Chapter 4. Risk and Vulnerability Assessment

4.1 Introduction

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 14). 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 the mitigation strategy. The answers provide essential data to determine mitigation strategies and to define specific prioritized mitigation projects.

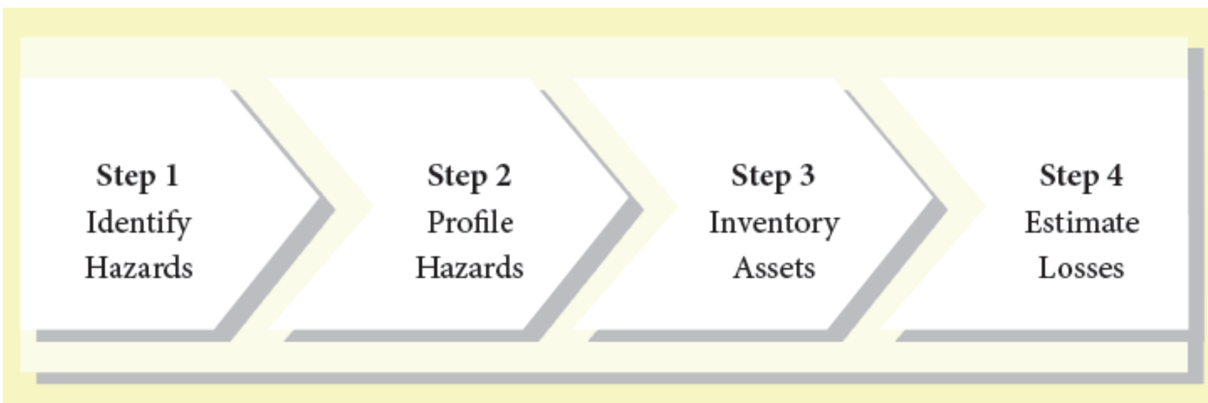

Figure 14: Risk Assessment Process

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.

The risk assessment is formatted to meet the Federal Emergency Management Agency's (FEMA) 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 2020, the risk assessment focuses on natural hazards and one man-made hazard, hazardous materials.

Hazard profiles, including a description of the hazard, historical occurrences, extent (or magnitude), location and vulnerability, beginning in Section 4.2 Coastal Erosion. Hazard profiles are presented in alphabetical order.

The 2020 Risk Assessment Chapter was completed between May 1 and May 22, 2020. In coordination with FEMA Region IX and the American Samoa State Hazard Mitigation Officer (SHMO), the chapter updates focused on major disaster declarations that have occurred since the 2015 plan including, COVID-19 and Tropical Storm Gita. Additions to the chapter include:

- Section 4.1.1 Estimated Losses to better define loss estimation methodology;
- A review and update of profile information for all hazards including description, location, previous occurrences, extent, probability, and vulnerability (as data permitted);
- Addition of climate changes considerations into each hazard profile vulnerability section;
- A new Public Health Risks hazard profile (including infectious disease);
- A new Extreme Heat hazard profile;
- A stand-alone Sea level Rise hazard profile;
- A stand-alone Subsidence profile;
- A review of new critical facilities;
- Revised formatting including the addition of section and subsection numbering and movement of previous occurrence table to Appendix C for navigability.

Given the expedited timeframe, limited available data, and limited changes in hazard data, and limited reported change in on island development, no new Geographic Information System (GIS) analysis or mapping was conducted for the 2020 update. Numerous new studies and documents were reviewed as cited throughout the plan.

For the 2025 plan, a complete update of the risk assessment will be completed including refreshed GIS analysis and mapping.

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, Ili ili, 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.

4.1.1 GIS Data for Buildings

Structure data was requested and collected through American Samoa agencies, federal agencies, state sources, non-profits, and Internet sources. New data was not integrated into the 2020 plan given the expedited timeframe; however, these datasets will be reassessed for the 2025 plan. Baseline building and critical data is as follows:

- Tutuila/Aunu'u Buildings: 2010 dataset. This dataset 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.

  - Tutuila/Aunu'u Critical Facilities: 2007 dataset. This dataset serves as the base for the existing vulnerability analysis. In addition, any new critical facilities constructed since the 2015 plan was completed were provided, though value information was not available. There are 18 new facilities on the island including 13 schools, a fire station/public safety building, FONO building, museum, shipyard office, and COVID-19-related testing/quarantine facility.[33] This brings the total to 256 critical facility structures. In addition, several additional holdings were included as critical facilities such as ASTCA infrastructure, tsunami sirens, and safe zones. In Appendix C, the complete list of critical facilities is available, including indication of new critical facilities for the 2020 plan update. Critical facilities include Territory assets.
- Ta'u Buildings: 2003 data set. Limited information on type was provided and no building values were provided.
  - Ta'u Critical Facilities: 2003 dataset. Name and type were provided. No building values were provided for the 2020 plan update.
- Ofu-Olosega Buildings: 2011 dataset. No information on type, name or building value was provided for the 2020 plan update.
  - 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

4.1.2 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. The list is reviewed for each plan update to determine if additional hazards are warranted. As noted above, new hazard profiles for public health risks and extreme heat were added to the 2020 plan. In addition, the sea level rise hazard and the subsidence hazard were made standalone hazard profiles. Further, the climate change hazard profile was deleted, and specific climate change considerations were integrated into each hazard profile where applicable. Table 10 indicates each hazard studied and the justification for inclusion in the mitigation plan. No commonly recognized natural hazards that impact the Territory were omitted.

