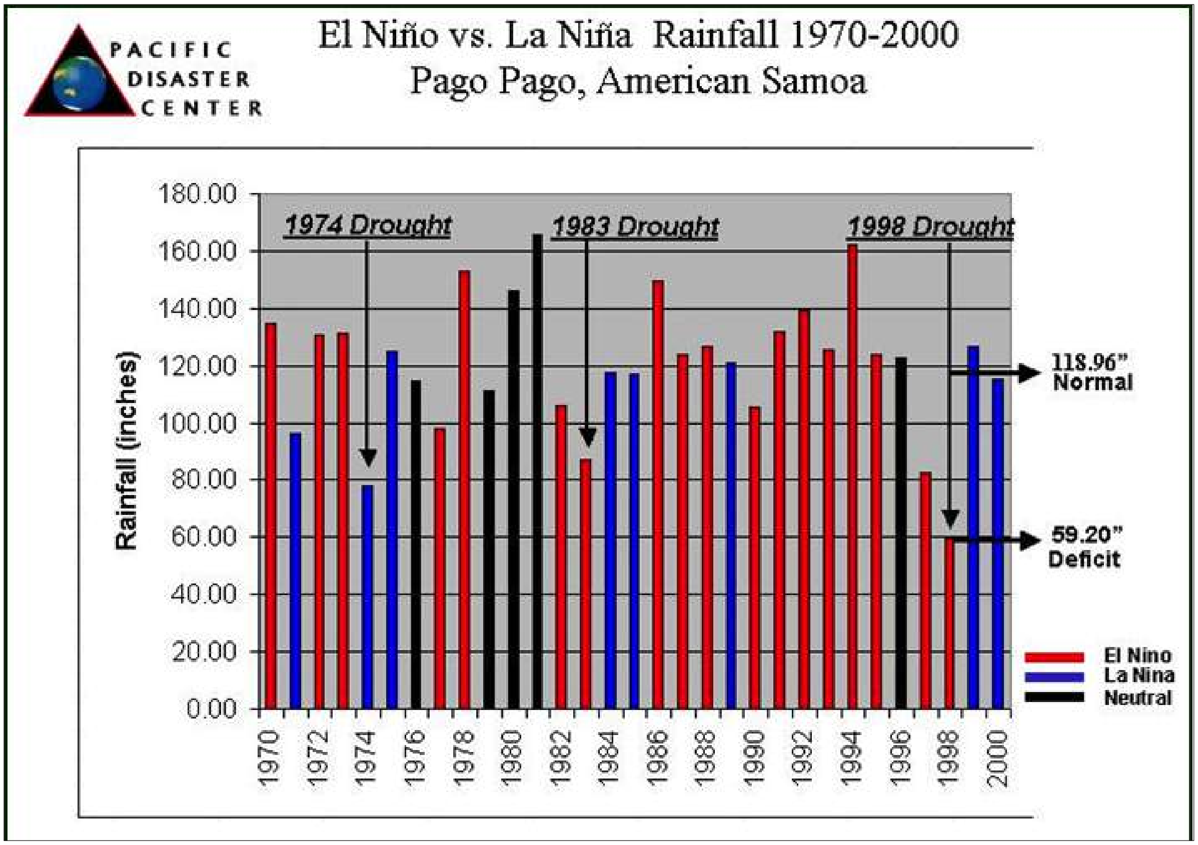

Figure 22
Comparison of Rainfall Amounts, Drought Occurrence and ENSO

Extent

While the U.S. Drought Monitor does not categorize reported drought events in American Samoa, conditions of past events can be used to approximate severity based upon it. The U.S. Drought Monitor characterizes the most severe drought conditions as exceptional: widespread crop/pasture losses; shortages of water in reservoirs, streams, and wells creating water emergencies." Exceptional drought conditions are possible in American Samoa. All U.S. Drought Monitor categories are defined in Categories Table.

In addition, average monthly rainfall amounts of less than three inches per month for three consecutive months are indicative of potential drought in American Samoa. Consecutive months where 50-80 percent of normal rainfall is received can also trigger severe drought. The 1998 drought was severe when just 10.11 inches of rainfall was received between April and August. Average rainfall would typically be over 40 inches during this period and would have exceeded 10 inches in April alone (as depicted in Figure 21).
Drought extent may also be classified in terms of the impacts caused. Any drought occurrence that prompts water conservation measures, impacts water supply or damages agricultural should be considered severe. Drought conditions and impacts may last for a few months but have the potential to last for several years. Drought severity may be impacted by:

- Inadequate catchment, reservoir capacity, and wells relative to population
- Leaky water pipes
- Strong to very strong El Niño episodes

Probability of Future Events

American Samoa, given its maritime location in the southwest Pacific and regular rainfall events, infrequently experiences severe drought conditions. When drought conditions do occur, local thunderstorms temper less serious droughts in the Territory, but do little to ease a major drought. Available data suggests that El Niño occurrences with strong to very strong classifications increase the chances for serious drought conditions. The strength and duration of El Niño periods increased during the 1990's, as compared with the previous two decades, perhaps coincident with climate change.

Research of historical rainfall totals, drought occurrences and revisit periods, and analysis of ENSO events contributed to the determination of probable occurrence for drought in American Samoa. Three significant droughts have affected American Samoa during the past 30 years, all directly following or at the tail end of a moderate to strong or very strong El Niño occurrence. This trend, however, has not manifested with the moderate El Niño conditions experienced in 2002-2003.

A moderately strong El Niño episode preceded the 1974-75 droughts, while the 1983-84 and 1998 droughts occurred at the tail end of strong to very strong El Niño periods. While not all El Niño events during the 43-year period of study led to drought conditions, there appears to be a connection between El Niño events and drought in American Samoa. It can be inferred that when the first signs of a moderate to strong or very strong El Niño event is forecast several months in advance, American Samoa should prepare for what could become severe drought conditions. In turn, this implies that during neutral or La Niña phases of ENSO, there is little probability of drought conditions in these islands.

In addition to events that followed ENSO trends, a fourth, less severe drought was reported in 2011. Stakeholder meetings also indicated that droughts are becoming more common, though they are not also long-lasting or exceptionally severe, prompting water conservation.

Using available historical data reporting from 1976 to 2014, four events were reported of which 3 were severe in nature. Based on this information, the probability of drought occurrence is between 7 and 11 percent annually. Focusing on events that may results in widespread impacts or water conservations measures, the annual probability can be summarized as possible, between 1% and 10% annually.

Vulnerability Assessment

The atmospheric nature of drought and lack of specific boundaries make it more conducive to a qualitative assessment as opposed to a quantitative analysis, such as GIS analysis. The entire planning area, including current and future buildings and populations, is at risk to drought. Drought may impact water supply, prompt water conservation measures and damage agricultural crops. Previous droughts have damaged banana and taro crops, resulting in local food shortages. While food can be imported, this it is much more expensive.

Droughts most devastating impacts may be to the local economy. If businesses, including the canneries, are forced to slow or stop production, this can impact supply (a top export) and employment. The canneries require approximately 1,200 gallons per minutes which can have localized impacts on water supply. In times of drought or water short, this impact is more severe. Historical droughts have resulted in fewer hours for government employees. This can have a ripple effect through the economy since workers may earn fewer wages if the canneries are forced to temporarily close.

Several measures are already in place to lessen the vulnerability of drought. There is a water conservation program that can be implemented and ongoing efforts to fix leaky pipes. The following lists historical impacts of droughts in American Samoa:

- Water conservation and rationing
- Agricultural crop damage
- Local food shortage
- Hindered cannery operations
- Decreased working hours
- School closures
- Water contamination (salinization)

In addition, it should be noted that extended drought, followed by heavy rainfall can be impetus for landslides. This occurred following the 1974/1975 drought. Landslides can have devastating impacts on the people and property throughout American Samoa. Please see the Landslide hazard section for additional information on hazard area.

Potential Losses

As noted above, the atmospheric nature of drought makes the hazard more conducive to a qualitative assessment. Losses are difficult to quantify since they are more associated with economic impacts and agricultural losses as opposed to structural losses. Previous events have led to fewer working hours and even a territory wide recession following the 1983 drought.

All counties and villages have equal vulnerability to drought hazard.

Earthquake

Description

The earth is made up four major layers and several sub layers (Figure 23): a solid inner core, a liquid outer core, a semi-molten mantle, and the rocky crust (the thin outermost layer of the earth). The upper portion of the mantle combined with the crust forms the lithosphere. This area is susceptible to fractures and can be thought of a shell. The lithosphere breaks up into large slabs, known as tectonic plates. It is this area where earthquakes occur.

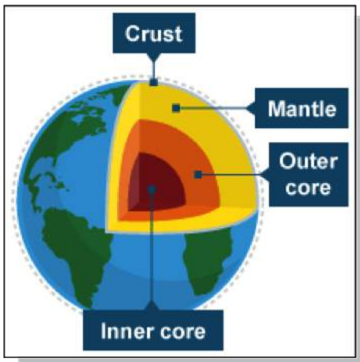

Figure 23 Earth's Sub layers [35]

There are approximately twelve major plates and several dozen more minor plates on the earth's crust, as shown in Figure 24. Plates are regions of the crust that continually move over the mantle. Areas where these plates meet, and either grind past each other, dive under each other, or spread apart, are called plate boundaries. Most earthquakes are caused by the release of stresses accumulated as a result of the sudden displacement of rock in the Earth's crust along opposing plates.

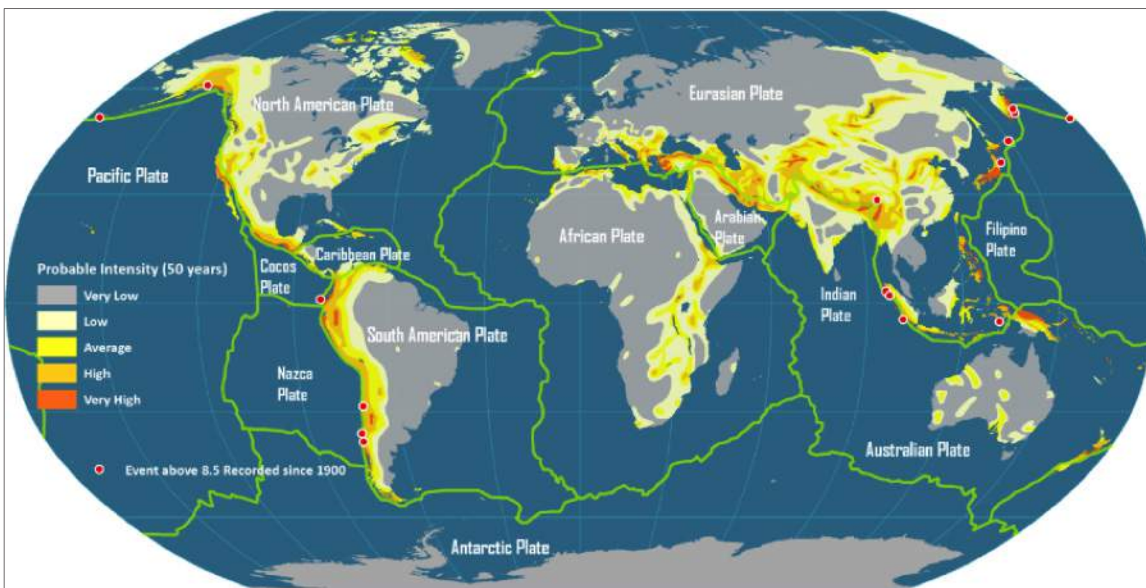

Figure 24 Global Plate Tectonics and Seismic Activity [35]

35 Tbe Earth's structure and plate movement. (2014). BBC. Retrieved August 8, 2014 from http://www.bbc.co.uk/bitesize/ks3/geography/physical_processes/plate_tectonics/revision/2/

The above map depicts plate boundaries and shows a global distribution of earthquake risk for significant earthquakes over the next 50 years, ranging from low probability to a very high probability (more a matter of when than if). The areas bordering the Pacific Plate, also known as the "Pacific Ring of Fire", are at a particularly high risk since most of the largest earthquake events of the last century took place in the region.[36] American Samoa falls within this area.

While earthquakes typically occur along plate boundaries, particularly in the Pacific Ocean, earthquakes may result from crustal strain, volcanism, landslides or the collapse of caverns. Earthquakes can affect hundreds of thousands of square miles, cause damage to property measured in the tens of billions of dollars, result in loss of life and injury to hundreds of thousands of persons and disrupt the social and economic functioning of the affected area. Scientifically, earthquakes are defined as the sudden release of strain in the earth's crust, resulting in waves of shaking that radiate outward from the earthquake source. The point where an earthquake starts is termed the focus or hypocenter and may be many miles to several hundred miles deep within the earth. The point at the surface directly above the focus is called the earthquake's epicenter. Earthquakes are measured in terms of their magnitude and intensity.

Magnitude is measured using the Richter Scale, an open-ended logarithmic scale that describes the energy release of an earthquake through a measure of shock wave amplitude (Table 14 Richter Scale). Each unit increase in magnitude on the Richter Scale corresponds to a 10-fold increase in wave amplitude, or a 32-fold increase in energy. Intensity is most commonly measured using the Modified Mercalli Intensity (MMI) Scale based on direct and indirect measurements of seismic effects. The scale levels are typically described using roman numerals, ranging from "I" corresponding to imperceptible (instrumental) events to "XII" for catastrophic (total destruction). A detailed description of the Modified Mercalli Intensity Scale of earthquake intensity and its correspondence to the Richter Scale is given in Table 15 Modified Mercalli Intensity Scale for Earthquakes.

Table 14 Richter Scale [37]

Richter Magnitudes	Earthquake Effects
< 3.5	Generally not felt, but recorded.
3.5 - 5.4	Often felt, but rarely causes damage.
5.4 - 6.0	At most slight damage to well-designed buildings. Can cause major damage to poorly constructed buildings over small regions.
6.1 - 6.9	Can be destructive in areas up to about 100 kilometers across where people live.
7.0 - 7.9	Major earthquake. Can cause serious damage over larger areas.
8 or >	Great earthquake. Can cause serious damage in areas several hundred kilometers across.

36 Global Plate Tectonics and Seismic Activity. (2014). The Geography of Transport Systems. Retrieved August 8, 2014 from https://people.hofstra.edu/geotrans/eng/ch9en/conc9en/plate_tectonics.html

37 Federal Emergency Management Agency (FEMA)

Table 15 Modified Mercalli Intensity Scale for Earthquakes[38]

Scale	Intensity	Description Of Effects	Corresponding Richter Scale Magnitude
I	Instrumental	Detected only on seismographs.	--
II	Feeble	Some people feel it.	< 4.2
III	Slight	Felt by people resting; like a truck rumbling by.	--
IV	Moderate	Felt by people walking.	--
V	Slight strong	Sleepers awake; church bells ring.	< 4.8
VI	Strong	Trees sway; suspended objects swing, objects fall off shelves.	< 5.4
VII	Very strong	Mild alarm; walls crack; plaster falls.	< 6.1
VIII	Destructive	Moving cars uncontrollable; masonry fractures, poorly constructed buildings damaged.	--
IX	Ruinous	Some houses collapse; ground cracks; pipes break open.	< 6.9
X	Disastrous	Ground cracks profusely; many buildings destroyed; liquefaction and landslides widespread.	< 7.3
XI	Very disastrous	Most buildings and bridges collapse; roads, railways, pipes and cables destroyed; general triggering of other hazards.	< 8.1
XII	Catastrophic	Total destruction; trees fall; ground rises and falls in waves.	> 8.1

Beginning in 2002, the USGS began using Moment Magnitude as the preferred measure of magnitude for all USGS earthquakes greater than magnitude 3.5. This was primarily due to the fact the Richter Scale has an upper bound, so large earthquakes were difficult to measure. Moment Magnitude also has a scale, but no instrument is used to measure it. Instead, factors such as the distance the earthquake travels, the area of the fault, and land that was displaced (also known as "slip") are used to measure moment magnitude. Table 16 Moment Magnitude Scale shows the Moment magnitude scale, and Table 17 shows a few examples of how the Moment Magnitude Scale compares to the Richter Scale.

Table 16 Moment Magnitude Scale

Scale Value	Effect
Less than 3.5	Very weak; unlikely to be felt
3.5 – 5.4	Generally felt; rarely causes damage
6.1-6.9	Will not cause damage to well-designed buildings; will damage poorly designed ones
7.0-7.9	Considered a "major earthquake" that causes a lot of damage
8 or greater	Large and destructive earthquake that can destroy large cities

38 Federal Emergency Management Agency (FEMA)

Earthquake	Richter Scale	Moment Magnitude
New Madrid, MO 1812	8.7	8.1
San Francisco, CA 1906	8.3	7.7
Prince William, AK 1964	8.4	9.2
Northridge, CA 1994	6.4	6.7

Table 17 Richter v. Moment Magnitude Values

Location

Very little information exists about earthquakes generated by local faults near American Samoa. In fact, earthquakes that occur in the sea and islands around it often impact American Samoa. This is evident in the review historic occurrences with many earthquakes occurring in the Tonga Trench, more than 100 miles southwest of the islands (Figure 25 Tonga Trench Location).

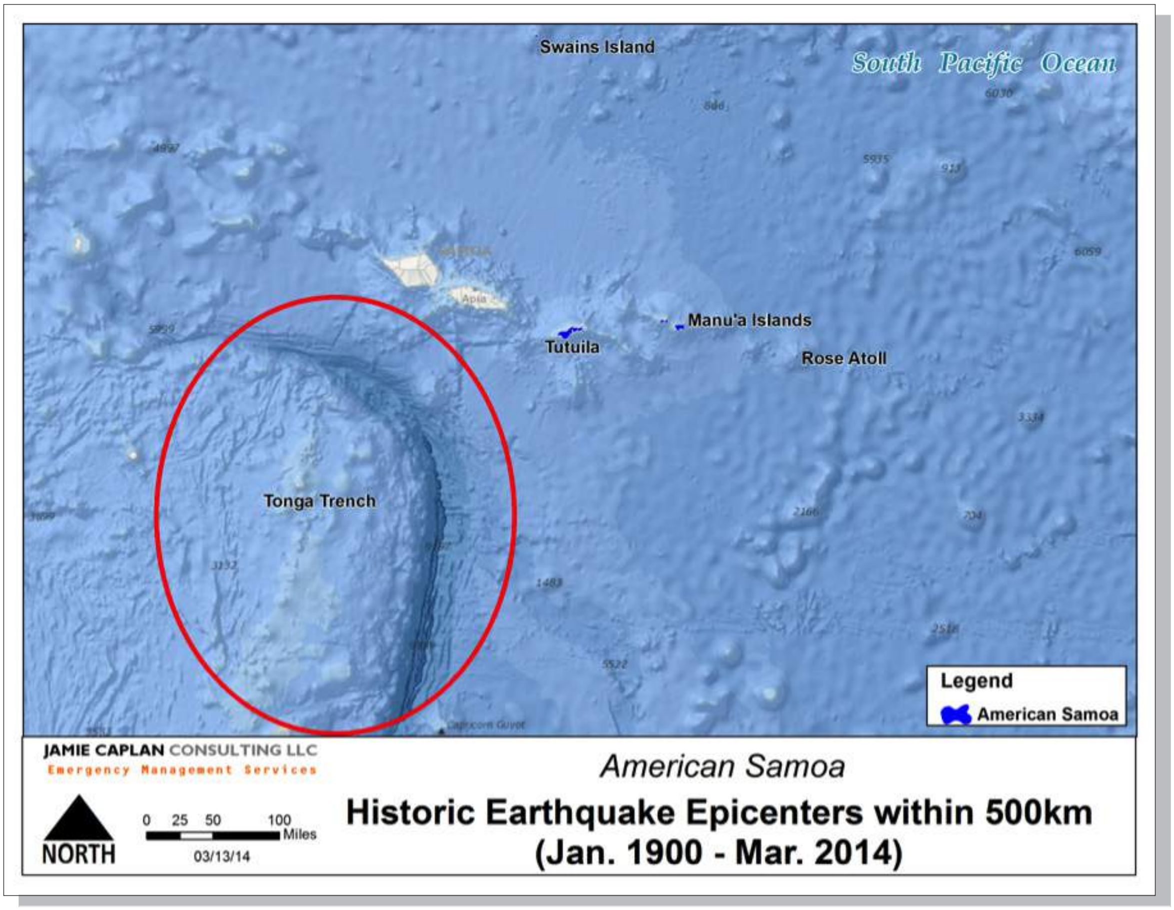

Figure 25 Tonga Trench Location

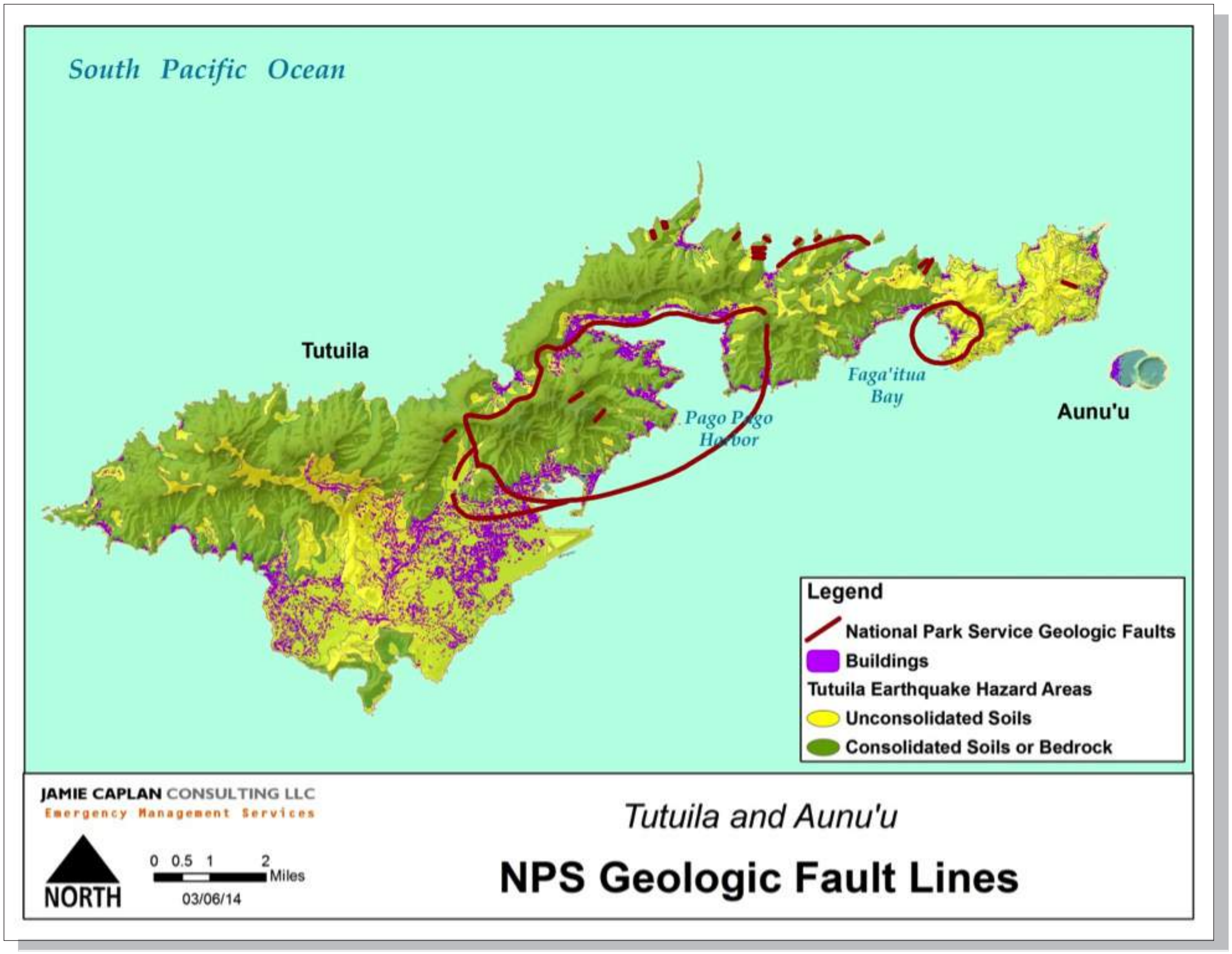

Figure 26 Tutuila Island and Aunu'u Island Earthquake Fault Lines and Hazard Areas

In addition to the Tonga Trench earthquake hotbed, there are several fault lines on the American Samoa islands. Although it should be noted that data does not indicate any recent earthquakes have originated from these areas. Figure 26 and Figure 27 show fault lines on the islands Tutuila/Aunu'u Islands and the Manu'a Islands, respectively. For Tutuila Island and Aunu'u Island (Figure 26), soil data was available to indicate areas of earthquake risk due to unconsolidated soil, shown in yellow. In addition, areas of development are shown in purple. Areas of unconsolidated soil will shake stronger and experience more extensive damage than areas with consolidated soil (harder, typically bed rock). Additional information on vulnerability, including number of buildings and critical facilities at risk, will be discussed in the vulnerability assessment and potential losses sections.

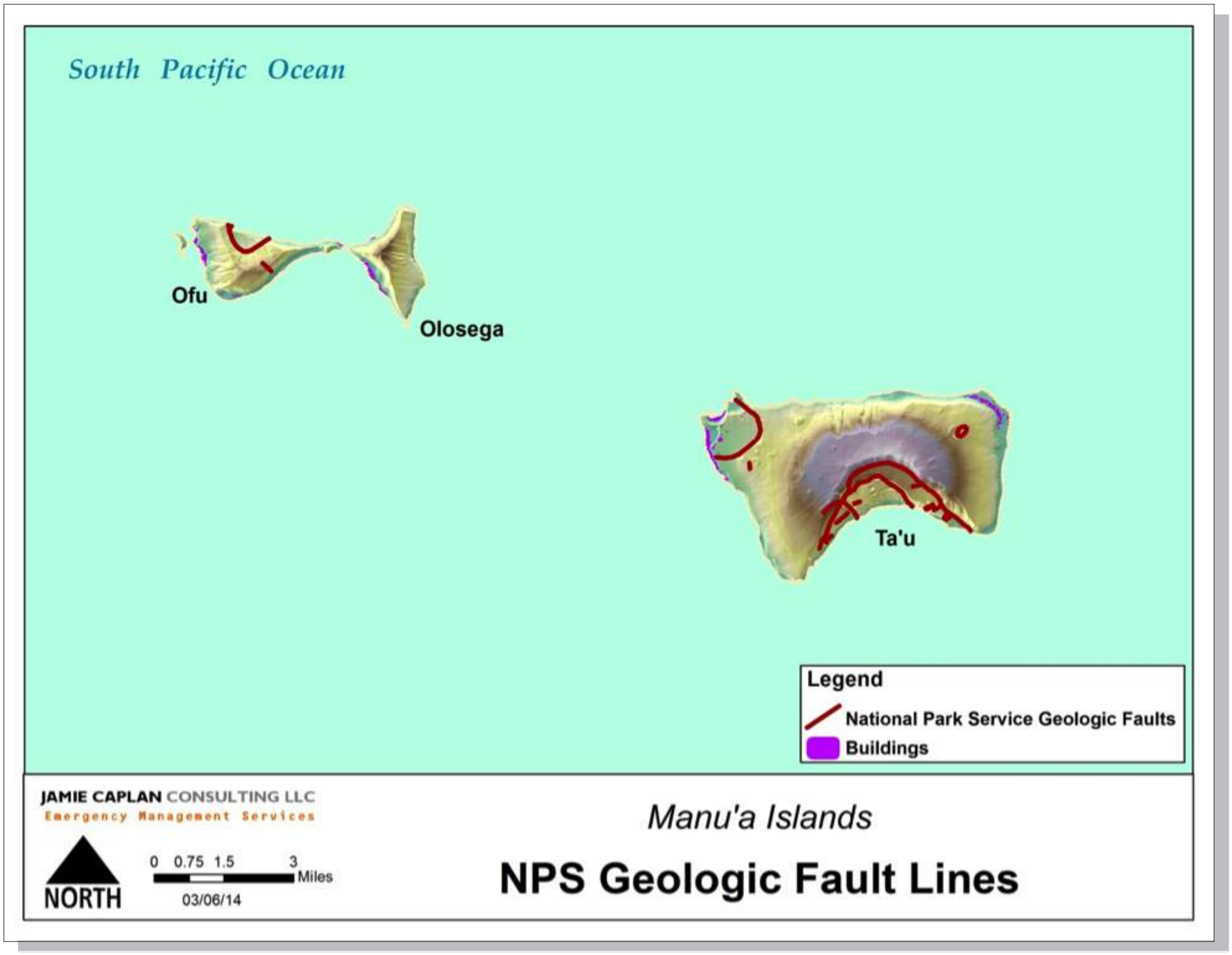

Figure 27 Manu'a Islands Earthquake Fault Lines

Previous Occurences

Earthquakes occur frequently in the area around American Samoa. However, their impact to American Samoa is limited. A 2012 USGS study noted that "while most of the historical damage has been caused by earthquake-induced tsunamis, ground motions occasionally reach a level that results in building, contents, or infrastructure damage (for example, 2010 M 7.5 Vanuatu earthquake)."[39] Earthquake history to the south and west of American Samoa is well documented for the Tonga Trench.

The northernmost section of the Tonga Trench (or Tonga-Kermadec Trench) is the primary source for earthquakes in American Samoa (Figure 25). The Tonga Trench is a seafloor geographic and tectonic feature created by the collision of the Pacific Plate that subducts westward beneath the Australian Plate (see Figure 24 above for locations of plates). The Pacific-Australian subduction zone is considered an area of high seismic activity, and the collision of these two plates is a source of large but distant earthquakes felt in American Samoa. Because American Samoa is far from Tongan Trench seismic activity, it rarely experiences violent or destructive shaking from earthquakes sourced from this region. Over this distance, the earth filters and diminishes the seismic waves, creating only perceived strong-to-very strong shaking, and not violent shaking. A major exception was the 8.1 magnitude earthquake from this region on September 29, 2009. This was a very significant event and not only caused very strong shaking but also triggered a catastrophic tsunami, which generated the majority of the damage on Tutuila Island.

Historical occurrences were reviewed from NCDC (no events listed), Pacific Disaster Center, and USGS. Figure 28 was updated for the 2015 plan update and shows the Historical Earthquakes near American Samoa as represented by the Pacific Disaster Center, Asia-Pacific Natural Hazards and Vulnerabilities Atlas. American Samoa is shown in green, indicating a low earthquake intensity zone.

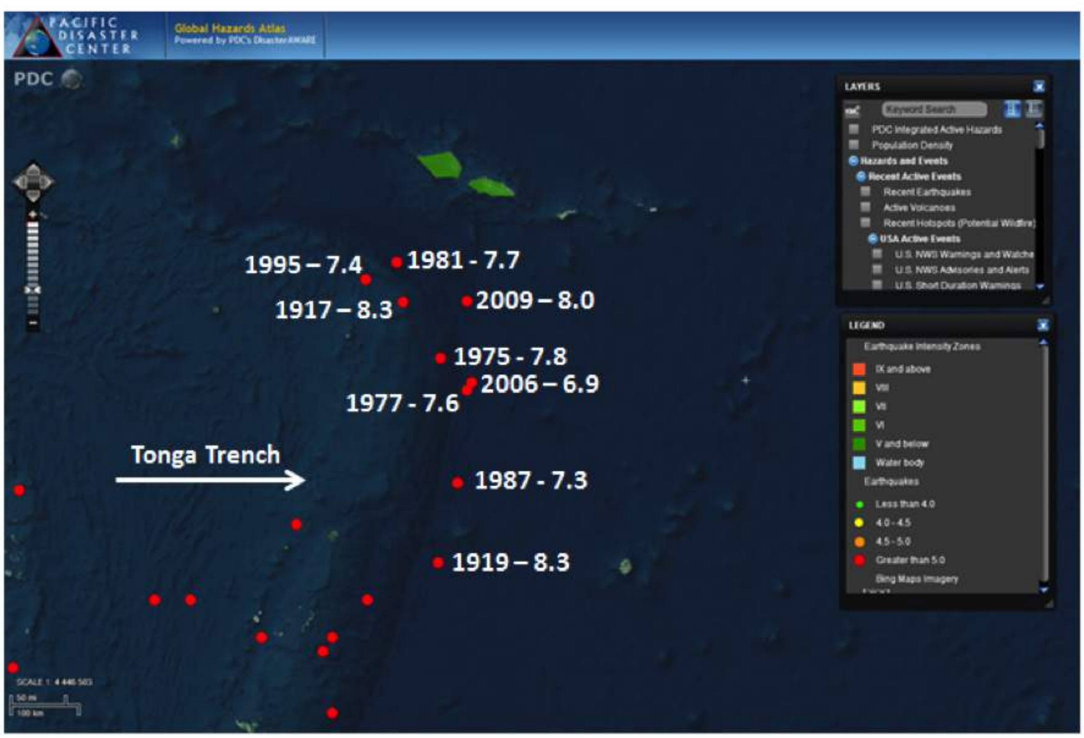

Figure 28 Historic Earthquakes over 7.0 and the Tonga Trench[40]

39 U.S. Geological Survey. Retrieved August 8, 2014 from http://pubs.usgs.gov/of/2012/1087/OF12-1087.pdf

40 Global Hazards Atlas. (2014). Retrieved August 8, 2014 from http://atlas.pdc.org/atlas/

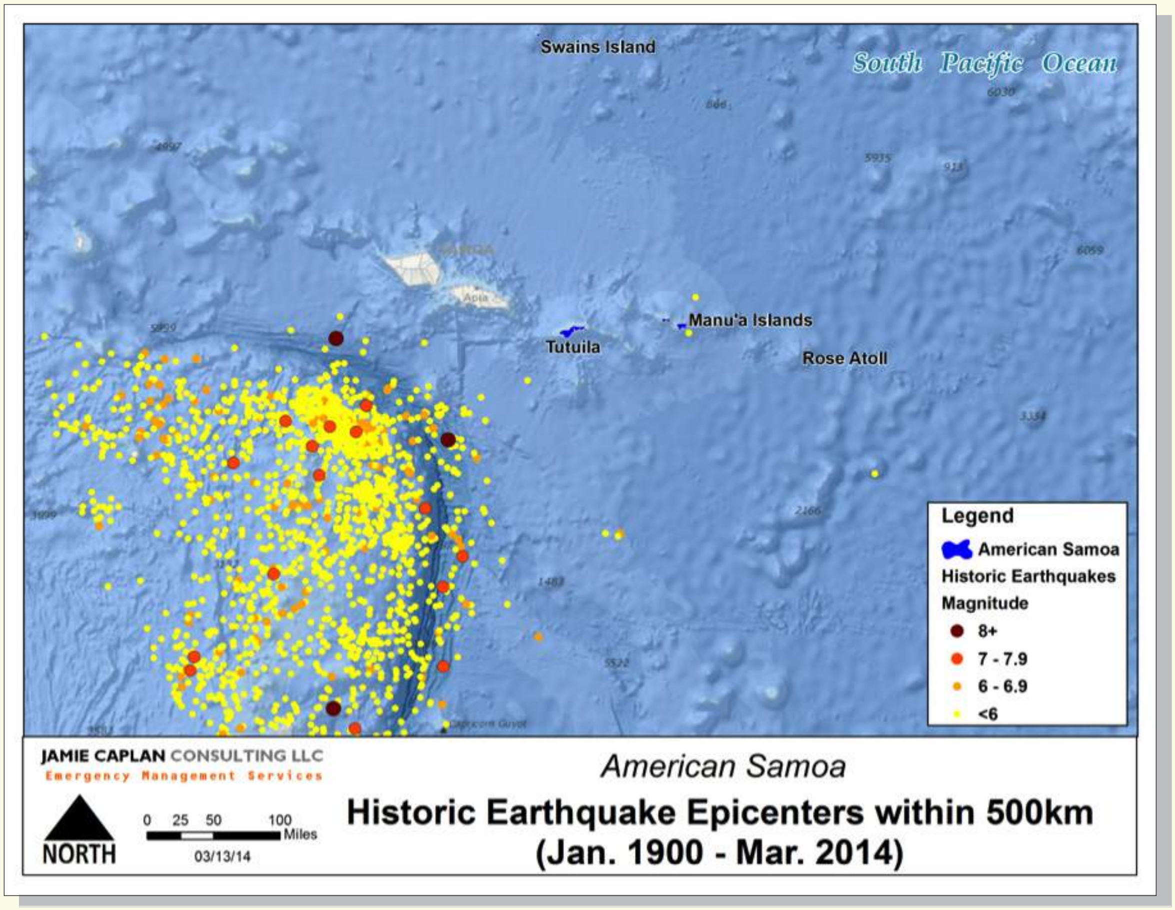

Figure 29 Historic Earthquakes near American Samoa

Figure 29 is an updated version of the previous historic earthquake events. Data was obtained from the United States Geological Survey from the Comprehensive Earthquake Catalog.[41] The map includes earthquakes from January 1900 to March 2014 with a magnitude 5.0 or greater. These are earthquakes that occurred within 500 kilometers of American Samoa and include the Tonga Trench. There were 1,788 earthquakes reported including 22 with a magnitude 7.0 or greater in the area. A total of 371 earthquakes were reported in the Samoa Island region specifically (closest to American Samoa). These include an 8.1 magnitude event (2009) and an 8.0 magnitude event (1917).

41 Earthquake Archive Search. (2014). USGS. Retrieved August 8, 2014 from http://earthquake.usgs.gov/earthquakes/search/

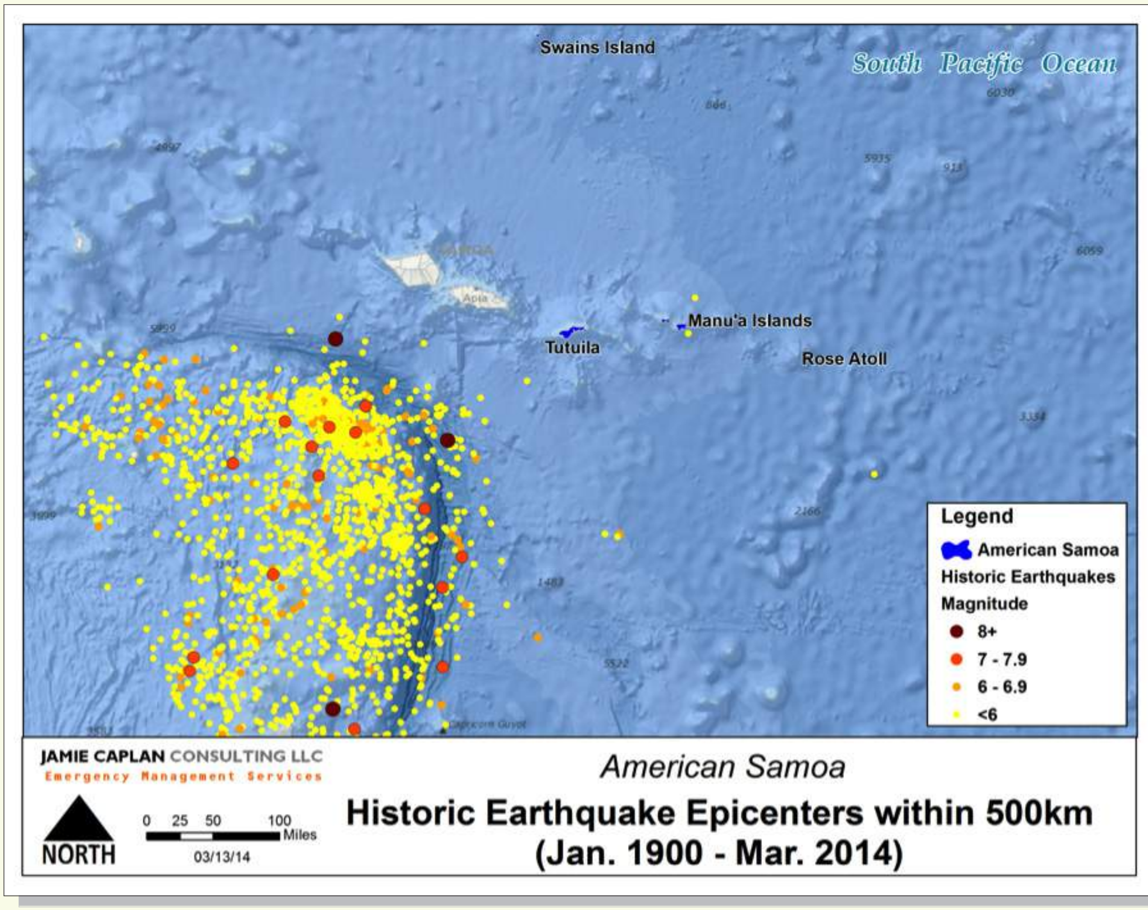

Figure 29 Historic Earthquakes near American Samoa

A secondary source for seismic activity is volcanic activity. The Samoan island chain was created by a 'hot spot' or soft spot in the earth's crust, which allows the escape of magma; creating submarine volcanoes that eventually form islands. The only active volcano in the American Samoa region is the submarine volcano Vanilulu'u. The Ofu-Olosega volcano last erupted in 1866, and the other volcanoes in the region have been silent for thousands of years. In 1995, a shallow earthquake swarm (concentrated events in time and space) was recorded in the region of the Vanilulu'u submarine volcano. These events are precursors to potential volcanic activity and are usually not a threat to the islands in terms of damage. Further, their activity has not been linked to earthquake events.

Fortunately, no deaths or injuries have been associated with historic earthquake activity, and no damage reports were reported for inclusion in this report. While not considered insignificant, earthquakes affecting American Samoa have not achieved the same impact as other hazards mentioned in this report. However, the 2009 Earthquake, Tsunami, and Flood event was significant. The earthquake did cause some significant damage. However, the tsunami that resulted from the earthquake caused catastrophic damage and 32 deaths and multiple injuries throughout the islands.

Extent

The previous occurrences in the section above measure magnitude on the Richter Scale, an indicator of severity or magnitude of earthquakes. These events indicate that earthquakes over 8.0 are possible in the American Samoa region. Earthquakes of this magnitude are near the greatest size on the Richter scale and can cause total destruction. However, the intensity of earthquakes impacting American Samoa is generally much lower since they are generated offshore and dissipate before reaching the islands. Earthquake magnitude can also be measured in terms of ground shaking.

One measure is peak horizontal ground acceleration (PGA). This measure is considered to be the best determinate of damage. It is also used for engineering purposes and for development of building codes. American Samoa is classified by FEMA as Seismic Zone 3, which means the probability of the Territory experiencing earthquake ground shaking of approximately 0.2g peak horizontal acceleration is once in 500 years (or a 10% probability of experiencing at least 0.2g every 50 years), where 1.0 g is equal to the acceleration of gravity. Higher values of g indicate higher shaking.

This level of ground shaking translates to light-to-moderate building damage. A 0.2g horizontal acceleration is similar to the turbulence required to knock a person walking down the aisle of an airplane off his or her feet. This Seismic Zone 3 designation considers all probable earthquake sources affecting American Samoa, local and distant, and translates their effects into different estimates of ground shaking. Seismic zones are also implemented as one of the design criteria in the Uniform Building Code. Seismic design calculations are input as part of the design criteria for construction of important structures to resist seismic forces.

In addition to FEMA, the United States Geological Survey (USGS) calculates and publishes the probabilities of ground shaking hazard for each Territory by conducting an in-depth seismic hazards analysis. This information was not available for previous plan updates but has now been completed and included for the 2015 plan update.

The 2012 USGS study investigated PGA for American Samoa as shown in the map below. PGA is measured in %g, percent of gravity, where a higher value indicates higher shaking. American Samoa resides in an area of 0 to 25 %g (0 -.25g) with a 10 percent probability of exceedance in 50 years. (A 10 percent chance of exceedance means that is there 90% chance that the shaking will NOT exceedance the value, thus indicating probable upper bounds (magnitude) of shaking.[42] Magnitude in terms of %g varies across islands as shown in Table 18 and Figure 30 below. In addition, Table 19 shows the associated damage level by percent acceleration force of gravity (% g).