[33] Most new facilities have multiple buildings but were listed as one. Alatuau II School, Manulele Tausala Elementary, Midkiff Elementary, and Nuuuli Poly Tech are new critical facilities for 2020 that were FEMA funded. The remaining new critical facilities were funding with capital improvement program (CIP) funding and other local funding sources.

Table 10: Hazards Included in the 2020 Hazard Mitigation Plan

Hazard	Justification for Inclusion
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% of critical facilities within critical erosion areas, potentially many of these structures at risk to future erosion.[34]
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 7.0 magnitude have been recorded. Further, earthquakes can be a precursor for a tsunami.
Extreme Heat	American Samoa's equatorial location generally keeps temperature consistent year-round with highs in the upper 80s. Recent years have resulted in more extreme temperatures including 3 records broken in 2020. Climate change impacts may exacerbate this trend.
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. Floods have resulted in substantial damages and often is a precursor for landslides.
Hazardous Materials	American Samoa stores extensive hazardous materials on the 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.[35]

[34] American Samoa Department of Commerce (2011). *Section 309 Assessment and Strategy for the American Samoa Coastal Management Program*.
[35] 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
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 the 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 slopes 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.
Public Health Risks (including infectious disease)	This a new hazard for the 2020 plan update. American Samoa is subject to numerous public health risks such as measles, dengue, and chikungunya which can impact the population health, the economy, and overall resiliency. There was a measles outbreak in 2019-2020, and COVID-19 resulted in a major disaster declaration in 2020.
Sea Level Rise	This hazard, formerly part of the Climate Change profile, was made a separate hazard in the 2020 plan update. Data indicates rising sea levels in American Samoa which will threaten areas further inland with flood impacts from storm surge.
Soil Hazards (including expansion and sinkholes)	These are low probability hazards. They were included because they are possible on the islands. Each of these hazards may result in property damage
Subsidence	Made a stand-alone hazard for the 2020 plan. Subsidence is thought to be rapidly increasing as a result of the 2009 earthquake and tsunami.
Tropical Cyclones and High Windstorms	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

Hazard	Justification for Inclusion
	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 the Resources.

In addition, reviewing previous disaster declarations provides insight to known hazards that impact the islands. Table 11 shows a list of FEMA declared disasters since 1966.

Table 11: FEMA Declared Disasters[36]

Year	Date	Disaster Types	Disaster Number
2020	4/1	American Samoa Covid-19 Pandemic	4537
2018	3/18	American Samoa Tropical Storm Gita	4357
2014	9/10	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

[36] FEMA (2020). *Disaster Declarations by State.* http://www.fema.gov/news/disasters_state.fema?id=60

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

4.1.3 Hazard Profiles

Each hazard mentioned above is profiled separately to describe the hazard and potential impacts on the islands of American Samoa. 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:
  - Unlikely: Less than 1% annual probability
  - Possible: Between 1% and 10% annual probability
  - Likely: Between 10+% and 90% annual probability
  - 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.
  - Climate Change Considerations: This section highlights potential climate change considerations and trends for each hazard.
  - 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.

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 Lealataua 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.

4.1.4 Estimating Losses

This risk assessment was conducted by using a two-fold, qualitative and quantitative approach to estimate vulnerability and potential losses. The quantitative assessment utilizes a GIS-based analysis. The qualitative approach draws on previous impacts in and near the planning area, as well as professional judgement to determine vulnerability throughout the Territory. More information on each approach and index is described below.

4.1.4.1 Quantitative Analysis

Geographic Information Systems

When possible, the vulnerability assessment for each hazard was completed utilizing a GIS-based analysis. Hazards that have specified geographic boundaries permit analysis using GIS. These hazards include:

- Coastal Erosion
- Earthquake
- Flood
- Hazardous Material Incidents
- Landslides
- Tsunami

The objective of the GIS-based analysis was to determine the estimated vulnerability of critical facilities and buildings for the identified hazards in American Samoa using best available geospatial data. ESRI® ArcGIS™ 10.5 was used to assess hazard vulnerability utilizing digital hazard data, such as FEMA Flood Insurance Rate Maps (FIRMs), building footprints, and building values. Digital data was collected from local, regional, state, and national sources for hazards. Using these data layers, hazard vulnerability can be assessed by estimating the number and of type of assets, as well as potential dollar losses, determined to be located in identified geographic hazard area boundaries.

4.1.4.2 Qualitative Analysis

A qualitative approach was employed for hazards that generally have the potential to impact, or occur within, the entire planning area. It was also used for such hazards that lack a geographic boundary or sufficient data to perform a reliable spatial analysis such as Public Health Risks. This includes hazards considered atmospheric such as drought. Many of the hazards listed above have the potential to affect all current and future buildings and all populations. Qualitative analyses were performed by using available research, data, and risk expertise to draw conclusions on probability and potential impacts across the entire planning area rather than applying a structure-specific approach.

4.1.4.2 Local Risk Assessments Losses

There are no local risk assessments to incorporate, thus local losses were not incorporated. However, efforts were made to identify risk by island (or county) as data permits.

4.1.4.3 Changes in Development

For the 2020 plan update, given the expedited timeframe, changes in development were discussed with the State Hazard Mitigation Officer (SHMO). The SHMO noted no new major developments or land use changes across the island since the previous plan was completed. (This is further evidenced by a limited population change since the previous plan was developed. The population has declined from 55,791 persons in 2014 to 55,212 persons in 2020.) However, several structures are currently being repaired or reconstructed as a result of Tropical Storm Gita impacts. New critical facilities constructed since the previous plan were also reviewed. The SHMO noted 17 new facilities on the island including 12 schools, a fire station/public safety building, FONO building, museum, shipyard office, and COVID-19-related testing/quarantine facility as listed in Appendix C. Eight of these new facilities are located in floodplain hazard areas (AE or VE). In the 2025 plan, the plan will be updated to reflect changes in the parcel information and building footprints, data permitting.

4.1.5 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 hazards. 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. in Section 4.19 Summary of Hazard Risk and Vulnerability 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 in Section 4.19 Summary of Hazard Risk and Vulnerability

Table 12: Priority Risk Index Criteria for American Samoa Hazard Mitigation Plan

PRI Category	DEGREE OF RISK			Assigned Weighing Factor
	Level	Criteria	Index Value	
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.	3	
	Large	All areas affected.	4	
Warning Time	More than 24 hours	Self-explanatory	1	10%
	12 to 24 hours	Self-explanatory	2	
	6 to 12 hours	Self-explanatory	3	

PRI Category	DEGREE OF RISK Level	Criteria	Index Value	Assigned Weighing Factor
	Less than 6 hours	Self-explanatory	4	
Duration	Less than 6 hours	Self-explanatory	1	10%
	6 to 12 hours	Self-explanatory	2	
	12 to 24 hours	Self-explanatory	3	
	More than 24 hours	Self-explanatory	4	

4.2 Coastal Erosion

4.2.1 Description

According to the U.S. Geological Survey (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.

Trade winds play a key role in wind and weather system, particularly in the Pacific. These winds can change during a climate pattern that is called the El Niño Southern Oscillation (ENSO). When trade winds are weaker than usual, that is described as an El Niño year; whereas stronger winds result in a La Niña year. While it is unknown exactly how the timing and intensity of ENSO patterns will change in the future, climate model results indicate a doubling of El Niño and La Niña extremes in the 21st century when compared to the 20th century.[37] These weather systems, particular La Niña events, can cause erosion.

[37] U.S. Global Change Research Program (2018). *Fourth National Climate Assessment. Chapter 27: Hawaii and U.S.-Affiliated Pacific Islands*. Retrieved from https://nca2018.globalchange.gov/chapter/27/.

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 damage 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 (Figure 15). The interlocking mechanism makes it very stable against wave action. In addition, coral reefs serve 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 across the island. However, the coral generally rebounds, making it known as some of the most resilient in the world.

Figure 15: Samoa Stone in Vatia[38]

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 16 below shows imagery of Vatia Village along the coast. The connecting roads parallel the shoreline, often at the seaward edge of the backshore berm.

[38] Google Maps Imagery, Rommel S. Dorado Photo.