Table 18 PGA Extent for American Samoa by Island

Island	Approximate Peak Horizontal Acceleration (% g) with 10 percent Probability of Exceedance in 50 years
Ta'u	20-25 (0.2-0.25g)
Olosega	15-25 (.15 -.25g)
Ofu	15-20 (.15 -.25g)
Tutuila	9-15 (.09 -.15g)
Aunu'u	8-10 (.08 -.10g)
Rose Atoll	2-4 (.02 -.04g)
Swains Island	0-1 (0 -.01g)

42 Earthquake Hazards 101 - The Basics. (2014). USGS. Retrieved August 8, 2014 from http://earthquake.usgs.gov/hazards/about/basics.php

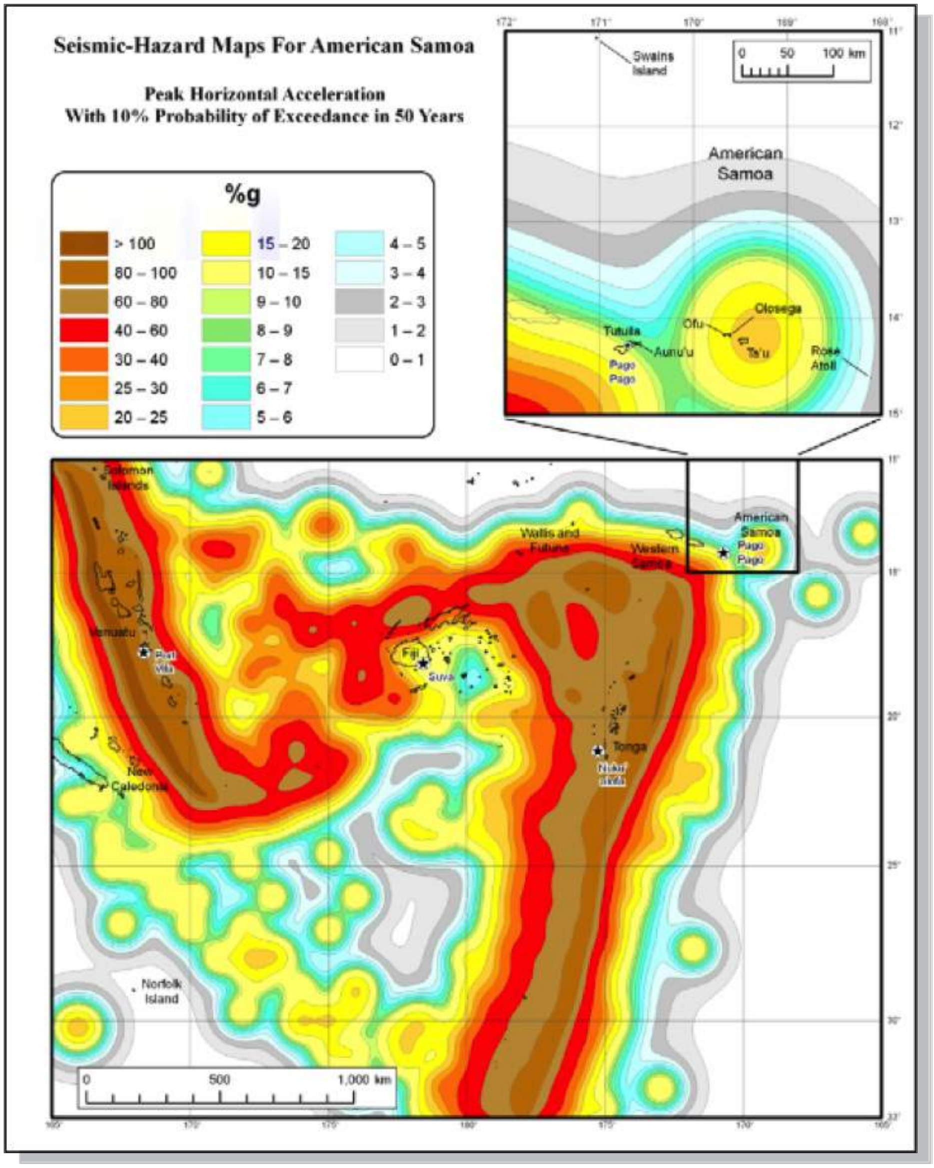

Figure 30 Peak Horizontal Acceleration in American Samoa[43]

Table 19 Damage Levels Associated with %g

Ground Motion Percentage	Explanation of Damages
1-2 % g	Motions are widely felt by people; hanging plants and lamps swing strongly, but damage levels, if any, are usually very low.
Below 10 %g	Usually cause only slight damage, except in unusually vulnerable facilities.
10-20 %g	May cause minor to moderate damage in well-designed buildings, with higher levels of damage in poorly designed buildings. At this level of ground shaking, only unusually poor buildings would be subject to potential collapse.
20-50 %g	May cause significant damage in some modern buildings and very high levels of damage (including collapse) in poorly designed buildings.
50 %g+	May causes higher levels of damage in many buildings, even those designed to resist seismic forces.

43 Peterson, D. Mark et al. (2012). "Seismic Hazard of AMerican Samoa and Neighboring South Pacific Islands - Data, Methods, Paramaters, and Results. U.S. Department of the Interior, and U.S. Geological Survey, p. 53. Retrieved August 8, 2014 from http://pubs.usgs.gov/of/2012/1087/OF12-1087.pdf

Using this information, it can be inferred that the Manu'a Islands have the greatest risk to earthquake shaking while the outlying atolls of Rose Atoll and Swains Island have the lowest risk.

Probability of Future Events

There are typically several measures that can be used to determine future probability. However, data and resources are limited for American Samoa. Therefore, research and statistical probability based on historic occurrences were utilized.

Research from the 2012 USGS report for American Samoa noted that "Since 1900, 242 earthquakes with magnitude (M) greater than or equal to 7 have been recorded, or an average rate of more than two large earthquakes per year."[44] This fact is based on previous occurrences from several different sources.

In addition, statistical probability of future occurrences was used for consistency throughout the document. The USGS historic occurrences for earthquakes greater than or equal to 7.0 in the Samoa and Tonga regions were included (used in Figure 29). The data ranges from 1906 to 2014 and includes 22 earthquakes over 7.0. This results in a probability of 0.2 or 20 percent probability each year, a categorization of "likely," (between 10 percent and 90 percent annually). It should be noted, however, that while several earthquakes are felt each year, few earthquakes result in damage.

Vulnerability Assessment

In the extent section, data indicated a range of 0.01-0.2%g with 10 percent probability of exceedance in 50 years. This indicates significant damage is possible in poorly designed buildings and minor damage is possible to buildings with a modern design. Areas that may exceed the peak ground acceleration are likely designated as "other soil types" compiled from the USDA/NRCS Soil Survey Map of American Samoa (1984), and appear in yellow on the Earthquake Hazard Maps (Figure 26) representing possible areas of unconsolidated soils and amplified ground motion.

Most low-lying areas on Tutuila correspond to the unconsolidated soils and may experience amplified ground motion from an earthquake. Another factor that increases seismic risk during an earthquake is the possible liquefaction of soils typically found in landfill areas, such as those surrounding the northwestern portion of Pago Pago Harbor (Figure 31).

Earthquakes in American Samoa have the potential to cause damage to buildings, infrastructure including roads and pipes. While earthquakes are possible and shaking will likely be felt occasionally, the damage is generally minor. However, it should be noted that extremely strong earthquakes are capable of causing widespread damages on the islands, particularly when building reside on unconsolidated soil. In addition, most buildings on the islands are not designed to withstand strong earthquakes. Further, all earthquake occurrences should be an indication to stay alert for possible a tsunami. For these reasons, earthquakes are a moderate hazard for the islands.

44 U.S. Geological Survey. Retrieved August 8, 2014 from http://pubs.usgs.gov/of/2012/1087/OF12-1087.pdf, page 2

Potential Losses

All current and future buildings and populations in American Samoa are at risk to earthquakes. However, some areas and structures may be at greater risk due to unconsolidated soil that may succumb to earthquake impacts. In addition, building design may also impact vulnerability and potential losses. Areas of high earthquake risk based on unconsolidated soil areas were also investigated using GIS intersect analysis to determine the number and type of buildings most at risk to earthquake shaking. This analysis was also used for critical facilities. Data was only available for the main island, Tutuila Island. The results are summarized in Table 20 below and several figures that follow.

Table 20 Buildings Potentially At Risk to Earthquake Hazard

County (District)	Total Number of Buildings	Total Number of Buildings in unconsolidated soil area	Percent	Type
TUTUILA ISLAND				
East Vaifanua (East District)	497	490	99%	4 not listed 486 residential[45]
Ituaa (East District)	1,075	1,008	94%	1,402 2 government 12 churches 32 commercial 959 residential
Lealataua (West District)	2,026	1,589	78%	6 schools 7 commercial 14 churches 37 not listed 1,523 residential
Leasina (West District)	474	460	97%	1 commercial 5 churches 6 government 448 residential
Maoputasi (East District)	2,246	1969	88%	1 school 1 Tedi of Samoa 1 new 6 unlisted 13 churches 32 commercial 68 government 1,847 residential
Saole (East District)	364	363	69%	1 business 2 unknown 260 residential
Sua (East District)	938	823	88%	4 unlisted 4 commercial 3 churches 812 residential

45 Building type listed in Territory GIS data

County (District)	Total Number of Buildings	Total Number of Buildings in unconsolidated soil area	Percent	Type
Tualatai (West District)	903	901	98%	48 not listed 12 churches 5 commercial 856 residential
Tualata (West District)	7,441	7,373	99%	12 not listed 73 churches 107 commercial 88 government 7,092 residential
West Vaifanua (East District)	172	166	97%	166 residential
Tutuila Island Total	16,315	13,858	85%	--
AUNU'U ISLAND				
Saole (East District)	179	N/A	--	--
Aunu'u Island Total	179	--	--	--
TA'U ISLAND				
Faleasoa (Manu'a District)	81	N/A	--	--
Fitiuta (Manu'a District)	180	N/A	--	--
Ta'u (Manu'a District)	208	N/A	--	--
Ta'u Island Total	469	N/A	--	--
OFU ISLAND				
Ofu (Manu'a District)	133	N/A	--	--
Ofu Island Total	133	N/A	--	--
OLOSEGA ISLAND				
Olosega (Manu'a District)	101	N/A	--	--
Olosega Island Total	101	N/A	--	--
TOTAL	**17,018**	**13,858**	--	--

The analysis indicates very high exposure and loss potential for all counties. East Vaifanua and Tualauta both show 99% of their buildings reside in a high earthquake hazard area. This is due to the high amount of unconsolidated soil area in the developed areas. However, losses from earthquakes will be largely dependent on building design and earthquake strength. Given the distance of the island from typical earthquake activity (Tonga Trench), severe shaking is not frequent.

A critical facility analysis was also performed using available data. The results indicated that nearly all critical facilities reside in unconsolidated soil areas, a potential risk to earthquake shaking. These structures are highlighted in Table 21 & Table 22 and Figure 31 through Figure 34 below. In addition, assembly areas, safe zones, tsunami sirens, and ASTCA communication infrastructure were analyzed for vulnerability. The results are reported below and in Appendix D.

Location	Total Number of Buildings	Total Number of CF in the 1 foot SLR area	Value
Tutuila Island CFs	240	235	$1,224,690,003
Ta'u Island CFs	42	N/A	N/A

Given the high number of critical facilities potentially at risk to earthquake, additional information is provided by county in Table 22.

Table 22 Number of Critical Facilities (CFs) Potentially at Risk to Earthquakes by County

County (District)	Total Number of Buildings	Total Number of CFs in unconsolidated soil area	Type	Value
TUTUILA ISLAND				
East Vaifanua (East District)	10	10	10 churches	$5,821,000
Ituaa (East District)	16	16	3 churches 13 schools (all Manulele Elementary)	$14,091,900
Lealataua (West District)	23	21	7 churches 13 schools (Leona High & Seetaga) 1 fire	$4,818,000
Leasina (West District)	7	7	7 churches	$4,818,000
Maoputasi (East District)	77	75	1 commercial 2 processing 39 schools (Aua Elementary, Pago Pago Elementary, Samoana High) 4 hospitals 3 churches 2 commercial (Starkist) 4 communication 2 fire 1 police 2 transportation 15 government (including Lt Gov.'s house)	$365,960,463
Saole (East District)	14	14	10 schools (Alofau Elementary) 3 churches 1 hospital	$9,206,000
Sua (East District)	27	27	6 churches 1 fire 1 police 19 school (Faqaitua High, Laulii Elementary and Elementary)	$23,283,000

County (District)	Total Number of Buildings	Total Number of CFs in unconsolidated soil area	Type	Value
Tualatai (West District)	3	3	3 churches	$2,164,000
Tualata (West District)	62	61	27 schools (Illiili Elementary and Pavaiai Elementary) 9 fuel storage (tank farm) 7 transportation (Pago Pago airport) 10 utility (APSA Tafuna plant) 5 churches 1 communication 1 government 1 fire	$784,361,640
West Vaifanua (East District)	1	1	1 church	$360,000
Tutuila Island Total	239	235	--	$1,213,964,003

Assembly areas

- 9 out of 26 assembly areas were found to intersect unconsolidated soil areas. In the event of an earthquake, these areas may be unsafe to assemble.

Safe Zones

- All 4 safe zone areas in Tutuila intersect unconsolidated soil areas. In the event of an earthquake, these areas may be unsafe.

Tsunami Sirens

- 31 out of 43 sirens were found to intersect unconsolidated soil areas (Figure 34). An earthquake could compromise their foundation and render them ineffective. This is of particular concern as earthquakes often trigger tsunamis.

ASTCA Infrastructure

- 52 out of 75 ASTCA infrastructure holdings were found to intersect unconsolidated soil areas.

A complete listing of critical facilities and associated information (such as assembly areas, safe zones, and tsunami sirens) can be found in Appendix D.

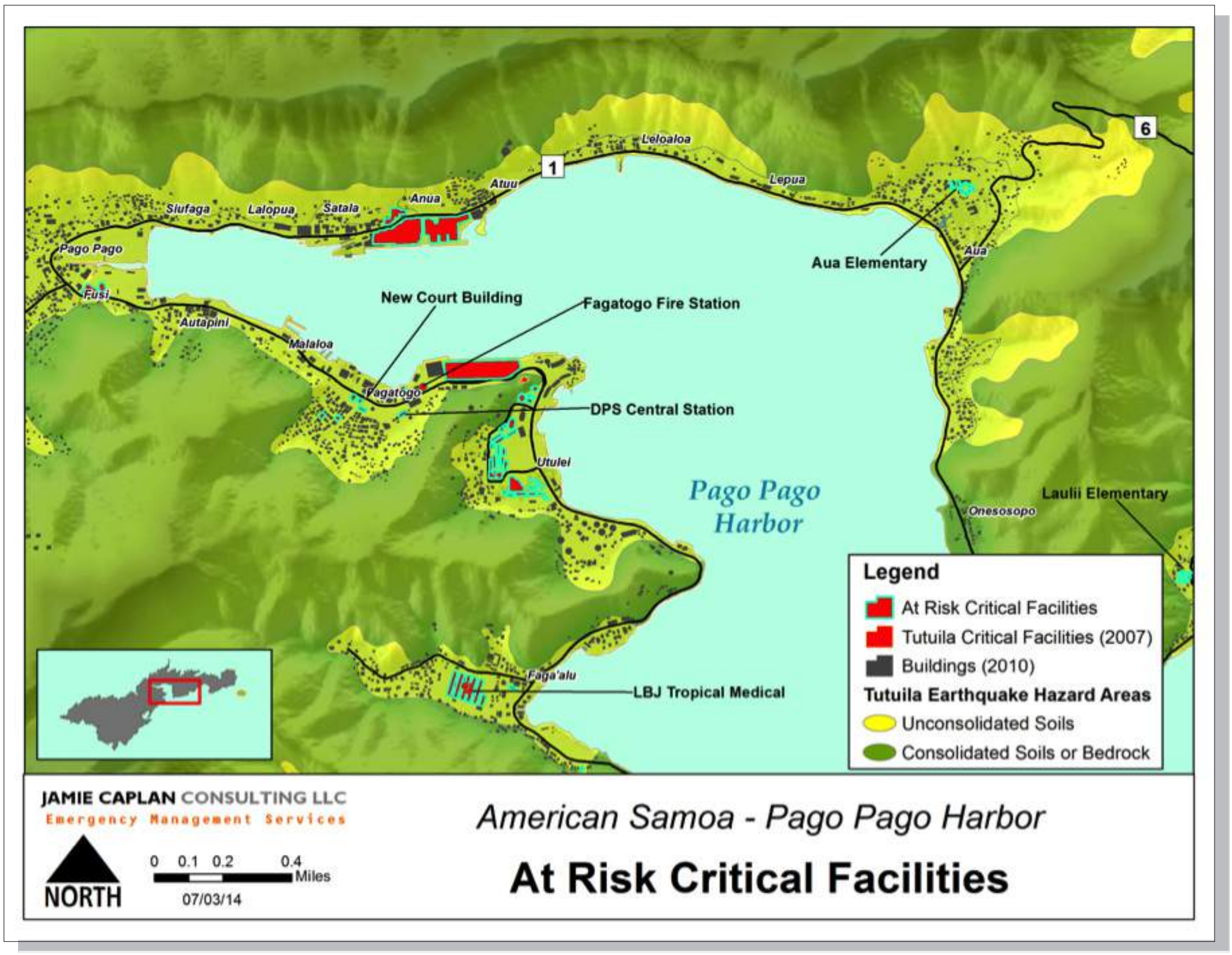

Figure 31 Critical Facilities Potentially At Risk to Earthquake (Pago Pago Area)

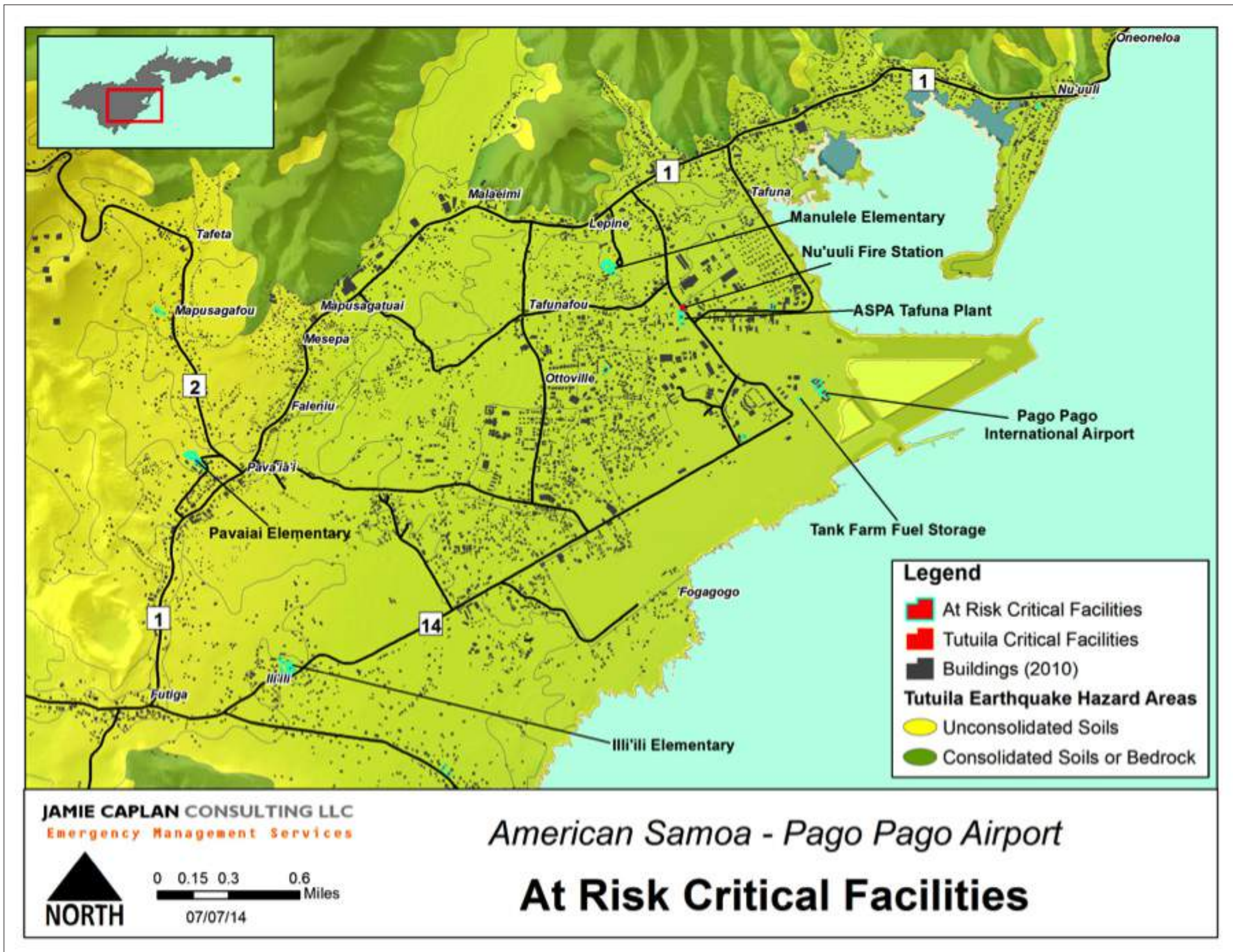

Figure 32 Critical Facilities Potentially At Risk to Earthquake (Tafuna Plain/Pago Pago Airport Area)

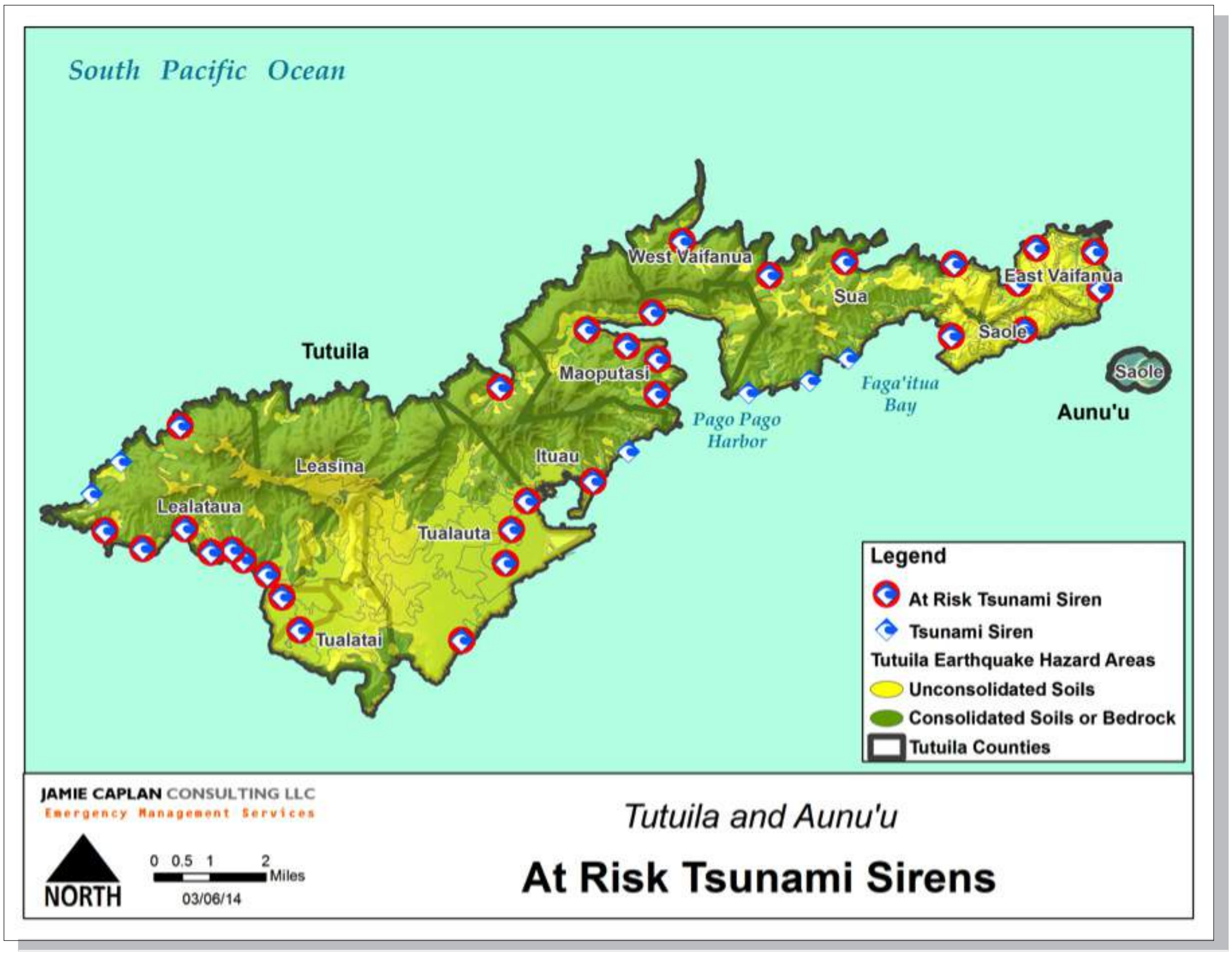

Figure 34 Tsunami Sirens in Unconsolidated Soil Areas (sirens at risk)

Flood

Description

Flooding is a very frequent, dangerous and costly hazard. It accounts for 40 percent of all natural disasters. Globally, flooding results in an average of over 6,500 deaths annually.[46] In the U.S. flooding results in an average of 89 deaths annually.[47] Nearly 90 percent of all presidential disaster declarations result from natural events where flooding was a major component. This holds in American Samoa where 11 out of 12 disaster declarations (92%) are assumed to have flood impacts (Table 2, page 8). Fortunately, flooding has not been directly responsible for fatalities on the islands, but has caused death due to associated hazards, such as landslides and tsunamis. Flooding has caused tremendous damage and creates significant debris. Flooding resulted in three out of eleven past disaster declarations in American Samoa. However, when also including cyclone-related disaster declarations, which likely had flooding impacts, the number jumps to ten out of eleven disaster declarations.

Flooding is the most common environmental hazard, due to the widespread geographical distribution of valleys and coastal areas, and the population density in these areas. The severity of a flooding event is typically determined by a combination of several major factors, including: stream and river basin topography and physiography; precipitation and weather patterns; recent soil moisture conditions; and the degree of vegetative clearing and impervious surface. Both of these flooding events can be brought on by severe (heavy) rain, which is a frequent occurrence in American Samoa. There are several types of flooding which are possible in American Samoa:

Flash Flooding

Flash floods occur within a few minutes or hours of heavy amounts of rainfall and can destroy buildings, uproot trees, and scour out new drainage channels. Heavy rains that produce flash floods can also trigger mudslides and landslides. Most flash flooding is caused by slow-moving thunderstorms or cyclones, repeated thunderstorms in a local area, or by heavy rains from hurricanes and tropical storms. Although flash flooding often occurs in mountainous areas, it is also common in urban centers where much of the ground is covered by impervious surfaces.

Sheet Flooding

Sheet flooding is a condition where storm water runoff forms a sheet of water to a depth of six inches or more. Sheet flooding and ponding are often found in areas where there are no clearly defined channels and the path of flooding is unpredictable. It is also more common in flat areas. Most floodplains are adjacent to streams or oceans, although, almost any area can flood under the right conditions where water may accumulate.

Coastal Flooding

Periodic flooding of land adjacent to the shoreline (known as the floodplain) is a natural occurrence. Coastal flooding brought about by high surf, storm surge associated with tropical cyclone activity, or tsunamis can cause significant damage to beaches and low-lying coastal areas. Storm surge, the rise of the ocean due to atmospheric pressure changes, may overrun barrier islands and push seawater up coastal rivers and inlets, blocking the downstream flow of inland runoff. Escape routes, particularly from barrier islands, may be cut off quickly, stranding residents in flooded areas and hampering rescue efforts.

46 Flood - Data and Statistics. (1980-2008). Prevention Web. Retrieved August 8, 2014 from http://www.preventionweb.net/english/hazards/statistics/?hid=62

47 Weather Facilities. (2013). NOAA National Weather Service. Retrieved August 8, 2014 from http://www.nws.noaa.gov/om/hazstats/resources/weather_fatalities.pdf

Urban Flooding

Urban flooding is usually caused by heavy rain over a short period of time. As land is converted from fields or woodlands to roads and parking lots, it loses its ability to absorb rainfall. Since sidewalks and roads are non-absorbent, rivers of water flow down streets and into sewers. Roads and buildings generate more runoff than tropical forestland. Fixed drainage channels in urban areas may be unable to contain the runoff that is generated by relatively small but intense rainfall events. Urbanization increases runoff two to six times over what would occur on natural terrain. This high volume of water can turn parking lots into lakes, flooding basements and businesses, and cause lakes to form in roads where drainage is poor or overwhelmed.

Urban flooding occurs where there has been development within stream floodplains. This is partly a result of the use of waterways for transportation purposes in earlier times. Sites adjacent to rivers and coastal inlets provided convenient places to ship and receive commodities. The price of this accessibility has increased flooding in the ensuing urban areas. Urbanization intensifies the magnitude and frequency of floods by increasing impermeable surfaces, amplifying the speed of drainage collection, reducing the carrying capacity of the land and, occasionally, overwhelming sewer systems.

Riverine Flooding

Periodic flooding of lands adjacent to non-tidal rivers and streams is a natural and inevitable occurrence. When stream flow exceeds the capacity of the normal watercourse, some of the above-normal stream flows onto adjacent lands within the floodplain. Riverine flooding is a function of precipitation levels and water runoff volumes within the watershed of a stream or river. The recurrence interval of a flood is defined as the average time interval, in years, expected to take place between the occurrence of a flood of a particular magnitude and an equal or larger flood. Flood magnitude increases with increasing recurrence interval.

Floodplains and Flood Zones

As noted above, the periodic flooding of lands adjacent to rivers, streams and shorelines (land known as floodplain) is a natural process that has some chance of occurrence each year. Floodplains are designated by the frequency (and severity) of the flood that is large enough to cover them. For example, the 10-year floodplain will be covered by the 100-year flood and the 100-year floodplain by the 1,000-year flood. Flood frequencies such as the 100-year flood are determined by plotting a graph of the size of all known floods for an area and determining how often floods of a particular size occur. Another way of expressing the flood frequency is the chance of occurrence in a given year, which is the percentage of the probability of flooding each year. For example, the 100-year flood has a 1.0-percent chance of occurring in any given year, and the 500-year flood drops to a 0.2-percent chance of occurring in any given year. Therefore, they are commonly referred to as the 1.0-percent annual chance flood and 0.2-percent annual flood, respectively. It should be noted that flooding is possible every year and even multiple times each year.

The U.S. Army Corp of Engineers and FEMA have a role in defining floodplain. The U.S. Army Corps of Engineers calls a 100-year flood an Intermediate Regional Flood, while a Standard Project flood describes a major flood that could be expected to occur from a combination of severe meteorological and hydrologic conditions. Most dam and flood-related structures have been designed to meet 100-year flood conditions.[48]
FEMA develops FIRMS to indicate areas where mandatory flood insurance requirement apply (the 100 year flood). They are also used for planning purposes to identify hazard areas. In May 1991, Flood Insurance Rate Maps (FIRMs) were published by FEMA for American Samoa in support of the National Flood Insurance Program designating zones according to potential risk and impact due to flooding.

48 Flood. (2003). North Carolina Division of Emergency Management. Retrieved August 8, 2014 from http://www.dem.dcc.state.nc.us/mitigation/flood.htm

The FIRM, a paper document, has been digitized to permit mapping. Although an all-inclusive description of FEMA flood zones is not included in this document, brief descriptions of the zones appearing on the FIRMs for the Territory are as follows:

Zone A

Zone A is the flood insurance rate zone that corresponds to the 100-year floodplains determined in the Flood Insurance Study by approximate methods. Because detailed hydraulic analyses are not performed for such areas, no Base Flood Elevations (BFEs) or depths are shown within this zone. Mandatory flood insurance purchase requirements apply.

Zone AE and A1-A30

Zones AE and A1-A30 are the flood insurance rate zones that correspond to the 100-year floodplains determined in the Flood Insurance Study by detailed methods. In most instances, BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone. Mandatory flood insurance purchase requirements apply. Note: Zone AE is used in place of Zone A1-A30 on new maps.

Zone VE

Zone VE is the flood insurance rate zone that corresponds to the 100-year coastal floodplains that have additional hazards associated with storm waves. BFEs derived from the detailed hydraulic analyses are shown at selected intervals within this zone, and mandatory flood insurance purchase requirements apply.

Zones B, C, and X

Zones B, C, and X are the flood insurance rate zones that correspond to areas outside the 100-year floodplains, areas of 100-year sheet flow flooding where average depths are less than one foot, areas of 100-year stream flooding where the contributing drainage area is less than one square mile, or areas protected from the 100-year flood by levees. No BFEs or depths are shown within this zone. Note: shade zone X is used in place of Zone B on new maps, and unshaded Zone X is used in place of Zone C on new maps.

It should be noted that flooding is possible outside of any defined flood zone. In fact, areas subject to flash flooding are often not captured on the maps. In addition, the flood event may be more severe than the 100-year or 500-year flood zones. In this case, water would go beyond these anticipated areas. Further, development can also alter where water goes in terms of the amount of drainage capability and where water travels. Areas that have not flood historically should not be considered immune from such an event.

Location

Areas susceptible to flooding (and rain amounts) vary across different islands and even villages. However, flood levels have not been captured well by historical record keeping. For example, it is known that Pago Pago and the areas near it receive a good deal of rain due to their location behind Rainmaker Mountain (Pioa Mountain). Its elevation is 1,716 feet and that height assists in "trapping" rain clouds that bring much rain to Pogo Pago Harbor. In addition, American Samoa topography features a shoreline and then sharp, steep increase in elevation into volcanic plugs (i.e., peaks, such as Rainmaker Mountain). Therefore, rain flows down from the mountainous areas, flooding areas below. In addition, coastal floods inundate the relatively narrow shoreline. The FEMA FIRM and Flood Insurance Study (FIS) can be used to determine the location of floods.[49]

49 The American Samoa FIS is dated as revised July 17, 2006.

Note that only the 100-year flood was modeled for American Samoa. Further, floodplains were not modeled for Rose Atoll or Swains Island. The maps (Map X1-X5) below show floodplain areas for each island at a high scale. Additional maps are provided in the vulnerability assessment section to show specific areas of detail.

Tutuila and Aunu'u

- A narrow band along the entire north shore and much of Tutuila's south shore lie in the 100-year floodplain (Figure 35).
- Pago Pago (Figure 36): The flood maps indicate the entire coast around Pago Pago is susceptible to 100-year flood levels annually. In addition, the villages of Aua, Lauli'ituai, Au'mu, Pago Pago, Fusi and Faga'alu have development inland residing in the 100-year flood zones. Further, areas inland along Route 5 from Fusi are indicated as being in the 100-year floodplain.
- Tafuna Plain East (Figure 37): This area highlights that Pago Pago international airport is surrounded by the 100-year floodplain. In additional to all areas around the coast, several inland villages are subject to the 100-year floodplain areas. Examples include Malaeimi, Tafuna, Lepine, Tafunaufou, and Nu'uuli, among others.
- Tafuna Plain West (Figure 38): Similar to Tafuna Plain East, Tafuna Plain West is subject to 100-year flooding (and greater) along the entire coast. In addition, the floodplain also impacts some inland villages such as Auma, Vaiala, and Malaeloa. There are several streams that are not indicated as being part of the 100-year flood. It should be noted that these areas might be subject to flooding during heavy rain events. However, there is less development along most of these streams as they move further inland.
- Aunu'u (Figure 39): The entire western portion of the island, where all development resides, is located in a 100-year floodplain. Additionally, the coastline around the entire island is in 100-year floodplain.

Manu'a Islands

- Ofu (Figure 40): The entire coast is subject to VE 100-year (wave action/velocity) floodplain. In addition, large areas of Ofu Village are subject to the 100-year floodplain, particularly on the western and northwestern coasts.
- Olosega (Figure 41): The entire coast is subject to VE 100-year (wave action/velocity) floodplain. In addition, limited areas in Olosega Village on the eastern coast are subject to the 100-year floodplain.
- Ta'u (Figure 42): The flood maps for Ta'u Island show limited floodplain area. The entire coast is subject to VE 100-year (wave action/velocity) floodplain. In addition, large areas of Luma Village are in the 100-year floodplain. In addition, a small area on the eastern side of the island near the coast is the in 100-year floodplain.

The FEMA designated floodplain areas are shown on the next page.

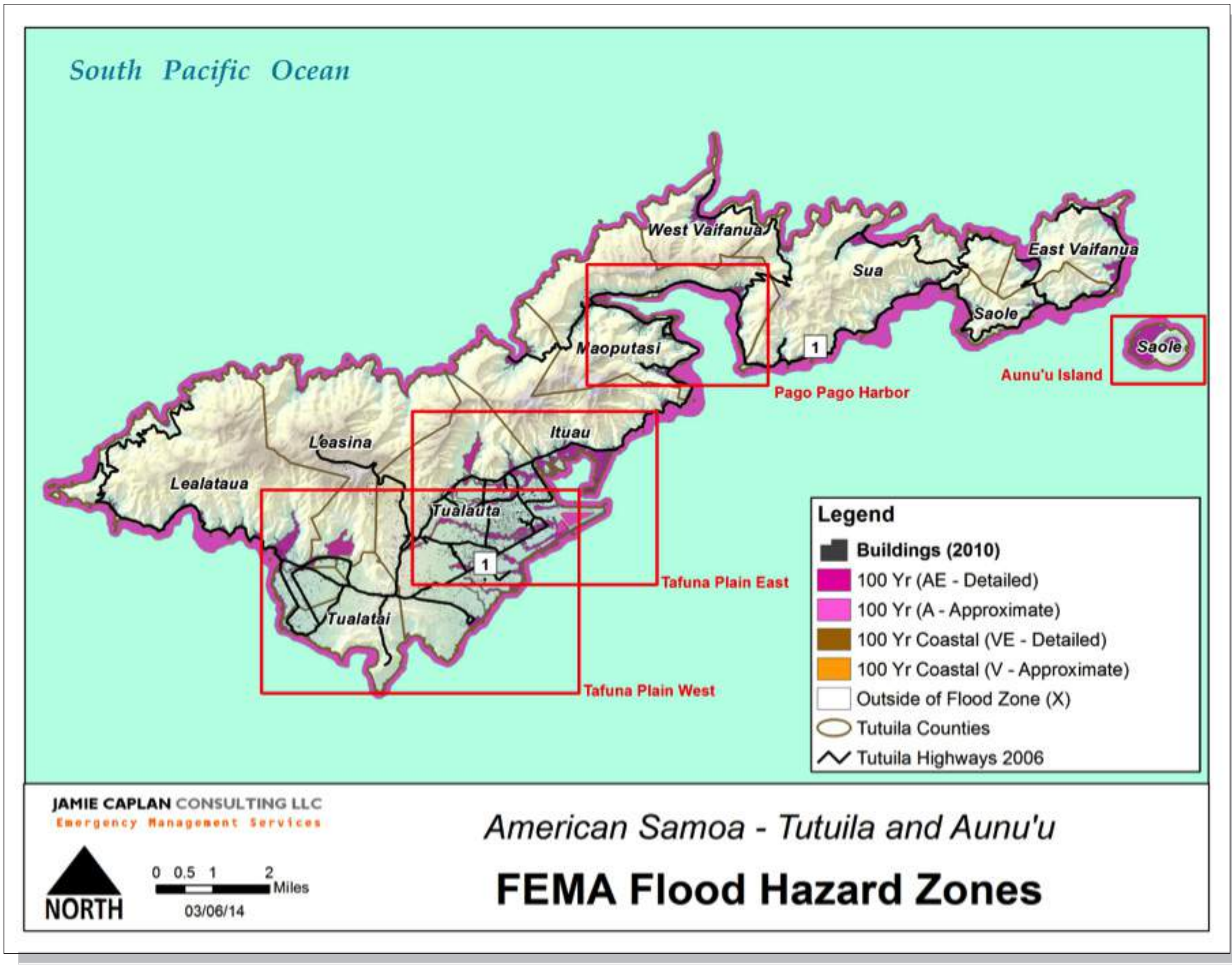

Figure 35 FEMA Flood Hazard Areas for Tutuila and Aunu'u Island

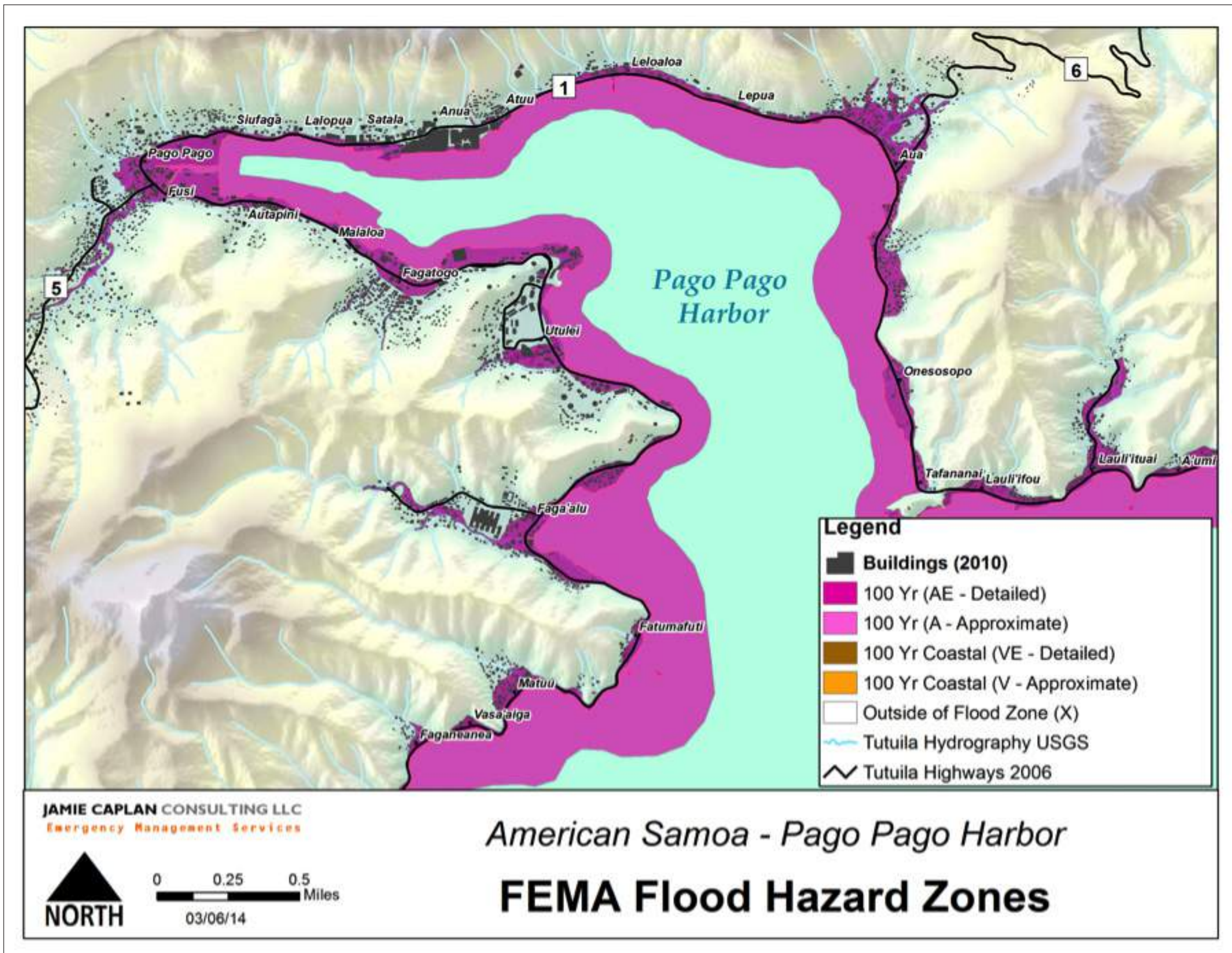

Figure 36 FEMA Flood Hazard Areas for greater Pago Pago

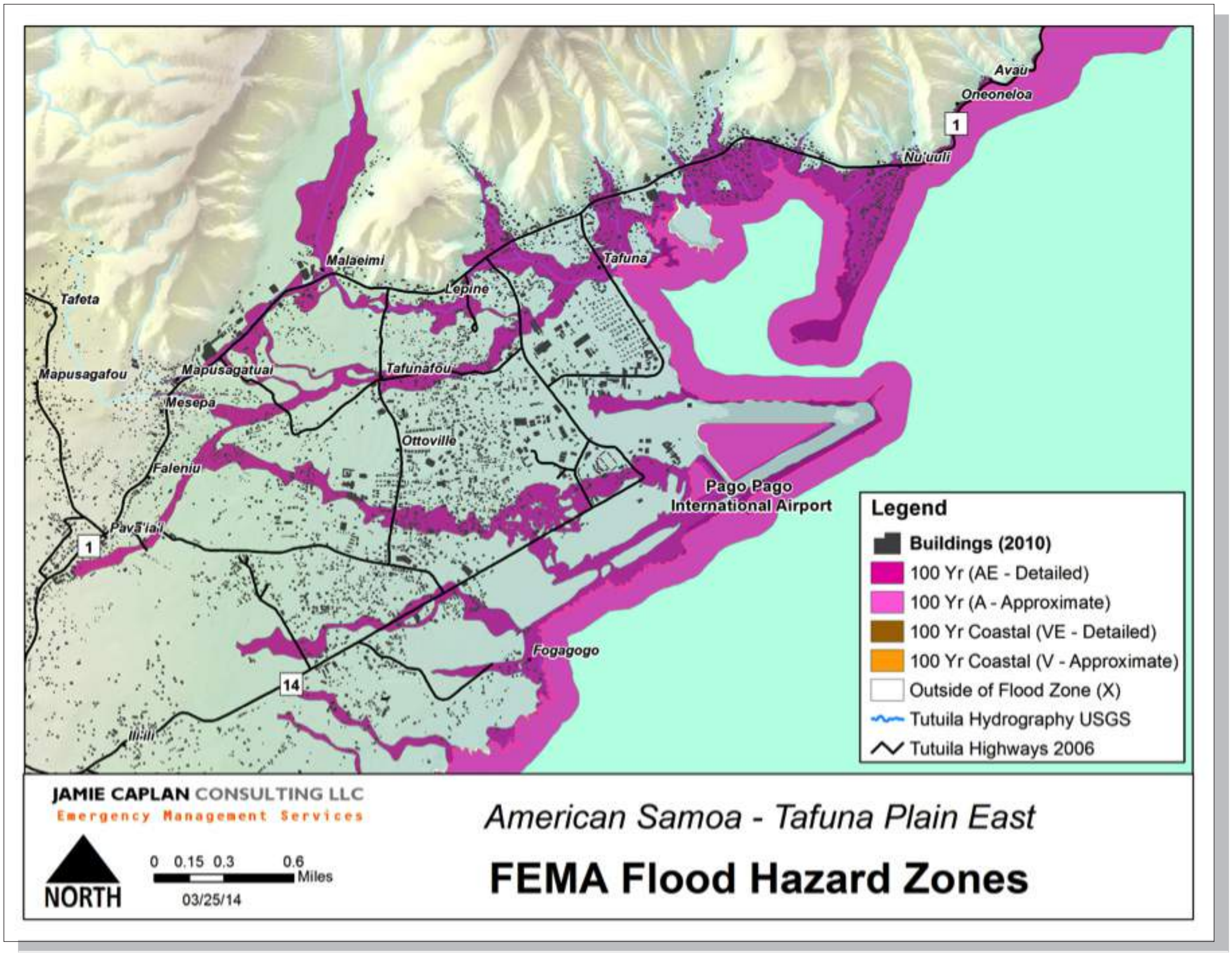

Figure 37 FEMA Flood Hazard Areas for Tafuna Plain East

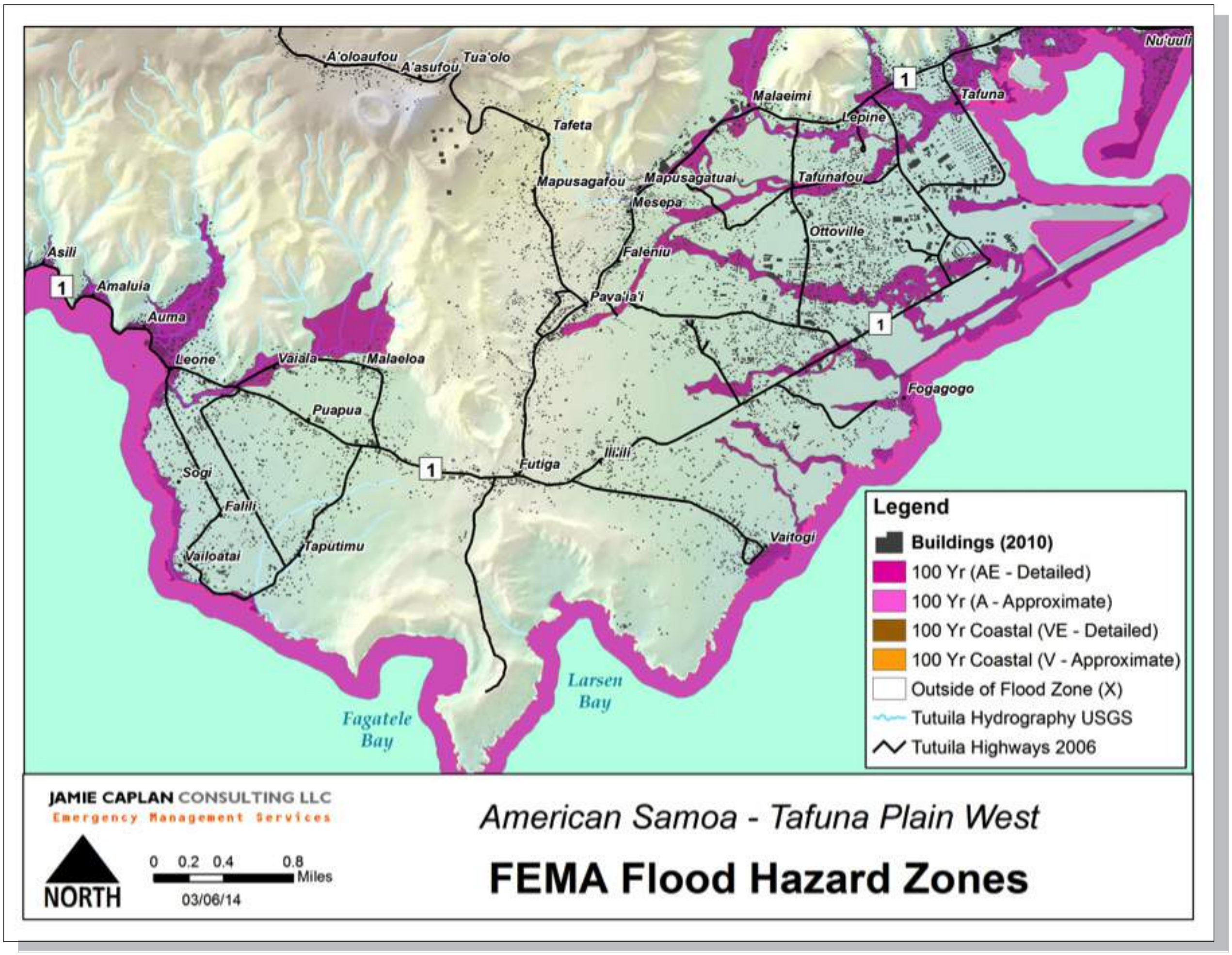

Figure 38 FEMA Flood Hazard Areas for Tafuna Plain West

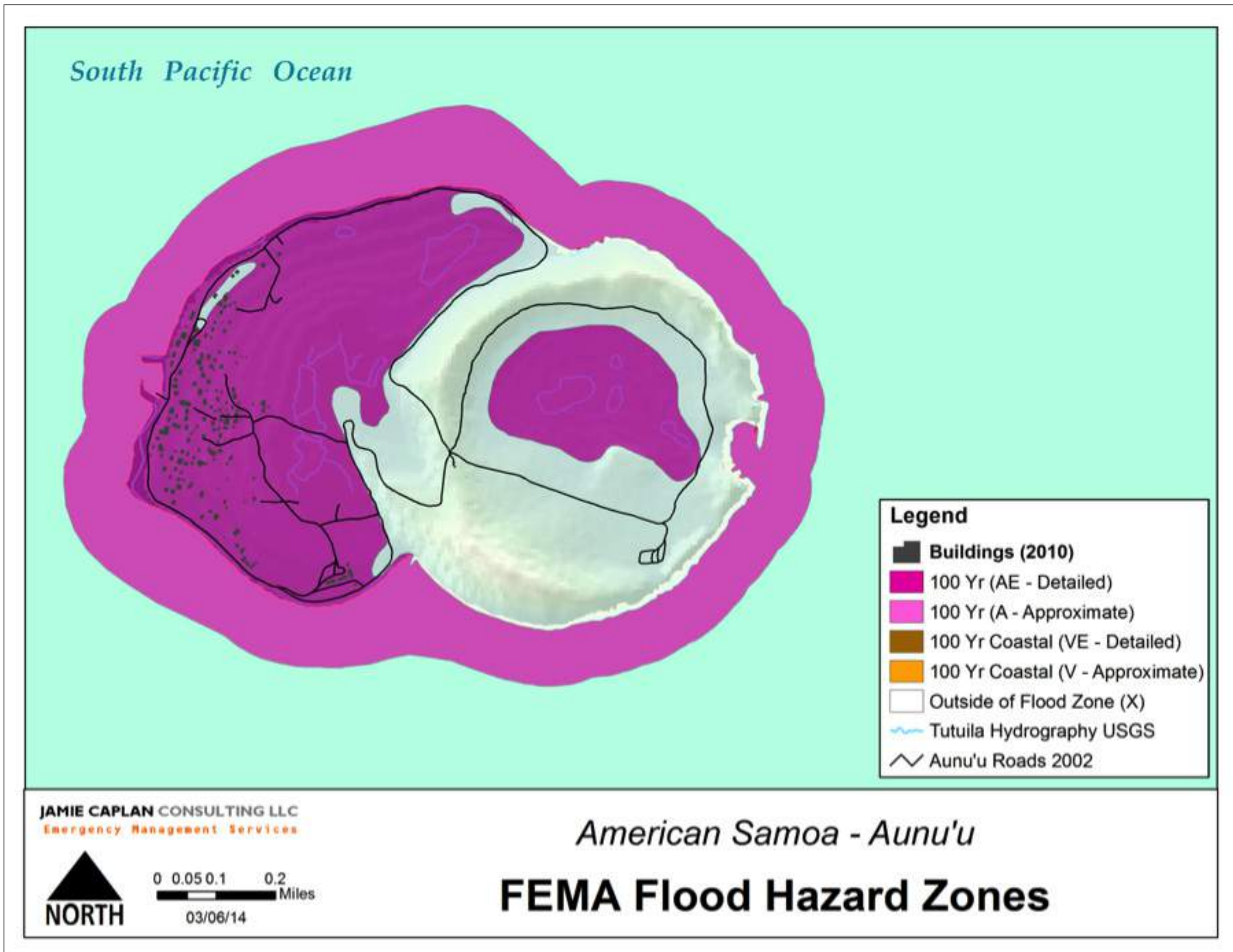

Figure 39 FEMA Flood Hazard Areas for Aunu'u

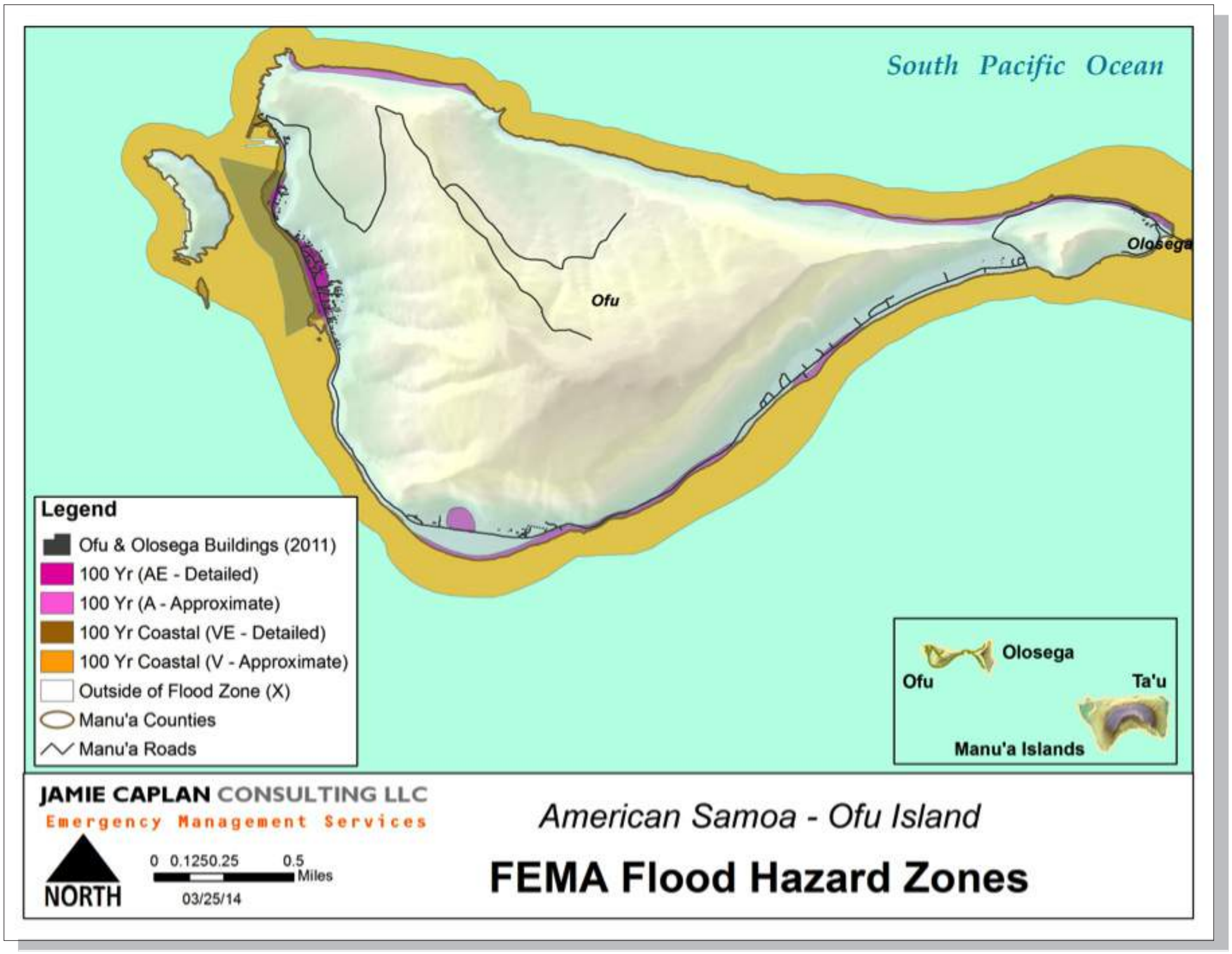

Figure 40 FEMA Flood Hazard Areas for Ofu

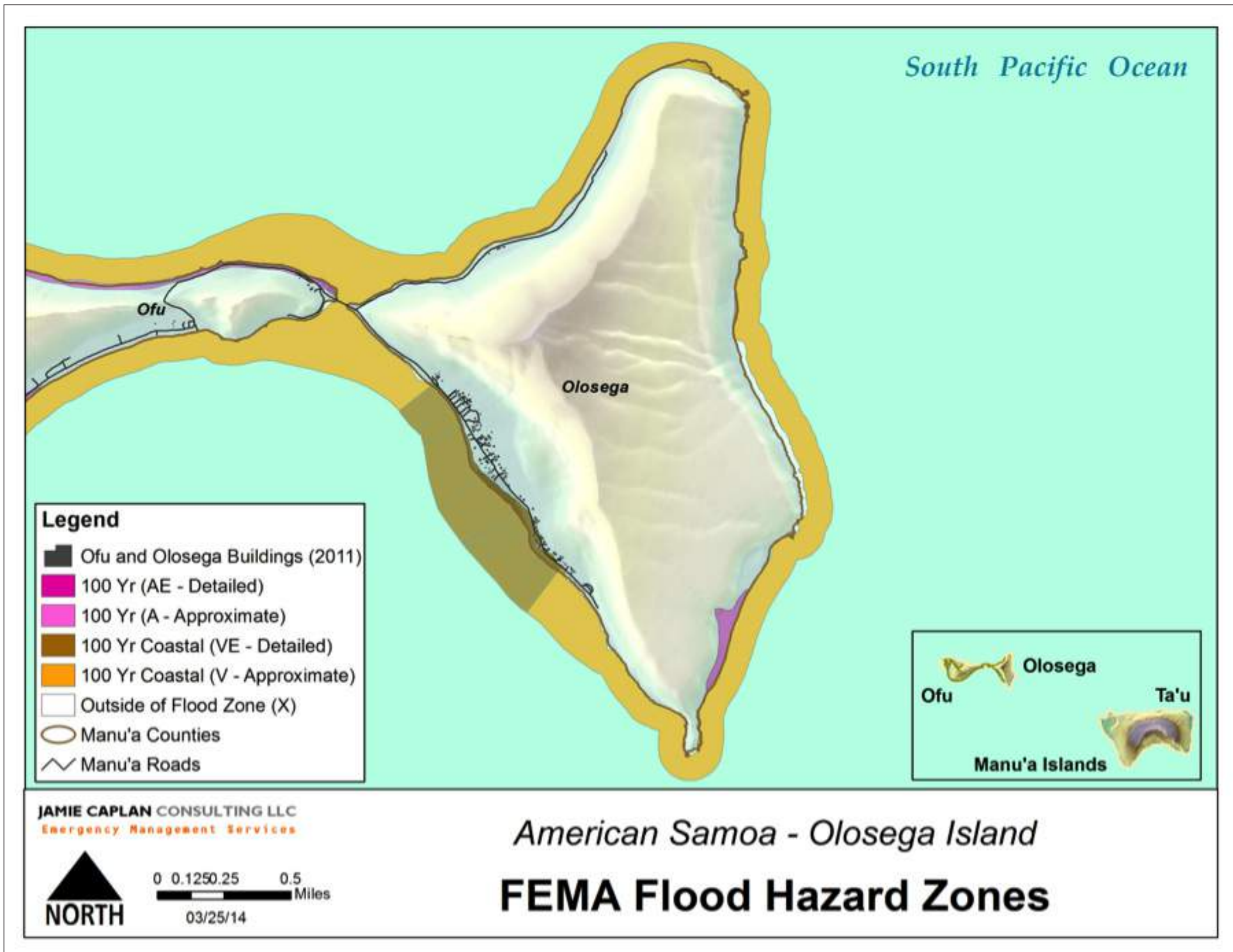

Figure 41 FEMA Flood Hazard Areas for Olosega

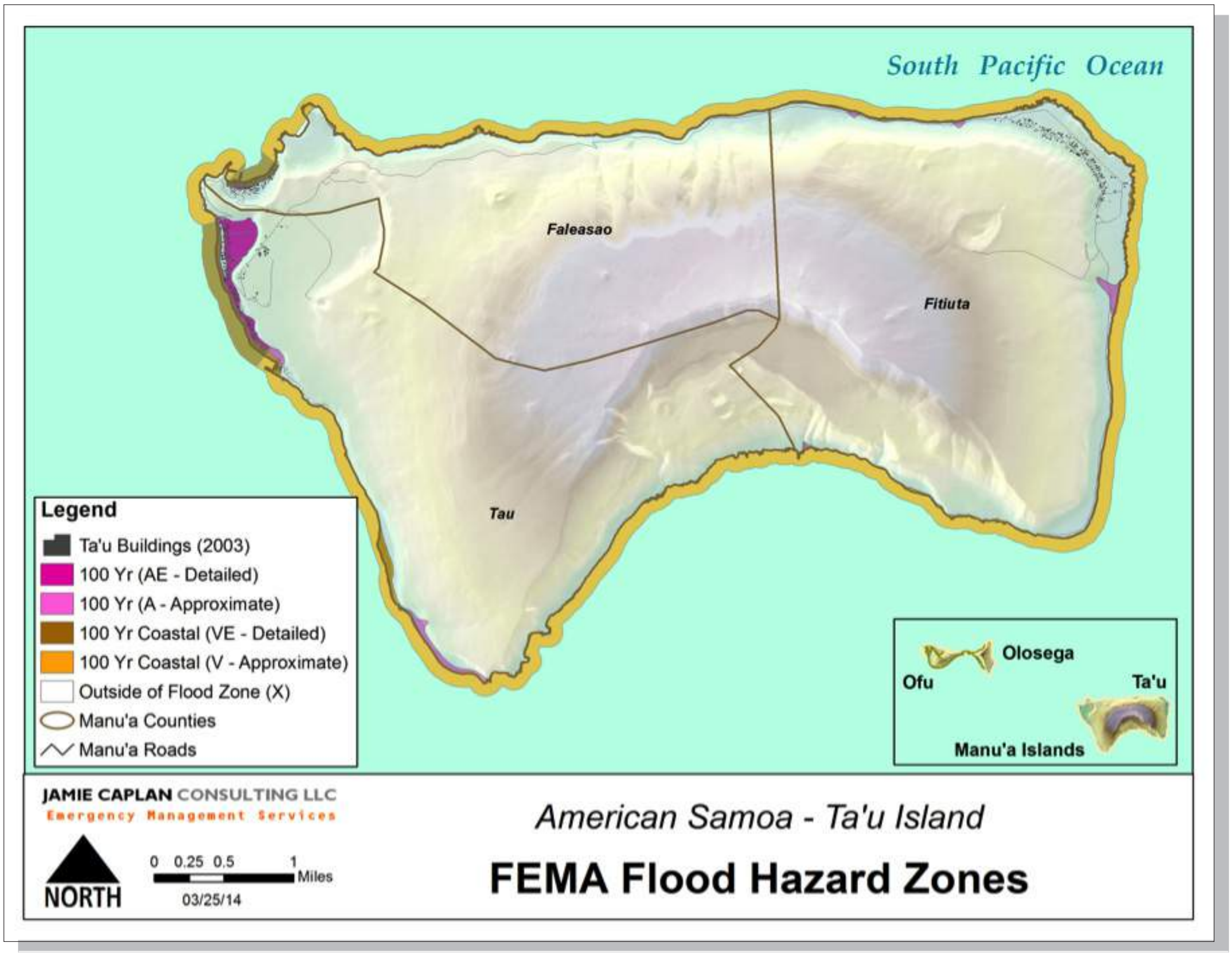

Figure 42 FEMA Flood Hazard Areas for Ta'u

Table 23 Amount of Floodplain by County in American Samoa

County (District)	Size of County (Sq. Mi.)	Size of A, AE Floodplain (Sq. Mi.)	Size of V, VE Floodplain (Sq. Mi.)
TUTUILA ISLAND			
East Vaifanua (East District)	2.13	0.24	0
Ituaa (East District)	4.89	0.44	0
Lealataua (West District)	9.22	0.41	0
Leasina (West District)	6.48	0.24	0
Maoputasi (East District)	6.69	0.44	0
Saole (East District)	1.68	0.16	0
Sua (East District)	6.87	0.33	0
Tualatai (West District)	2.53	0.03	0
Tualauta (West District)	9.91	1.13	0
West Vaifanua (East District)	2.19	0.12	0
Tutuila Island Total	52.59	3.54	0
AUNU'U ISLAND			
"Saole (East District)"	0.59	0.32	0
Aunu'u Island Total	0.59	0.32	0
MANU'A ISLANDS			
TA'U ISLAND			
Faleasoa (Manu'a District)	4.59	0.004	0.05
Fitiuta (Manu'a District)	6.73	0.03	0.04
Ta'u (Manu'a District)	6.23	0.14	1.84
Ta'u Island Total	17.55	0.16	1.93
OFU ISLAND			
Ofu (Manu'a District)	2.83	0.10	1.88
Ofu Total	2.83	0.10	1.88
OLOSEGA ISLAND			
Olosega (Manu'a District)	2.03	0.02	3.79
Olosega Total	2.03	0.02	3.79
TOTAL	**75.59**	**4.144**	7.6

As noted above, flooding is possible outside of designated flood zones. The flood event may be more severe than the depicted flood zones, for example. Additionally, changes in development can impact where water goes or much capacity there is for it to drain. Previous rain events may impact the capacity of natural and manmade systems to handle additional water. Flooding is possible along streams and in urban areas.

Previous Occurences

The most notable weather elements that influence disastrous flooding in the islands of American Samoa include events generally associated with low-pressure systems, such as thunderstorms, tropical cyclones, and tsunamis. These tropical downpours can occur as isolated incidents or in conjunction with tropical cyclones that come close to the islands. These downpours are of fairly short duration, but can release large volumes of water that at times cause flooding in low-lying areas, especially at the base of gulches, and in places where ponding is caused by faulty or inadequate drainage systems in low-lying urban areas.

Inland floods occur regularly in American Samoa, especially during the rainy season of December through March. They are primarily caused by excessive or prolonged rainfall combined with inadequate drainage capacity. As expected, urban flooding on Tutuila is most noticeable around population centers. This type of flooding has become more widespread in recent years due to population increases and associated increase of impervious surfaces.

Tropical cyclones carry immense rain with them and are a source of serious coastal flooding on American Samoa's low-lying shores and inland areas. While tsunamis are a dangerous flood and safety threat but are a less frequent threat to coastal areas. Appendix J: Summary of Significant Flooding Events

Table 24 Summary of Significant Flooding Events shows a summary of flooding events reported in American Samoa by the National Climatic Data Center. This data source begins in 1994. It indicates a total of fourteen flood events in the Manu'a Islands (7 flood, 6 flash flood, 1 heavy rain) and 66 flood events in Tutuila (39 flood, 25 flash flood, 2 heavy rain). These events resulted in over $55 million in damages reported in Tutuila (including a $50 million flood event with associated landslide damage). Additional events collected in other sources are also included. One death was reported due to flooding, and five deaths resulted due to landslides associated with flooding. Bolded events indicate more significant occurrences (such as known associated damages).

Extent

Extent can be measured by reviewing the mapped hazard areas and previous occurrences. The FEMA DFIRMs indicate areas of the 1.0-percent (100-year) annual chance flood areas. In addition, more severe floods, such as the 0.2-percent (500-year) annual chance flood or greater, are possible in the planning area. In these cases, additional land will be submerged and higher water levels are possible. Previous occurrences indicate ponding and flooding levels of a few inches to 3 feet in streets and structures throughout American Samoa. Lastly, it should be noted that future event may be more severe than what has been recorded to date. This is of particular concern given climate change impacts and an increase of severity in all types of hazard events.

Probability of Future Events

The probability of flooding was largely determined using the number of historical occurrences as discussed below. However, it is also relevant to note the potential connection to the ENSO cycle.

During El Niño years, there is an increased chance for flooding when tropical storms or hurricanes come close to, or impact American Samoa. On the other hand, without the tropical cyclone factor, there are less frequent localized flooding events caused by thunderstorm flooding during El Niño years. During the La Niña phase of ENSO, there are fewer tropical cyclones, leading to a lower probability for flooding rainfall. In contrast, there is often more thunderstorm activity during La Niña periods, suggesting an increased flood potential from that source.

The probability of flooding rainfall can be high to very high with the arrival of any tropical cyclone. As previously mentioned, slow-moving storms with high moisture can wreak havoc on the islands, even with lower wind speeds, due to flooding impacts. The likelihood of inland and coastal flooding can be severe during tropical cyclones.

In terms of determining a statistical measure of probability, the FEMA DFIRMs and historic events provide insight. It can be assumed that areas located in the base flood area on the DFIRMs have a one percent annual chance of flood occurrence (a categorization of Possible). However, flooding can occur outside of these areas and often does in American Samoa with heavy rain and tropical cyclone events. For this reason, historic events are also investigated.

According to the National Climatic Data Center, there were sixty-five flood and flash events reported in Tutuila since 1994, a 20-year reported period. There were fourteen events reported since 1944 in the Manu'a Islands. Based on these events, there is 100 percent annual probability of a flood event in Tutuila (highly likely) and a 70 percent annual probability (likely) of a flood event in Manu'a. However, it is important to note that the conclusions presented here are based on reported events and additional flood events may have occurred that were not reported. Further, some areas of the islands may be more susceptible to flooding.

National Flood Insurance Program Participation

American Samoa is a participant in the National Flood Insurance Program (NFIP), however they do not have any active policies at this time. To date, all NFIP policies in American Samoa have expired. Some policies were written following the 2009 Tsunami disaster declaration. However, all lapsed following the eligibility period since they were not renewed. Most policies expired in November 2012. Following the 2009 Tsunami, a total 462 policies were written in the villages as shown in Table 24.

Table 24 NFIP Policies by Village Following the 2009 Tsunami

Village	Number of Policies	Village	Number of Policies
Afao	3	Futiga	1
Afono	21	Laauli'i	4
Alao	28	Leloaloa	1
Alofau	23	Leone	43
Amaluia	15	Maloata	2
Amanave	9	Masausi	1
Amaua	1	Masefau	19
Amouli	3	Matu'u	3
Aoa	2	Nua	5
Asili	12	Nu'uuli	2
Aua	19	Olosega	1
Auasi	1	Onenoa	2
Aunu'u	1	Pagai	3
Auto	14	Pago Pago	48
Fagaalu	8	Poloa	2
Fagaitua	19	Sailele	2
Fagalii	5	Seetaga	25
Fagamalo	2	Tafuna	1
Faganeanea	2	Tula	33
Fagasa	43	Utusia	2
Fagatogo	2	Vaitogi	1
Failolo	1	Vatia	26
Fatumafuti	1	--	--
TOTAL	--	--	462

Vulnerability Assessment

Flooding is an increasingly serious problem in many areas of American Samoa, and a number of factors exacerbate this problem. Steep terrain in some areas results in high velocity stream flow. Shallow or ill-defined stream channels can rapidly overflow leading to overbank flooding, and urban development exaggerates these flooding extremes, since grading of the land can promote changes in drainage direction in streams. Development may also lead to increases in impervious surfaces thus reducing drainage capacity.

In some cases, stream channels have been redirected or moved to accommodate buildings, and this has caused sharp bends in the stream flow. Inadequately sized culverts are unable to accommodate stream flows during intense rainfall, causing a backup of floodwaters. Coastal roads are particularly vulnerable to flooding due to high surf, storm surge associated with tropical cyclones, or tsunamis. Lush vegetation and highly absorbent soil are two conditions that decrease vulnerability to flood hazards in American Samoa.

Previous occurrences indicate several impacts due to flooding including salinization of ground water drinking supply, damaged or structures homes and businesses, flooding of the hospital, mudslides, landslides, debris-blocked roads, flooded streets, traffic congestion, evacuation, sheltering needs and runoff. These impacts often result in costly cleanup and business interruption.

Although the flood hazard does have a defined boundary, all current and future structures and populations should be considered at risk. As noted throughout this section, flooding my not occur in designated areas. Changes in development and climate have increased the severity of this hazard for the islands and flood is considered a high hazard based on the PRI results.

Potential Losses

A GIS analysis of buildings that are potentially at risk to flooding was conducted. This analysis does include any information on building elevation. In other words, if a structure is elevated to withstand flooding, this analysis would not account for that. However, it assumed that most buildings are not elevated given older construction and local knowledge of the islands.

Tutuila has buildings at risk along almost the entire coastline. The northwestern portion of the coast is least impacted, though there is very limited development there. In addition, the greater Pago Pago area has several structures at risk along the coast. The Tafuna Plain, especially Tafuna Plain East has significant risk, including inland areas in Tualauta and Ituau counties. There is also risk in east Tutuila. Aunu'u has risk in the eastern portion of the island, where development is concentrated. Nearly all of the island's structures appear to be at risk to flooding. Maps can Tutuila and Aunu'u can be found on the proceeding pages starting with Figure 43 on page 109 and in the table below.

Buildings are also at risk in Manu'a. On Ofu, building risk is concentrated on the northwestern portion of the island. On Ofu, most development is out of the floodplain. However, a small cluster of buildings resides on the southwestern edge of the island. Maps for Ofu and Olosega buildings at risk can be found in Figure 49 below. On Ta'u, development is concentrated in the northeastern and northwestern portions of the island (Figure 50). However, only the northwestern portion has buildings at risk. This information is reinforced in the table and figures below.

Table 25 below highlights the approximate number of buildings in the A and V flood zones on Tutuila, Aunu'u and Manu'a Group islands.

Table 25 Buildings Potentially At Risk to the A/AE Zones and V/VE Zones

County (District)	Total Number of Buildings	Total Number of Buildings in A, AE zones	Percent of Buildings in A, AE zones	Total Number of Buildings in V, VE zones	Percent of Buildings in V, VE zones	Percent of Buildings flood zones
TUTUILA ISLAND						
East Vaifanua (East District)	497	298	60%	0	0%	60%
Ituau (East District)	1,075	592	55%	0	0%	55%
Lealataua (West District)	2,026	612	30%	0	0%	30%

County (District)	Total Number of Buildings	Total Number of Buildings in A, AE zones	Percent of Buildings in A, AE zones	Total Number of Buildings in V, VE zones	Percent of Buildings in V, VE zones	Percent of Buildings flood zones
Leasina (West District)	474	78	16%	0	0%	16%
Maoputasi (East District)	2,246	756	34%	0	0%	34%
Saole (East District)	543	352	65%	--	0%	65%
Sua (East District)	938	493	53%	0	0%	53%
Tualatai (West District)	903	4	0%	0	0%	0%
Tualata (West District)	7,441	920	12%	0	0%	12%
West Vaifanua (East District)	172	141	82%	0	0%	82%
Tutuila Island Total	16,315	4,246	26%	0	0%	26%
AUNU'U ISLAND						
Saole (East District)	179	175	98%	0	0%	98%
Aunu'u Island Total	179	175	98%	0	0%	98%
MANU'A ISLANDS						
TAU ISLAND						
Faleasoa (Manu'a District)	81	17	21%	3	4%	25%
Fitiuta (Manu'a District)	180	0	0%	0	0%	0%
Ta'u (Manu'a District)	208	124	60%	9	4%	64%
Ta'u Island Total	469	141	30%	12	3%	33%
OFU ISLAND						
Ofu (Manu'a District)	133	40	30%	4	3%	33%
Ofu Total	133	40	30%	4	3%	33%
OLOSEGA ISLAND						
Olosega (Manu'a District)	101	0	0%	7	7%	7%
Olosega Total	101	0	0%	7	7%	7%
TOTAL	17018	4427	26.0%	23	0.1%	26.1%

It is clear from the analysis that all counties are subject to flood risk and potential losses. The analysis indicates that West Vaifanua County has the greatest percent of buildings in the floodplain Maoputasi (Pago Pago Harbor) has the highest number of buildings in the floodplain. This area is highly developed. In addition, NFIP claims following the tsunami were highest in Pago Pago (Maoputasi County), Fagasa (Ituau), Leone (Lealataua), and Tula (East Vaifanua). These counties cover the far eastern county, far western county and Tafuna Plain.

A critical facility analysis was also performed using available data. It should be noted, however, that the GIS analysis performed does not account for building elevation. The buildings identified may be constructed to withstand the 100-year flood or greater flood events. The results indicated that 84 critical facilities, including the new district court building, schools and fire stations, were reported as in the A/AE floodplain in Tutuila. These structures have an approximate combined value of $320,032,311. No additional structures were determined to be located in the V/VE zone on Tutuila. Eighteen critical facilities were reported in Ta'u (no values provided). In Ta'u, several stores and the hospital reside in the floodplain according to the analysis results. As previously discussed, no critical facilities were provided for the Ofu and Olosega Islands. The following table, Table 26, highlights the results. Several figures also note the location of these critical facilities beginning with Figure 51.

Table 26 Number of Critical Facilities (CFs) in the Floodplain hazard Area

Location	Total Number of Buildings	Total Number of CFs in the A, AE Zones Areas	Estimated Value	Total Number of CFs in the V, VE Zones Areas	Value
Tutuila Island CFs	241	85	$320,032,311	0	$0
Ta'u Island CFs	42	18	N/A	6	N/A

Assembly Areas

- One assembly area was found to intersect the A/AE flood zone. It is important to realize that these areas are subject to flooding and would not be a safe assembly locations during flood events.

Safe Zones

- No safe zone areas in Tutuila intersect the A/AE flood zone.

Tsunami Sirens

- Thirty-one sirens are located in the A/AE flood zone, and one siren is located in the V/VE flood zone (on Ta'u). These structures, mostly new and made of metal, are largely fortified from flood. However, frequent flooding may compromise their foundation. The complete list of at risk sirens can be found in Appendix D.

ASTCA Infrastructure

- Eleven ASTCA infrastructure items were including 2 ASTCA stores, 4 cell sites, 2 microwaves towers, 1 cell tower, and 2 DCO buildings. The buildings, in particular, are at risk to flood. The remote cell sites are typically on a pole and could be damaged if the pole is displaced. The towers are less likely to be impacted by flood.

A complete listing of critical facilities and associated information (such as assembly areas, safe zones, and tsunami sirens) can be found in Appendix D.

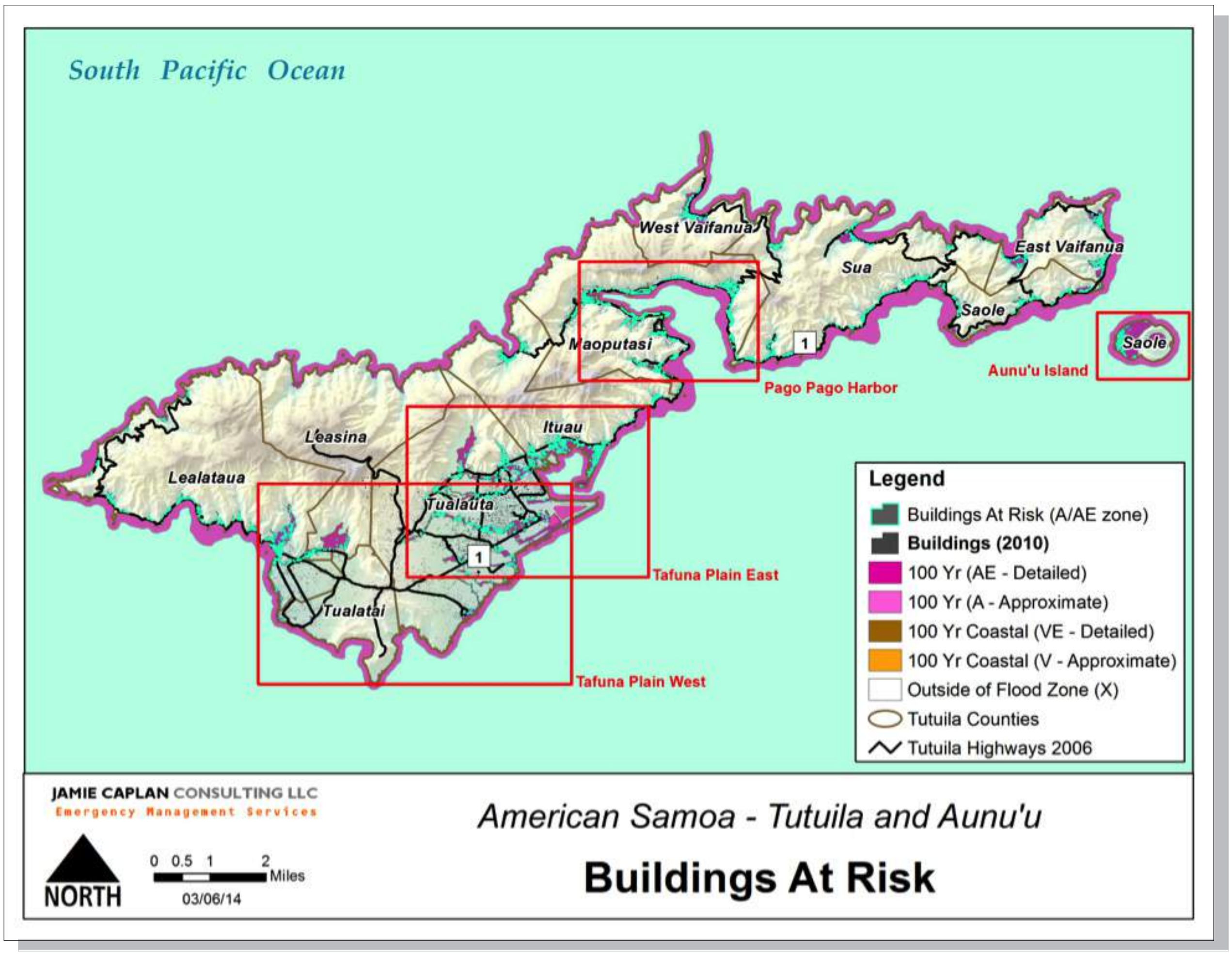

Figure 43 Buildings Potentially At Risk to Flooding on Tutuila and Aunu'u Islands