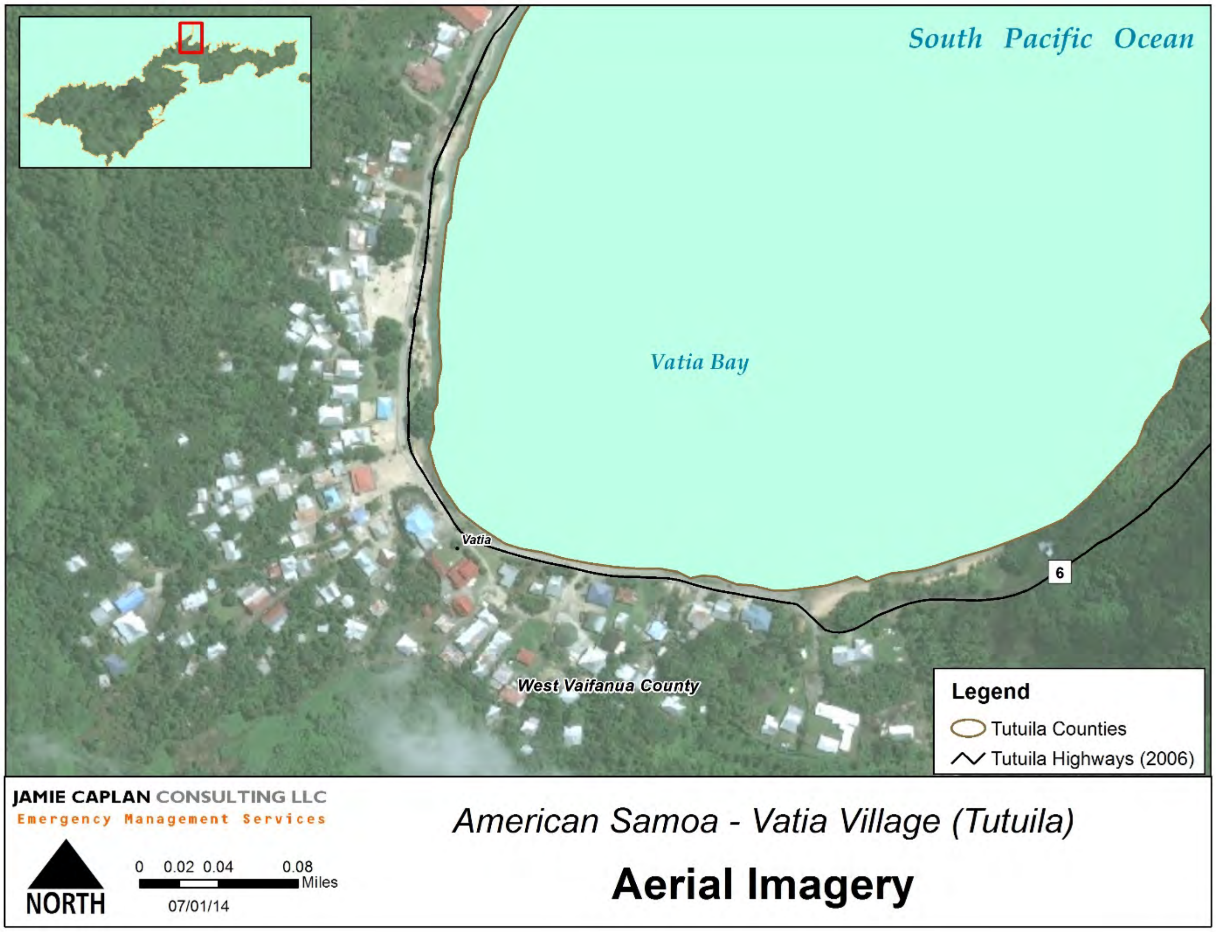

Figure 16: Typical Building Proximity to the Coast (Vatia Village)

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 U.S. Environmental Protection Agency (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.

4.2.2 Location

There are approximately 120 miles of shorelines across the seven 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 and climate change impacts, may exacerbate the process.

In 2004, the Coastal Engineers of the U.S. Army Corp of Engineers (USACE), Honolulu District, conducted a shoreline study for Tutuila and Aunu'u Islands. (Of note, for the 2020 plan update, more current studies were sought to update the plan. However, no current comparable resources were found.) The USACE study 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

The table below indicates the amount of critical areas in American Samoa on Tutuila and Aunu'u Islands. The following maps (Figure 17 through Figure 20) 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 16). 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 13: Amount of Critical Shoreline on Tutuila

County	Approx. Measured Shoreline (miles)[39]	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 (East District)	5.69	0.92	16%
Leasina (East District)	N/A	N/A	
Maoputasi (East District)	7.42	0.65	9%
Saole* (East District)	4.4	.63	14%

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

County	Approx. Measured Shoreline (miles)[39]	Critical Shoreline (miles)	Percent Critical Shoreline
Sua (East District)	6.70	1.99	30%
Tualatai (West District)	1.29	.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

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

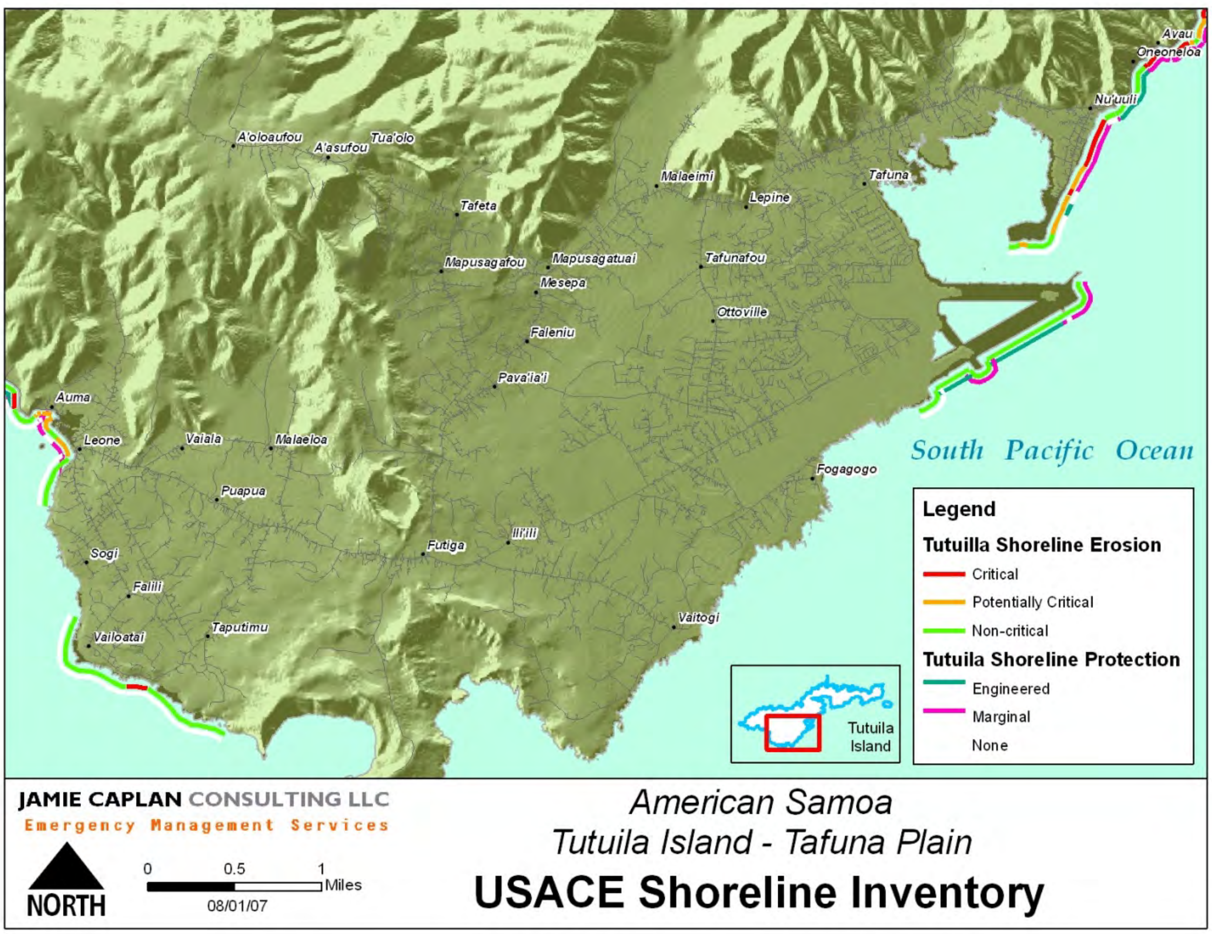

Figure 17: Tutuila Island – Tafuna Plain, USACE Shoreline Inventory

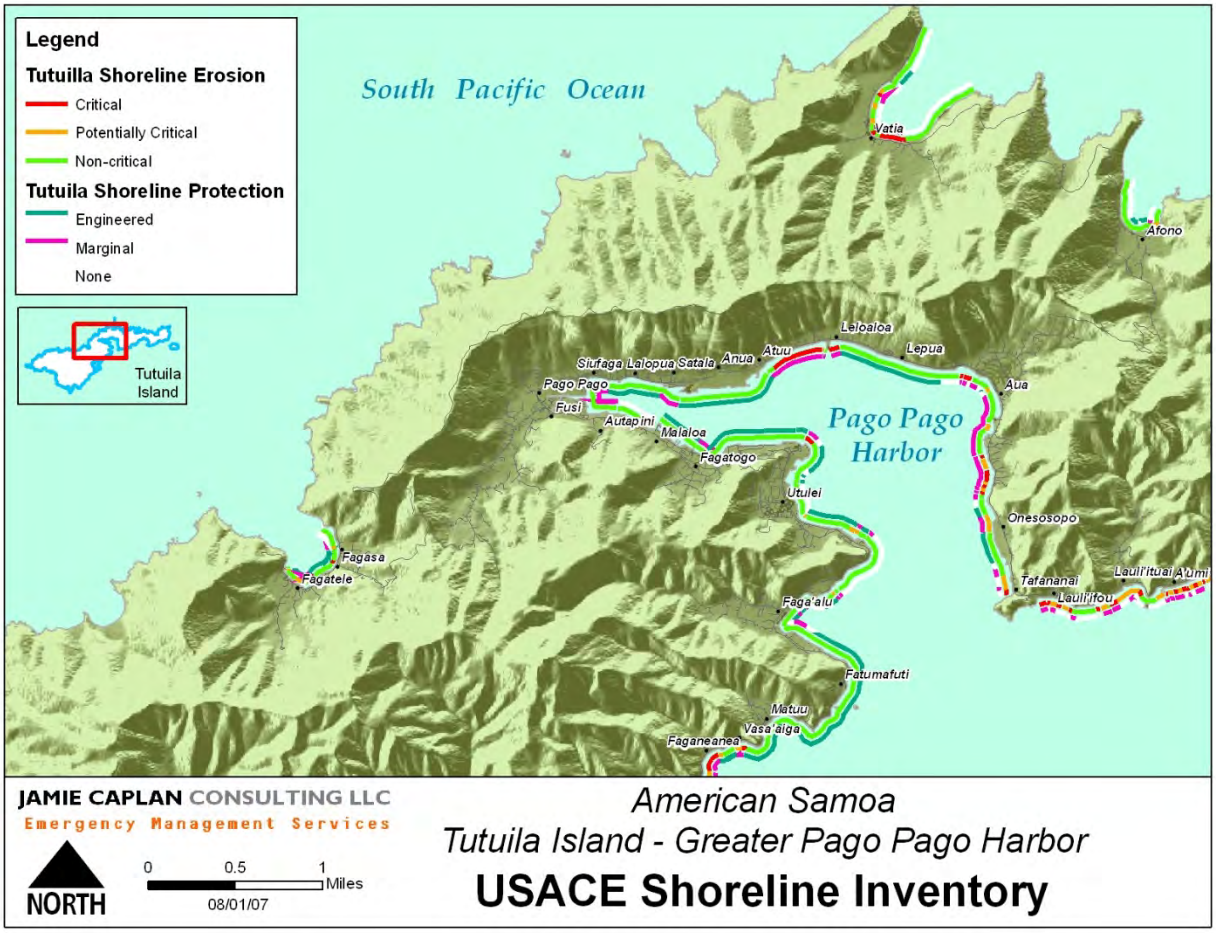

Figure 18: Tutuila Island – Greater Pago Pago Harbor, USACE Shoreline Inventory

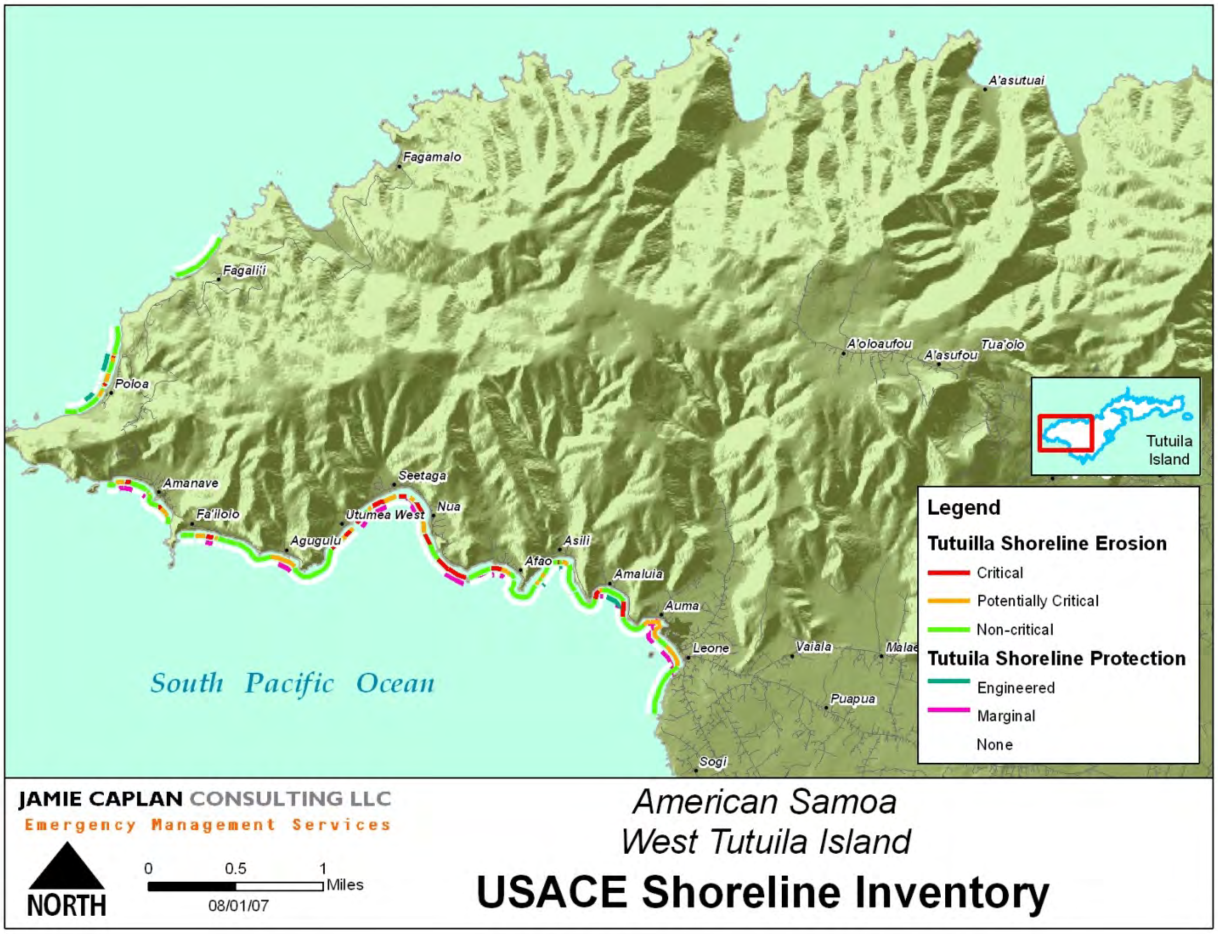