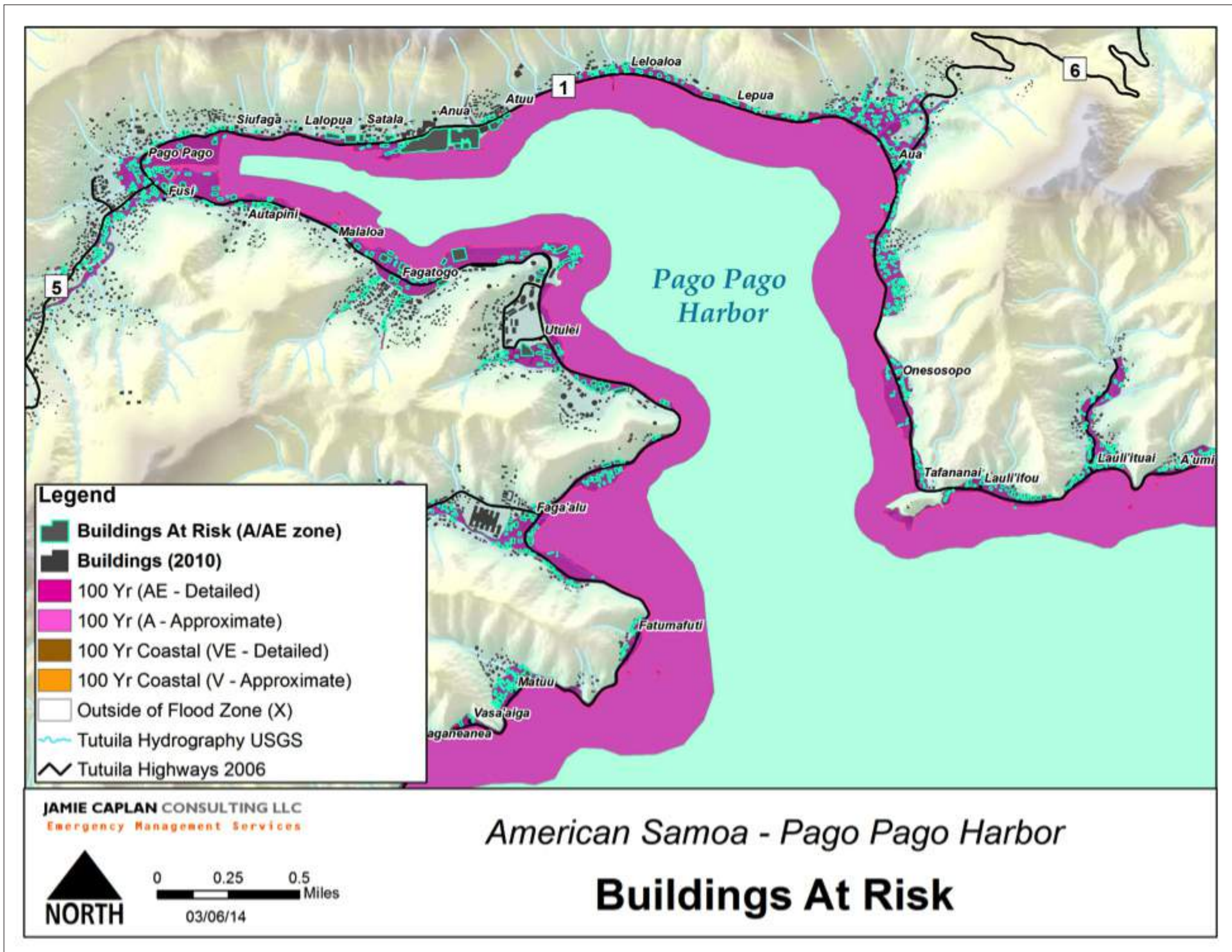

Figure 44 Buildings Potentially At Risk to Flooding in Greater Pago Pago

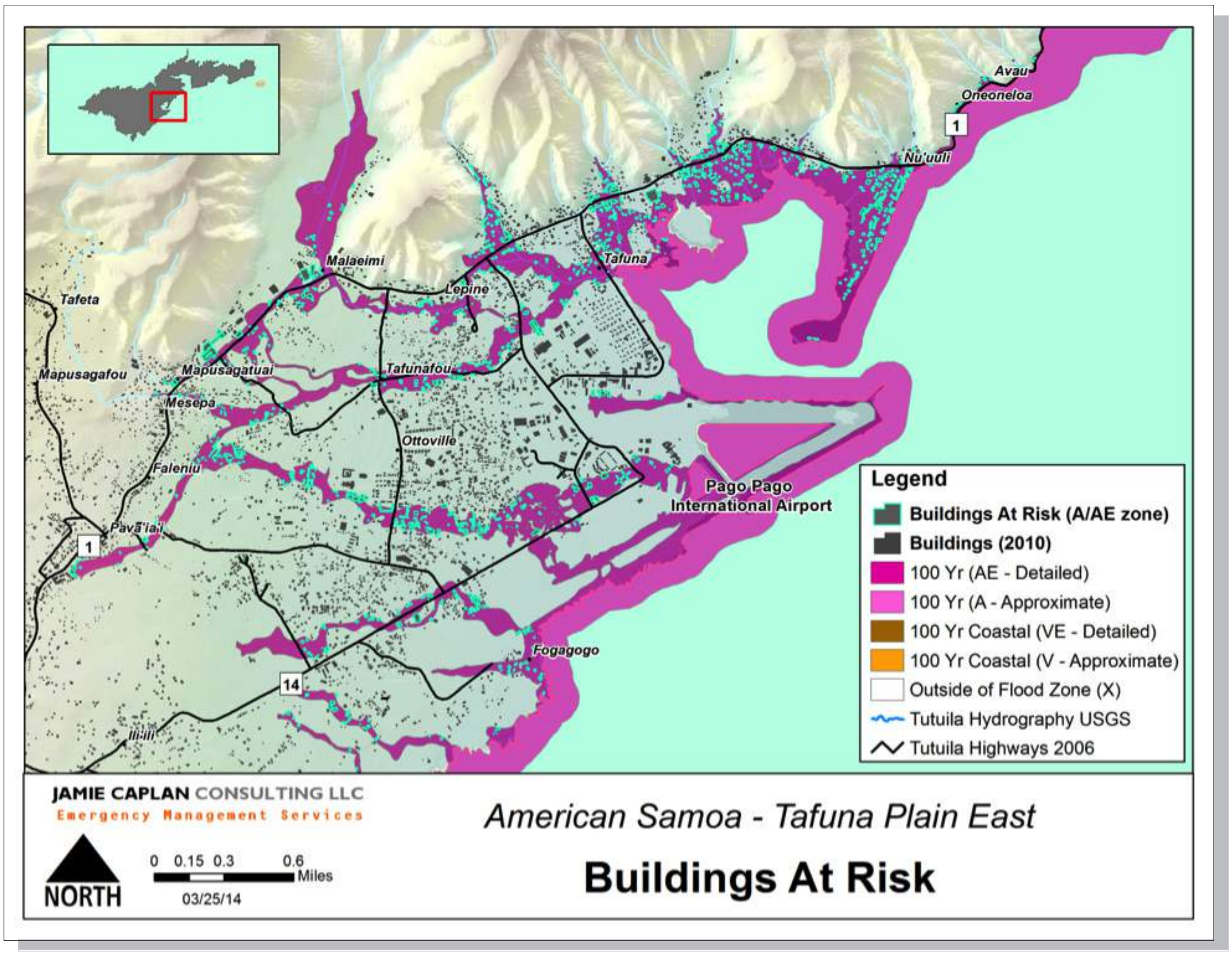

Figure 45 Buildings Potentially At Risk to Flooding in Tafuna Plain East

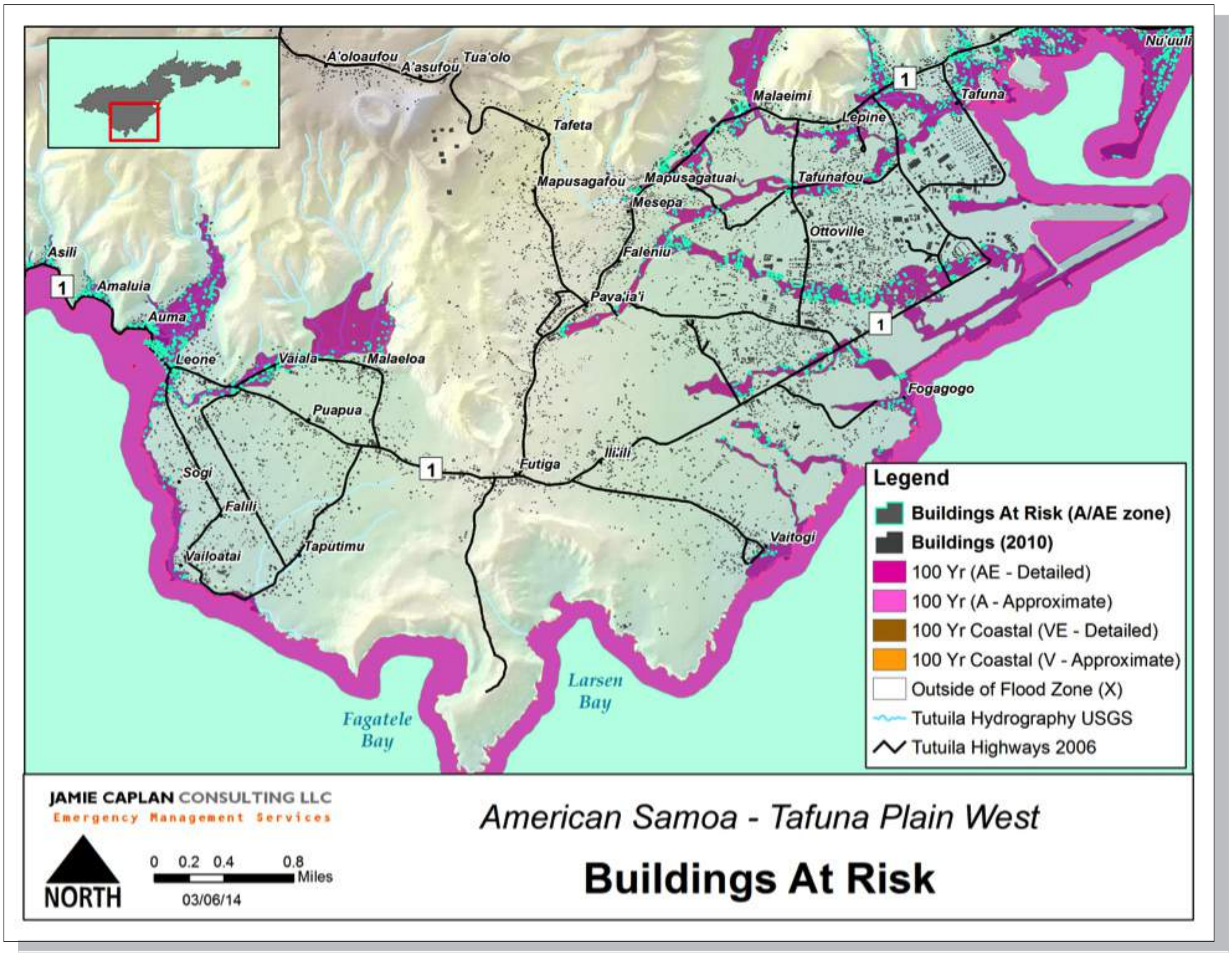

Figure 46 Buildings Potentially At Risk to Flooding in Tafuna Plain West

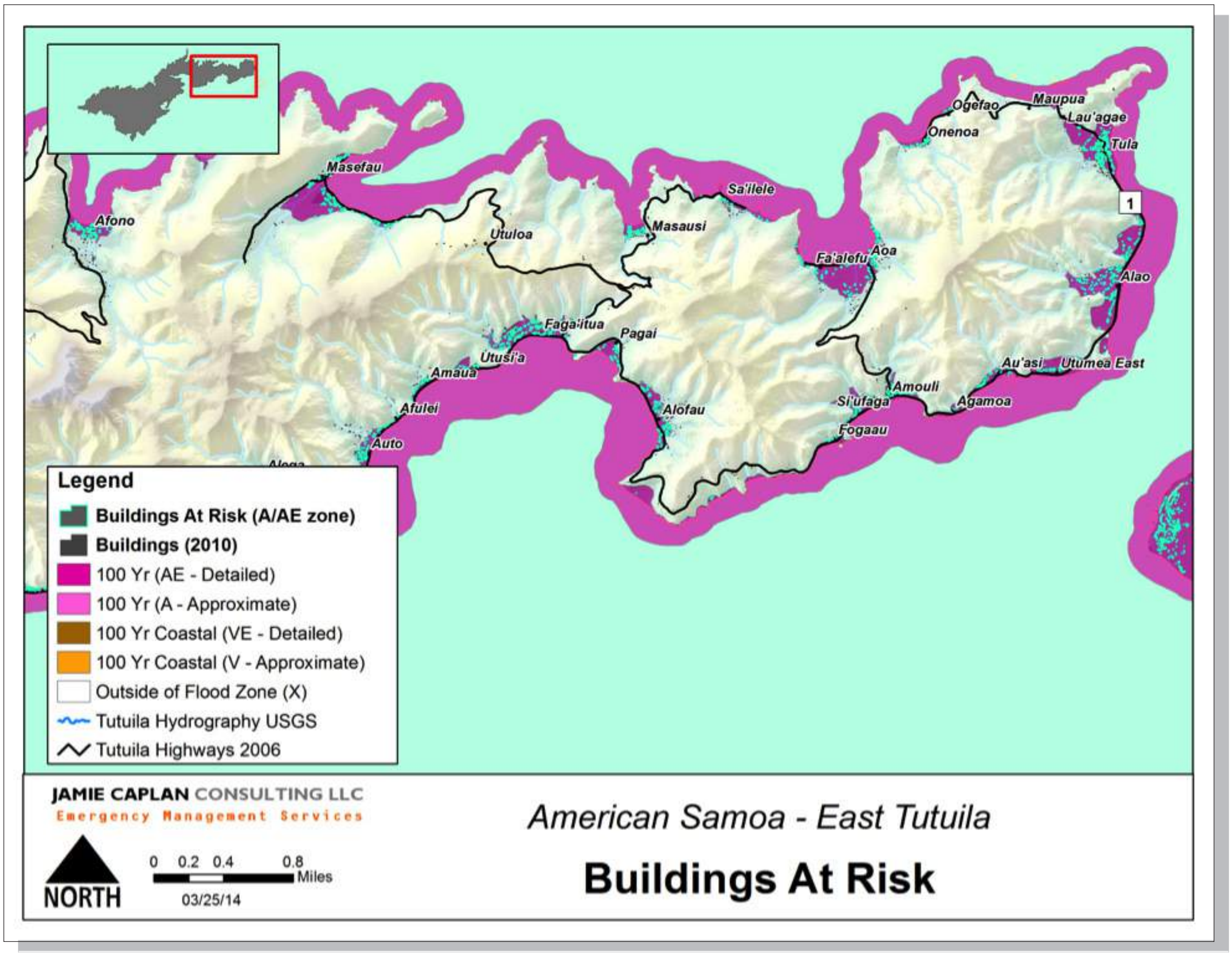

Figure 47 Buildings Potentially At Risk to Flooding in East Tutuila

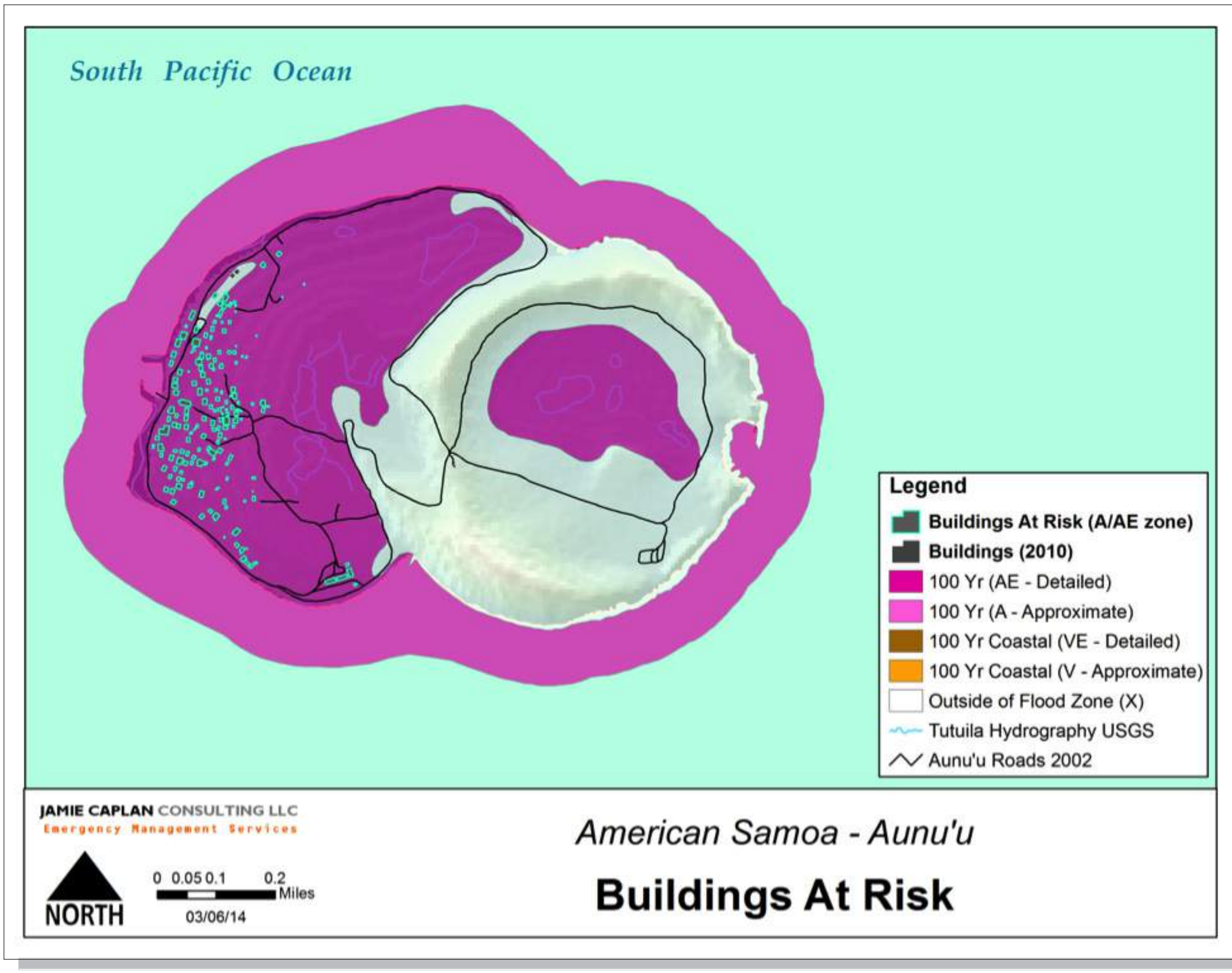

Figure 48 Buildings Potentially At Risk to Flooding on Aunu'u Island

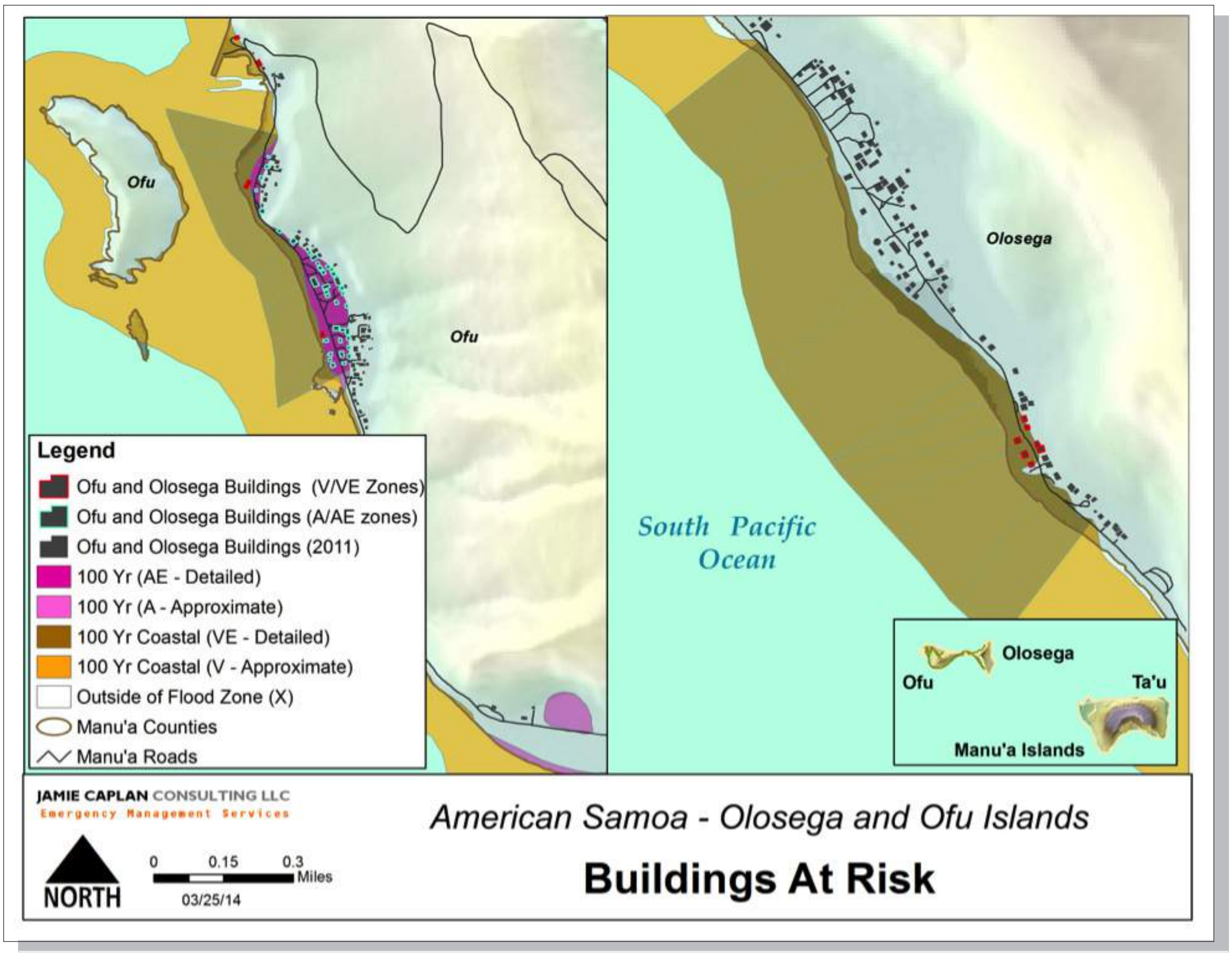

Figure 49 Buildings Potentially At Risk to Flooding on Olosega and Ofu Islands

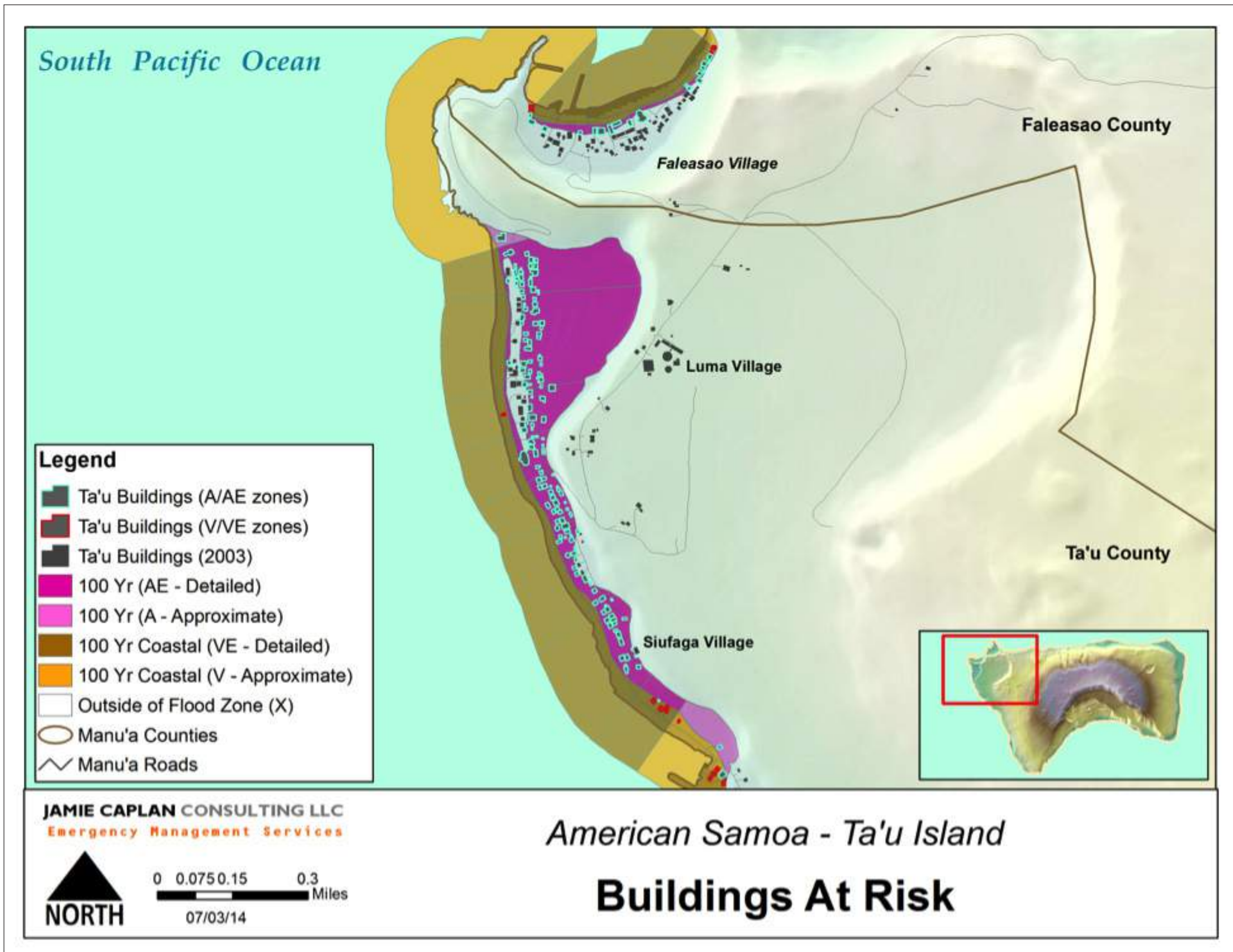

Figure 50 Buildings Potentially At Risk to Flooding on Ta'u Island

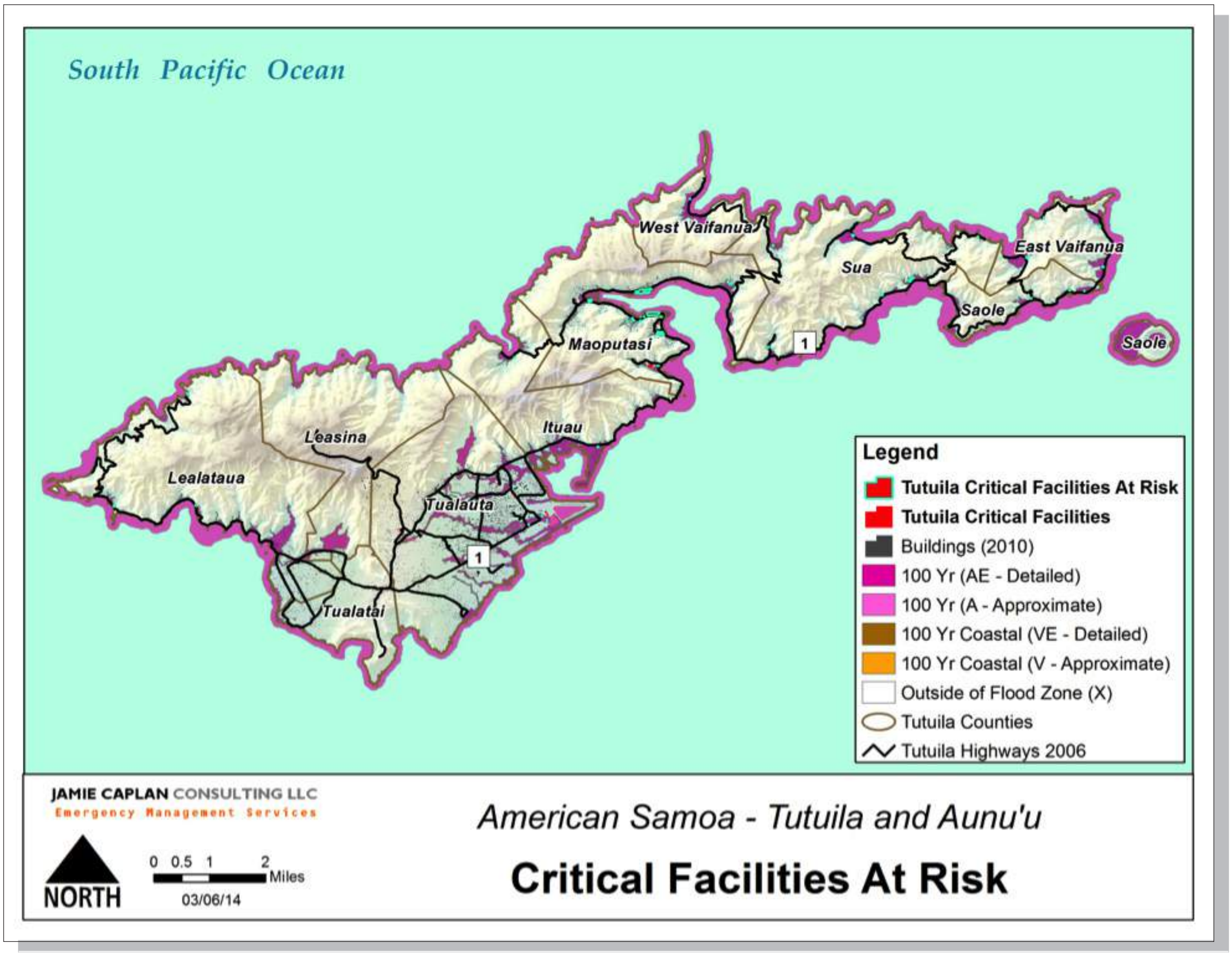

Figure 51 Critical Facilities Potentially At Risk to Flooding in Tutuila

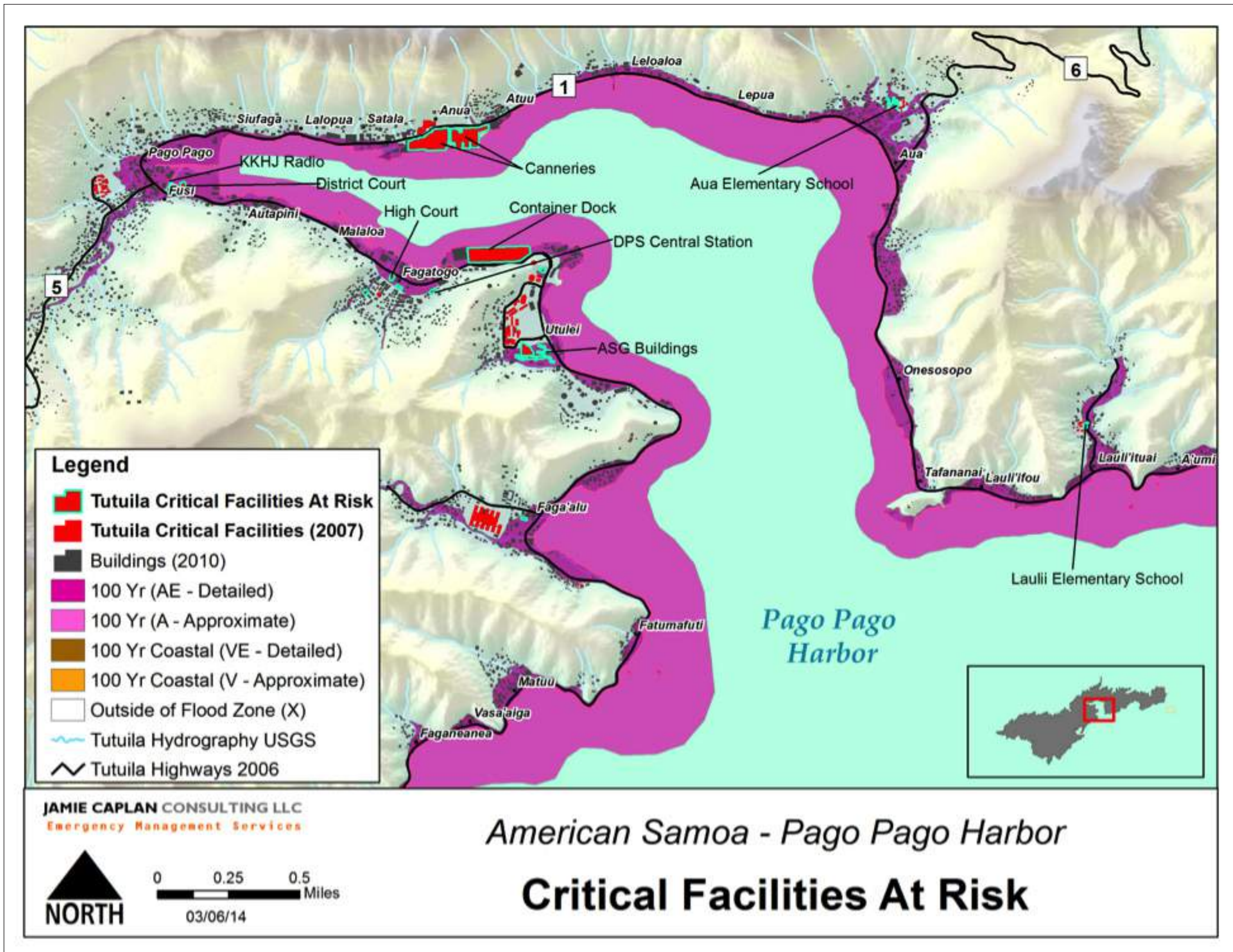

Figure 52 Critical Facilities Potentially At Risk to Flooding in Greater Pago Pago

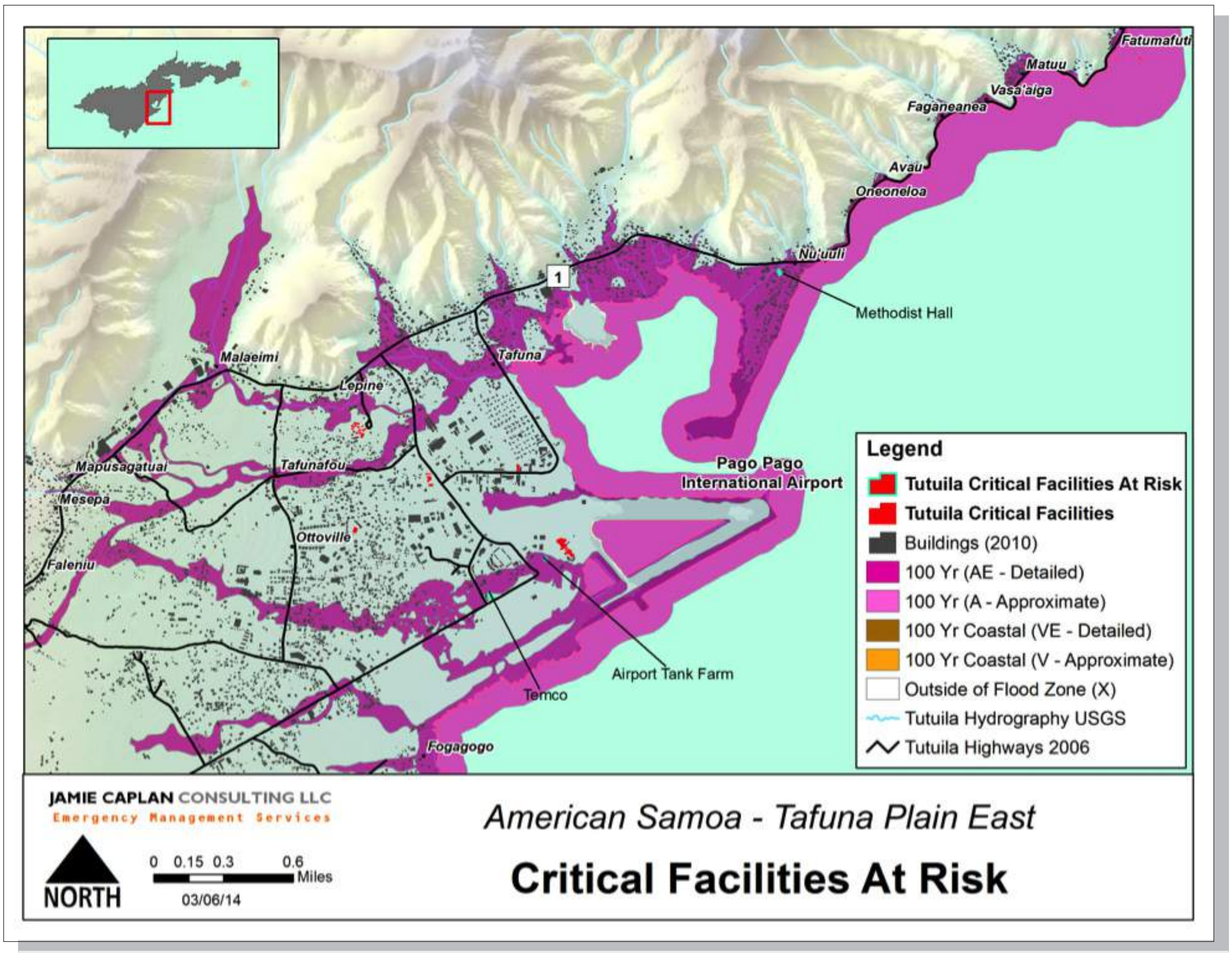

Figure 53 Critical Facilities Potentially At Risk to Flooding in Tafuna Plain East

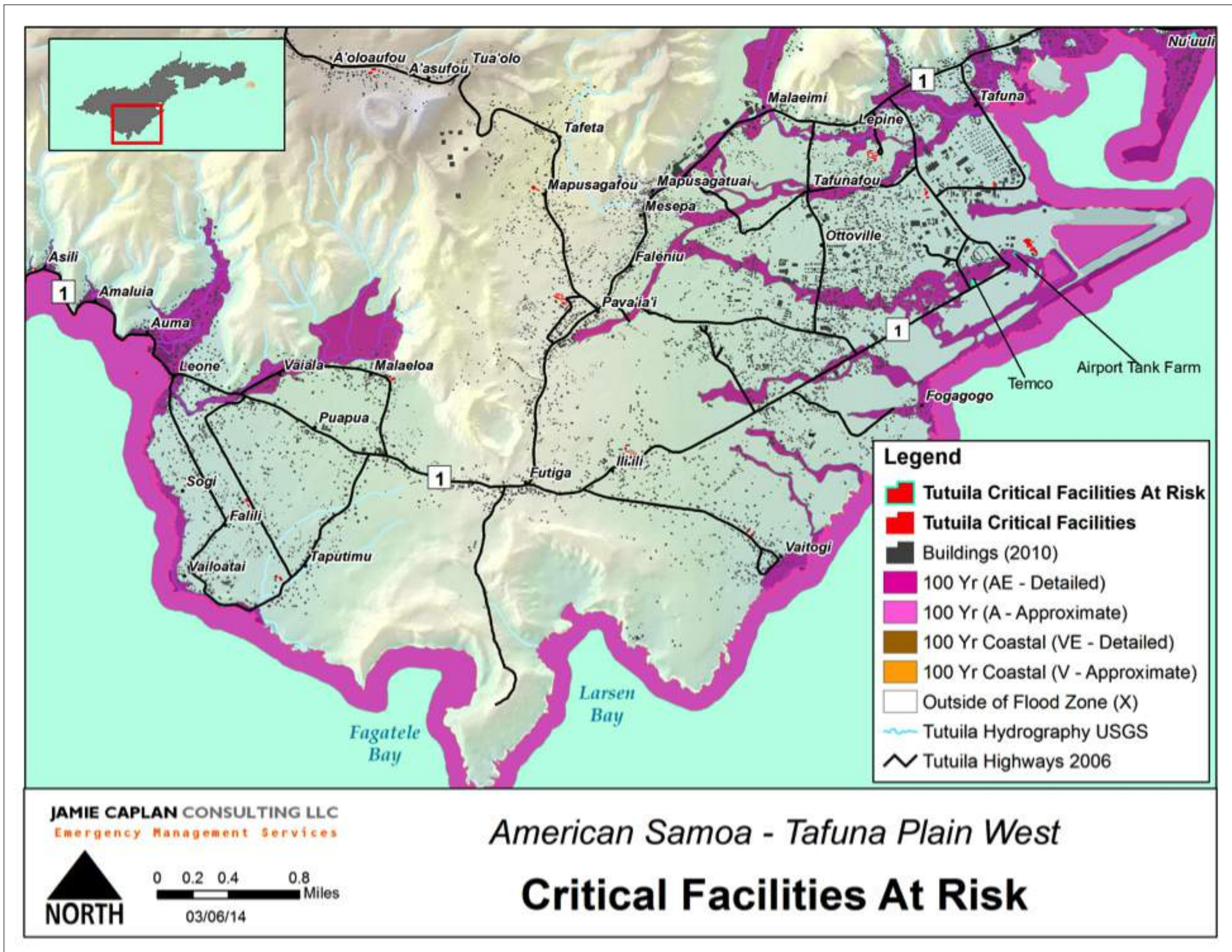

Figure 54 Critical Facilities Potentially At Risk to Flooding in Tafuna Plain West

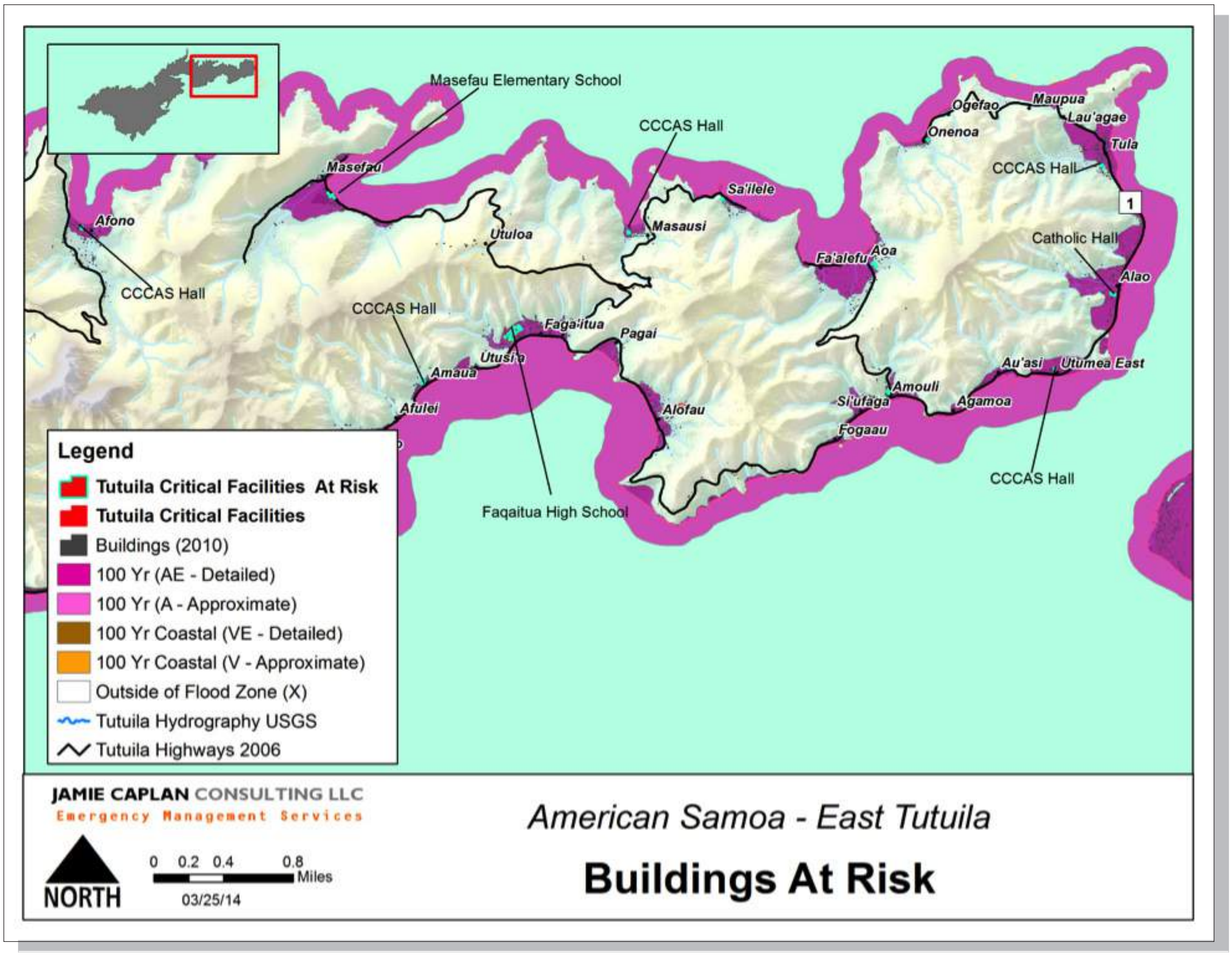

Figure 55 Critical Facilities Potentially at Risk to Flooding in east Tutuila

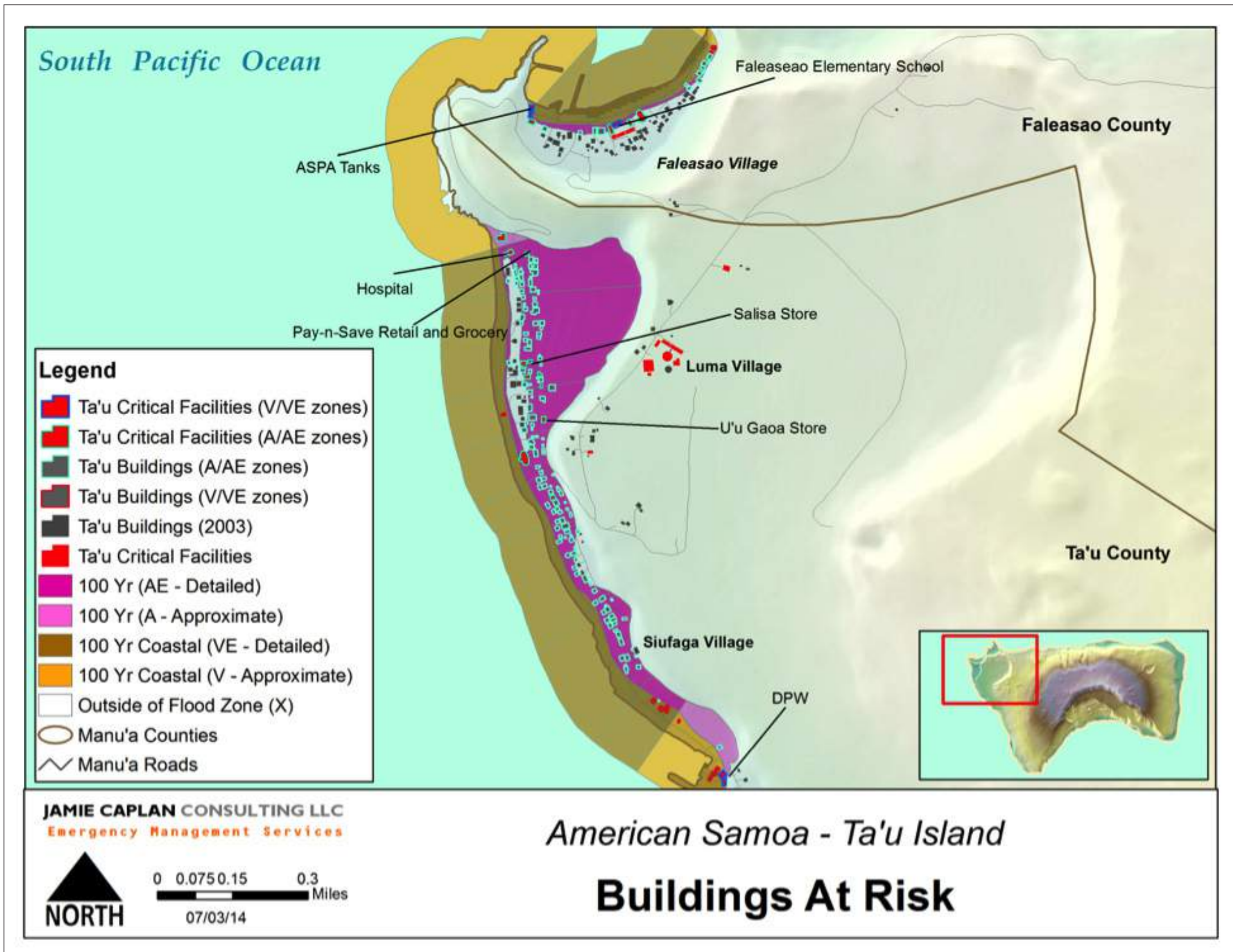

Figure 56 Buildings and Critical Facilities Potentially At Risk to Flooding on Ta'u Island

Hazardous Materials

While the focus and federal requirement of the hazard mitigation plan is for natural hazards, American Samoa does have a notable hazardous materials (HAMZAT) presence on island. For that reason, HAZMAT is briefly discussed in the plan. In the 2011 update, American Samoa noted that it is working to improve their HAZMAT protocols. In fact, American Samoa will soon have a multi-agency HAZMAT team in place. It was noted that American Samoa stores and distributes about 38 million gallons of diesel, jet fuel and gasoline every year. Distribution is by pipeline and road, and the roads are often in poor repair. American Samoa officials train a wide cross section of the community regularly on spill response and mitigation and have been successful at limiting accidental discharges both in transit and in storage. One facility that continues to pose a large risk is the storage facility at the airport. It is located in the middle of the public parking lot and as such presents a risk and a public safety hazard. American Samoa would like to relocate the facility to a safer location in the future.

HAZMAT disposal is also a major issue in American Samoa. Dangerous hazardous materials are being abandoned which creates a safety and health issue to nearby dwellings and to the environment. Abandoned hazardous materials or hazardous waste have the potential to impact public health, streams, coastal waters, can destroy coral reefs, impact groundwater resources, and degrade of the quality of life if they are not applied, handled and stored properly in accordance with the label.

The American Samoa Environmental Protection Agency (ASEPA) often disposes of abandoned hazardous materials/waste by using different types of neutralizing/diluting methods. On some occasions, US EPA has provided assistance as to the proper disposal of some of the lethal hazardous materials/waste that ASEPA was able to identify.

ASEPA is currently working collaboratively with ASPA and Department of Port Administration on proper measures to remove the existing scrap metal site to a new permanent site and to restore the old site by conducting bio-remediation work. This is an on-going effort and until American Samoa can secure a new location for the new scrap metal facility, the old site remains hazardous in the event of a natural disaster. Two schools and a popular fast food restaurant (McDonalds) are located in close proximity to the scrap metal site.

Further, ASEPA is in the process of providing Department of Education compliance assistance on properly managing quantity and volume of purchased laboratory chemicals. In the past 3 to 4 years, ASEPA, with the assistance of US EPA continues to collect old chemicals from high school Laboratories island wide for disposal. Unfortunately, not all chemicals can be disposed on Island and have to be stored properly until other disposal or shipping measures are arranged or established.

According to the Federal Register notice of July 1, 1994, the impact of a complete discharge of the largest tank of 54,293 barrels (2,280,306 gallons) would affect a radius of five (5) miles. This would impact the entire harbor, including all environmentally sensitive and all vulnerable areas. However, this is unlikely since all tanks are held within a diked area. In the event of a spill into the harbor, the actual impact would be highly dependent on currents, tides and the wind. The prevailing wind between 7 and 15 mph from the southeast will tend to push the oil to the western side of the harbor.[50]

50 Non-Transportation Related Facility Response Plan, January 2007 p.36.

High Surf

Description
High Surf is defined by NOAA as large waves breaking on or near the shore resulting from swells spawned by a distant storm. High surf may range from waves a few feet to 20 or more feet above normal. They often result in rip tides and beach erosions. A High Surf Advisory is issued when breaking wave action poses a threat to life and property within the surf zone. High surf criteria vary by region and are issued by NOAA for American Samoa. High surf conditions are possible at any time but are common between May and October in American Samoa.

In addition, American Samoa could see waterspout activity (tornadoes over water), which can be dangerous to small craft, and bring very strong and gusty winds ashore. High surf generated by the approach of a strong to very strong hurricane can cause large breaking waves to arrive several days before the hurricane's center impacts the area. These high surf episodes can start in the 5 to 10-foot range, but can quickly increase in size to 15-20+ feet as the storm gets closer. High surf damage can increase during higher than normal tides, although a barrier reef or a sea wall can mitigate the associated damage to some degree.

Location
High surf is possible along all shorelines of the American Samoa islands. However, given the formation and typical tracks of low pressure and tropical systems from the south and west, the south-facing shorelines receive high surf conditions much more frequently than northern-facing area.

Previous Occurrences
A total of 44 high surf events were reported in American Samoa between 1994 and 2008 as shown in the table below according to NCDC. (It is unknown why events were not reported after 2008. It is known that high surf continues to impact the islands.) Two additional high surf advisories were reported in 2014 (it is likely that high surf advisories were reported in other years but information was not found.) Of the 44 events, 23 were reported across all islands, 18 were reported on Tutuila, and 1 was reported for the Manu'a Islands. All of these occurrences are included in Appendix L: Previous Occurrences of High Surf.

Extent
Previous occurrences of high surf indicate high surf conditions ranging from 3 to 30 feet. Higher surf is possible in American Samoa but would be a rare event as is evident by very few events over 14 feet. A mode and median of approximately twelve feet was calculated.

Probability of Future Events
A total of 44 high surf events were reported in American Samoa between 1994 and 2008, a fourteen-year reporting period. Of the 44 events, 23 were reported across all islands, 18 were reported on Tutuila. This results in an overall annual probability of high surf of 100 percent for all islands and Tutuila alone. However, high surf events where heights above 12 feet (the mean) were less frequent. This resulted in 10 events reported for all islands (an approximate annual probability of 71 percent) and 6 events reported in Tutuila alone (an approximate annual probability of 43 percent). The overall probability of any high surf on American Samoa is highly likely (greater than 90% annual probability), though the probability of strong events (waves greater than 12 feet), is likely (between 10% and **90% annual probability).**

Vulnerability Assessment

The previous occurrence narratives provide insight to the impacts of high surf in American Samoa. High surf does not typically result in property damage but has caused damage to roads and beaches. Impacts reported include washed-up coral debris, coastal flooding, roadblocks and traffic congestions due to washed up debris, rip tides, and coastal erosion. Since there is risk of coastal flooding due to high tide, all existing and future structures and populations residing in coastal areas are considered at risk. Of particular concern, are those in the FEMA V or VE flood zones.

High surf can also have significant impacts on the economy. High surf may prevent fishermen from going out to sea due to rough saves and high waves along the coast. It may also cause waves in Pago Pago Bay, which can hinder port activity and deter beach goers which can also impact local businesses.

High surf also poses a safety risk. The hazard has resulted in one death to date, when a police officer went to rescue a person in the high seas. It has also resulted in injury to crew abroad fishing vessels when the vessels capsized. Lastly, riptides caused by high surf may injure or kill swimmers or fishermen in the ocean waters.

Potential Losses

All current and future structures and populations along the coast are at risk to high surf. All counties have coastline, which makes them equally vulnerable to high surf impacts and losses. While this hazard has not caused notable damage to date, continued climate changed and increased hazard occurrence may lead to greater impacts in the future.

Landslides

Description

According to the United States Geological Survey, each year landslides cause $5.7 billion (2014 dollars) in damage and between 25 and 50 deaths in the United States.[51] A landslide is the downward and outward movement of slope-forming soil, rock, and vegetation, which is driven by gravity. Landslides may be triggered by both natural and human-caused changes in the environment, including heavy rain, rapid snow melt, steepening of slopes due to construction or erosion, earthquakes, volcanic eruptions, and changes in groundwater levels. Other contributing factors include:

- Erosion by rivers, road construction, or ocean waves that create over-steepened slopes
- Rock and soil slopes weakened through saturation by heavy rains
- Earthquakes that make weak slopes fail
- Earthquakes of magnitude 4.0 and greater have been known to trigger landslides
- Volcanic eruptions produce loose ash deposits
- Excess weight from accumulation of rock or ore, from waste piles, or from man-made structures may stress weak slopes to failure

Slope material that becomes saturated with water may develop a debris or mudflow. The resulting slurry of rock and mud may pick up trees, houses, and cars, thus blocking bridges and tributaries causing flooding along its path.

51 Landslide Hazards – A National Threat. (2005).United States Geological Survey (USGS) - United States Department of the Interior.

There are several types of landslides: rock falls, rock topple, slides, and flows. Rock falls are rapid movements of bedrock, which result in bouncing or rolling of rocks, often from a steep slope. A topple is a section or block of rock that rotates or tilts before falling to the slope below.

Slides are movements of soil or rock along a distinct surface of rupture, which separates the slide material from the more stable underlying material. Landslides are typically associated with periods of heavy rainfall and tend to worsen the effect of flooding that often accompanies these events. In areas burned by forest and brush fires, a lower threshold of precipitation may initiate landslides. Some landslides move slowly and cause damage gradually, whereas others move so rapidly that they can destroy property and take lives suddenly and unexpectedly.

Mudflows, sometimes referred to as mudslides, debris flows, lahars or debris avalanches, are fast-moving rivers of rock, earth, and other debris saturated with water. They develop when water rapidly accumulates in the ground, such as heavy rainfall, changing the soil into a flowing river of mud or "slurry" (a typical debris flow). Debris flows can flow rapidly down slopes or through channels, and can strike with little or no warning at avalanche speeds. Debris flows can travel several miles from its source, growing in size as it picks up trees, cars, and other materials along the way. As the flows reach flatter ground, the mudflow spreads over a broad area where it can accumulate in thick deposits.

Among the most destructive types of debris flows are those that accompany volcanic eruptions. A spectacular example in the United States was a massive debris flow resulting from the 1980 eruptions of Mount St. Helens, Washington. Areas near the bases of many volcanoes in the Cascade Mountain Range of California, Oregon and Washington are at risk from the same types of flows during future volcanic eruptions.

Areas that are generally prone to landslide hazards include previous landslide areas; the bases of steep slopes; the bases of drainage channels; and developed hillsides where leach-field septic systems are used. Areas that are typically considered safe from landslides include areas that have not moved in the past; relatively flat-lying areas away from sudden changes in slope; and areas at the top or along ridges, set back from the tops of slopes.

Location

Landslides (including rock falls and debris flows) are possible throughout American Samoa. However, areas along or at the base of mountains or steep terrain are particularly susceptible. Many of the steep slopes that rise toward the center of the Tutuila Island are considered high landslide risk, whereas the Tafuna Plain's gentler slope makes it a lower landslide risk. Historical occurrences of landslides are one indicator of future landslide risk. On Tutuila, where data on historic landslides is available, landslides have primarily occurred along the western edge of the island in Lealataua County. There are also recorded occurrences along the southern coast of Ituau County and southwestern Sua County near Faga'itua Bay. The maps for historic landslides can be found in the section below.

In addition to historic landslides, some data exists on landslide risk location. The USDA/NRCS landslide risk map for the island of Tutuila distinguishes between three categories of risk. These areas are described below and shown in Figure 57.

- o Low-risk areas are characterized by gentle slope (20% or less slope) and/or soils that are not slide prone and/or good vegetation cover. Structures in low-risk areas are not immediately down slope of, or built on, steep or moderate slopes. Low risk areas are depicted in green in the maps below.
- o Medium-risk areas include structures that are immediately down slope of, or built on, steep slopes with less slide prone soils or are on/near moderate slopes (20% to 60% slope) with high slide-prone soils. Medium-risk areas are depicted in yellow.
- o High-risk areas are those that include structures immediately down slope of, or built on, steep slopes (60% to 80+% slope). There are approximately 14,125 acres of high-risk landslide area. These areas are shown in red and make up 42% of Tutuila Island.

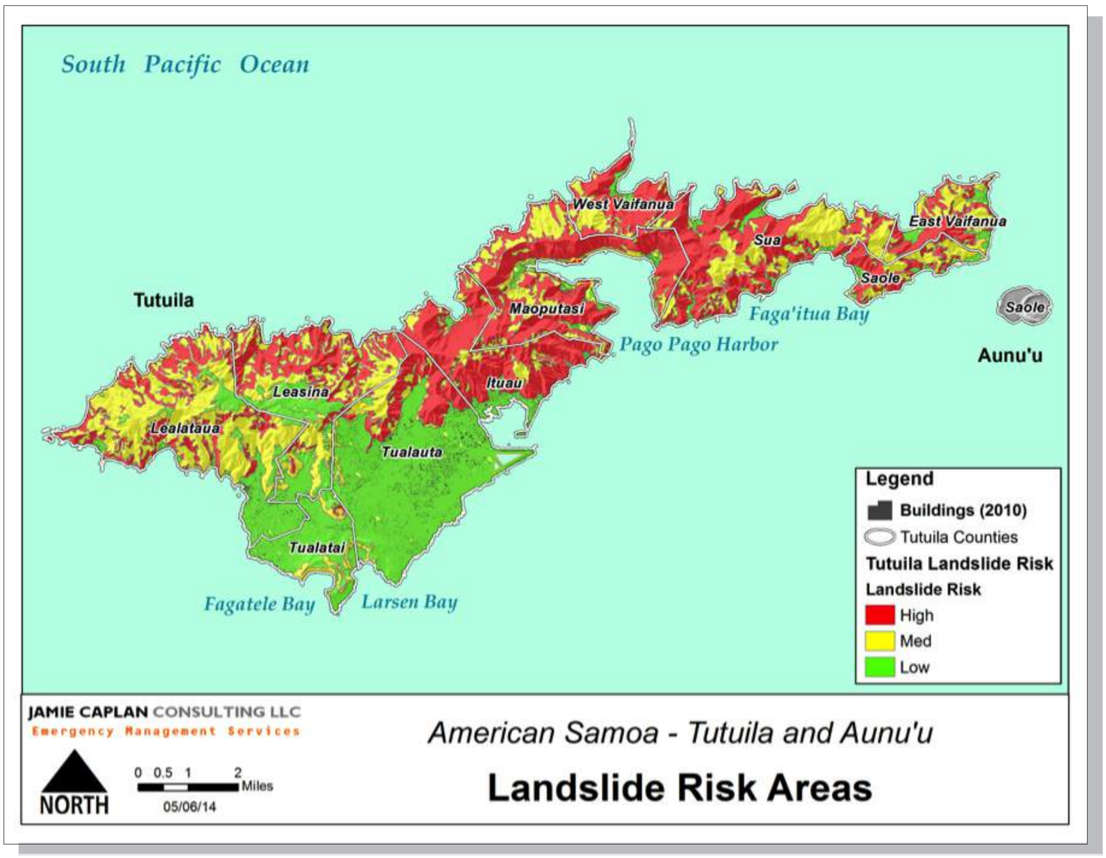

Figure 57 Landslide Risk Areas on Tutuila

The USDA Landslide data was not available for the Manu'a Islands. No additional existing data could be located for the islands. Therefore, an approximate measure of risk was calculated using GIS analysis. A digital elevation model was processed to determine percent rise. A calculated value of 0 percent is a flat surface, while a calculated value of 100 percent is a 45-degree angle of slope. As the surface becomes steeper, the percent rise becomes increasingly larger. The values reached 584 percent in Manu'a. This information was then arbitrarily grouped into low, medium and high-risk ranges based on slope as follows:

- Low: 0 percent to 25% (approximately 20 degree slope)
- Medium: 25%+ to 100 percent (20 degree to 45 degree slope)
- High: greater than 100 percent (greater than 45 degree slope)

On all islands, a majority of the development resides is low risk areas. A narrow band of high-risk area is inland along the southern and northern borders. On Olosega, a band of high-risk area circles the island away from the coast. On Ta'u, a majority of the high-risk areas can be found on the southern portions of the island, though there are portions in the northern parts of the island as well. The following maps, Figure 58 & Figure 59, show slope levels to indicate landslide risk on the Manu'a Islands.

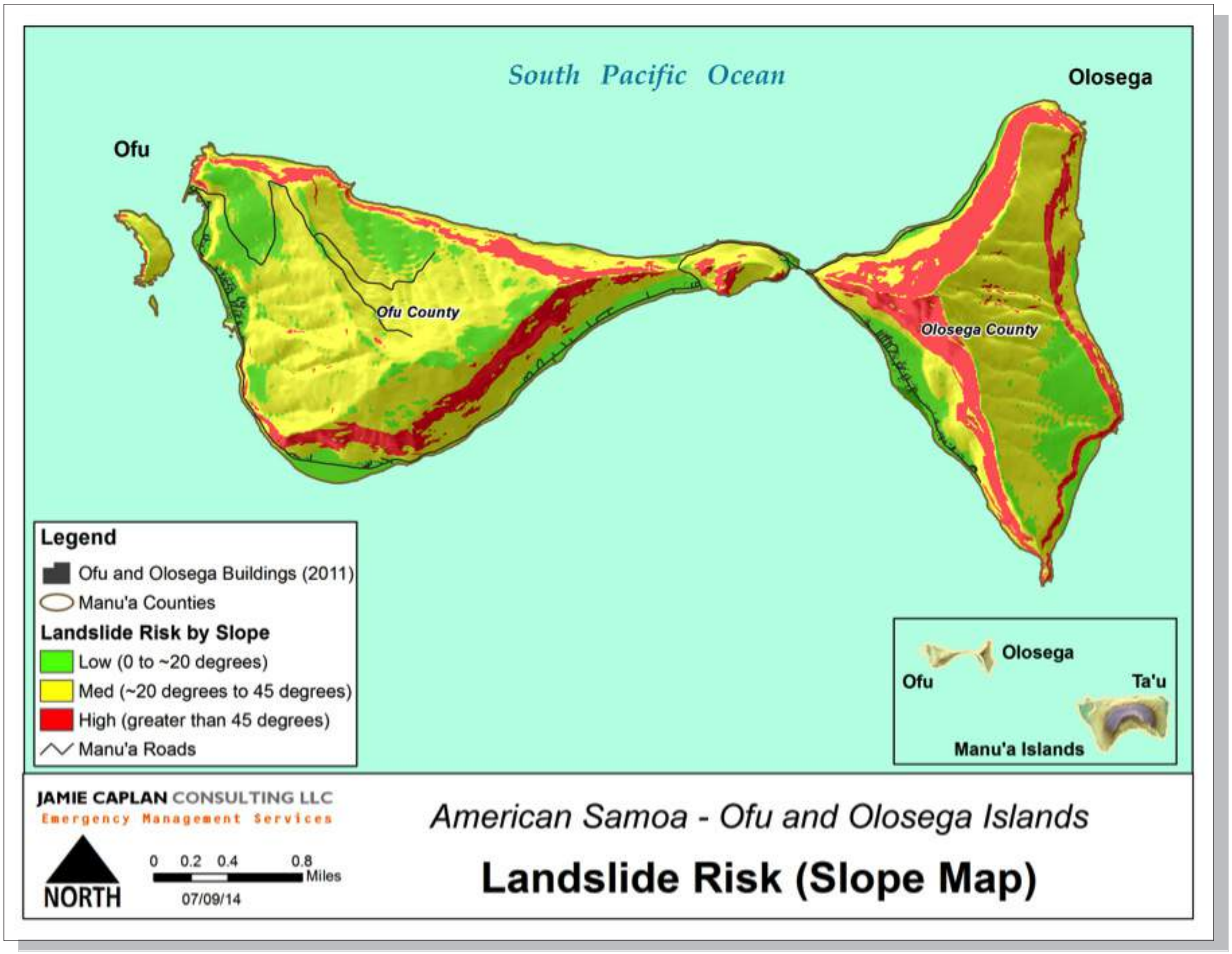

Figure 58 Landslide Risk on Ofu and Olosega Islands

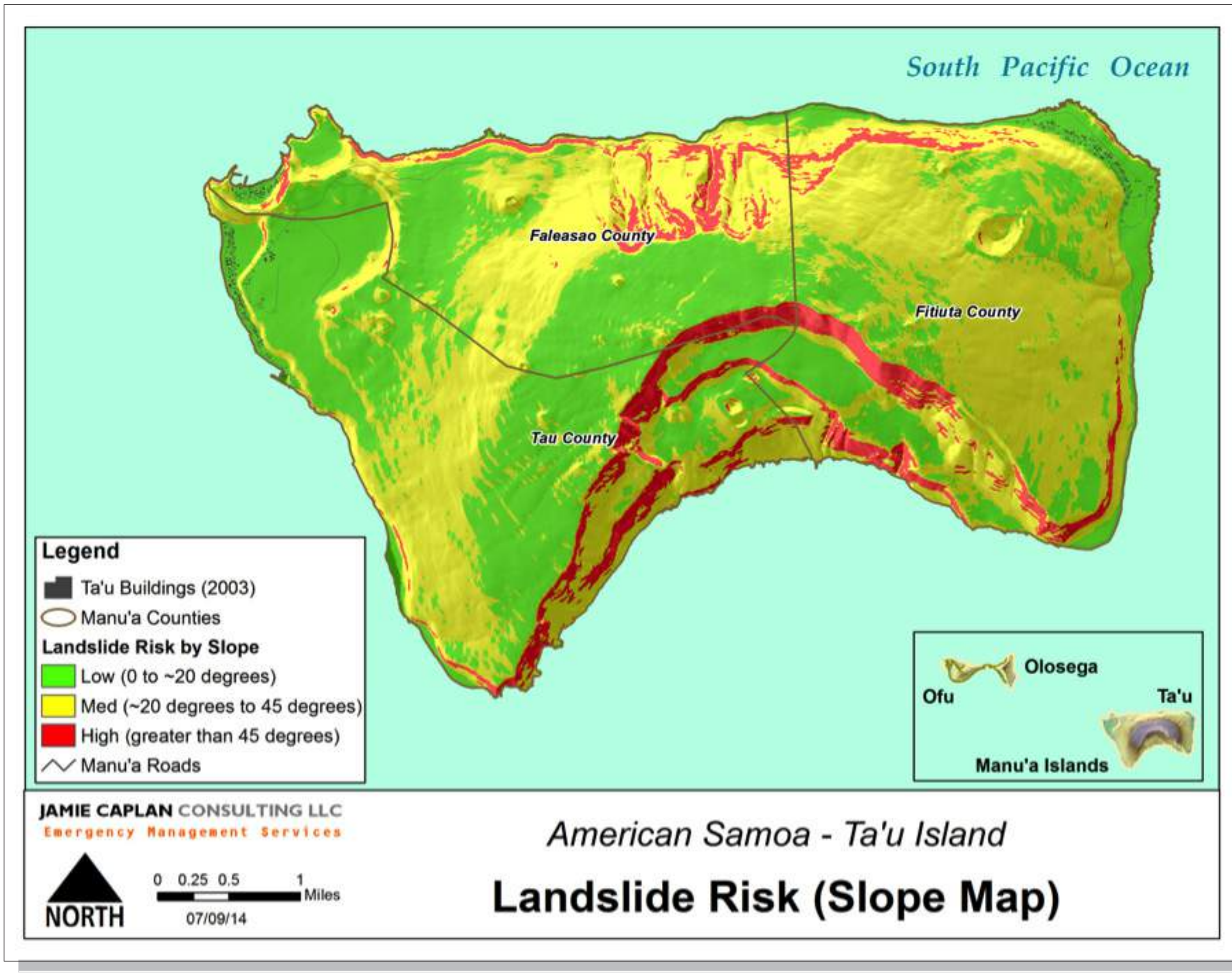

Figure 59 Landslide Risk on Ta'u Island

Previous Occurrences

On the island of Tutuila, landslides tend to be either naturally occurring steep slope failures or steep slope failures associated with slope cuts made for road or building construction. Historically, most landslides occurred during very heavy rains. Table 30 shows a summary of significant landslide events. It should be noted that these events only listed based on available data. Conditions are favorable for landslides and rock falls on the Manu'a Islands as well.

Table 30 Summary of Significant Landslides Events

Event Name, Date	Number of Occurrences	Cause	Geographical Extent	Impacts	Deaths/ Injuries
Landslide, October 28, 1979	60+	Rain storms	Western portion of Tutuila. Se'etaga debris flow	Four people killed in Se'etaga debris flow. Significant structural damage.	4/0
Landslide, 1985	1	Rain storms	Nua, western Tutuila	School building destroyed.	0/0

Event Name, Date	Number of Occurrences	Cause	Geographical Extent	Impacts	Deaths/ Injuries
Landslides, 1989	23	Rain, Water Leak	Fagasa, Aua,	Information drawn from the Pacific Disaster Center GIS Shapefile (limited metadata on source)	0/0
Landslide, February 2-4, 1990	10+	During Hurricane Ofa	Central ridge top, Tutuila	Most occurred along the central ridge top of Tutuila on extremely steep and largely inaccessible slopes. Most likely caused by heavy rain, and contributed to by the toppling of large trees carrying soil as they fell down slope.	0/0
Landslide, Almost yearly	8	Rainfall	Aua-Afono Road, Tutuila	Aua-Afono Road blocked.	0/0
Landslide, May 12, 1999	1+	Flood	Tutuila	Some homes were flooded with the significant rise of water. Broken trees and gravel washed off nearby mountains blocking roads at some villages, like Nu'uuli. Landslides across Tutuila	0/0
Landslide, September 12, 1999	1+	Flood	Poloa and Fagamalo	The heavy showers associated with a stationary trough flooded and overflow many of the streams. Mud and landslides occurred at Poloa and Fagamalo causing temporary blockage of the road.	0/0
Landslide, 2000	1	Rainfall	Nu'uuli-Pago Pago Road	Nu'uuli-Pago Pago Road rock fall.	1/0
Rock fall, February 27, 2000	1+	Flash Flooding	Laauli'i lookout	A man narrowly escaped injury as his car was smashed by a large rock at the Laauli'i lookout because of a landslide, one of the various land and mudslides being reported by TEMCO across the territory.	0/0
Landslides and mudslides, March 23, 2001	1+	Flood	West of Poloa	The police reported mud and landslides west of Poloa.	0/0

Event Name, Date	Number of Occurrences	Cause	Geographical Extent	Impacts	Deaths/ Injuries
Landslides and mudslides, March 27, 2001	1+	Flood	Tutuila	These heavy showers and heavy runoffs has cause flooding of low lying areas and overflow of small streams as well as causing mud and landslides across the Tutuila.	0/0
Landslide, May 26, 2002	1+	Flood	Auauuli, Tau	Residences of Tau reported heavy runoffs and landslide at the Auauuli due to heavy showers.	--
Landslide, May 19-21, 2003	10+	Heavy rainfall	Pago Pago, Fagatogo, Nu'uuli, Fagaalu, & Utulei, Tutuila.	Heavy rainfall caused widespread debris flows, rock falls, and slumps. Deaths were a result of the landslides, while most property damage was flood related.	5/0
Landslides, December 4, 2006	1+	Heavy rainfall	Tutuila	Thunderstorms and heavy rainfall were associated with an active trough near the Islands. The Weather Service Office recorded about 4.72 inches of precipitation for this event; residents reported widespread flooding and landslides across the Island of Tutuila.	0/0
Landslides, November 21, 2011	1+	Heavy rainfall	--	A nearly stationary trough to the southwest of the Samoan Islands has triggered heavy rainfall for a couple of hours. Flash flooding, landslides, and heavy run-off were reported from across the Island of Tutuila. The Weather Service office received 2.56 inches of rainfall for this episode.	0/0
Landslides, July 29 – August 3, 2014	1+	Heavy rain	Utulei and Gataivai	A landslide destroyed at least three homes and damaged the church.	0/0
Landslides	At least annually		Mt. Alava	The road to Mt. Alava is very dangerous and is subject to frequent landslides. There is a main communication tower/ antennae on top, so access is necessary.	--

Landslide (1979)
During the storms of 1979, 4 people were killed by the debris flow/landslide in Se'etaga, Tutuila.

Landslide (1985)
In 1985, a school building was destroyed in Nua, Tutuila. [52]

Landslide (1990)
In September 1990, high winds and very heavy rain from Hurricane Ofa contributed to 10 landslides, although these slides were in mostly uninhabited areas.

In February 1990, some 10 slides were seen following the wind and very heavy rains of Hurricane Ofa. The USDA/NRCS Landslide Hazard Mitigation Study published in October 1990 noted that: "Strong correlations were found between landslides and certain soils, geology, slopes, and vegetation. Slides were concentrated in areas of Fagasa and Aua soils, ash and talus geology, slopes greater than 60%, and where the natural vegetation had been disturbed. Concentrations of water from springs, runoff, or man's activities were often contributing factors to many slides."

Landslide (2000)
In 2000, a motorist was killed by a rock fall on the coastal road between Nu'uuli and Pago Pago. The sheer rock faces along this section of road make it a high-risk area, although some mitigation efforts had been put in place since the 1990 study. The road between Aua and Afono had at least eight separate slides associated with the construction of the road there.

Landslide (2003)
Between May 19-21, 2003, heavy rainfall caused flooding, landslides, and mudslides on the Island of Tutuila near Pago Pago, Fagatogo, Nu'uuli, Fagaalu, and Utulei, prompting the Territory to declare an emergency. Rainfall on May 19 at Pago-Pago totaled 10.68 inches. Widespread debris flows, rock falls, and slumps occurred due to the extremely heavy rains. Five people were killed in landslides, although much of the property damage was flood related.

Landslide (2014)
Landslides and flooding resulted in a disaster declaration. Landslides displaced several residents in are residents of both Utulei and Gataivai, where a landslide destroyed at least three homes and damaged the church.

A map of historical landslides is also included on the following page in Figure 60. However, these landslides are dated 1979, 1989, and 2001. Since the timeframe is so limited, they likely show frequent hot spots for landslide rather than all activity. Unfortunately, no information on historic landslides was located for the Manu'a islands.

52 White, F. David, and Charles E. Stearns. (1990). U.S. Department of Agriculture. Retrieved August 8, 2014 from http://www.botany.hawaii.edu/basch/uhnpscesu/pdfs/sam/White1990AS.pdf

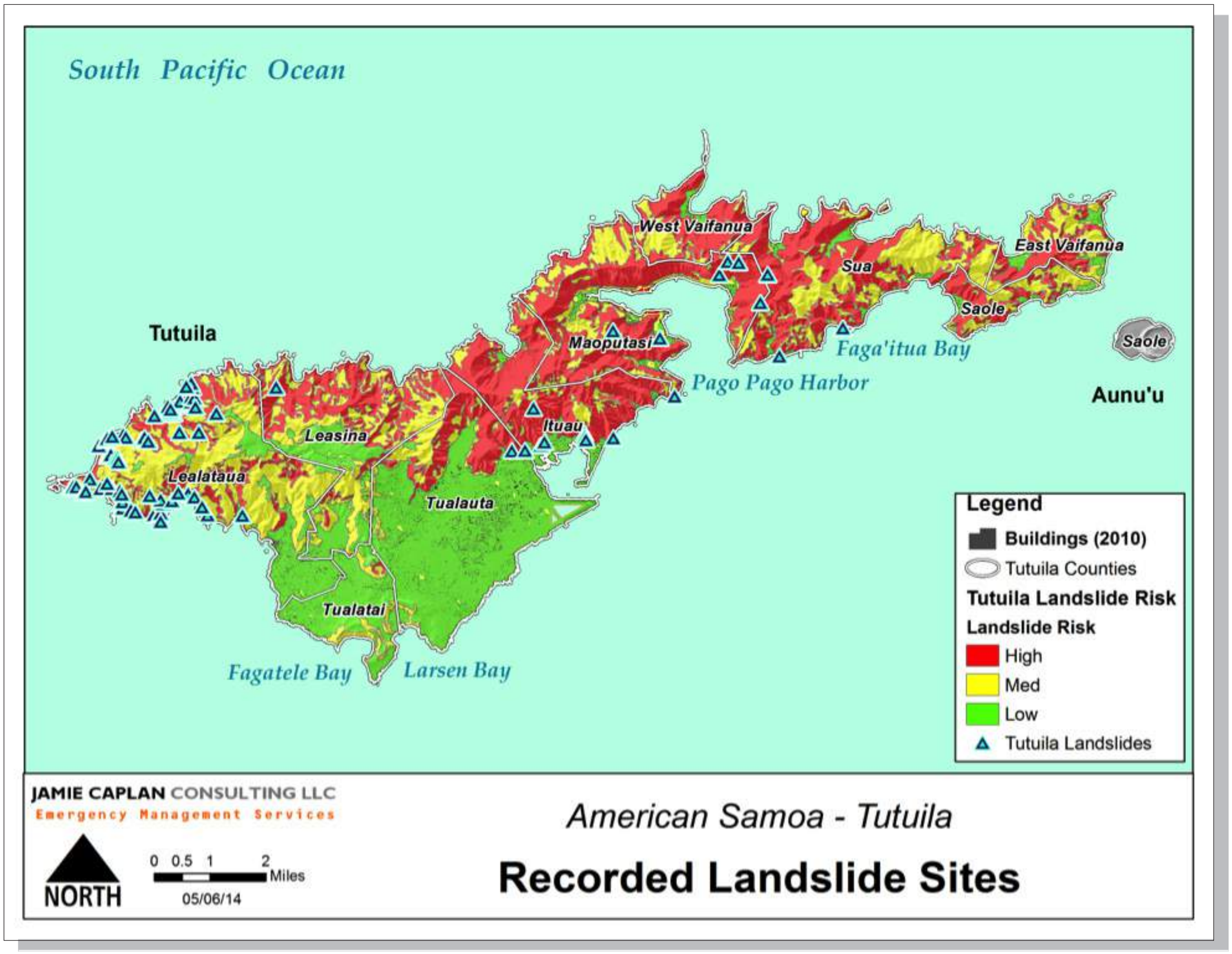

Figure 60 Recorded Landslide Sites in Tutuila

Extent

At this time, there is no known landslide magnitude scale. The most severe landslides are those that result in damage, injury or death. These landslides are more likely to occur in high risk areas identified by the USDA/NRCS landslide study. Forty-two percent of the Tutuila resides in a high-risk area.

Other methods to determine landslide extent include amount of debris produced and size. No information was found regarding debris creation or removal for landslides. However, the previous plan mentions that landslides are typically small, between 50 and 250 feet wide.

Probability of Future Events

Determining a statistical probability for landsliding was challenging given the lack of recorded events and known high frequency. It is known that landslides are a common occurrence in American Samoa on all islands. Rockslides are also common throughout the year and may occur at any time. The frequency increases following heavy rain, cyclones, and flooding. These landslides are likely to occur in the highest risk areas (Figure 57, Figure 58 and Figure 59).

Data created by the Pacific Data Center contains detailed landslide information for the year of 1989 that helps to determine probability. During 1989, 23 landslide events were reported, making the probably 100 percent, highly likely. A probability using information over time from the National Climatic Data Center was also referenced as a crosscheck for a greater time period. Because heavy rains tend to be the main trigger for Tutuila's landslides, the probability of the heaviest rain events were studied in order to determine how often the conditions contributed to landslides in a 13-year period between 1999 and 2013. Based upon the frequency of historical rainfall events reported in NCDC, the probability of occurrence for landslides is 69%, a categorization of likely (between 10% and 90% annually). However, local input indicates that landslides (including rock falls) are quite frequent and be expected on an annual basis. Given the climate and topography, landslides and rock falls are a certain occurrence in the future, so the probability is defined as highly likely.

Vulnerability Assessment

Vulnerability to landslides in American Samoa is high. The frequency of landslides increases following heavy rain, cyclones or flooding. Water makes the soil heavier, resulting in a collapse. In addition, landslides are possible following extended drought for several reasons. The soil following a drought can be brittle and the root systems of stabilizing vegetation may be damaged during drought. Further, when rainfall arrives to alleviate the drought, it can have amplified impacts. The landslides are likely to occur in areas where slopes are very steep as defined in Figure 57 through Figure 60.

Landslides in American Samoa bare several typical characteristics:

- The slides are typically small (50 to 250 feet wide).
- They tend to affect the upslope edges of populated areas where the degree of slope begins to climb to a point of unsuitability for residential development.
- Their affects are not island-wide or particularly widespread at a single time.
- Deaths and property losses are probable as slides usually occur without warning.
- Slides that threaten or temporarily block main roads are probable.

While landslides will continue to occur, there are a number of conditions that increase or decrease the vulnerability of infrastructure, residential, and public buildings to damage from this hazard.

Factors that increase vulnerability to the hazard:

- Clearing established vegetation from steep slopes;
- Cutting rock faces at near vertical angles;
- Excavation of large traditional housing pads on steep grades;
- Excavating for roadways without allowing for adequate drainage;
- Allowing water sources, such as water tanks or leaking water lines, to pool above slopes;
- Rain events;
- Drought events.

To help reduce vulnerability and mitigate risk:

- Do not develop in the steepest of areas, such as those identified as high risk for landslides in the 1990 USDA report and supporting maps. Many of these areas are currently unpopulated and undeveloped, so frequent slides cause little damage;
- Do not build below previous landslides or on their recent deposits;
- Leave locally occurring vegetation in places. Slides are relatively uncommon in areas that have not been cleared in some manner;
- Treat near vertical cut rock faces with screens, concrete guardrails, and so forth;
- Provide for the non-eroding drainage of house pads and roadways.

Potential Losses

Areas of high landslide risk were also investigated using GIS intersect analysis to determine the number and type of buildings most at risk to landsliding in the planning area. This analysis was also used for critical facilities. The results are summarized below. This information should be used to determine areas where the greatest vulnerability occurs.

Table 31 Buildings Located in High Risk Landslide Areas

County (District)	Total Number of Buildings	Total Number of Buildings in High Risk Landslide Areas	Percent of Buildings	Type
TUTUILA ISLAND				
East Vaifanua (East District)	497	138	28%	2 not listed 135 residential
Ituaa (East District)	1,075	297	28%	1 church 1 government 7 commercial 288 residential
Lealataua (West District)	2,026	135	7%	1 church 3 schools 131 residential
Leasina (West District)	474	1	0%	1 residential
Maoputasi (East District)	2,246	879	39%	2 not listed 4 churches 6 commercial 16 government 851 residential
Saole (East District)	364	81	22%	2 unknown 79 residential
Sua (East District)	938	336	36%	3 church 4 not listed 329 residential
Tualatai (West District)	903	0	0%	-
Tualata (West District)	7,441	166	2%	1 church 1 commercial 1 government 163 residential
West Vaifanua (East District)	172	13	8%	13 residential
Tutuila Island Total	16,315	2,046	12%	--
AUNU'U ISLAND*				
Saole* (East District)	179	N/A	--	--
Aunu'u Island Total	179	N/A	--	--
TA'U ISLAND				
Faleasoa** (Manu'a District)	81	2	2%	unknown

County (District)	Total Number of Buildings	Total Number of Buildings in High Risk Landslide Areas	Percent of Buildings	Type
Fitiuta (Manu'a District)	180	0	--	0
Ta'u (Manu'a District)	208	0	--	1
Ta'u Island Total	469	0	--	1
OFU ISLAND				
Ofu (Manu'a District)	133	0	--	2
Ofu Island Total	133	0	--	2
OLOSEGA ISLAND				
Olosega (Manu'a District)	101	--	--	--
Olosega Island Total	101	--	--	--
TOTAL	**17,018**	**2,048**	12%	--

**No data was available for Aunu'u Island (Saole County).*

***Although just 2 buildings are in the high hazard area, several building in the village of Faleasao or just below a high risk area*

It is clear from the analysis that many counties are subject to landslide risk and potential losses. The analysis indicates that Maoputasi and Sua Counties have the greatest percent and number of buildings in the high risk landslide areas. The map also indicates a concentration in the center Tutuila Island from east Tualauta County to east Sua County. In addition, the northern coast of Tutuila has significant high hazard areas.

A critical facility analysis was also performed using available data. The results indicated that 20 critical facilities including schools, the Governor's House, and Star Kist reside in high-risk landslide areas. These structures have an approximate combined value of over $48 million as indicated in Table 32. Specific buildings are also highlighted in Figure 61. No critical facilities were determined to be located on the Manu'a islands.

Table 32 Number of Critical Facilities (CFs) in High Risk Landslide Areas

Location	Total Number of Buildings	Total Number of CF in High Risk Landslide Areas	Value
Tutuila Island CFs	241	20	$48,298,740
Ta'u Island CFs	42	0	--

Assembly areas

- o Sixteen out of 26 assembly areas were found to intersect the high-risk landslide areas.

Safe Zones

- o All four safe zone areas in Tutuila intersect with high-risk landslide areas.

Tsunami Sirens

- o Three sirens are located in high-risk landslide areas.

ASTCA Infrastructure

- o Eleven ASTCA sites and towers were determined to be located in high-risk landslide areas including 6 cell sites, 2 towers, 1 DCO, and 1 generator building.

A complete listing of critical facilities and associated information (such as assembly areas, safe zones, and tsunami sirens) can be found in Appendix D.

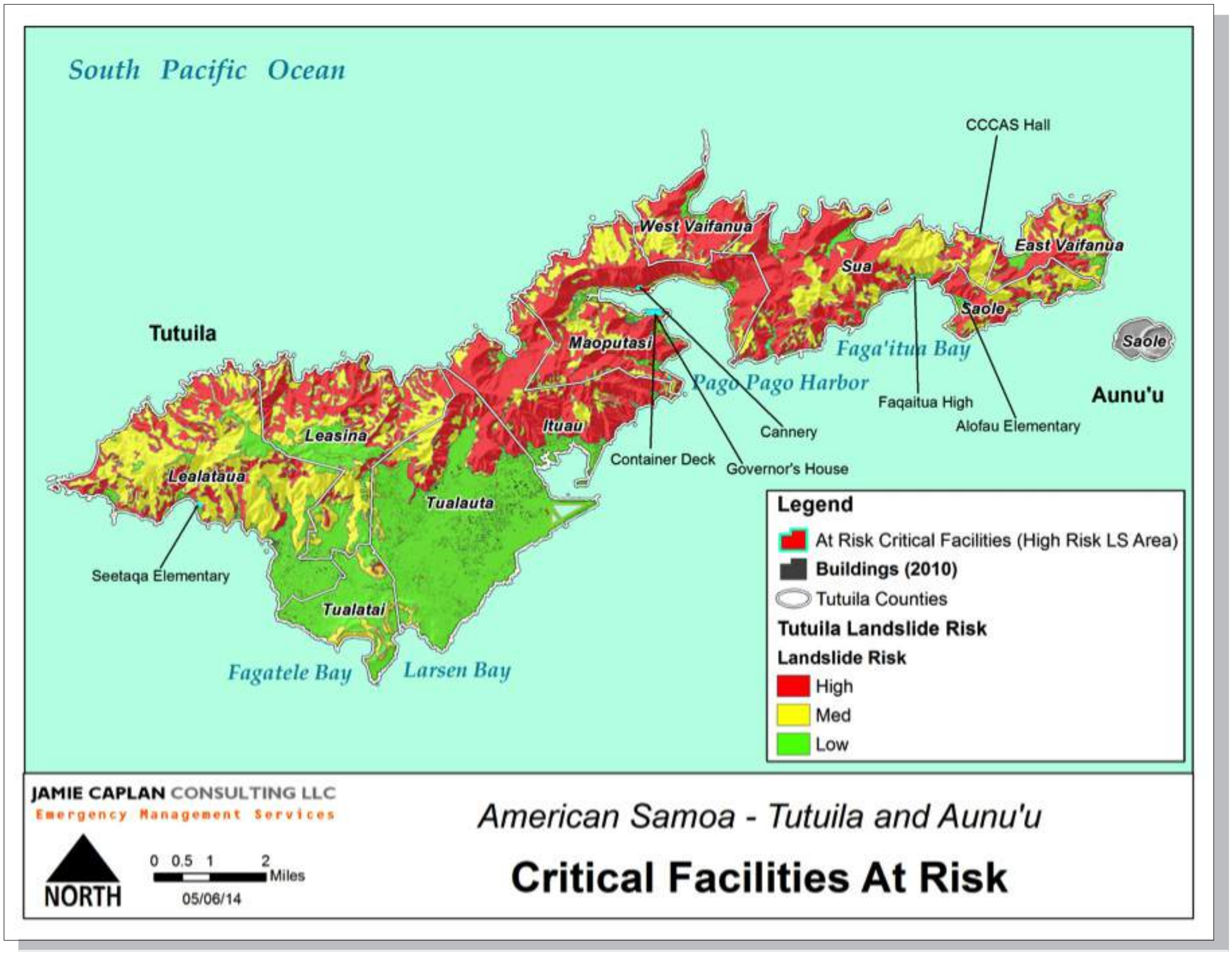

Figure 61 Critical Facilities Located in High Risk (higher likelihood) Landslide Areas

Lightning

Description

Lightning, a hazard typically associated with thunderstorm, was added to this update of the mitigation plan. According to NIAA, lightning is a discharge of electrical energy resulting from the buildup of positive and negative charges within a thunderstorm, creating a "bolt" when the buildup of charges becomes strong enough. This flash of light usually occurs within the clouds or between the clouds and the ground. A bolt of lightning can reach temperatures approaching 50,000 degrees Fahrenheit. Lightning rapidly heats the sky as it flashes but the surrounding air cools following the bolt. This rapid heating and cooling of the surrounding air causes the thunder, which often accompanies lightning strikes. While most often affiliated with severe thunderstorms, lightning may also strike outside of heavy rain and might occur as far as 10 miles away from any rainfall.

Location

Lightning strikes can happen anywhere so all areas are assumed to be at risk. However, areas over water are less susceptible to frequent strikes. Figure 62 below, which show both extent and location of previous occurrences of lightning strikes globally, exemplifying this point.

Previous Occurences

Previous occurrences were researched through a variety of mechanisms including local news sources and online weather reports. Only two reported strikes were found. According to the National Climatic Data Center, two lightning strikes were reported between 1996 and 2013. A lightning strike on April 4, 2006 that caused a death and an injury. The second event reported by NCDC caused damage to electronics. All reported events are reported in Table 33 below. It is likely that additional events have occurred but were not reported.

Table 33 Reported Lightning Occurrences in American Samoa[53]

County (District)	Village	Date	Deaths	Injuries	Property Damage (2014)
Tualauta (West District)	Vaitogi	4/4/2006	1	1	0.00K
Maoputasi (East District)	Pago Pago	3/27/2010	0	0	$40,753

April 4, 2006:

Two teenagers, a 15 year-old girl and a 14 year-old boy, were at home lowering blinds of their guesthouse when they were both struck by lightning. The boy survived, but his sister died from this incident. An area of showers and isolated thunderstorms moved over Tutuila during the late afternoon through evening hours.

March 27, 2010:

Numerous thunderstorms and lightning damaged several phone lines, cables and Internet on Tutuila, including the WSO NOAA Weather Radio transmitter and the MicroArt Radiosonde computer and equipment. Several televisions and electronic appliances were electronically damaged during this event. No injuries or fatalities were reported.

53 National Climatic Data Center

Extent

Figure 62 below was compiled with NASA data from 1998 to 2012 to show the frequency of lightning strikes per square kilometer per year.[54] This can be used to measure extent. American Samoa appears to receive approximately 1 lightning strike per year (though additional lightning flashes that do not strike are likely). The low frequency of occurrence is an added level of risk for this hazard since there is likely limited public awareness.

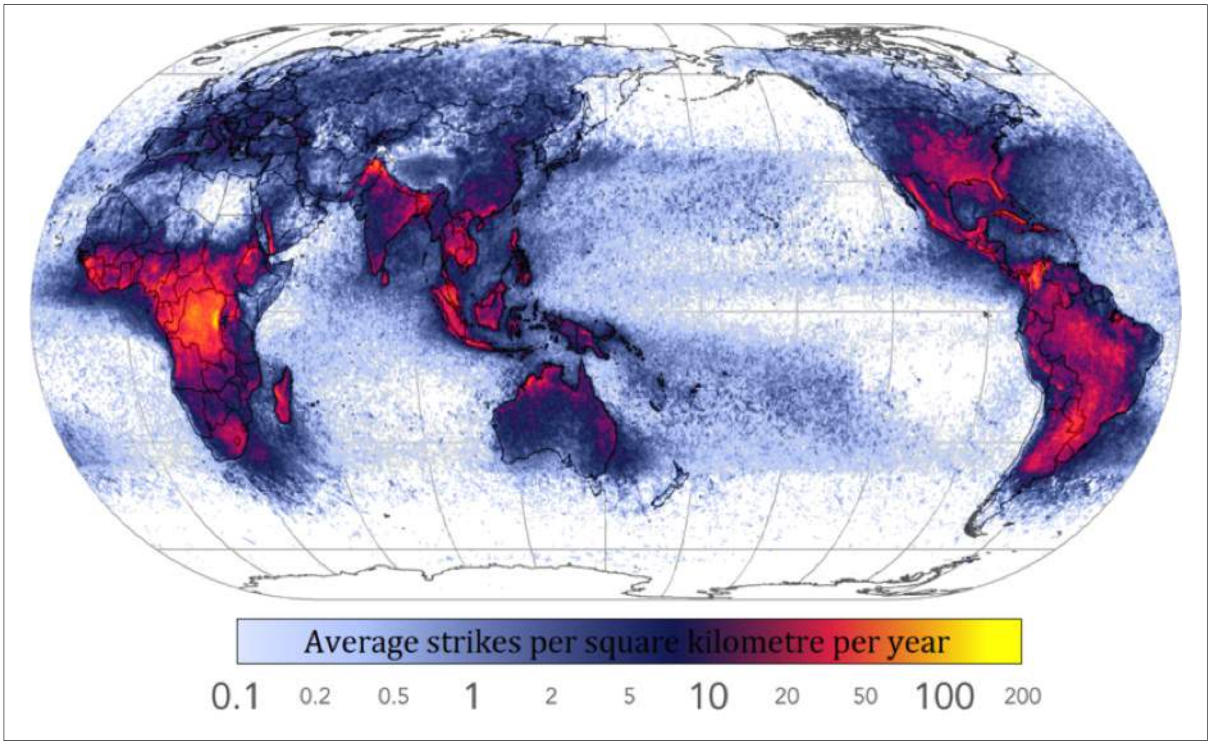

Figure 62 Average Lightning Strikes per square kilometer per year (1998-2012) [55]

Probability of Future Events

Based on two events reported between 1996 and 2014, there is a 11% annual probability of a lightning strike. This results in a probability categorization of likely (between 10% and 90% annually).