Figure 19: West Tutuila Island, USACE Shoreline Inventory

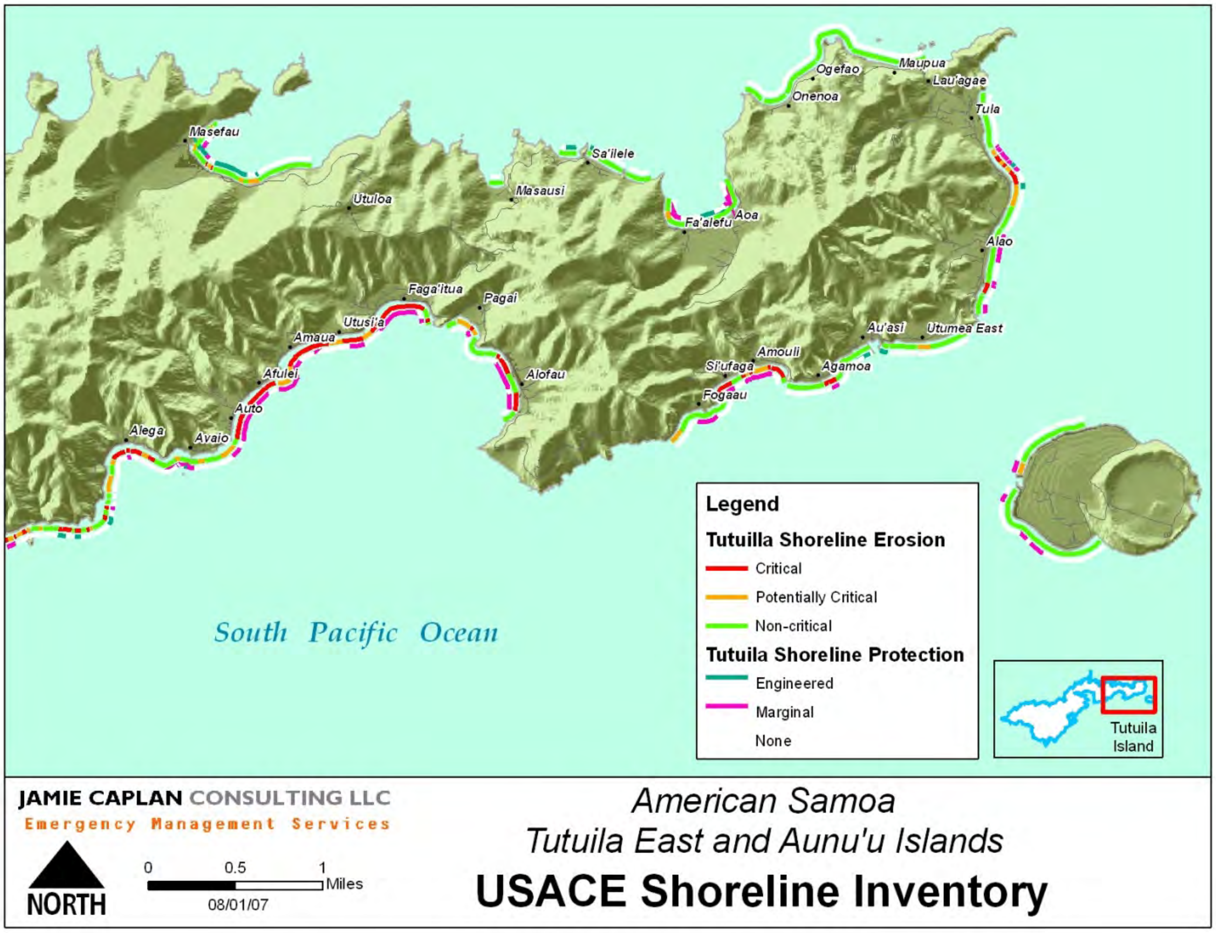

Figure 20: Tutuila East and Aunu'u Island, USACE Shoreline Inventory

4.2.3 Previous Occurrences

The National oceanic and Atmospheric Administration's (NOAA's) Storm Events Database and additional online sources were research for previous occurrences. One erosion event was reported in the Storm Events Database 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. However, related hazard reports from the Storm Events Database, including hurricane and high surf also reference erosion impacts.