Vulnerability Assessment

This atmospheric hazard has the potential to impact the entire planning area including all islands. Therefore, all current and future buildings and populations are at risk to these hazards. Since lightning is not a frequent occurrence in American Samoa, the vulnerability for it can be even greater since there is likely limited public awareness on how to react to it. Previous occurrences have resulted in death, severe injury and electrical damage in American Samoa. In addition, lightning strikes may spark a structural or wildfire. Critical facilities are particularly susceptible to electrical damage or fire due to a lightning strike. All critical facilities are at risk.

Potential Losses

Since there is no boundary for this hazard, determining specific structures and associated values at risk is not feasible. As noted above, all current and future structures and populations should be considered at risk. Losses will typically be to individual structures rather than multiple buildings from a single lightning strike. However, it is possible for the strike to result in a fire that destroys several buildings.

54 Global Lighting Strikes. (2008). Wikipedia. Retrieved August 8, 2014 from http://en.wikipedia.org/wiki/File:Global_lightning_strikes.png, Citynoise

55 NASA (data), Citynoise (map)

Soil Hazards (Expansion, Subsidence and Sinkholes)

Description

Soils hazards are defined here as soil expansion, land subsidence, and sinkholes. It should be noted that these are considered low hazards in the territory though they are possible. Very limited information on these hazards exists at this time. As additional information becomes available, research on this hazard will be expanded.

Soil expansion occurs when soils expand due to added water and shrink when they dry out. This continuous change in soil volume can cause homes built on this soil to move unevenly or result in foundation cracks. The shrink-swell process could change the volume of soil by up to 30 percent.

According to the USGS, "land subsidence occurs when large amounts of groundwater have been withdrawn from certain types of rocks, such as fine-grained sediments. The rock compacts because the water is partly responsible for holding the ground up. When the water is withdrawn, the rock falls in on itself.[56]" Essentially, it is lowering of land-surface elevation. It occurs gradually, and goes overlooked until the problem is severe. It is common in coastal areas. Land subsidence often occurs due to man-made activities, such as pumping groundwater, oil or gas.

According to the USGS, sinkholes are common with limestones; carbonate rock, salt beds, or rocks that can naturally be dissolved by groundwater circulating through them. They typically occur when karst terrain is present (bedrock that is easily dissolved). The movement of water through the rock eventually creates a hole, which may ultimately result in the surface collapsing. Typically sinkholes form gradually. In American Samoa, given the volcanic soils composition, sinkholes may be formed due to man-made activities such as leaky pipes, eroding soil or removal of subsurface groundwater or material.

Location

Soil expansion is possible throughout American Samoa where soil is present.

Land subsidence is a threat in American Samoa, particularly in coastal areas, according to the territory's Coastal Management Plan.[57] Sinkholes are possible throughout American Samoa. As noted above, they are most likely to be formed due to leaky pipes and other human causes.

Previous Occurences

No information on previous soil hazards was found. As additional information becomes available, this hazard will be updated.

56 Land Subsidence. (2000). USGS. Retrieved August 8, 2014 from http://water.usgs.gov/edu/earthgwlandsubside.html

57 Section 309 Assessment and Strategy for the American Samoa Coastal Management Program. (2011). American Coastal Management Program. Retrieved August 8, 2014 from http://coastalmanagement.noaa.gov/mystate/docs/as3092011.pdf

Extent

Soil expansion

The combination of the shallow depth of soil and the soil composition in American Samoa limit the severity of this hazard. There are a few inches of partially clay soil on top of volcanic rock in most areas. This hazard will be of greatest concern in times of drought. Expansion may result in soils expanding/contracting up to 30 percent of their original composition. Given the limited documentation of this hazard, extent is assumed to be limited.

Land Subsidence

This is noted as a low hazard in the Coastal Management Plan for American Samoa. Little research has been conducted and no communities are mapped. Subsidence may be less than one inch to several feet. Given the limited information documented in territory, subsidence impacts are assumed to be limited (less than a few inches of subsidence).

Sinkholes

Sinkhole surface collapse areas may range from a few feet to hundreds of feet in diameter. The depth of sinkholes also varies tremendously. Given limited documentation of the sinkholes in the territory, extent is assumed to be fairly small (less than 10 feet wide and 10 feet deep and likely a result of human activities.

Probability of Future Events

Given the limited information on these hazards, probability is assumed to be unlikely (less than1 percent annual chance).

Vulnerability Assessment

Since no known mapping has been completed and limited information on previous occurrences is available, only general conclusions on vulnerability can be made about this hazard. All current and future buildings and populations are considered at risk to these hazards. Possible impacts are described below.

Soil expansion

- Foundation cracking
- "Flatwork" cracking (paved areas such as patios, sidewalks, roads)
- Structure shifting

Land subsidence

- Displaced foundation
- Lowered elevation may increase flooding probability

Sinkholes

- Injury or damage to anything that falls into a sinkhole (people, structures, livestock, vehicles, etc.)

Potential Losses

Although a low probability exists, all current and future buildings and populations should be considered at risk to soil hazards. All counties have equal vulnerability to losses. These hazards are unlikely to result in death or injury but may cause extensive structure damage to buildings in American Samoa. It can be concluded that soil hazards are a low risk, low probability hazard.

Tropical Cyclone

Description

Over the past 20 years, coastal and low-lying areas in small island nations have been devastated by hurricane related hazards, costing the world economy billions of dollars (U.S.), and resulting in a significant loss of life. A hurricane, cyclone and typhoon are generally the same phenomenon but located in different places throughout the world.[58] Cyclones and typhoons are the term used in the South Pacific (though hurricane is sometimes used as well). By definition, tropical cyclones are any closed circulation developing around a low-pressure center in which the winds rotate counter-clockwise in the Northern Hemisphere (or clockwise in the Southern Hemisphere) and whose diameter averages 10 to 30 miles across. A tropical cyclone refers to any such circulation that develops over tropical waters. Tropical cyclones act as a "safety-valve," limiting the continued build-up of heat and energy in tropical regions by maintaining the atmospheric heat and moisture balance between the tropics and the pole-ward latitudes.

The key energy source for a tropical cyclone is the release of latent heat from the condensation of warm water. Their formation requires a low-pressure disturbance, warm sea surface temperature, rotational force from the spinning of the earth and the absence of wind shear in the lowest 50,000 feet of the atmosphere. The South Pacific hurricane season is from November 1st to April 30th, but events are possible throughout the year. Each season, the South Pacific experiences about nine typical cyclones and about half are Category 3 or higher in intensity.[59] The most predominant and destructive hazards associated with hurricanes include high winds, heavy rain, and storm surge.

High Winds

Hurricane winds can reach speeds up to 155 miles per hour in the eye-wall of the hurricane, with gusts exceeding 224 miles per hour. The destructive power of these winds increases by the square of its speed; thus, a tripling of wind speed increases destructive power by a factor of nine. Consequently, these winds can devastate agricultural crops, uproot large trees, and flatten entire forests. Man-made structures are also vulnerable, with buildings shaking or even collapsing. In addition, the drastic barometric pressure differences in a hurricane can cause windowless structures to explode, uplift rooftops and even entire buildings. However, the primary wind related cause of death, destruction, and injury is flying debris.

Heavy Rain

The rain that accompanies hurricanes is extremely variable and difficult to predict. The speed of a hurricane also impacts rain – slow-moving storms with lots of moisture may saturate an area, fast moving systems may not cause substantial flooding. Intense rainfall can cause different types of destruction. Seepage of water into buildings can cause structural damage and if the rain is steady and persistent, the structures may simply collapse from the weight of the absorbed water. Inland flooding means that building structures and critical transportation facilities, such as roads and bridges in valleys and low-lying areas, are at risk. In addition, heavy rain often triggers landslides, typical in areas with medium to steep slopes that have become over-saturated.

58 What is the difference between a hurricane, a cyclone, and a typhoon? (2014). NOAA. Retrieved August 8, 2014 from http://oceanservice.noaa.gov/facts/cyclone.html

59 South Pacific Tropical Cyclone Season - 2014 - 2015. (2014). U.S. Passports & International Travel. Retrieved August 8, 2014 from http://travel.state.gov/content/passports/english/alertswarnings/south-pacific-cyclone-season.html

Storm Surge

Storm surge is the rise of the ocean due to atmospheric pressure changes. It is a great dome of water often 50 miles wide that comes sweeping across the coastline near the area where the eye of the hurricane makes landfall, and can inundate low-lying areas up to several miles inland. Aided by the hammering effects of breaking waves, surge acts like a giant bulldozer, sweeping everything in its path. The stronger the hurricane, the higher the storm surge will be. If heavy rain accompanies the storm surge and landfall occurs at a peak high tide, the consequences can be catastrophic. The excess water from the heavy rains inland can cause an increase in sea level heights and riverine flooding, thus blocking the seaward flow of rivers and effectively leaving nowhere for the water to go. Sea level rise can also exacerbate storm surge as more water inundates more land. In sum, storm surge is unquestionably the most dangerous part of a hurricane, accounting for 90% of all hurricane related fatalities.

Areas at risk to storm surge are identical to tsunami risk areas and mapped according to FEMA's velocity wave hazard, or VE zones.

For the purposes of this assessment, flooding due to heavy rains associated with tropical cyclones is discussed under the "flood hazard." This section primarily covers the impacts of high wind and storm surge commonly accompanying all categories of hurricanes. Tropical cyclones are also classified by strength, most notably wind.

Tropical cyclones are measured in several ways. The main forecasting center for American Samoa is the Joint Typhoon Warning Center (through the Pacific Disaster Center), which covers all U.S. holdings in the South Pacific. However, given their proximately to Australia/New Zealand, information comes from their weather agencies as well. Also, since American Samoa is a U.S. Territory, NOAA and National Hurricane Center monitor and record information. Each of these agencies has a different way of classifying typhoons. The National Hurricane center utilized the Saffir-Simpson Hurricane Scale. The National Hurricane Center and Joint Tropical Warning Center utilize 1-minute sustain winds for classification while others use 10-minute sustained winds. These are shown in Table 34.

Table 34 Cross-comparison of Tropical Cyclone Categories [60]

<table>
<tr><th>1-minute sustained winds</th><th>10-minute sustained winds</th><th>National Hurricane Center/Saffir-Simpson Scale (Atlantic Ocean, USA)</th><th>Joint Tropical Warning Center (U.S. holdings)</th><th>Japan Meteorology Association</th><th>Indian Meteorology Association (N Indian Ocean)</th><th>France Meteorology Association (SW Indian Ocean)</th><th>Bureau of Meteorology /Fiji Meteorology Service (Australia and South Pacific)</th></tr>
<tr><td><32 knots (37 mph; 59 km/h)</td><td><28 knots (32 mph; 52 km/h)</td><td rowspan="2">Tropical Depression</td><td rowspan="2">Tropical Depression</td><td rowspan="3">Tropical Depression</td><td>Depression</td><td>Zone of Disturbed Weather</td><td rowspan="3">Tropical Disturbance Tropical Depression Tropical Low</td></tr>
<tr><td>33 knots (38 mph; 61 km/h)</td><td>28–29 knots (32–33 mph; 52–54 km/h)</td><td rowspan="2">Deep Depression</td><td>Tropical Disturbance</td></tr>
<tr><td>34–37 knots (39–43 mph; 63–69 km/h)</td><td>30–33 knots (35–38 mph; 56–61 km/h)</td><td rowspan="3">Tropical Storm</td><td rowspan="3">Tropical Storm</td><td>Deep Depression</td></tr>
<tr><td>38–54 knots (44–62 mph; 70–100 km/h)</td><td>34–47 knots (39–54 mph; 63–87 km/h)</td><td>Tropical Storm</td><td>Cyclonic Storm</td><td>Moderate Tropical Storm</td><td>Category 1 tropical cyclone</td></tr>
<tr><td>55–63 knots (63–72 mph; 102–117 km/h)</td><td>48–55 knots (55–63 mph; 89–102 km/h)</td><td>Severe Tropical Storm</td><td>Severe Cyclonic Storm</td><td>Severe Tropical Storm</td><td>Category 2 tropical cyclone</td></tr>
</table>

60 Tropical cyclone. (2014). Wikipedia. Retrieved August 8, 2014 from http://en.wikipedia.org/wiki/Tropical_cyclones

<table>
<tr><th>1-minute sustained winds</th><th>10-minute sustained winds</th><th>National Hurricane Center/Saffir-Simpson Scale (Atlantic Ocean, USA)</th><th>Joint Tropical Warning Center (U.S. holdings)</th><th>Japan Meteorology Association</th><th>Indian Meteorology Association (N Indian Ocean)</th><th>France Meteorology Association (SW Indian Ocean)</th><th>Bureau of Meteorology /Fiji Meteorology Service (Australia and South Pacific)</th></tr>
<tr><td>64–71 knots (74–82 mph; 119–131 km/h)</td><td>56–63 knots (64–72 mph; 104–117 km/h)</td><td rowspan="2">Category 1 hurricane</td><td rowspan="6">Typhoon</td><td>Severe Tropical Storm</td><td>Severe Cyclonic Storm</td><td>Severe Tropical Storm</td><td>Category 2 tropical cyclone</td></tr>
<tr><td>72–82 knots (83–94 mph; 133–152 km/h)</td><td>64–72 knots (74–83 mph; 119–133 km/h)</td><td rowspan="5">Typhoon</td><td rowspan="5">Very Severe Cyclonic Storm</td><td rowspan="3">Tropical Cyclone</td><td rowspan="3">Category 3 severe tropical cyclone</td></tr>
<tr><td>83–95 knots (96–109 mph; 154–176 km/h)</td><td>73–83 knots (84–96 mph; 135–154 km/h)</td><td>Category 2 hurricane</td></tr>
<tr><td>96–97 knots (110–112 mph; 178–180 km/h)</td><td>84–85 knots (97–98 mph; 156–157 km/h)</td><td rowspan="2">Category 3 Hurricane</td></tr>
<tr><td>98–112 knots (113–129 mph; 181–207 km/h)</td><td>86–98 knots (99–113 mph; 159–181 km/h)</td><td rowspan="2">Intense Tropical Cyclone</td><td rowspan="2">Category 4 severe tropical cyclone</td></tr>
<tr><td>113–122 knots (130–140 mph; 209–226 km/h)</td><td>99–107 knots (114–123 mph; 183–198 km/h)</td><td>Category 4 Hurricane</td></tr>
</table>

<table>
<tr><th>1-minute sustained winds</th><th>10-minute sustained winds</th><th>National Hurricane Center/Saffir-Simpson Scale (Atlantic Ocean, USA)</th><th>Joint Tropical Warning Center (U.S. holdings)</th><th>Japan Meteorology Association</th><th>Indian Meteorology Association (N Indian Ocean)</th><th>France Meteorology Association (SW Indian Ocean)</th><th>Bureau of Meteorology /Fiji Meteorology Service (Australia and South Pacific)</th></tr>
<tr><td>123–129 knots (142–148 mph; 228–239 km/h)</td><td>108–113 knots (124–130 mph; 200–209 km/h)</td><td rowspan="2">Category 4 Hurricane</td><td>Typhoon</td><td rowspan="3">Typhoon</td><td>Very Severe Cyclonic Storm</td><td>Intense Tropical Cyclone</td><td rowspan="3">Category 5 severe tropical cyclone</td></tr>
<tr><td>130–136 knots (150–157 mph; 241–252 km/h)</td><td>114–119 knots (131–137 mph; 211–220 km/h)</td><td rowspan="2">Super Typhoon</td><td rowspan="2">Super Cyclonic Storm</td><td rowspan="2">Very Intense Tropical Cyclone</td></tr>
<tr><td>>137 knots (158 mph; 254 km/h)</td><td>>120 knots (140 mph; 220 km/h)</td><td>Category 5 hurricane</td></tr>
</table>

A "Super-typhoon" is a term utilized by the U.S. Joint Typhoon Warning Center for typhoons that reach maximum sustained 1-minute surface winds of at least 65 m/s (130 kt., 150 mph). This is the equivalent of a strong Saffir-Simpson category 4 or category 5 hurricane in the Atlantic basin or a category 5 severe tropical cyclone in the Australian basin.[61]

Table 34 & Table 35 show the damages expected from the Saffir-Simpson scale and the Australian Cyclone Severity Scale, respectively.

61 FAQ: What is a super-typhoon?. (2014). Hurricane Research Division. Retrieved on August 8, 2014 from http://www.aoml.noaa.gov/hrd/tcfaq/A3.html

Table 35
Hurricane Damage Classification on the Saffir-Simpson Scale[62]

Storm Category (Sustained Winds - MPH)	Damage Level	Description of Damages	Photo Example
1 (74-95)	MINIMAL Very dangerous winds will produce some damage	No real damage to building structures. Damage primarily to unanchored mobile homes, shrubbery, and trees. Also, some coastal flooding and minor pier damage. An example of a Category 1 hurricane is Hurricane Dolly (2008).	
2 (96-110)	MODERATE Extremely dangerous winds will cause extensive damage	Some roofing material, door, and window damage. Considerable damage to vegetation, mobile homes, etc. Flooding damages piers and small craft in unprotected moorings may break their moorings. An example of a Category 2 hurricane is Hurricane Francis in 2004.	
3 (111-129)	EXTENSIVE Devastating damage will occur	Some structural damage to small residences and utility buildings, with a minor amount of curtain wall failures. Mobile homes are destroyed. Flooding near the coast destroys smaller structures, with larger structures damaged by floating debris. Terrain may be flooded well inland. An example of a Category 3 hurricane is Hurricane Ivan (2004).	
4 (130-156)	EXTREME Catastrophic damage will occur	More extensive curtain wall failures with some complete roof structure failure on small residences. Major erosion of beach areas. Terrain may be flooded well inland. An example of a Category 4 hurricane is Hurricane Charley (2004).	
5 (157+)	Catastrophic	Complete roof failure on many residences and industrial buildings. Some complete building failures with small utility buildings blown over or away. Flooding causes major damage to lower floors of all structures near the shoreline. Massive evacuation of residential areas may be required. An example of a Category 5 hurricane is Hurricane Andrew (1992).	

62 National Hurricane Center, FEMA

Table 36 Australian Cyclone Severity Scale [63]

Category	Strongest Gusts (km/h)	Averaged Wind Speeds (km/h)	Typical effects (indicative only)	Examples
Category 1	90 - 125	63-88	Negligible house damage. Damage to some crops, trees and caravans. Craft may drag moorings.	Cyclone Olga 2010
Category 2	125 - 164	89 - 117	Minor house damage. Significant damage to signs, trees and caravans. Heavy damage to some crops. Risk of power failure. Small craft may break moorings.	Cyclone Anthony 2011
Category 3	165 - 224	118 - 159	Some roof and structural damage. Some caravans destroyed. Power failure likely.	Cyclone Magda 2010
Category 4	225 - 279	160 - 199	Significant roofing loss and structural damage. Many caravans destroyed and blown away. Dangerous airborne debris. Widespread power failure.	Cyclone Tracy 1974 & Cyclone Larry 2006
Category 5	> 279	> 200	Extremely dangerous with widespread destruction.	Cyclone Yasi 2011

Note: Average wind speed is for 10-minute average. 1 km/h ~ .54 kt. or .63 mph

Location

A tropical cyclone has the potential to impact all islands and areas of American Samoa. Therefore, it is assumed the entire American Samoa planning area is susceptible to a tropical cyclone event. All existing and future buildings and populations, including critical facilities, are at risk to this hazard. However, the impact and extent will vary based on storm track and location.

Previous Occurences

American Samoa lies outside of the most active tropical cyclone belt in the southwest Pacific Ocean. Although many years can pass between major hurricanes, when they do impact American Samoa, the effects are devastating.

Figure 63 depicts all storm tracks between 1945 and 2012 that have occurred within approximately 200 miles of Tutuila (encompassing all of the American Samoan Islands). Typhoon (hurricane) tracks are illustrated in pink, tropical storms are yellow, and tropical depressions are green. Of these events, three had center tracks that passed directly through American Samoa.

63 Tropical Cyclones FAQ. (2014). NOAA. Retrieved August 8, 2014 from http://www.aoml.noaa.gov/hrd/tcfaq/D2.html

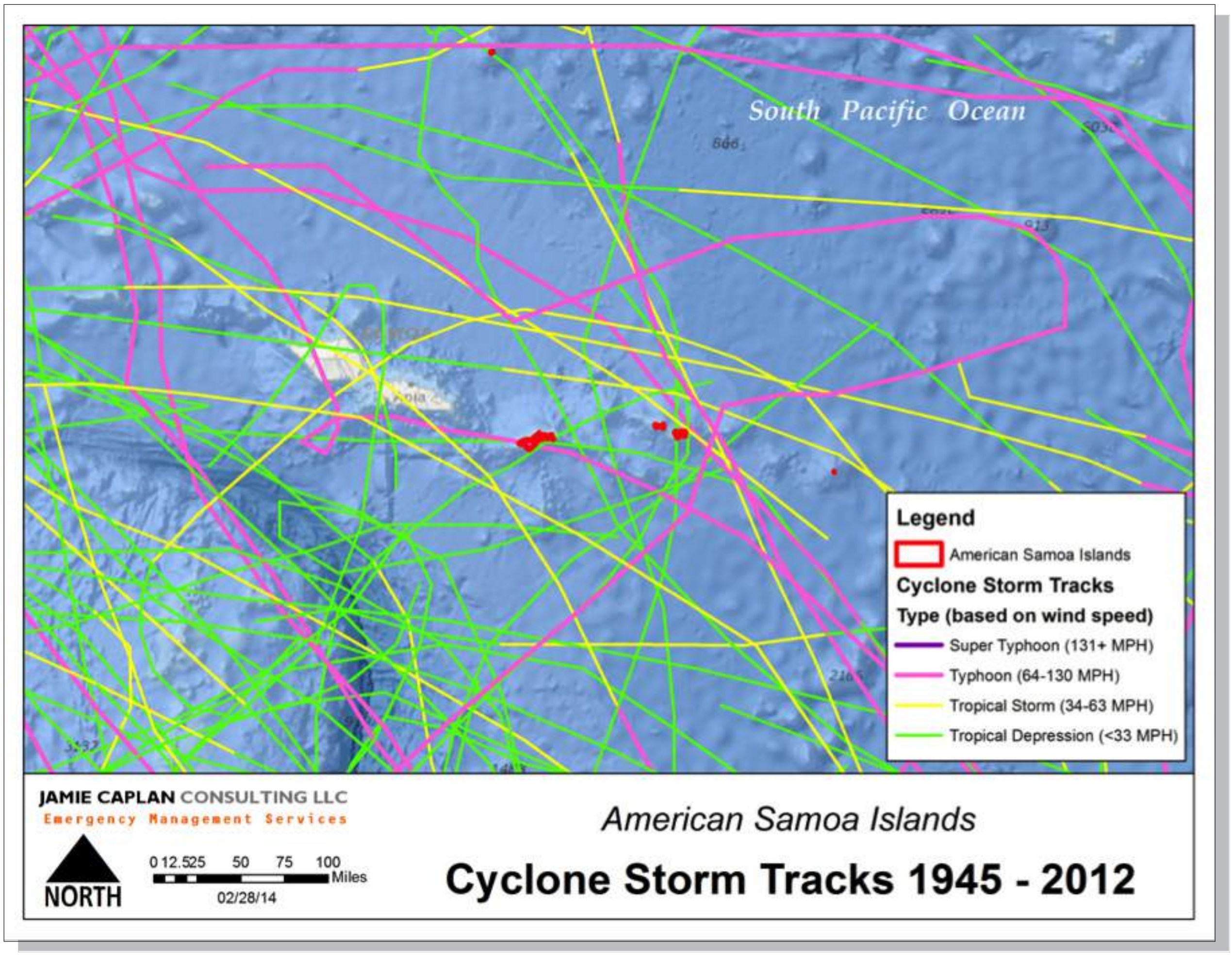

Figure 63 Historic Hurricane Tracks

An additional 27 storms were reported within 75 miles of the islands. This is the area where tropical cyclone tend to impact. However, extremely large events may impact the islands from even greater distances so those were included if known impacts occurred. An example is 2005 Category 5 Heta, which was 150 miles away. Conversely, not all storms within the 75-mile range caused damage. For that reason, significant events are described in Table 37.

Table 37 Hurricane Tracks with 75 miles of American Samoa (1945 and 2012)

Date	Name	Wind Speed	Type (max within 75 miles of American Samoa based on Saffir-Simpson Scale)	Islands Traversed
Direct Hits				
1/24/1966	unnamed	Not reported	Tropical Depression	Tutuila
2/3/1957	unnamed	Not reported	Cyclone	Ta'u
12/10/1991	unnamed	103	Tropical Depression	Tutuila
Within 75 miles of American Samoa Islands				
2/9/1959	unnamed	Not reported	Tropical Depression	-
2/22/1959	unnamed	Not reported	Tropical Depression	-
3/17/1960	unnamed	Not reported	Tropical Depression	-
1/20/1964	unnamed	Not reported	Tropical Depression	-
12/14/1967	unnamed	Not reported	Tropical Depression	-
2/13/1978	Charles	74	Tropical Storm	-
3/1/1981	unnamed	57	Tropical Storm	-
2/28/1982	Isaac	Not reported	Tropical Depression	-
1/15/1987	Tusi	115	Category 3 Cyclone	-
3/1/1987	unnamed	51	Tropical Storm	-
4/24/1987	Zuman	63	Tropical Storm	-
2/3/1990	Ofa (100 west of Pago Pago)	100	Category 4 Cyclone	-
12/9/1991	Val	115	Category 4 Cyclone	-
3/15/1992	Fran	34	Tropical Depression	-
2/4/1993	unnamed	28	Tropical Depression	-
1/13/1997	Drena	74	Tropical Storm	-
1/3/1998	Susan	74	Tropical Storm	-
1/27/1998	Tui	28	Tropical Depression	-
2/1/1998	Veli	40	Tropical Depression	-
1/13/2004	Heta (150 miles away)	160	Category 5 Cyclone	-
2/18/2005	Olaf	166	Category 5 Cyclone	-
2/27/2005	Percy	126	Category 3 Cyclone	-
1/4/2006	Tam	35	Tropical Storm	-
1/28/2010	Nisha	67	Tropical Storm	-
2/1/2010	Oli	Not reported	Tropical Storm	-
2/9/2010	Rene	Not reported	Category 1 Cyclone	-
3/9/2010	Thomas	Not reported	Not reported	-

During the last 50+ years, eight major hurricanes have impacted American Samoa. They have been fairly uniform in frequency and more or less evenly distributed during this period. Details regarding storm severity, affected geographical areas, damages, and estimated losses for previous significant tropical cyclones are listed in Table 38.

Table 38 Previous significant tropical cyclones

Event Name, Date	Geographical Extent	Severity (Category)	Impacts	Deaths/ Injuries	Estimated Losses ($)
Un-named hurricane January 29-30, 1966	Throughout American Samoa, Tutuila, Aunu'u, Swains Island	Category 2, 100+ mph gusts	Substantial structural damage, beach erosion and flooding. Over 50,000 lost their homes. This event was prior to any hurricane structural building or retrofitting.	90/0	$4.3 million
Hurricane Tusi January 16-20, 1987	Manu'a Islands	Category 3, Max sustained winds 110 mph, gusts to 120 mph	Tusi destroyed: 100% of structures in the villages of Faleasao, Fitiuta, and Sili; 90% of the structures in Ta'u and Ofu; 50% of those on Olosega. It left 98% of the 2,000 people in the islands homeless. Plantations were totally devastated, and the islands were denuded of forests and coconut palms. Stripped vegetation took five years to recover. There was severe storm surge on the north shores. FEMA disaster declaration.	0/0	$5 – 10 million

Event Name, Date	Geographical Extent	Severity (Category)	Impacts	Deaths/ Injuries	Estimated Losses ($)
Hurricane Ofa February 2-4, 1990	Islands of Tutuila, Aunu'u, Ofu, Olosega, Ta'u, and Swains	Category 2, Max sustained winds 90 mph, gusts to 100 mph, 20+ inches of rain, high surf, storm surge, 10+ landslides	Ofa caused coastal damage due to storm surge and high surf plus high tides heaviest along north shores of Ta'u and Olosega and some coastal villages on north shore of Tutuila. NW facing villages sustained the greatest damage. Fagasau roads were wiped out, and the road was destroyed at Poloa. Poloa and Amanave evacuated. Sailele lost 750 feet of road, cutting off the village. Extensive wind damage to airport buildings. Office of Procurement warehouse incurred structural damage. Dept. of Agriculture building lost. Four schools badly damaged in Poloa, Aoa, Masafau, Faleasau (at Ta'u). Tafuna high school gym collapsed. Special Ed. Building in Utulei a total loss. 95% of water supply lost due to loss of power at water-well pumping stations. 10+ large landslides on Tutuila.	10/0	$10 million (PPG); Public losses $28,761,983 (FEMA); Damage to roads $4,400,000 (FEMA); $200,000 (ReIns:Swiss)
Hurricane Val December 6-10, 1991	Tutuila and Manu'a Islands	Category 3, Max sustained winds of 100 mph, gusts to 123 mph, high surf, storm surge, 20+ inches of rain	Severe damage to structures (40% of housing), and utility lines. High surf and wave action washed away several sections of coastal roads on Tutuila, and the Manu'a Islands. Damage caused by high winds closed down harbor operations for a week. Containers strewn about the port, crane broken, 5-7 luxury yachts were destroyed, along with 11 long-line fishing vessels causing major impacts on the fishing industry. Cannery and airport heavily impacted by storm surge affecting the southern shore of Tutuila.	15/0	$13 million (PPG); Public losses $80,473,533 (FEMA); $50-80 million overall damage to seaport, $11 million to seaport infrastructure (AS Dir. Port Authority); $167,700 (ReIns:Swiss)

Event Name, Date	Geographical Extent	Severity (Category)	Impacts	Deaths/ Injuries	Estimated Losses ($)
Tropical Cyclone Heta – FEMA DR #:1506 1/13/04	High Winds, High Surf and Heavy Rainfall	Category 5	10% of inhabitants are now homeless, destroyed valuable crops	0/20	$50-$150 million
Tropical Cyclone Olaf – FEMA DR #: 1582 2/18/05	Tropical Cyclone Olaf, including High Winds, High Surf, and Heavy Rainfall	Category 5	Wiped out almost all homes on Manu'a Islands	0/0	$723,000
Tropical Cyclone Tam 1/12/2006	Tutuila, Manu'a Islands	Tropical Cyclone (Saffir-Simpson)	Destroyed 70 percent of local crops; some roof tops lost; 30-35 mph sustained winds; landslides; flooding; power outages	0/0	$10,000 - $26,000
Tropical Cyclone Nisha 1/26/2010	Tutuila, Manu'a Islands	Tropical storm (Saffir-Simpson)	4.66 inches of rainfall reported at the weather service office; gust of 67 mph reported from the Island of Manu'a; Several homes were flooded between Pago Pago and Fagaitua villages on the Island of Tutuila. Mudslides; broken tree branches and debris; high surf of 14-16 feet	0/0	--

Un-named hurricane (1966)

An un-named hurricane struck Tutuila on January 29-30, 1966 killing 90 people and causing an estimated $4.3 million in damage. Winds of over 100 miles per hour and rainfall amounts of 6 to 14 inches caused flooding and substantial structural damages.

Tropical Cyclone Tusi (1987)

Tropical cyclone Tusi, a Category 3 hurricane, passed to the northeast of the Manu'a Islands between January 16 and 20 1987, causing an estimated $5 to $10 million in damage and destroying virtually 100% of the structures in the villages of Faleasao and Fiti'uta on the island of Ta'u, and Sili village on the island of Olosega.[64] In Ta'u and Ofu, 90% of the structures were destroyed, as were 50% of those in Olosega. High winds stripped most of the vegetation from the island of Ofu, which took five years to grow back. Storm surge heavily impacted the north shores of the islands. Tusi is considered by many local residents to be the worst storm to affect American Samoa in recorded history.

64 American Samoa Government. American Samoa. (2003). Retrieved August 8, 2014 from http://www.asg-gov.com/island-info.htm

Tropical Cyclone Ofa (1990)

In February 1990, American Samoa suffered the most severe storm in more than 160 years. Winds gusted up to 100 mph. severe forest damage occurred with only 1% of the primary forest surviving. Hurricane Ofa hit the Samoan Islands on Friday, February 2, finally passing to the south on Sunday, February 4, 1990. It left a path of destruction that obliterated whole villages in Western Samoa and destroyed or damaged almost every building in American Samoa. Although the center never got closer than 180 miles to the islands, American Samoa was directly in its path until the hurricane veered south. Even so, the winds were stronger and the storm bigger in diameter by the time it passed by, so the Territory received the brunt of the storm.

One eyewitness account reported, "Winds were clocked at the airport at 107 miles per hour… Power was lost on Saturday the 3rd, along with all communications…Trees went down everywhere, along with power poles, and sheet metal roofing flew off like playing cards to litter yards and roads. Some villages in low-lying areas were totaled from the wind and waves. In unprotected harbors, small boats and ships alike were driven up on the reefs."[65]

Tropical Cyclone Val (1991)

After passing through Western Samoa, tropical cyclone Val, a Category 3 hurricane, tracked across the southwestern portion of Tutuila on December 9, 1991 with maximum sustained winds of 100 mph and gusts to 123 mph. After 12 hours of battering winds, heavy rain, and destructive high surf, Val then continued a southeastern track, passing about 30 miles to the south of, and impacting the Manu'a Islands the next day. Fifteen people died in the storm.

High winds caused severe damage to housing, electric power distribution systems, and water and sewage systems. High surf washed away several sections of the coastal road between Faga'alu and Nu'uuli on Tutuila Island, as well as roads on the Manu'a Islands. However, traffic was apparently interrupted more due to downed utility poles than problems associated with the roadbed. More than 20 inches of rain fell during the storm, and high winds defoliated over 90% of primary forest. One report estimated damage at $13 million.[66]

FEMA's Hazard Mitigation Strategies document for Hurricane Val reported severe damage to the electric power system, primarily to the distribution feeder and transmission lines. Switching gears were also damaged. Damage to the power system left water and sewer systems non-functional and downed power lines rendered intra-island communication non-existent. Local anecdote stated that the island lost power for three to six months. However, communication off the island and cellular use was largely unaffected.[67]

Hurricane Val affected 40% of the housing in American Samoa. The Office of Development Planning reported that low-income households were the most severely impacted group due to the type of home construction. However, homes constructed by FEMA following hurricanes Tusi and Ofa, and those constructed under the office of Emergency Preparedness received very little damage.

65 Webb, L. Robert. (2003). "Hurricane Ofa – American Samoa". Retrieved August 8, 2014 from http//www.motivation-tools.com/hunky-dory/feb27-90.htm

66 "American Samoa Flood Mitigation Plan." (2003). PPG Consultants.

67 Hurricane Val. DR-927-AS. FEMA. (1991). Federal Emergency Management Agency, Hazard Mitigation Strategies.

The Director of the Port Authority on Tutuila described hurricane Val as the most destructive hurricane to affect the islands. High winds caused $50-80 million of damage to the overall port, including vessels, with $11 million in damage to seaport infrastructure that closed down operations for a week. Containers stacked four high were strewn about the port, a crane was broken, five to seven luxury yachts were destroyed, as were 11 long-line fishing vessels, which had a major impact on the fishing industry. [68]

Both the cannery and the airport were heavily impacted by storm surge on the southern shore of the island. Neither of these facilities has backup power, making both particularly vulnerable.

Tropical Cyclone Heta

January 13, 2004 FEMA declared American Samoa a disaster area due to Tropical Cyclone Heta (FEMA DR #1506). The damage Heta caused on Tonga, Niue, and American Samoa was estimated at $150 million dollars (2004 USD), with most of the damage occurring in American Samoa; the cyclone was also responsible for two deaths (not in American Samoa). Heta precipitated a massive relief and clean-up operation that lasted throughout 2004.

It reached a maximum intensity of 160 mph and exerted an estimated pressure of 915 millibars before dissipating on January 11, 2004. The high winds destroyed over 600 homes and damaged 4,000 others. Offshore, the storm brought waves up to 44 feet high along the north and western part of the island. The combination of rough surf and storm surge damaged or destroyed many boats near Swains Island. Although no deaths were reported, the storm injured 20 people. Power was lost but only for a few days in certain parts of the island. It was not as severe as Hurricane Val (1991) as a result of mitigation projects. Several utilities lines were moved underground and utility supply structures were hardened.

The damage from the cyclone caused an evacuation of 140 residents to relief shelters, thirteen of which were opened after the storm. In addition, the Small Business Administration (SBA) offered $40,000-$200,000 (2004 USD) in repair loans for residents and $1.5 million (2004 USD) in repair loans for businesses. The federal government offered $22 million (2004 USD) in relief aid through FEMA. The United Church of Christ also provided $5,000 in relief aid.[69]

More than 9,100 American Samoa residents and business owners registered with FEMA to apply for aid. FEMA has issued approximately $11.4 million in temporary disaster housing grants to people whose homes were severely damaged and to those repairing their primary residences to make them safe, sanitary and functional. The agency has provided more than $13.6 million for other serious needs directly related to Heta. The bulk of funding went towards the cost of restoring and repairing utilities (specifically, electrical power and telephone lines) as well as replacing and repairing public buildings.

Tropical Cyclone Olaf

February 18, 2005 FEMA declared American Samoa a disaster area due to Tropical Cyclone Olaf. Olaf had wind gusts up to 190 mph, making it a Category 5 storm, the most intense. The weather service said the storm generated destructive waves of 30 to 40 feet on the shores of all islands. The cyclone passed 50 miles to the north of Samoa, officials said. Prior to its change of track, the storm was heading directly toward the small nation, prompting it to declare a state of emergency. The islands suffered some damage from winds, heavy rain and pounding seas and 15 people were treated for minor injuries. There were no reports of deaths from the

68 Pago Pago Harbor. Personal Interview. (2003). Seugogo Ben Schirmer, Director of the Port Authority. Pago Pago, American Samoa.

69 Cyclone Heta. (2014). Wikipedia. Retrieved August 8, 2014 from http://en.wikipedia.org/wiki/Cyclone_Heta

islands, home to some 2,000 people, but many houses were seriously damaged, officials said. Olaf damaged several water stations in the Manu'a Islands causing a water shortage. The cyclone caused telephone service interruption to the Manu'a Islands of Ta'u, Ofu and Olosega.

Direct Federal Assistance was authorized to American Samoa under DR #1582. This allowed for Public Assistance for the repair or replacement of disaster-damaged facilities and debris removal and emergency protective measures

Under the declaration, federal funds will be provided for the territory and affected local governments and certain private nonprofit organizations to pay 75 percent of the eligible costs for debris removal and emergency services related to the storm that began on February 15. The funding also covers the cost of requested emergency work undertaken by the federal government.

Tropical Cyclone Tam

Tropical Cyclone Tam was the first storm of the 2005-2006 season. Tam, a weak tropical storm, was not a severe wind issue but did bring heavy rain causing flooding and mudslides.[70] Weather Service Office recorded sustained winds of 30 to 35 mph peaking to 59 mph for this episode. Unsecured rooftops were lost in Tutuila. Unfavorable conditions and high winds caused landslides in other areas for the Island of Tutuila. No injury reported.

Tropical Cyclone Nisha

On January 26, 2010 Tropical Cyclone Nisha was centered at its closest point to American Samoa, about 175 miles southeast of Tutuila.[71] The storm was not a major cyclone but was of significance because many people were still sheltering in tents following the 2009 tsunami.[72] It largely spared Tutuila and Aunu'u as it formed but did result in minor damage over the Manu'a Islands. Heavy rainfall and strong gale force winds were reported across the Samoan Islands, with the highest wind gust of 67 mph reported from the Island of Manu'a. The weather service office received 4.66 inches of rainfall during this event. Several homes were flooded between Pago Pago and Fagaitua villages on the Island of Tutuila. Mudslides, broken tree branches and debris were found on the main road. Hazardous surf of 14 to 16 feet impacted east and south facing reefs on all Islands.

Extent

As the previous occurrences show, powerful Category 5 cyclones, such as Hurricane Olaf and Hurricane Heta, are possible in American Samoa. However, it appears that due to American Samoa's close proximity to the equator (840 miles south of the 0 degree latitude line), the most intense tropical cyclones in the vicinity of American Samoa are rare.

Probability of Future Events

The previous occurrences indicated 30 events within 75 miles of the planning area over a 67-year reporting period. Of these events, three made direct impact with the islands. Based on these occurrences, tropical cyclones have an approximate annual probability of about 47 percent, a categorization of likely. However, when we investigate these based on major cyclones (category 3/111 mile per hour winds or greater), just five events apply. This results in an approximate annual probability of seven percent, a categorization of possible (between 1% and 10% annually) for category 3 or above events.

70 National Climatic Data Center

71 Ibid.

72 Cyclone Nisha buffets American Samoa. (2010). Radio New Zealand. Retrieved August 8, 2014 from http://www.radionz.co.nz/international/pacific-news/188421/cyclone-nisha-buffets-american-samoa

The ENSO cycle appears to have bearing on the probability of occurrence. The following list illustrates the phase of the ENSO cycle active during storms between 1966 and 1998:

- Unnamed hurricane 1966 – Weak El Niño
- Tropical Storm 1973 – Moderate El Niño
- Tropical Storm Esau 1981 – Neutral
- Hurricane Tusi 1987 – Weak El Niño
- Tropical Storm Gina 1989 – La Niña/Neutral
- Hurricane Ofa 1990 – Weak El Niño
- Hurricane Val 1991 – Moderate/Strong El Niño
- Tropical Storm Tui 1998 – Strong/Very strong El Niño
- Tropical Cyclone Heta, Dec 2003-2004-El Niño
- Tropical Cyclone Olaf, Feb 2005-Nuetral
- Tropical Cyclone Tam, 2006-El Niño
- Tropical Cyclone Nisha, 2010-La Niña

ENSO

As Figure 64 illustrates, over a 25-year period, four highly destructive (Category 2-3) hurricanes occurred in 1966, 1987, 1990, and 1991 (All El Niño years). Heta (2004) occurred during a phase that was El Niño. Olaf (2005) occurred during a phase that was neither El Niño nor La Niña, which is known as El Niño Neutral.

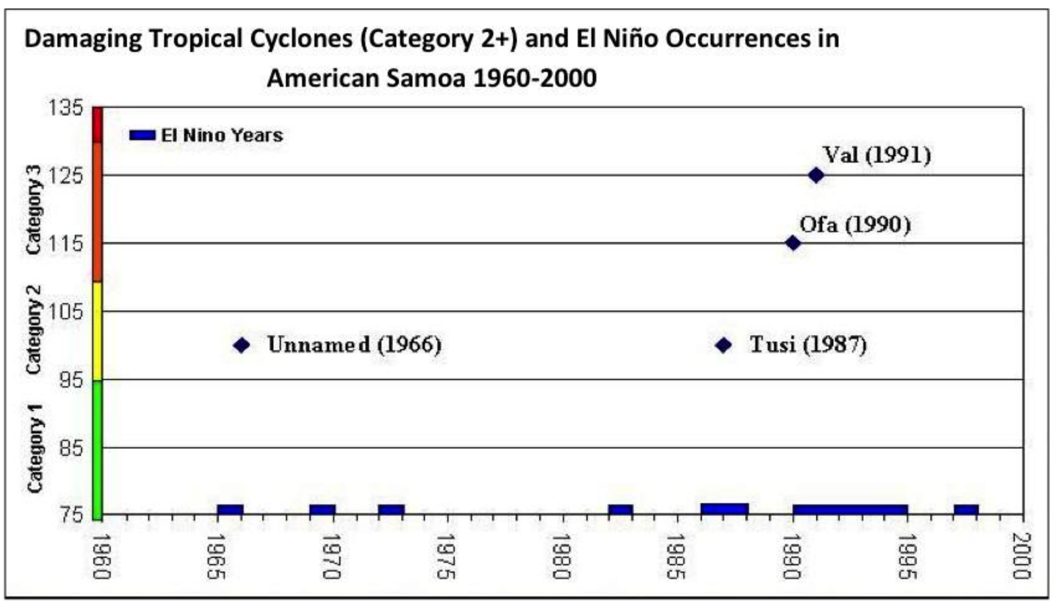

Figure 64 Tropical Cyclone Concurrence with El Niño

Vulneratbility Assessment

Cyclones typically approach the islands from a west, northwest, or northerly direction. This characteristic approach affords some protection to the opposite sides of the islands with respect to incoming seawater as waves. Storm surge would typically accompany a hurricane center's landfall, which could most frequently be expected to impact the west through northern exposures of the Territory. This typically spares Pago Pago Harbor from the worst of the storm surge flooding and battering effects.

However, there have been exceptions to this, such as Category 3 Hurricane Val, which resulted in severe damage to buildings in the harbor and closure of harbor operations for a week.

Hurricanes carry sustained wind speeds between 74 mph and 155+ mph. The array of associated hazards with strong to very strong hurricanes affecting American Samoa include winds of damaging force, heavy rainfall of flooding proportions, and high surf that can cause extensive structural damage, as well as coastal flooding along exposed shorelines.

Historical information regarding past tropical cyclone hazards is limited, and specific locations of concentrated or extreme damage due to high winds are unavailable and therefore not mappable. It is possible, however, to indicate areas that are likely to be affected by storm surge. These areas are designated as VE zones on FEMA's Flood Insurance Rate Maps, coincident with areas vulnerable to wave action resulting from tsunamis. However, all impacts would likely be territory-wide. Development and population surge in hazard prone areas increases the vulnerability to tropical cyclones.

Tropical cyclones are considered territory-wide events, to which all islands of American Samoa are vulnerable. Category 2 and 3 hurricane winds, waves and rainfall would certainly be felt island-wide, with Category 1 hurricanes felt to a lesser degree. Depending upon storm severity the direction of approach, and the effects of high winds, high surf and storm surge would vary. Terrain features play a role in increasing or decreasing wind speeds, but given that the highest mountains on Tutuila are nearly 2,000 feet, little protection from the wind is afforded from one side of the island to the other. Some amplification, however, could be expected in places, as winds could be accelerated over ridges and through valleys. The island of Ta'u is about 1,000 feet higher than Tutuila, which gives the leeward side somewhat more protection. However, there are wind and rain amplification factors that arise with the associated terrain features.

Previous occurrences have reported the following impacts from hurricanes:

- Structural damage from wind
- Structural damage from flooding
- Ship/yacht damage
- Beach erosion
- Flooding and storm surge
- Storm surge (north surge)
- Tree and agricultural crop loss
- Vegetative debris
- Road washout
- Water supply impacts
- Landslides (Ofa)
- Evacuations
- Injury, death
- Downed utility lines
- Harbor closure

Potential Losses

All current and future structures and populations are considered at risk to the tropical cyclone hazard. All counties and villages within have equal vulnerability to this hazard. This includes all critical facilities and infrastructure.

Tsunami

Description

In the last several years there have been significant tsunamis worldwide. The 2004 Indian Ocean Tsunami (Sumatra) caused over 200,000 deaths. The 2011 Chile earthquake and tsunami caused approximately 1,000 deaths. The 2011 Japan tsunami caused approximately 20,000 deaths. In 2009, American Samoa was impacted by the South Pacific Tsunami, which caused widespread destruction and over 100 deaths. The islands are still recovering and implementing mitigation measures due to this event. Due to the probability of a tsunami and its potential for death and destruction, attention is warranted for this hazard.

Tsunami (soo-NAH-mee) is a Japanese word, which translates in English as "harbor wave," and is now used internationally to describe a series of waves traveling across the ocean of extremely long wavelength (10-500 kilometers) and long period between waves (up to an hour). They are generated by a sudden displacement in the sea floor due to landslides, earthquakes, or volcanic activity, which is described further below.[73] The displacement causes a huge release of energy that allows tsunami waves to travel for hundreds or even thousands of miles. Tsunami waves involve the movement on the entire water column, from the surface to the ocean floor, as opposed to normal waves, which just involve surface movement. In deep water, tsunami waves can travel at 700 kilometers/hour, the speed of a jet plane, though the waves may only be a few inches high. [74] However, as the waves reach shallow water, the topography and water depth slows them. The slower speed results in a higher wave height. Further, waves from behind are traveling faster than those in the front, thus creating a piling effect and a wall of water. In some cases, the waves may measure 30 meters (90 feet) high.

As tsunamis approach the shoreline, the sea floor is often exposed. According to National Geographic, "A tsunami's trough, the low point beneath the wave's crest, often reaches shore first. When it does, it produces a vacuum effect that sucks coastal water seaward and exposes harbor and sea floors. This retreating of sea water is an important warning sign of a tsunami, because the wave's crest and its enormous volume of water typically hit shore five minutes or so later."[75] Observing this phenomenon is a clear indication to go to higher ground away from the shoreline.

Another characteristic of tsunamis is that they "surround" islands with waves. The waves bend around islands in what is coined the wrap-around effect. During the wrap-around effect, the energy of the tsunami often decreases resulting in smaller wave heights. Conversely, tsunami waves may reflect off of a landmass instead of bending around, thus increasing wave height of the approaching wave.[76]

Tsunamis are shallow-water waves, but are different from the wind-generated waves many have seen from the beach. Wind-generated waves usually have a period (the time between two successive waves) of 5 to 20 seconds and a wavelength (the distance between two successive waves) of about 330 to 660 feet (100 to 200 meters). Tsunamis in deep water can have a wavelength greater than 300 miles (482 kilometers) and a period of about an hour. This is very different from the normal California-type tube wave, which generally has a wavelength of about 330 feet (100 meters) and a period of about 10 seconds.

73 Tsunami. (2014). NOAA. Retrieved August 8, 2014 from http://www.tsunami.noaa.gov/

74 Tsunami Facts and Information. (2014). Australian Government Bureau of Meteorology. Retrieved August 8, 2014 from http://www.bom.gov.au/tsunami/info/index.shtml

75 Tsunamis - Killer Waves. (2014). National Geographic. Retrieved August 8, 2014 from http://environment.nationalgeographic.com/environment/natural-disasters/tsunami-profile/

76 Tsunami FAQ. (2009). NOAA Pacific Tsunami Warning Center. Retrieved August 8, 2014 from http://ptwc.weather.gov/faq.php

Since tsunamis are shallow-water waves, the ratio between water depth and wavelength is very small. The deeper the water, the faster and shorter the wave travels because shallow-water waves move at a speed equal to the square root of the product of the acceleration of gravity and the water depth. Tsunami waves have a very long reach, and may transport destructive energy from the initial source location to coastlines thousands of miles or kilometers away.

As noted above, tsunamis are caused by any disturbance that displaces a large volume of water. In the case of earthquake-generated tsunamis, the earthquake causes the sea floor to abruptly uplift or subside, disturbing the equilibrium of the overlaying water column and resulting in a tsunami. Submarine landslides, which often accompany large earthquakes, can also generate tsunamis due to the sudden down slope movement and redistribution of sediment and rocks across the sea floor. Similarly, a violent submarine volcanic eruption can create an impulsive force uplifting the water column from its equilibrium and generating a tsunami. In 1883, Indonesia's Mt. Krakatoa erupted violently, generating a tsunami that killed more than 30,000 people.

Conversely, super marine (above water) landslides and space born impacts can disturb the water column by the transfer of momentum from falling debris to the water into which the debris falls. In 1958, a huge landslide generated a 1,722-foot (525 meter) tsunami in Lituya Bay, Alaska. In general, tsunamis generated by these non-seismic mechanisms dissipate quickly and rarely affect coastlines far from the source area.
It should be noted that there are many misnomers about tsunamis. Some refer to tsunamis as "tidal waves," which is misleading. Although a tsunami's impact on a coastline is dependent upon the tidal level at the time of impact, tsunamis are unrelated to the tides. Tides result from the gravitational influences of the moon, sun, and planets on the earth's oceans. The scientific community once referred to tsunamis as "seismic sea waves," which is also misleading. "Seismic" implies an earthquake-related generation mechanism, and a non-seismic event, such as a landslide, meteorite impact, or sub-marine volcanic eruption can also generate a tsunami.[77]

Location

The entire coastline of American Samoa would be affected in the event of a tsunami. Wave heights along the shoreline would be directly related to the energy of the wave and direction in which it was generated. The majority of the coastline of Tutuila is relatively protected by basalt cliffs and high seawalls; however the pocket coves and bays of the island would be at higher risk of damage due to shallow bathymetry and the amplifying effect of the wave energy as it nears the shore.

The 2009 tsunami inundation areas are shown in Figure 65. While this was a catastrophic event, future tsunamis may impact areas beyond those impacted in 2009. Tsunamis are often associated with wave action making the FEMA maps one tool of identifying areas A/AE and V/VE along the coast can be considered at risk. However, there are no areas of V/VE identified on Tutuila from the FEMA maps. Figure 66 shows the flood zones and corresponding 2009 tsunami inundation areas. Areas around Leone (Lealataua County), Tula (East Vaifanua County) and Masefau (Sua County) experienced tsunami inundation well beyond the designated floodplain areas.

77 Tsunami Facts and Information. (2014). Australian Government Bureau of Meterology. Retrieved August 8, 2014 from http://www.bom.gov.au/tsunami/info/index.shtml

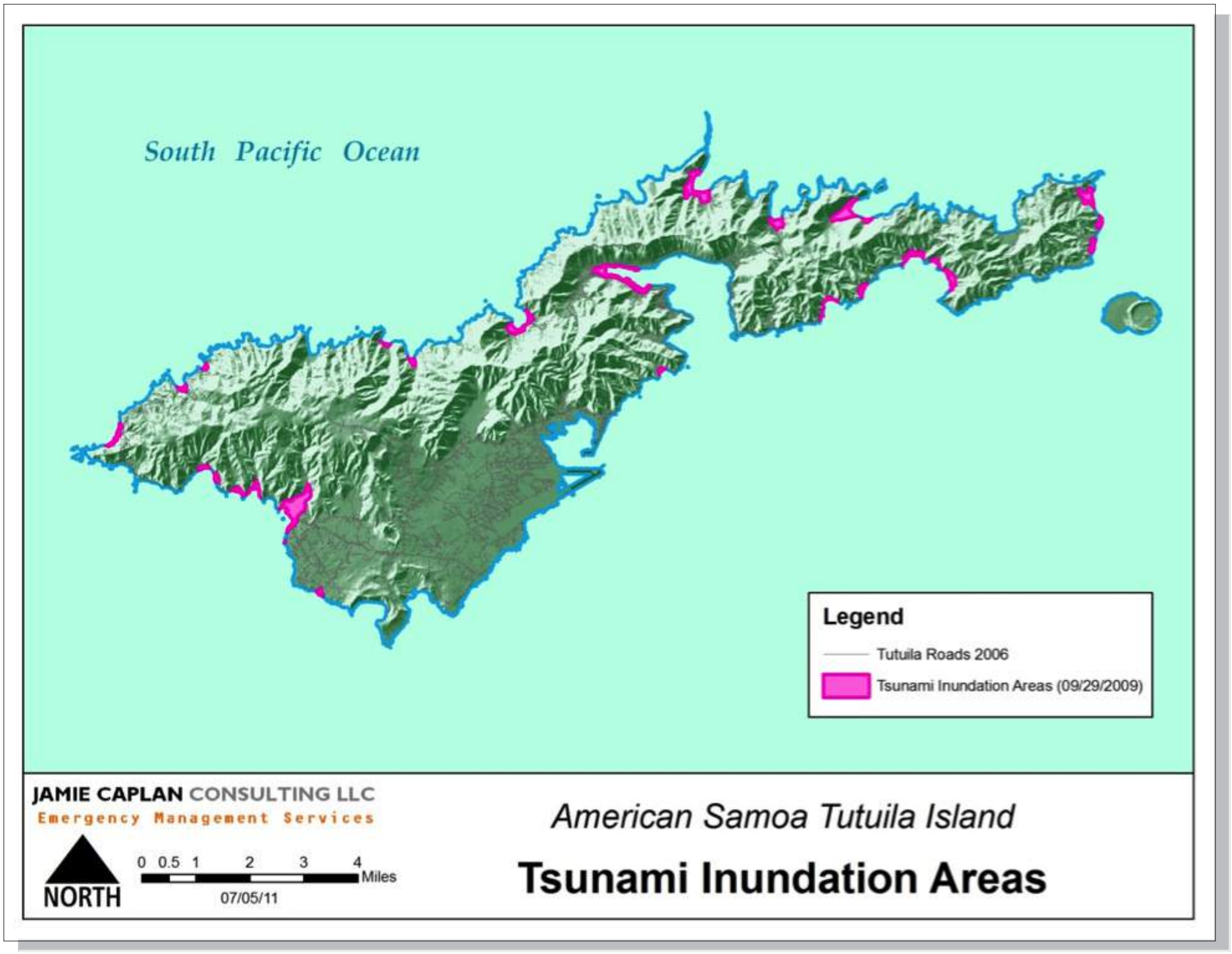

Figure 65 2009 Tsunami Inundation Levels

Bays typically experience greater damage due to the amplification effects of the tsunami. Pago Pago Harbor could sustain the worst damage due to amplification and narrowing of the channel. Additional threats would include the severe erosion of the coastline due to resonance of waves inside the narrow northwestern tip of the harbor as the sea surface returns to equilibrium. A significant number of buildings and critical facilities lie within tsunami risk area, including fire stations, communications, government buildings, and transportation buildings.

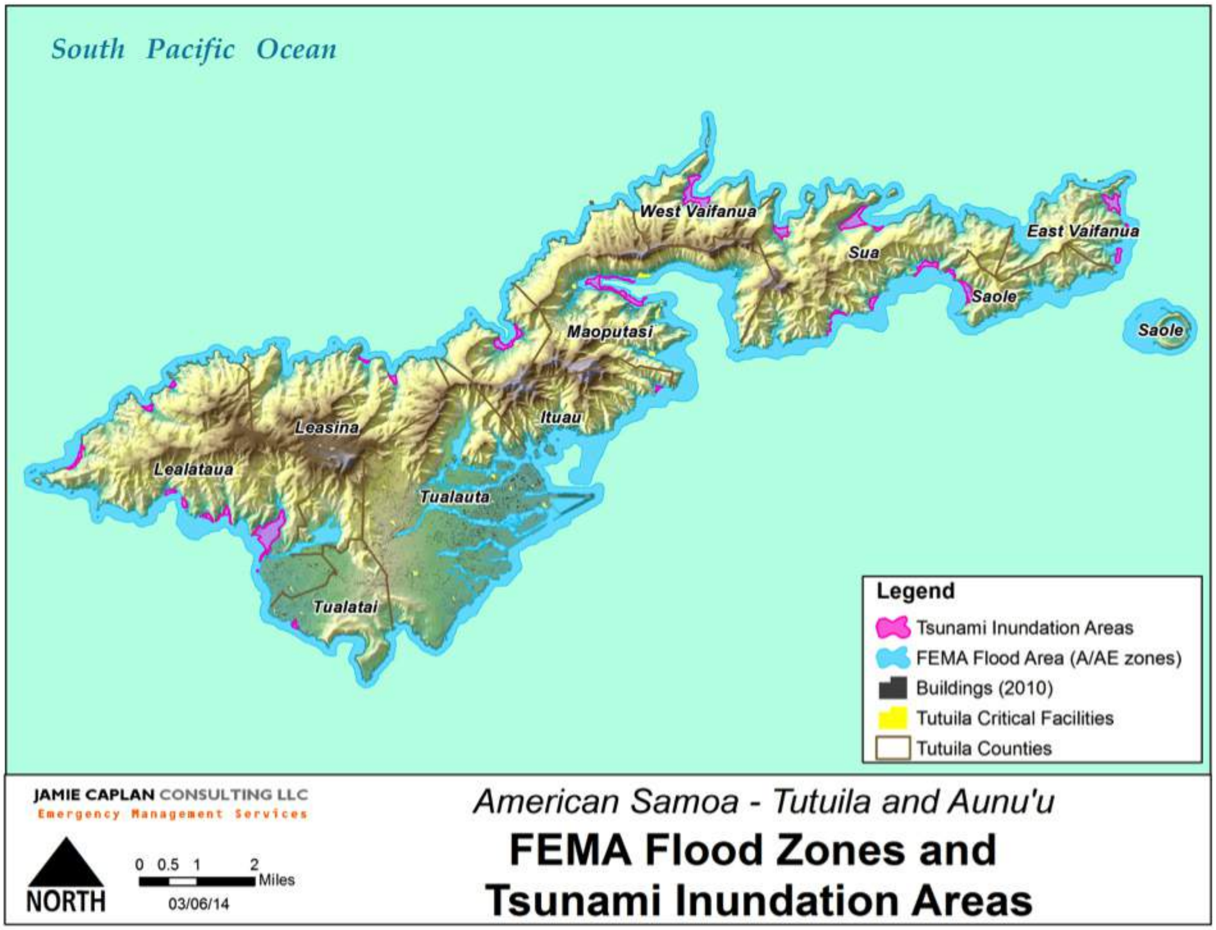

Figure 66 FEMA Flood Zones and 2009 Tsunami Inundation Areas Comparison

Previous Occurence

Between 1837 and February 2013, there were 98 tsunami events reported for American Samoa from NOAA's National Geophysical Data Center (NGDC) Historical Tsunami Database.[78] However, many of these events were part of the same event that impacted different locations. One additional event was reported in April 2014 due to the Chilean earthquake; however waves were less than 1 foot.[79] When viewing each tsunami as an event, there were 78 separate tsunami events between 1837 and 2013 recorded. Run-up (water height) ranged from 0.3 feet (0.1 meters) to 39.4 feet (12 meters) with 23 unreported events. A minimum run-up of 1.5 feet (0.5 meter) is required to cause significant damage. Of the historical listings, 24 reports met this threshold totaling 11 separate tsunamis. Table 39 lists the eleven tsunami events with max wave height over 0.5 meters. Damage reports for the events were scarce and inconclusive in most cases but details are included when possible. For events from 1937 to 1980, details and impacts were provided from the "Catalog of Tsunamis in the Samoan Islands." [80]

78 National Geophysical Data Center. Retrieved August 8, 2014 from http://www.ngdc.noaa.gov/nndc/struts/form?t=101650&s=167&d=166

79 Strong 7.6-Magnitude Aftershock Jolts Chile. (2014). Accuweather. Retrieved August 8, 2014 from http://www.accuweather.com/en/weather-news/breaking-magnitude-80-quake-st/25144298

80 Pararas-Carayannis, George, and Bonnie Dong. (1980). International Tsunami Information Center. Retrieved August 8, 2014 from http://www.drgeorgepc.com/TsunamiSamoaIslandsCatalog.pdf

Table 39 Summary of Significant Tsunami Events

Event Name, Date	Geographical Extent	Details	Severity (Run-up, Max Water Height	Impacts
November 11, 1837	Pago Pago	A Chilean earthquake occurred.	1.9 feet (0.6 meter)	unknown
February 2, 1915	Manu'a Islands	Said to be a hurricane, earthquake and tidal wave. However, not information could be found to support seismic activity. Since it only impacts Manu'a, there is possibility it was indeed a tidal wave and not a tsunami; unprecedented damage; American gunboat Princeton provided food, clothing, assistance	7.9 feet (2.4 meters)	3 deaths, entire villages swept away, ¾ of cocoa palms destroyed, shipped damaged; 3,000 without shelter;
Local tsunami (Tonga Trench) June 26, 1917	Pago Pago Harbor, Tutuila Locations in	A magnitude 8.5 earthquake occurred 150 miles SW of Apia	7.9 feet (2.4 meters) (anecdotal reports say 8- 40 feet high)	Many houses destroyed, 2 church damaged (one in Pago Pago and one in Leone; harbor water retreated (up to 6 feet in Pago Pago)
April 30, 1919	Pago Pago	Earthquake followed by waves	7.9 feet (2.4 meters)	Harbor water receded 6 feet below the low water mark. It return 6-8 feet above the high water mark
November 11, 1922	Pago Pago	None reported	3.0 feet (0.9 meters)	Slight damage indicated but not reported in news sources
Aleutian tsunami April 1, 1946	Pago Pago Harbor	None reported	2.6 feet (0.8 meter)	Pacific-wide impacts. Several huts washed away in Pago Pago; accounts of harbor water receded 5 feet.
Kamchatka, Russia tsunami November 4, 1952	Pago Pago Harbor	None reported	2.7 feet (0.9 meter)	Pacific-wide tsunami. No documented damage.

Event Name, Date	Number of Occurrences	Cause	Geographical Extent	Impacts
Aleutian tsunami March 9, 1957	Pago Pago Harbor, Fagasa	None reported	4 feet (1.2 meters) 4.9 feet (1.5 meters)	Road flooded that was 4 feet above mean tide. In water Pago Pago, the water receded before advancing; water oscillated for hours; Fagasa observers said water advanced and had waves of 5 feet above high tide.
Chilean tsunami May 22, 1960	Pago Pago Harbor, Tutuila Faga'alu	None reported	4.5 feet (1.4 meters) at harbor entrance, 10.7 feet (3.3 meters) at the inner end of harbor (PPG), 15.5 feet Pago Pago Village 16 feet (4.9 meters) Tutuila, 8 feet (2.4 meters) Pago Pago (NGDC website) 2.6 feet (0.8 meters) in Faga'alu	$50,000 reported in Pago Pago village (west portion of Pago Pago Harbor), one house was reportedly moved 10 feet inland and other washed out to sea; a school constructed on concrete piers was rotated a foot
South Pacific Tsunami September 29, 2009	Pago Pago Harbor, Tutuila	A 7.9 earthquake that occurred about 120 miles southwest of Pago Pago. The wave took 15 minutes to reach the Samoan islands. The wave went inland as far as 1 mile.	Run up 10.35 feet (314 cm); waves ranged from 15 feet at Pago Pago harbor to 40 feet at Poloa village on the Tutuila (NCDC)	Extensive damage, 32 deaths and many injuries. Widespread damage to infrastructure from flooding. Power plant, schools, business damaged. Approximately $81 million in damages
February 27, 2010*	All Islands	An 8.5 magnitude earthquake on Chile generated a 3 to 5 feet tsunami on the Island of Tutuila. The tsunami reached half a mile inland on the village of Pago Pago	3 to 5 feet (NCDC)	--

Event Name, Date	Number of Occurrences	Cause	Geographical Extent	Impacts
March 11, 2011*	All Islands	A 9.1 magnitude earthquake near Japan generated tsunami waves across the Pacific.	peaked near 3.5 feet (NCDC)	

*NCDC source for details.

Tsunami September 29, 2009

Figure 67 Location of Earthquake Epicenter in Relation to American Samoa[81]

On September 29, 2009, American Samoa was struck by and 8.3 magnitude earthquake. The earthquake generated a tsunami with waves reaching 5.1 feet in Pago Pago, the territory's capital, causing flooding on portions of the island. More than 30 people were killed and hundreds were injured. The combinations of the earthquake, tsunami, and flooding resulted in a devastating amount of damage on the island of Tutuila. A local power plant was disabled, 241 homes were destroyed, 308 homes had major damage another 2,750 dwellings reported some damage, one school was destroyed and four others sustained substantial damage. The tsunami rather than the earthquake caused most of the damage.[81]

An unusual type of earthquake that occurs near ocean trenches generated the September 2009 Samoa tsunami. Unlike typical tsunamigenic earthquakes that occur on the thrust fault that separates tectonic plates

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in a subduction zone (termed the inter-plate thrust), outer-rise earthquakes, as they are called, occur within the subducting plate before it enters the subduction zone (Figure 67). There have only been a few verified instances of tsunamis generated by outer-rise earthquakes, but those that have occurred have been devastating. The 1933 Sanriku tsunami generated from a magnitude 8.6 outer-rise earthquake resulted in over 3,000 deaths in Japan and significant damage on the Island of Hawaii. The 1977 Sumba magnitude 8.2-8.3 outer-rise earthquake resulted in 189 deaths in Indonesia. The 2009 Samoa outer-rise earthquake could have resulted in comparable fatalities and was the fourth largest outer-rise earthquake that has been instrumentally recorded since 1900.[82]

FEMA's Post Tsumani Disaster Assistance[83]

Within 24 hours of the earthquake and tsunami, the President issued a federal disaster declaration. The declaration authorized funds for Individual Assistance (IA), such as temporary housing; Public Assistance (PA), such as debris removal and emergency protective measures; Hazard Mitigation; and other forms of assistance. Two amendments were made to the original disaster declaration.

Figure 68 Tsunami Damage from 2009

These amendments provided for:

- 90% federal cost share for permanent repairs, and
- 100% federal cost share for debris removal and emergency protective measures for the first 30 days following the disaster.

Public Assistance

Under the Robert T. Stafford Disaster Relief and Emergency Assistance Act (Public Law 100-707) (Stafford Act), FEMA can provide multiple forms of assistance to disaster-affected areas. The Public Assistance grant program provides assistance to state, local, and tribal governments, as well as certain nonprofit organizations, so that communities can quickly respond to and recover from major disasters or emergencies. Grants may be used for debris removal; emergency protective measures; the repair, replacement, or restoration of publicly owned facilities such as utilities, schools, and hospitals damaged in the disaster; and road and bridge repair. The Individual Assistance grant program provides assistance, including temporary housing or rental assistance, to individuals affected by a disaster or emergency. Mission assignments allow FEMA to engage other federal agencies to carry out specific tasks, such as debris removal and power restoration.

82 Preliminary Analysis of the September 29, 2009 Samoa Tsunami, Southerwest Pacific Ocean. (2009). USGS. Retrieved August 8, 2014 from http://walrus.wr.usgs.gov/tsunami/samoa09/index.html

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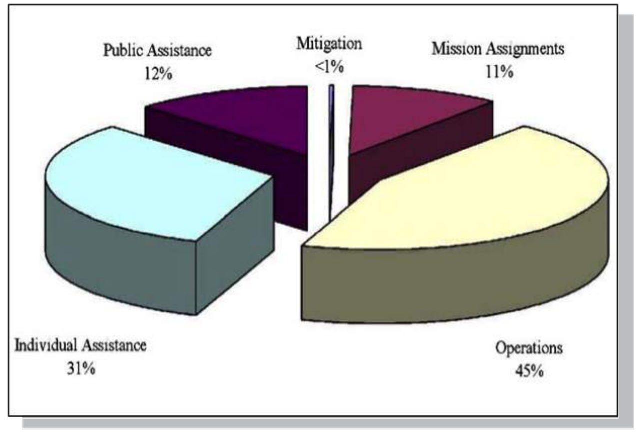
Since the disaster declaration, federal assistance to American Samoa, including FEMA's operation expenses, has exceeded $125.5 million, and an additional $4.3 million is planned for distribution. As of September 21, 2010:

- More than $37.4 million in disaster assistance was granted for housing and disaster related needs;
- 321 individuals received assistance grants of $30,300 each;
- More than $102.8 million was requested for debris removal, emergency protective measures, and the repair or rebuilding public buildings and other infrastructures;
- Temporary housing and sheltering was provided to those whose homes were destroyed or left uninhabitable; and
- Funds were allocated for the construction of approximately 45 permanent homes.



FEMA and its federal partners project that more than $18.6 million will be used to reduce or eliminate long-term hazard risk to the people and their property in American Samoa.

Although the relief aid efforts were well received by the American Samoan people, FEMA faced a number of challenges in providing assistance. Samoan culture has strong indigenous customs and traditions that revolve around the extended family (the aiga) and the communal land system. In Samoa, a matai (chief), controls the family's communally owned land for the common good of all family members. Family members are expected to help the matai by providing the resources and financial contributions needed for special occasions and events, such as church building dedications, weddings and funerals. Ultimately, the matai decides who can live or build on the communally owned land as well as what type of resources and contributions are needed from family members. FEMA acknowledged this custom, and worked with the people to come to an agreement on the distribution and ownership of the homes to be built.

Extent

A 6-point, Sieberg-Ambraseys Tsunami Intensity Scale, was devised in 1927 but it is rarely used according to NOAA. In addition, a new 12-point scale was proposed in 2001 but does not seem to be used in current practice. According to NOAA, tsunamis are most often characterized by heights at the shore and run up on land.
The 2009 tsunami brought run up of 10.35 feet and wave height of 15-40 feet. Inundation areas are nearly a half to 1 mile in some areas such as Leone and Masefau villages. While this is the most severe tsunami recorded in American Samoa to date, more severe events are possible.

Probability of Future Events

Between 1837 to 2014, a 177-year period, a total of 78 events were reported. This results in an approximate annual probability of 44 percent, a categorization of likely (between 10% and 90% annually). It should be noted, that a majority of these events did not result in damage. The 2009 tsunami was by far the most destructive tsunami experienced on island. The information for American Samoa suggests a probability of a potentially destructive tsunami occurring 2 to 3 times every 50 years (4% to 6% annual chance).

Vulnerability Assessment

Areas along the coast are most vulnerable to the impacts of tsunami. It is likely that tsunamis bringing a run-up of 2.6 feet (0.8 meter) or greater in American Samoa will cause significant damage. Damage will be particularly severe in terms of economic loss and property damage since the majority of commercial and residential buildings reside along the low-lying coastal regions and are rarely protected by barriers such as sea walls. The areas at highest risk of damage are the bays of Tutuila, particularly Pago Pago Harbor, due to the amplification of the wave energy as it approaches the shore. Bays and harbors experience more damage due to their shape. The impacts are concentrated and slosh back and forth.[84]

Since the 2009 tsunami, several sirens have been installed and public awareness is high. In addition, several tsunami evacuation areas have been identified, and signs have been installed to direct people to these areas. These factors will help to lessen the chance of loss of lives. However, future building decisions should also consider the possibility of future tsunamis. While major events are not a regular occurrence, they should still be planned for. Additional measures such as installing more seismic sensors to detect for locally generated tsunamis are encouraged.

Potential Losses

In order to estimate losses due a tsunami, a .25-mile buffer (inland from the shoreline) was applied using GIS analysis to the FEMA designated floodplain area. This buffer includes all of the 2009 tsunami inundation areas as well as land further inland. It is likely an overestimate since all floodplain areas (including that inland such as that around Tafuna Plain) is included in the buffer (Figure 69). However, it does provide a potential estimate for an event even more devastating than the 2009 tsunami event.

84 Tsunami fact-ite. Geofacts and Activities for the classroom. Retrieved August 8, 2014 from http://www.gsa.org.au/resources/factites/factitesTsunami.pdf

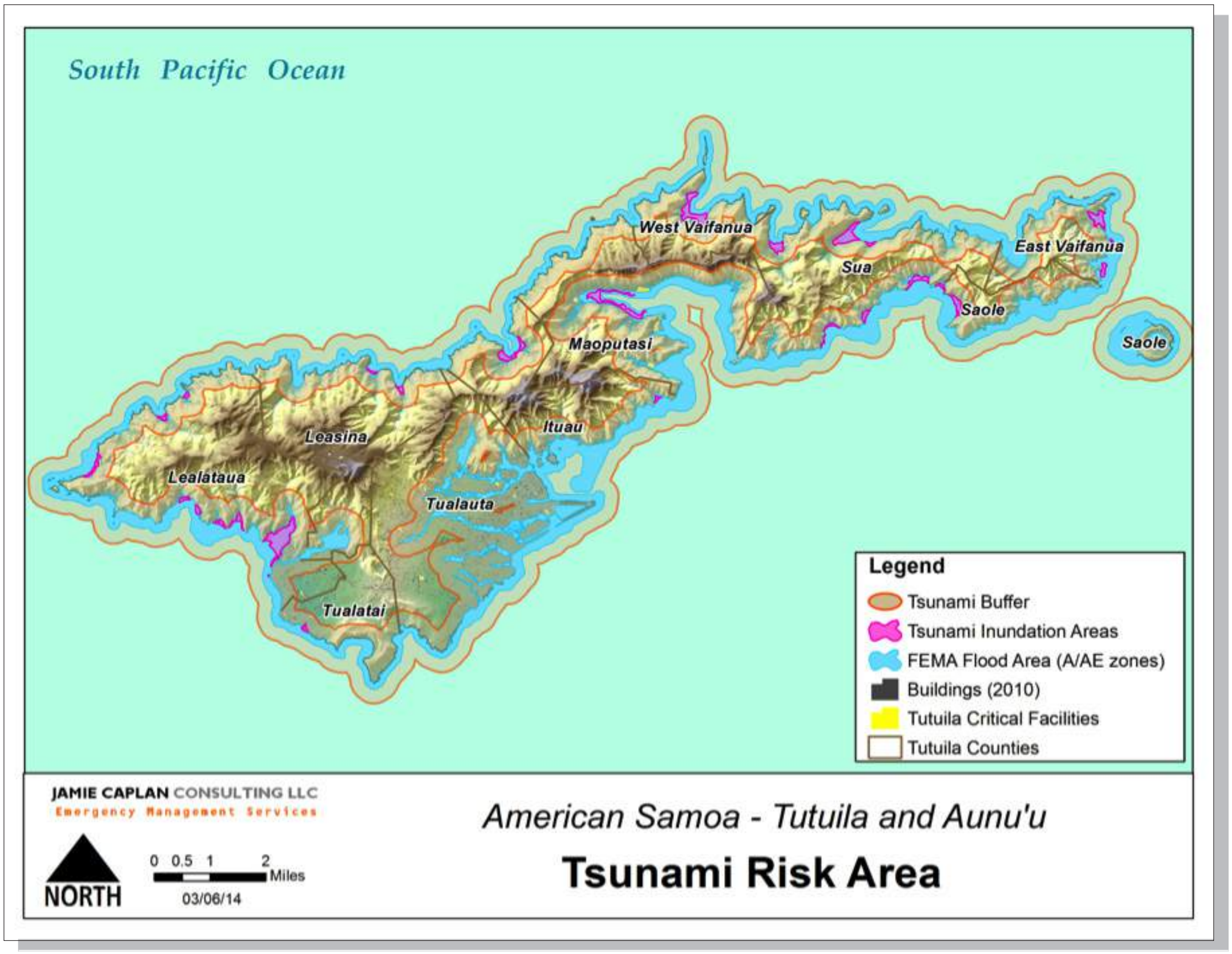


Figure 69 Tsunami Risk Area Based on Calculated Buffer

Table 40 Buildings Potentially At Risk to Tsunami Based on Buffer Area

County (District)	Total Number of Buildings	Total Number of Buildings in Tsunami Buffer Zone	Percent of Buildings in Tsunami Buffer Zone	Type of Buildings
TUTUILA ISLAND				
East Vaifanua (East District)	497	436	88%	491 residential 1 church 4 unknown
Ituaa (East District)	1,075	1,075	100%	1,402 2 government 12 church 32 commercial 1,028 residential
Lealataua (West District)	2,026	1,473	73%	13 churches 22 unknown 4 commercial 6 schools 1,432 residential
Leasina (West District)	474	161	34%	1 church 160 residential
Maoputasi (East District)	2,246	2185	97%	1 community hall 1 new 1 school 1 Tedi 6 unknown 13 churches 33 commercial 77 government 2,058 residential
Saole (East District)	364	360	99%	1 business 359 residential
Sua (East District)	938	902	96%	4 churches 4 commercial 5 unknown 889 residential
Tualatai (West District)	903	467	52%	2 commercial 7 churches 28 unknown 430 residential
Tualata (West District)	7,441	6,082	82%	1,832 12 unknown 68 church 87 government 95 commercial 5,819 residential

County (District)	Total Number of Buildings	Total Number of Buildings in Tsunami Buffer Zone	Percent of Buildings in Tsunami Buffer Zone	Type of Buildings
West Vaifanua (East District)	172	167	97%	172 residential
Tutuila Island Total	16,136	13,308	82%	--
AUNU'U ISLAND				
Saole (East District)	179	179	100%	178 residential
Aunu'u Island Total	179	179	100%	
MANU'A ISLANDS				
TA'U ISLAND				
Faleasoa (Manu'a District)	81	80	99%	-
Fitiuta (Manu'a District)	180	180	100%	-
Ta'u (Manu'a District)	208	191	92%	-
Ta'u Island Total	469	451	96%	-
OFU ISLAND				
Ofu (Manu'a District)	133	133	30%	4
Ofu Island Total	133	133	30%	4
OLOSEGA ISLAND				
Olosega (Manu'a District)	101	101	0%	7
Olosega Island Total	101	101	0%	7
TOTAL	17,018	13,721	81%	-

It is clear from the analysis that all counties are subject to tsunami impacts. It can be assumed that the greater the amount of coastal development, the greater the loss potential. Loss potential is extremely high in Ituau, Matupasi, West Vaifunua, Saole, and Sua Counties on Tutuila. In addition, all counties in Manu'a have a high vulnerability to loss.

A critical facility analysis was also performed using available data. It should be noted, however, that the GIS analysis performed does not account for building elevation. If buildings are elevated, they may be able to withstand some of the flooding brought on by the tsunami. However, regardless of elevation, the velocity of the tsunami may still impact buildings. As previously discussed, no critical facilities were provided for the Ofu and Olosega Islands. Table 41 highlights the results. Several figures also note the location of these critical facilities beginning with Figure 70 on 186.

Table 41 Number of Critical Facilities (CFs) in the Tsunami Buffer Zone

Location	Total Number of Critical Facilities	Total Number of Critical Facilities in Tsunami Buffer Zone	Value
Tutuila Island CFs	241	215	$1,198,572,003
Ta'u Island CFs	42	34	N/A

Assembly areas

- All 26 assembly areas were found to intersect the tsunami buffer zone. It is important to be aware that these areas are subject to inundation and are potentially not a safe assembly location during tsunami events.

Safe Zones

- All safe zone areas in Tutuila intersect the tsunami buffer area. It is important to be aware that these areas are subject to inundation and are potentially not a safe assembly location during tsunami events.

Tsunami Sirens

- 40 sirens are located in the tsunami buffer zone. These structures, mostly new and made of metal, are largely fortified from tsunami. Ideally, they would serve their purpose and sound prior to the tsunami impact.

ASTCA Infrastructure

- 60 out of 75 ASTCA infrastructure items were noted as being in the tsunami buffer area. The buildings, in particular, are at risk to flood and velocity impacts from the tsunami. The remote cell sites are typically on a pole and could be damaged if the pole is displaced. The towers are less likely to be impacted by tsunami.

A complete listing of critical facilities and associated information (such as assembly areas, safe zones, and tsunami sirens) can be found in Appendix D.

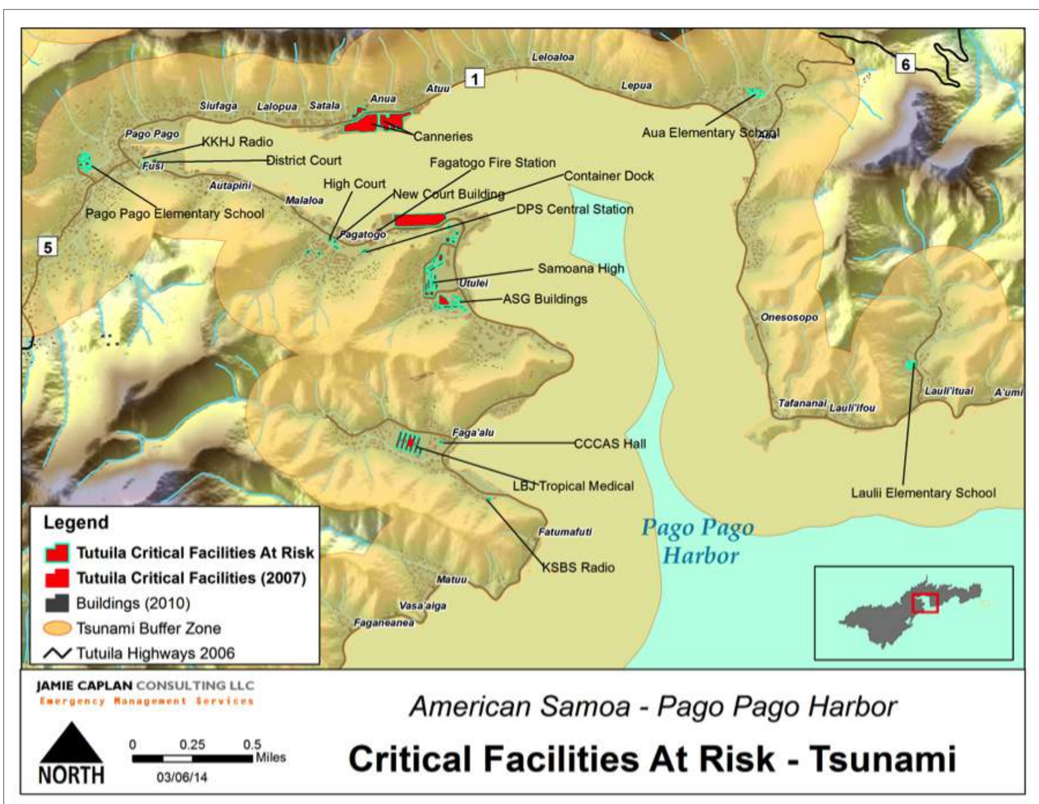


Figure 70 Critical Facilities Potentially At Risk To Tsunami–Greater Pago Pago Harbor

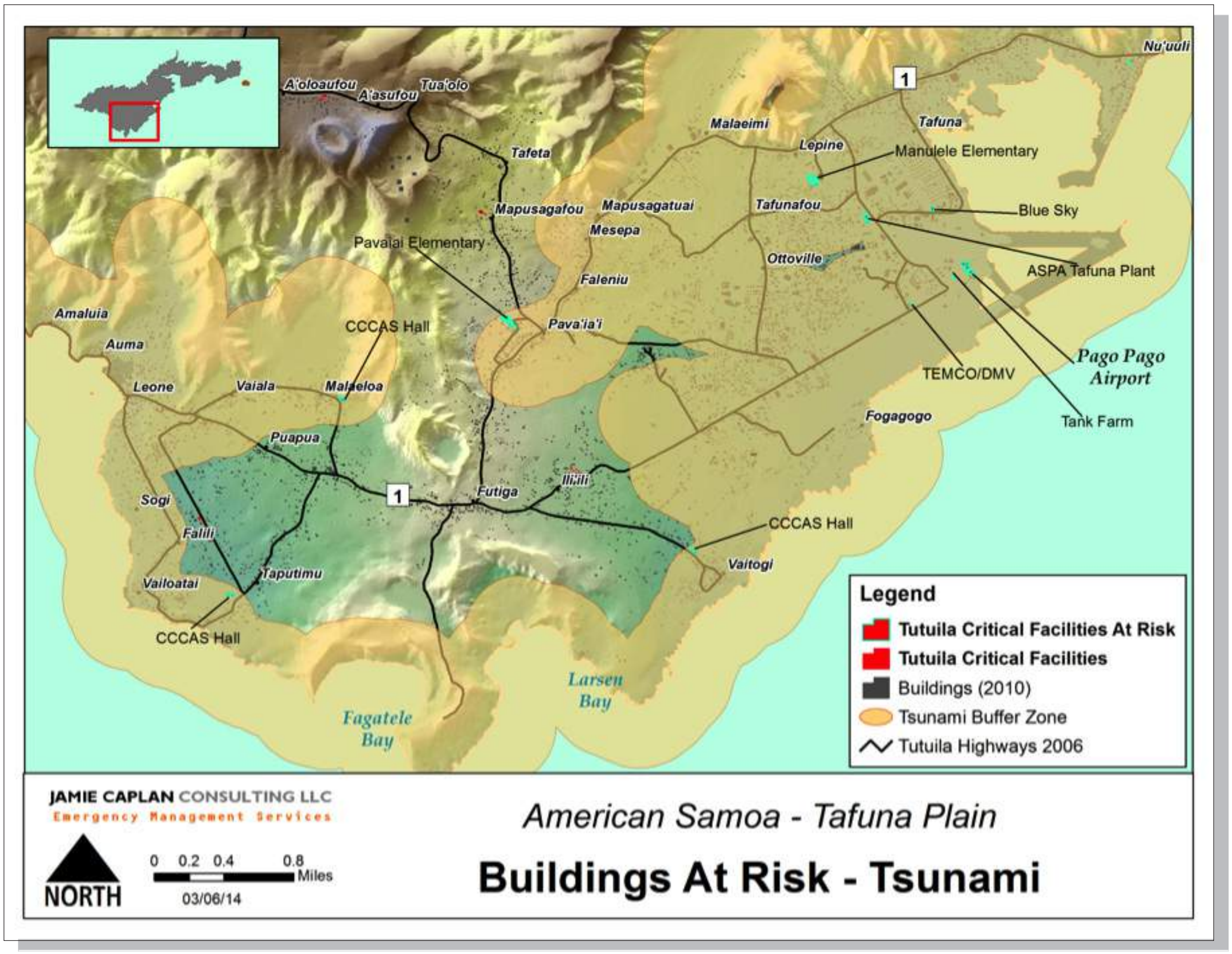


Figure 71 Critical Facilities Potentially At Risk To Tsunami–Tafuna Plain

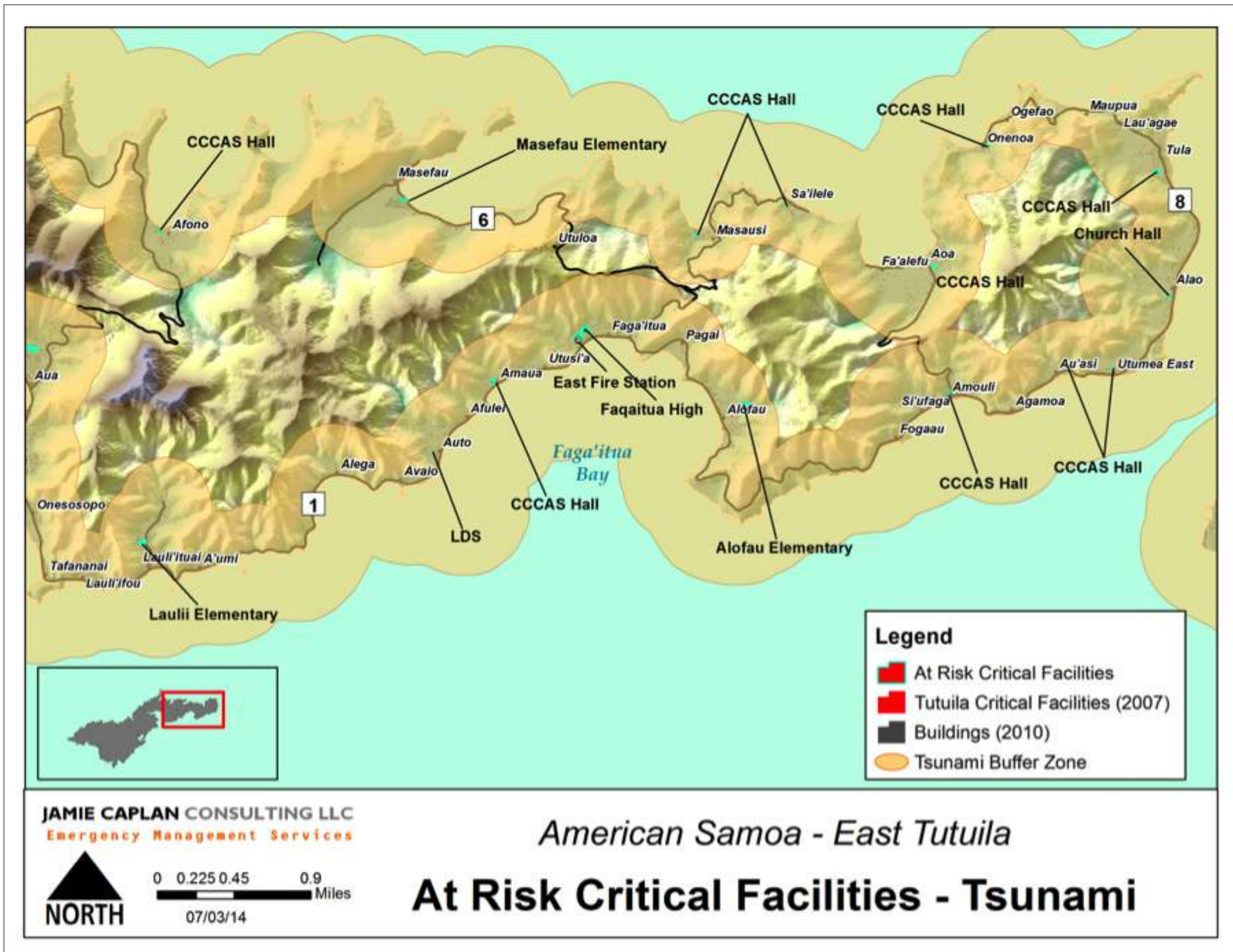


Figure 72 Critical Facilities Potentially At Risk To Tsunami–East Tutuila

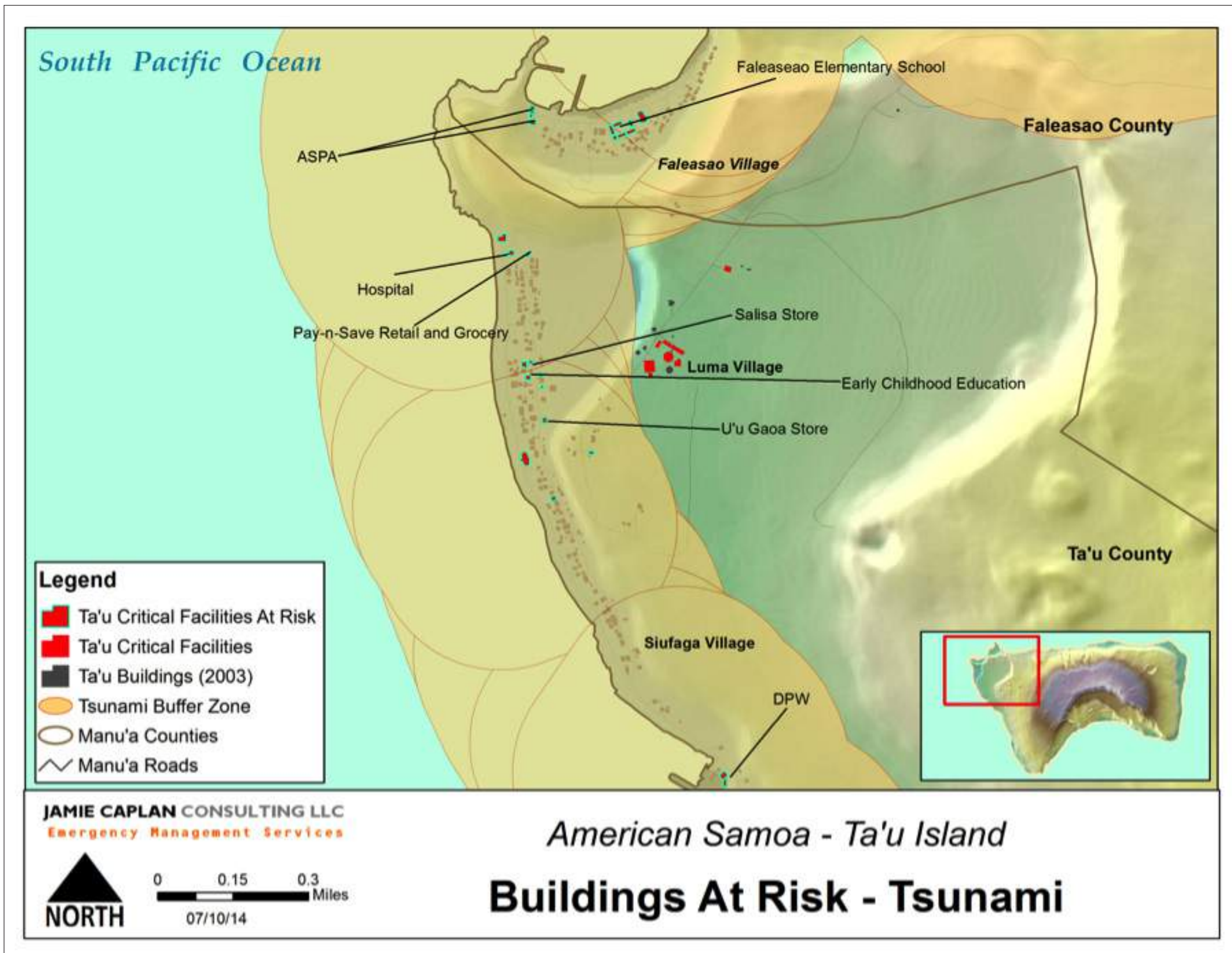


Figure 73 Ta'u Critical Facilities Potentially At Risk to Tsunami

Volcano

Description

Volcanic eruptions are one of Earth's most dramatic and violent agents of change. Not only can powerful explosive eruptions drastically alter land and water for tens of kilometers around a volcano, but tiny liquid droplets of sulfuric acid erupted into the stratosphere can change our planet's climate temporarily. Eruptions often force people living near volcanoes to abandon their land and homes, sometimes forever. Those living farther away are likely to avoid complete destruction, but their cities and towns, crops, industrial plants, transportation systems, and electrical grids can still be damaged by tephra, ash, lahars, and flooding.

Fortunately, volcanoes exhibit precursory unrest that if detected and analyzed in time allows eruptions to be anticipated and communities at risk to be forewarned with reliable information in sufficient time to implement response plans and mitigation measures.[85]

There are three main types of volcanoes as described below. Volcanoes may be visible above the surface or submarine on the ocean floor[86]:

Shield

They are built almost entirely of fluid lava flows. Flow after flow pours out in all directions from a central summit vent, or group of vents, building a broad, gently sloping cone of flat, domical shape, with a profile much like that of a warrior's shield. They are built up slowly by the accretion of thousands of highly fluid lava flows called basalt lava that spread widely over great distances, and then cool as thin, gently dipping sheets.

Stratovaolcanoes – (also called composite volcanoes)

They are typically steep-sided, symmetrical cones of large dimension built of alternating layers of lava flows, volcanic ash, cinders, blocks, and bombs and may rise as much as 8,000 feet above their bases.

Cinder cones

They are built from particles and blobs of congealed lava ejected from a single vent. As the gas-charged lava is blown violently into the air, it breaks into small fragments that solidify and fall as cinders around the vent to form a circular or oval cone. Most cinder cones have a bowl-shaped crater at the summit and rarely rise more than a thousand feet or so above their surroundings.

Eruptions occur with magma rises from the below the earth's crust (the mantle). The mantle rock melts, becoming liquid magna. It has a temperature of 700-1300 Celsius. The magma rises from the crust and surfaces through a volcanic vent. Once it reaches the surface, it is called lava. Lava, like magna, is molten rock. Eruptions are typically categorized as effuse (outpouring of lava onto the ground) or explosive (violent, high volume of debris into the sky). Volcano eruptions vary tremendously in their magnitude. A scale known as the Volcanic Explosivity Index (VEI) shows a measurement of volcano eruptions as shown in Table 42.

85 USGS Volcano Hazards Program

86 Principal Types of Volcanoes. (2011). USGS. Retrieved August 8, 2014 from http://pubs.usgs.gov/gip/volc/types.html

Table 42 Volcanic Explosivity Index (VEI) (based on global observations) [87]

VEI	Description	Plume Height	Volume	Classification	How often	Example
0	non-explosive	< 100 m	1000s m3	Hawaiian	daily	Kilauea
1	gentle	100-1000 m	10,000s m3	Haw/Strombolian	daily	Stromboli
2	explosive	1-5 km	1,000,000s m3	Strom/Vulcanian	weekly	Galeras, 1992
3	severe	3-15 km	10,000,000s m3	Vulcanian	yearly	Ruiz, 1985
4	cataclysmic	10-25 km	100,000,000s m3	Vulc/Plinian	10's of years	Galunggung, 1982
5	paroxysmal	>25 km	1 km3	Plinian	100's of years	St. Helens, 1980
6	colossal	>25 km	10s km3	Plin/Ultra-Plinian	100's of years	Krakatau, 1883
7	super-colossal	>25 km	100s km3	Ultra-Plinian	1000's of years	Tambora, 1815
8	mega-colossal	>25 km	1,000s km3	Ultra-Plinian	10,000's of years	Yellowstone, 2

Volcanoes can also erupt underwater. An area where magma rises upward from the earth's mantle until it erupts on the sea floor is called a "hot spot."[88] Underwater eruptions may create algae plumes on the ocean's surface. Algae plumes form as a result of pumice, hot water, acid and nutrients that rise to surface. The algae can be detected via satellite so that is one method used to track submarine eruptions. While most submarine eruptions remain underwater, pumice and smoke plumes may crest above the surface. New islands are also formed in this manner: magma erupts from the earth's mantle layer and cools as lava. Eventually, the lava builds up above the sea level and forms an island, such as the Samoa and Hawaii Island chains. Strong submarine eruptions may result in earthquakes or tsunamis. It takes about 100 years to go from lava to garden. Cooled lava, the earth's surface is broken down by the wind to become soil. Spores traveling through the air land on the island, which are then nurtured by the abundant tropical sun, and rain. Eventually, the island will be abundant with flora and fauna.

Vog (volcanic smog) is a hazard associated with volcanic eruptions. Vog forms when volcanic gases (such as sulfur dioxide and hydrogen sulfide) mix with oxygen, moisture and sunlight in the atmosphere to form particles. Vog creates a haze across the impacted area. The impacted areas change based on the direction of the wind and volume of gases being released.

Unfortunately, the particles are small enough to be absorbed by the lungs, and it is assumed the impacts may be similar to pollution and smog. According to the USGS, limited studies have been completed on vog and its long-term health effects.[89] However, the Hawaii State Department of Health developed a VOG index based on EPA standards for sulfur dioxide. Advisory levels range from good to hazardous. While there are no reported historical events of vog impacting American Samoa, it is possible.

87 Volcano World. (2014). Retrieved August 8, 2014 from http://volcano.oregonstate.edu/education/eruption_scale.html
88 How did the Hawaiian Islands form? (2014). NOAA. Retrieved August 8, 2014 from http://oceanservice.noaa.gov/facts/hawaii.html
89 Vog: A Volcanic Hazard. (1996). USGS - Hawaiian Volcano Observatory. Retrieved August 8, 2014 from http://hvo.wr.usgs.gov/volcanowatch/archive/1996/96_05_29.html

This index could be used for American Samoa for future volcano eruptions. The sulfur dioxide index can be found here: http://www.hiso2index.info/assets/FinalSO2Exposurelevels.pdf.

Volcanic ash clouds are another associated hazard. They pose an economic hazard as they disrupt air traffic, as well as a safety risk to air travelers. The ash contains tiny rocks that can remove the plane's protective film or enter the plane's engine. The heat from the plane engines melts particles, causing them to stick to turbine blades. This can cause engine failure.

Given American Samoa's low frequency of eruptions, both vog and ash clouds are not considered major threats. However, volcanic eruptions are possible from the active submarine volcano east of Manu'a. Locations are described below.

Location

Figure 74 below identifies the location of the four major volcano areas in American Samoa. The proceeding graphic, Figure 75, shows a geomorphologic interpretation of major volcanic structures within American Samoa and their associated rift zones.[90] The proceeding text describes each location. Just one volcano in American Samoa is active today. It is known as Vailulu'u and is located east of the Manu'a Group. However, it should be noted that there is a semi-active volcano in Western Samoa (Savai'i) that last erupted in 1911.

90 Wright, Dawn. Oregon State University.

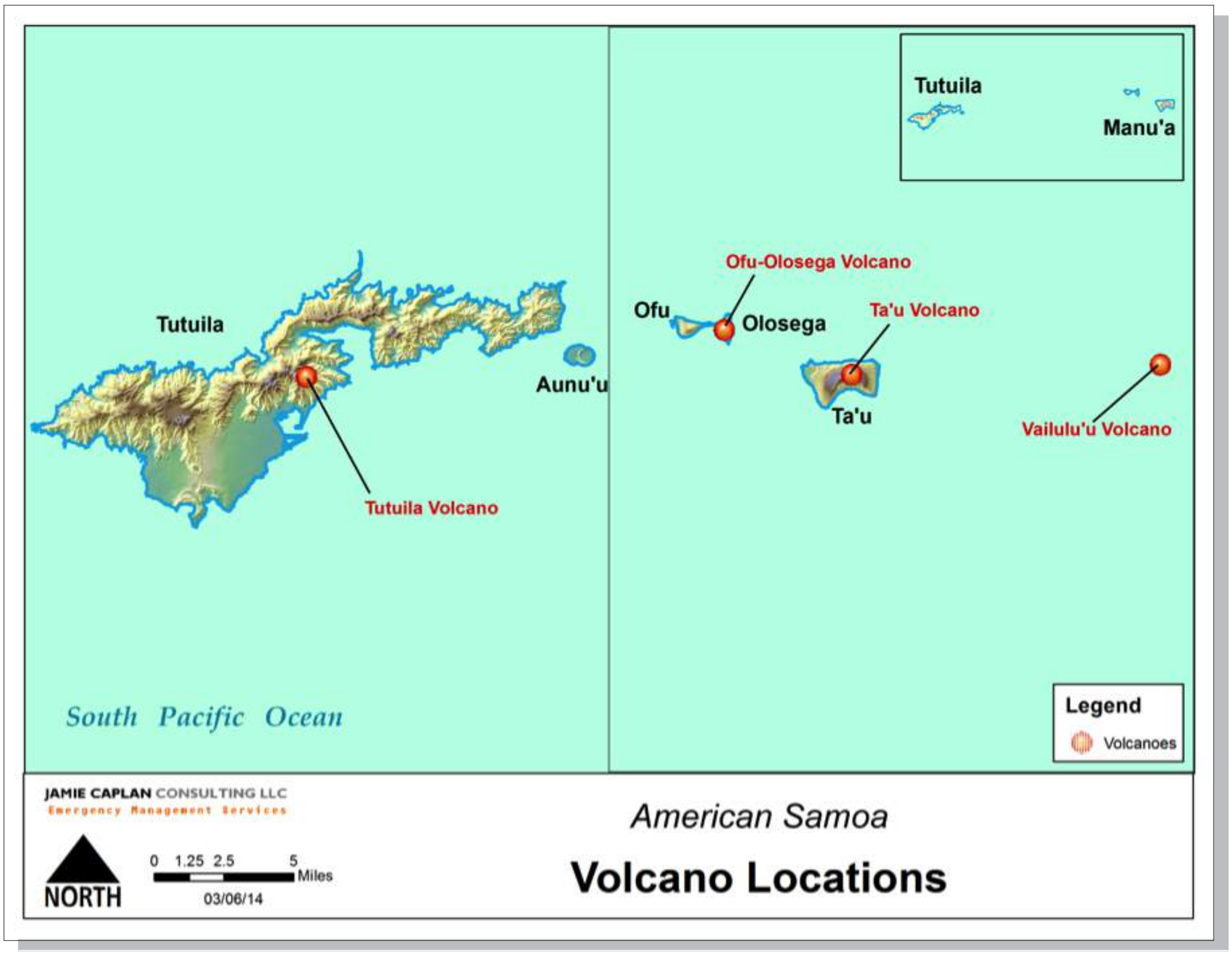


Figure 74 Volcano locations in American Samoa

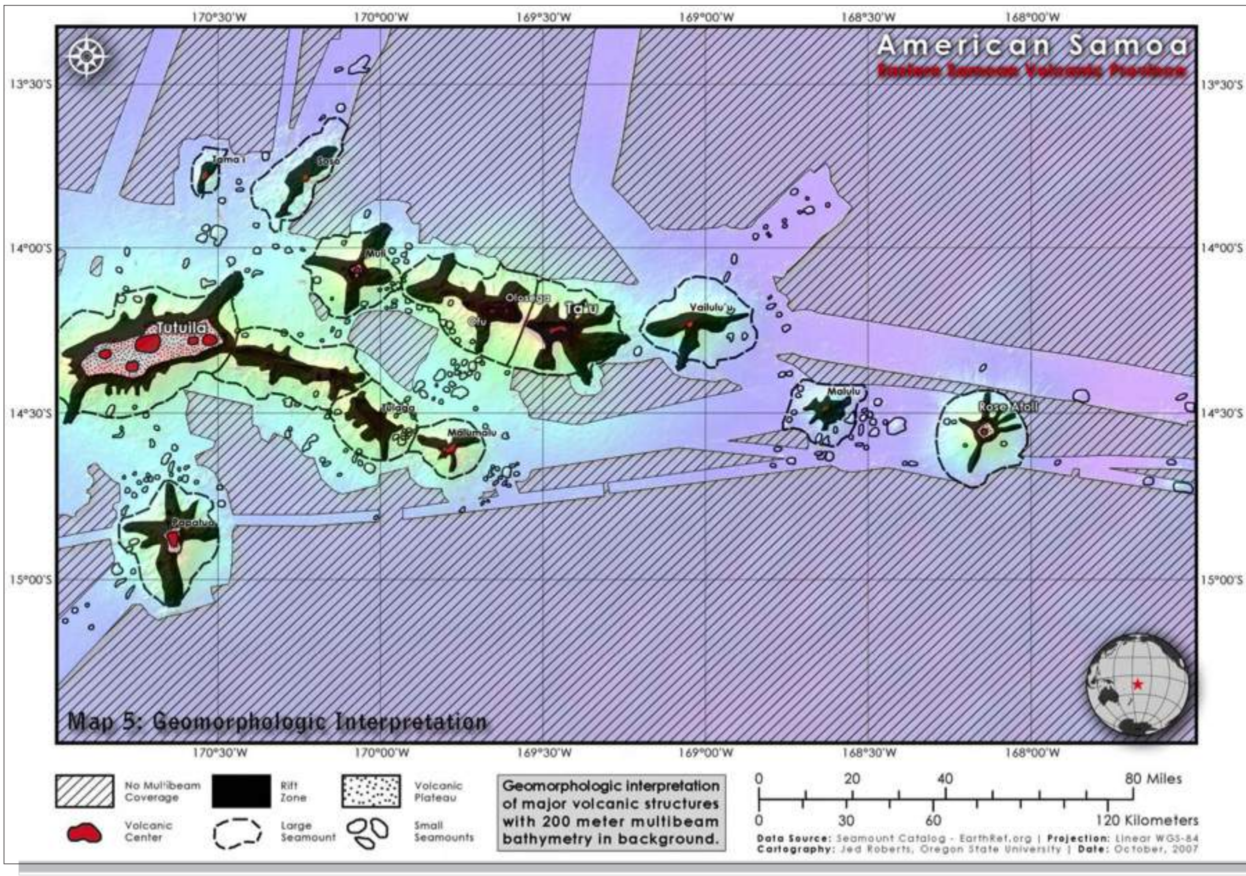


Figure 75 Volcanos and Rift Zones

Vailulu'u

A massive volcanic seamount, not discovered until 1975, rises 4200 m from the sea floor to a depth of 590 m about one-third of the way between Ta'u and Rose islands at the eastern end of the American Samoa. The basaltic seamount, named Vailulu'u, is considered to mark the current location of the Samoan hotspot. The summit of Vailulu'u contains a 2-km-wide, 400-m-deep oval-shaped caldera. Two principal rift zones extend east and west from the summit, parallel to the trend of the Samoan hotspot, and a third less prominent rift extends southeast of the summit. The rift zones and escarpments produced by mass wasting phenomena give the seamount a star-shaped pattern. On July 10, 1973, explosions from Vailulu'u were recorded by SOFAR (hydrophone records of underwater acoustic signals). An earthquake swarm in 1995 may have been related to an eruption from the seamount. Additional activity was reported in 2003.[91] Turbid (muddy) water above the summit shows evidence of ongoing hydrothermal plume activity.[92] In 2005, researchers discovered a submarine 300-meter tall volcano cone growing in the summit crater of Vailulu'u, since named Nafanua. The formulation is growing so quickly that it may surface within decades.[93] Vailulu'u is considered to be a very active underwater volcano. Figure 76 shows a cross section and location orientation figure of the hotspot.

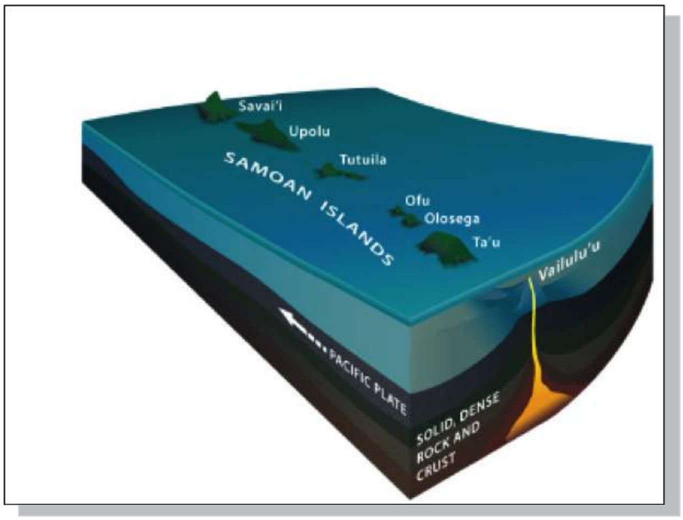


Figure 76 Illustration of Vailulu'u Samoan Hotspot[94]

Ta'u

The large, 6 x 10 km sea cliffs ring, which is Ta'u Island, located at the eastern end of the Samoan islands. The 931-m-high island is the emergent portion of the large Lata shield volcano. Collapse and landsliding of the southern portion of the basaltic shield volcano have left an arcuate, south-facing embayment with a steep headwall overlooking several flat benches today. Two smaller shields were constructed along two rift zones at the northwestern and northeastern tips of the island. A tuff-cone complex that draped sea cliffs and ejected large dunite xenoliths and coral blocks extends the northwest corner of the island. Numerous Holocene post-caldera-aged (11,700 years ago to present) cones occur at the summit and flanks of the Lata shield volcano.[95] No eruptions have been recorded at this location and it is considered to be extinct.

Ofu-Olosega

A narrow strait separates the two triangle-shaped islands of Ofu and Olosega in eastern Samoa, with a combined length of 6 km. The islands are formed by two eroded, coalescing basaltic shield volcanoes whose slopes dip to the east and west. Steep cliffs up to 600-m high truncate the northern and southern sides of the islands. The

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91 Lee, Siebert, Tom Simkin, Paul Kimberly. (2010). Volcanoes of the World: p.74. University of California Press.

92 Most Recent Bulletin Report. (2005). Smithsonian Institution National Museum of Natural History. Retrieved August 8, 2014 from http://www.volcano.si.edu/world/volcano.cfm?vnum=0404-00-

93 Staudigel, Hubert et al. (2006). "Vailulu'u Seamount, Samoa: Life and death on an active submarine volcano." Proceedings of the National Academy of Sciences of the U.S.A.: Vol. 103. no. 17. Retrieved August 8, 2014 from http://www.pnas.org/content/103/17/6448.full

94 Doucette, Jayne. (2005) Woods Hole Oceanographic Institution.

95 Ta'u. (2013). Smithsonian Institution National Museum of National History. Retrieved August 8, 2014 from http://www.volcano.si.edu/world/volcano.cfm?vnum=0404-001

narrow, steep-sided ridge forming the eastern tip of Ofu Island consists of a dike complex. The shield volcano on Ofu is cut on the north by the A'ofa caldera; bathymetry suggests that a caldera may also exist on the Sili shield volcano of Olosega.

The Nu'utele tuff cone, forming a small crescent-shaped island immediately off the west end of Ofu Island, is Holocene in age (11,700 years ago to present). A series of submarine eruptions took place in September and November of 1866 at the opposite end of the two islands, 3 kilometers southeast of Olosega, along the ridge connecting Olosega with Ta'u Island.[96]

Tutuila

The elongated, extensively eroded Tutuila Island in the center of the Samoan Islands consists of five Pliocene-to-Pleistocene (~2.5 million years ago) volcanoes constructed along two or three rifts trending south-southwest and north-northeast. The Pago basaltic-to-andesitic shield volcano in the center of the 32-km-long island is truncated by an eroded, 9-km-wide caldera that encloses Pago Pago harbor on its west side. The caldera is now partially filled by cinder cones and trachytic lava domes. Following a lengthy period of erosion, submergence, and the development of a barrier reef, the Leone volcanoes erupted during the Holocene (12,000 years ago) (Stearns, 1944), forming a group of initially submarine tuff cones and subsequent subaerial cinder cones that produced fresh-looking pahoehoe lava flows.[97] No recent eruptions have been recorded at this location and it is considered dormant.

Previous Occurences

As mentioned above, Vailulu'u is most active volcano in American Samoa today. The Ofu-Olosega volcano also had reported activity in 1866. In addition, there is a semi-active volcano in Western Samoa. The Savai'i has documented evidence of three historic eruptions (1760; 1902; 1905-1911).[98] Eruptions from this volcano could impact air quality in American Samoa. Table 43 below shows the known eruptions for volcanos on American Samoa.

Table 43 Recorded Eruptions on American Samoa's Islands [99]

Volcano Name	Primary Volcano Type	Last Eruption Year	Total Reported Eruptions	Elevation	Population within 5km	Population within 10km	Population within 30km
Ofu-Olosega	Shield(s)	1866	1	639	220	384	1387
Ta'u	Shield	Unknown	0	931	95	1154	1538
Tutuila	Tuff cone(s)	Unknown	0	653	16653	49763	56239
Vailulu'u	Submarine	2003	3 (2003, 1995, 1973)	-592	0	0	0

96 Ofu-Olosega. (2013). Smithsonian Institution National Museum of National History. Retrieved August 8, 2014 http://www.volcano.si.edu/world/volcano.cfm?vnum=0404-01=

97 Tutuila. (2013). Smithsonian Institution National Museum of National History. Retrieved August 8, 2014 http://www.volcano.si.edu/world/volcano.cfm?vnum=0404-02-, http://www.volcanodiscovery.com/tutuila.html

98 Taylor, Paul, and Lameko Talia. (1999). "Volcanic Hazards Assessment of Savai'i, Samoa. Australian Volcanological Investigations Apia Observatory, Samoa. Retrieved August 8, 2014 from http://ict.sopac.org/VirLib/TR0295.pdf

99 Database Search. (2013). Smithsonian Institution National Museum of National History. Retrieved August 8, 2014 http://www.volcano.si.edu/search_volcano_results.cfm

Extent

One way to measure volcano extent is through the Volcanic Explosivity Index (VEI), which was described in the hazard description section above. The Savai'i Volcano eruptions during the early 1900s were categorized as "0," non-explosive.[100] Known eruptions from the Vailulu'u volcano were also non-explosive.[101] However, it should be noted that this scale does not account for the amount of sulfur dioxide that is released. The release of this gas could have very devastating impact on American Samoan air quality.

These volcanoes are not likely to be catastrophic for American Samoa if they erupt in the future. The Savai'i volcano is characterized by lava flows, release of volcanic gases, tephra falls (airborne debris), and volcanic earthquakes. Similarly, eruptions could result in vog, ash clouds, or algae outbreaks for submarine areas. It should also be noted that if the wall of a volcano were to collapse (edifice collapse), tsunami formation is possible. This could also impact American Samoa.

Probability of Future Events

The probability of future volcanic eruptions is low. None of the volcanoes on American Samoa are thought to be active. Limited information on probability, historic events, and monitoring could be found, making it difficult to quantify a probably. However, data does suggest that the Savai'i volcano has increased its frequency of eruptions throughout history, and it may be most active now. Similarly, the submarine volcano is thought to be very active.

The available data suggests that

- The Savai'i volcano has erupted 3 times over a 254 year period (0.01 percent annual chance)
- The Vailulu'u volcano has erupted 3 times over a 41 year period (7 percent annual chance)
- The Ofu-Olosega volcano has eruption 1 time over a 148 year period (0.6 percent annual chance)

Combining these known eruptions over a 254-year period yields a 1 percent annual chance. The estimated probably of an eruption is unlikely, less than a 1 percent chance per year.

Vulnerability Assessment

All existing and future building and populations are considered to be at risk to future volcanic eruptions in American Samoa. Given that there are no active volcanoes on island, vulnerability should be measured in terms of active surrounding volcanoes. This includes the submarine volcano east of Manu'a (Vailulu'u), the submarine Ofu-Olosega Volcano, and the volcano in Western Samoa (Savai'i).

Nearby eruptions may impact air quality through ash clouds, vog, and sulfur dioxide. The associated hazards can have impacts on short-term and long-term health efforts Submarine eruptions may result in algae plums and fish die-off.

In addition, nearby eruptions may result in pyroclasts (airborne fragments from eruptions), tephra (fragments of volcanic debris that has fallen to the ground) or ash may damage crops, industrial plants, transportation (particularly air travel) systems, and electrical grids.

100 The Savai'i Volcanic Eruoption. (2014). Retrieved August 8, 2014 from http://volcanic-eruptions.findthebest.com/l/348/Savai-i

101 Vailulu'u. (2013). Smithsonian Institution National Museum of National History. Retrieved August 8, 2014 from http://www.volcano.si.edu/volcano.cfm?vn=244000

Potential Losses

As noted above, all existing and future buildings and populations are considered to be at risk to future volcanic eruptions in American Samoa. Potential losses, even with a catastrophic eruption of a nearby earthquake, are expected to be minimal, although some damage is possible from falling ash, for example. All jurisdictions are assumed equally vulnerable. Greater issues will be ensuring the health of people and marine life in the area.

Wildfires

Description

A wildfire is an unplanned fire that requires measures of control. This uncontrolled burning can occur in vegetation, structures and other improvements. Dry conditions at various times of the year increase the potential for wildfires. Common causes include lightning, human carelessness, arson, volcano eruption, and pyroclastic cloud from active volcano. Heat waves, droughts, and cyclical climate changes such as El Niño can also have a dramatic effect on the risk of wildfires. The evaporation of water in plants is balanced by water absorbed from the soil. Below this threshold, the plants dry out and under stress release the flammable gas ethylene. A consequence of a long hot and dry period is therefore that the air contains flammable essences and plants are drier and highly flammable.

American Samoa has a low chance of wildfire according to Peter Craig, American Samoa National Park Biologist. For that reason, American Samoa has a limited response plan. However, several rangers on staff are expert wild fire fighters and form part of a team of seventeen American Samoans who go to the United States every fire season to help. They have been written up several times as an excellent crew and are in demand. Wildfire has not occurred with any significance on American Samoa.

Additional information will be added to the wildfire profile as it becomes available. At this time, limited information exists. Several sources were investigated from historical information and geo-spatial data.

- National Fire and Aviation Management – none reported (http://fam.nwcg.gov/fam-web/weatherfirecd/index.htm)
- United States Department of Agriculture – Forest Service (http://www.fs.usda.gov/rds/archive/Product/RDS-2013-0009)
- Pacific Wildland Fire Sciences Lab
- Pacific Disaster Center
- American Samoa Department of Public Safety
- National Interagency Fire Center (http://www.nifc.gov/fireInfo/fireInfo_statistics.html)
- American Samoa Government website
- ArcGIS online
- Landfire
- NOAA

Location

Wildfires are possible anywhere on the island given the amount of vegetation. Intentionally set brush fires occasionally get out of control. According to information from American Samoa fire officials, the western district of American Samoa is more populated and that results in more fires.

Previous Occurences

No wildfire events were reported by the National Climatic Data Center. Several sources were investigated for wildfire data. Unfortunately, very few tracking mechanisms seem to be in place. A stakeholder meeting with fire officials yielded good information about fire events, however. Brush fires in American Samoa are common practice, especially on agricultural lands. However, at times these brush fires get out of control and become wildfires. According to the island fire officials:

- Typically there are 5 per brush fires per month (that require fire response). However, in times of drought, there are more like 10 fires per day (that require assistance).
    - Most fires are small and burn around ¼ acre.
- There was a very large fire in Vaitogi Village approximately 50 years ago. Each year, between September 15 and September 16 the village goes under a 24-hour curfew to observe and remember the fire. Little information about this fire could be found. It is assumed that it may have been started as a brushfire but ultimately destroyed several structures.

In addition, the 2011-2015 American Samoa Forest Assessment and Resource Strategy (June 2010) summarize the findings from the 2007 American Samoa Community Wildfire Protection Plan (produced by the American Samoa Department of Public Safety). It states that in 2007, there were a total of 98 structure fires and 45 brush/wildfires. Most fires are caused by arson or human activities such as burning rubbish or clearing weeds. As additional information is tracked and provided, it will be included into the plan.

Extent

Most wildfires in American Samoa are small (around ¼ acre) are best described as brush fires. However, they have the potential to grow much larger in size and even impact properties.

Probability of Future Events

Given information provided by fire officials and studies, it is appropriate to assume that wildfire is an annual occurrence in the territory (5 brush fires per month in typical conditions). However, it is apparent that few wildfires have posed a risk to American Samoa people or structures. Probability can be categorized as highly likely (greater than 90 percent annual chance) for small brush fires or unlikely (less than 1 percent annual chance) for large, damaging fires.

Vulnerability Assessment

Brush fires do occur on island and have the potential to grow out of control. A wildland fire risk assessment in 2008 referenced in the American Samoa Forest Assessment and Resource Strategy Plan concluded that American Samoa as a whole fell into the high-risk range due to the ignitability of the many wood-sided structures, volume of fuels close to these structures, and fire history. The plan's principle recommendations in order of priority were reduction of fuels along roads, empty lots, and common areas; prevention education and outreach; and improvement of community egress and firefighter ingress. No spatial analysis was included in the plan."[102]

The Forest Assessment and Resource Strategy also noted "areas of Aoloaufou, Leone, and Tafuna villages are being targeted for fuel load reduction and improvement of egress and access by reducing vegetation along roadsides and empty lots, in common areas and areas near homes. Green waste pick-up and creation of fuel breaks will also occur in these areas. ASCC CNR has obtained a chipper, which is made available to clients with yard wastes. The chipped material is used for composting pig manure from area piggeries. The Department of

102 American Samoa: Forest Assessment and Resource Strategy (2011-2015). Forestry Program Division of Community and Natural Resources American Samoa Community College. Retrieved August 8, 2014 form http://www.wflccenter.org/islandforestry/americansamoa.pdf

Public Safety Fire Division will partner with ASCC CNR to educate the public in fire prevention, focusing on proper, safe burning of rubbish, yard and farm wastes. Educational materials, including TV and radio spots, posters, and handouts, will be developed and distributed." There are additional several factors that impact vulnerability in American Samoa.

Drought Conditions
Wildfire probability and vulnerability is greater in times of drought. American Samoa fire officials stated that recent years, perhaps due to climate change, have had more drought occurrences. In addition to drier land during drought conditions, fire may spread faster and water conservation measures may be in effect. Limited water overall means less capability to combat wildfire (and structural fires).

Location
In remote areas of the island, there are no hydrants, which may increase vulnerability of wildfires caused by brush fires getting out of control. When hydrants cannot be accessed, the fire is fought with water available from the trucks. This is a limited amount.

Areas in the urban/wildland fringe are also at increased to damage from wildfire.

In addition, buildings are not numbered (unless government owned) which makes locating a fire area particularly difficult. In the past, the island population was small and everyone knew each other. It was easy to spread the word and explain by landmarks. Growth in the previous decades has hindered this method. According to fire officials, response time should be around 3 minutes, but it is much longer.

Truck size
Many of the larger fire trucks have a difficult time navigating through narrow streets and traffic. This puts people at greater risk due to increased response time.

Regulations
Currently, there are no regulations that determine where and when people can burn on their land. This creates increased risk during drought and makes determining where fires may occur less controlled. In addition, people frequently build without permits and use extension cords to connect power from other sources. This creates a very high fire probability.

Outreach and training
American Samoa fire officials are aware that burning brush often turns into fires. Therefore, they have an outreach program to teach people (grades K-12) about how to burn brush properly. In addition, dispatchers are trained to take calls and help locate buildings given that there are no numbers.
In conclusion, while wildfires are typically small events, they have the potential to turn into larger events that place people and property in danger.

Figure 77 Debris Burning in American Samoa

Potential Losses
All current and future buildings and populations should be considered at risk. All jurisdictions are considered equally at risk. However, developed areas that abut rural areas may have greater vulnerability. In general, wildfire losses are not expected to be severe. In most cases, they will be contained to agricultural lands or a few structures.

Summary of Hazard Risk

Summary of Risk
Table 44 below provides a brief overall of the hazards that impact American Samoa. The table lists impacts, number of occurrences and associated timeframe, spatial extent, probability and estimated of losses to date. In addition, it highlights whether or not critical facilities may be at risk.

The estimations of accumulated losses have been based upon historical loss information, which varies greatly, and is in many cases non-existent. The loss figures represent sums of the largest amounts recorded per event for each hazard type.

Table 44 Summary of Hazards in American Samoa

Hazard Type	Potential Impacts	Count	Time Period (years)	Spatial Extent	Probability	Estimation of Accumulated Losses ($)	Critical Facilities At Risk?
Climate Change (including SLR)	Flooding; increased hazard occurrence; increased floodplain	N/A	N/A	Territory-wide; coast	Likely	N/A	YES
Coastal Erosion	Loss of beach area; Loss of structures along coast/cliffs	N/A	N/A	Coast	Highly Likely	N/A	YES
Droughts	Water rationing; Food shortage; Cannery closures; School closures; Groundwater depletion; Depletion of wells and catchment; Economic recession;	4	38	Territory-wide	Possible	Losses to agriculture crops and economy	NO
Earthquakes	Damage to infrastructure and buildings; Injuries, loss of life;	22 over 7.0M	108	Territory-wide	Likely	reported damage but not the amount	YES

Hazard Type	Potential Impacts	Count	Time Period (years)	Spatial Extent	Probability	Estimation of Accumulated Losses ($)	Critical Facilities At Risk?
Floods	Damage to roads, homes, businesses; Loss of access to emergency services; Inundation of urban and low-lying areas Erosion; Landslides; Power failures; Death/injury	66	20	Territory-wide	Highly Likely	$55+ million	YES
Hazardous Materials	Water contamination; Fire	N/A	N/A	Territory-wide	Low	None reported	YES
High Surf	Debris; Road washout; Hindered fishing efforts; Death, injuries	44	14	Coastal areas	Likely	$4.1 Million	NO
Landslides	Injuries, loss of life; Loss of access to emergency services; Property loss; Blocked or damaged roads, buildings; Liquefaction of fill soil types; Amplified ground shaking of unconsolidated soils.	1+ annually	35	Territory-wide	Highly Likely	Damage reported but not exact amount; loss of structures including homes, schools, churches	YES
Lightning	Electrical damage; Electrical fire; Death, injury	2	18	Territory-wide	Likely	$41,000	YES
Soil Hazards	Cracked foundation; Loss of structural integrity	0	N/A	Territory-wide	Unlikely	None reported	YES
Tropical Cyclones (including storm surge) and High Wind Storms	Flooding rainfall; High wind damage to infrastructure and buildings; High surf, storm surge, coastal erosion; Death, injury	30	67	Territory-wide	Likely	$150+ million	YES

Hazard Type	Potential Impacts	Count	Time Period (years)	Spatial Extent	Probability	Estimation of Accumulated Losses ($)	Critical Facilities At Risk?
Tsunamis	Inundation of low-lying areas; Injuries, loss of life; Damage to buildings and infrastructure; Coastal erosion	78	177	Territory-wide	Possible	Over $100 million	YES
Volcano	Volcanic eruptions are possible but not likely. Impacts from neighboring islands include Respiratory issues; fish kills, coral impacts, vog, smoke	0	N/A	N/A	Unlikely	None reported	NO
Wildfire	Loss of natural and manmade resources; Structure fire	Annual brushfires	N/A	Territory-wide	Unlikely	None reported	YES

PRI Results and Hazard Ranking

The process of completing the hazard profiles above informed the PRI input. Table 45 shows the PRI results for American Samoa. These values were then arbitrary categorized into high, moderate and low risk categories based on available information. The ranking of hazards can be found below in Table 46.

Table 45 Summary of PRI Results for American Samoa

Hazard	Category/Degree of Risk					PRI Score
	Probability	Impact	Spatial Extent	Warning Time	Duration	
Climate Change	Highly Likely	Minor	Moderate	More than 24 hours	More than one week	2.6
Coastal Erosion	Highly Likely	Minor	Moderate	More than 24 hours	More than one week	2.6
Droughts	Possible	Limited	Large	More than 24 hours	More than one week	2.5
Earthquakes	Likely	Limited	Large	Less than 6 hours	Less than 6 hours	2.8
Floods	Highly Likely	Critical	Moderate	6 to 12 hours	Less than 24 hours	3
Hazardous Materials	Possible	Critical	Small	Less than 6 hours	Less than 24 hours	2.7
High Surf	Highly Likely	Minor	Moderate	Less than 24 hours	Less than 24 hours	2.5
Landslides	Highly Likely	Critical	Moderate	Less than 6 hours	Less than 6 hours	3.2

Hazard	Category/Degree of Risk					PRI Score
	Probability	Impact	Spatial Extent	Warning Time	Duration	
Lightning	Likely	Limited	Negligible	Less than 6 hours	Less than 6 hours	2.2
Soil Hazards	Unlikely	Minor	Small	More than 24 hours	More than one week	1.5
Tropical Cyclones	Likely	Catastrophic	Large	More than 24 hours	Less than 24 hours	3.0
Tsunamis	Possible	Catastrophic	Large	Less than 6 hours	Less than 6 hours	3.1
Volcano	Unlikely	Limited	Negligible	Less than 24 hours	Less than 1 week hours	1.6
Wildfire	Unlikely	Minor	Small	Less than 24 hours	Less than 1 week	1.7

Landslides, tsunamis, floods, and tropical cyclones emerge as the greatest hazard risks to the islands. Landslides, while not island-wide at a single time, can be deadly. They also occur without warning and can occur is many parts of the island, particularly where steep slopes exist. Tsunamis can be catastrophic in nature and result in multiple fatalities. The 2009 tsunami was such an example of this. There impacts will be largely along the coast. It is possible for them to occur without warning but, in general, some advanced warning is known reducing the loss of lives. Flood impact the islands frequently. Damage may be limited to catastrophic based on the amount and previous rainfall. Floods may also trigger landslides. Tropical cyclones often result in territory-wide impacts and devastating associated hazards such as high winds, storm surge, and flooding rainfall.

Ranking	Primary Volcano Type
High	Landslides Tsunami Flood Tropical Cyclone
Moderate	Earthquake HAZMAT Climate Change (including SLR) Coastal Erosion Drought High Surf
Low	Lightning Wildfire Volcano Soil Hazards

Table 46 Ranking of American Hazards