Of note, the 2009 tsunami caused extension erosion damage. Information was gathered from the Geer Association.[40] Figure 21 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

40 http://www.geerassociation.org/GEER_Post%20EQ%20Reports/American%20Samoa_2009/AmSamoa09_Ch05.html

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 few reported events, coastal erosion in American Samoa is a regular occurrence given the volcanic composition of the island and subjectivity to high winds, sea level rise, and tropical storms. Coastal erosion is a slow onset hazard, meaning that very small changes over time may eventually result in large problems.

Figure 21: Bluff Erosion in American Samoa

4.2.4 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. Structure along the coast, including businesses, homes, critical facilities, and cultural resources are at risk to succumbing to the ocean with severe erosion. Additionally, 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).

4.2.5 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. When considering future probability, climate change is expected to exacerbate this hazard (Section 4.2.6.1) which will increase its location, extent, intensity, and frequency. With consideration to past and future events, the probability for coastal erosion is indicated as highly likely, greater than 90% annual probability.

4.2.6 Vulnerability Assessment

As erosion continues along the shoreline, impacts to structures, beaches, environment (e.g., mangroves, coral reefs), and cultural resources and activities can be expected. In severe cases, erosion may force populations to be relocated, often breaking a link to centuries of ties to ancestral land. Figure 22 below shows a recent example of coastal erosion in American Samoa (photo taken on 2014 site visit; structure likely impacted by tsunami).

Figure 22: Severely Eroded Shoreline in Village of Leone (Tutuila Island)

4.2.6.1 Climate Change Considerations

El Niño or La Niña events, which will likely be exacerbated by climate change impacts, can also have an impact on coastal erosion.[41] During El Niño cycles, winds tend to be calm and the air is dry, leading to less erosion. Conversely, during La Niña cycles are characterized by strong winds, which degrades shoreline and pushes water inland, leading to increased coastal erosion.

[41]Pacific Island Climate Education Partnerships (2014). *Climate Change in American Samoa.* Retrieved from: http://www.soest.hawaii.edu/coasts/publications/AmSamoa%20Climate%202016.pdf

Coastal storms can lead to significant impacts on shoreline erosion. According to a 2016 USGS study which downscaled high resolution climate data, climate change trends in American Samoa indicated fewer weak tropical storms, but more frequent strong tropical storms are also predicted.[42]
Coral reefs can serve as natural mitigators to coastal erosion. Coral reefs are sensitive to numerous climate stressors, including ocean acidification, sea surface temperature, tropical storms, runoff/streamflow, coastal erosion, currents, mixing, and stratification. A 2016 EcoAdapt study reviewed American Samoa's coral health to climate stressors.[43] In five ranking categories ranging from low to high, American Samoa's coral reef habitat was found to be moderately vulnerable (a ranking of 3). It was also found to have moderate-high (a ranking of 4) adaptive capacity, though less so to human stressors (a ranking of 3).

Climate change is expected to exacerbate this hazard which will increase its location, extent, intensity, and frequency.

4.2.6.1 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 may be experiencing coastal erosion due to recent coastal storms.[44]
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 14 below.

Table 14: 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

[42] Wang, Yuqing (2016). Final Report - 21st Century High-Resolution Climate Projections for Guam and American Samoa PICSC Final Report Wang DD_Guam&Tutuila 2016 11 17.pdf. Retrieved from https://www.sciencebase.gov/catalog/file/get/583331f6e4b046f05f211ae6?f=__disk__4f%2F74%2F9f%2F4f749ff0b894d05a9ae36bd2fd2e206c5c130539
[43] EcoAdapt (2016). *American Samoa Coral Reefs Climate Change Vulnerability Assessment Summary*. Retrieved from: http://ecoadapt.org/data/documents/AmericanSamoa_VASummary_CoralReefsHabitat.pdf
[44] The USACE Erosion data is current as of 2004. This was the most current data available for the planning area for the 2020 plan.

County (District)	Total Number of Buildings	Total Number of Buildings in Critical Erosion Areas	Percent of Buildings at Risk	Type
Ituau (East District)	1,075	125	12%	1 business 1 commercial 123 residential
Lealataua (East District)	2,026	297	15%	4 church 293 residential
Leasina (East District)	474	0	-	-
Maoputasi (East District)	2,246	154	7%	1 Tedi 2 commercial 5 gov't 146 residential
Saole* (East District)	364	130	24%	1 business 129 residential
Sua (East District)	938	285	30%	2 unknown 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 15 and Figure 23. In addition, assembly areas, safe zones, tsunami sirens, and ASTCA communication infrastructure were analyzed for vulnerability. The results are reported below.

Table 15: 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. However, there was no associated GIS data for their location. 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 C.

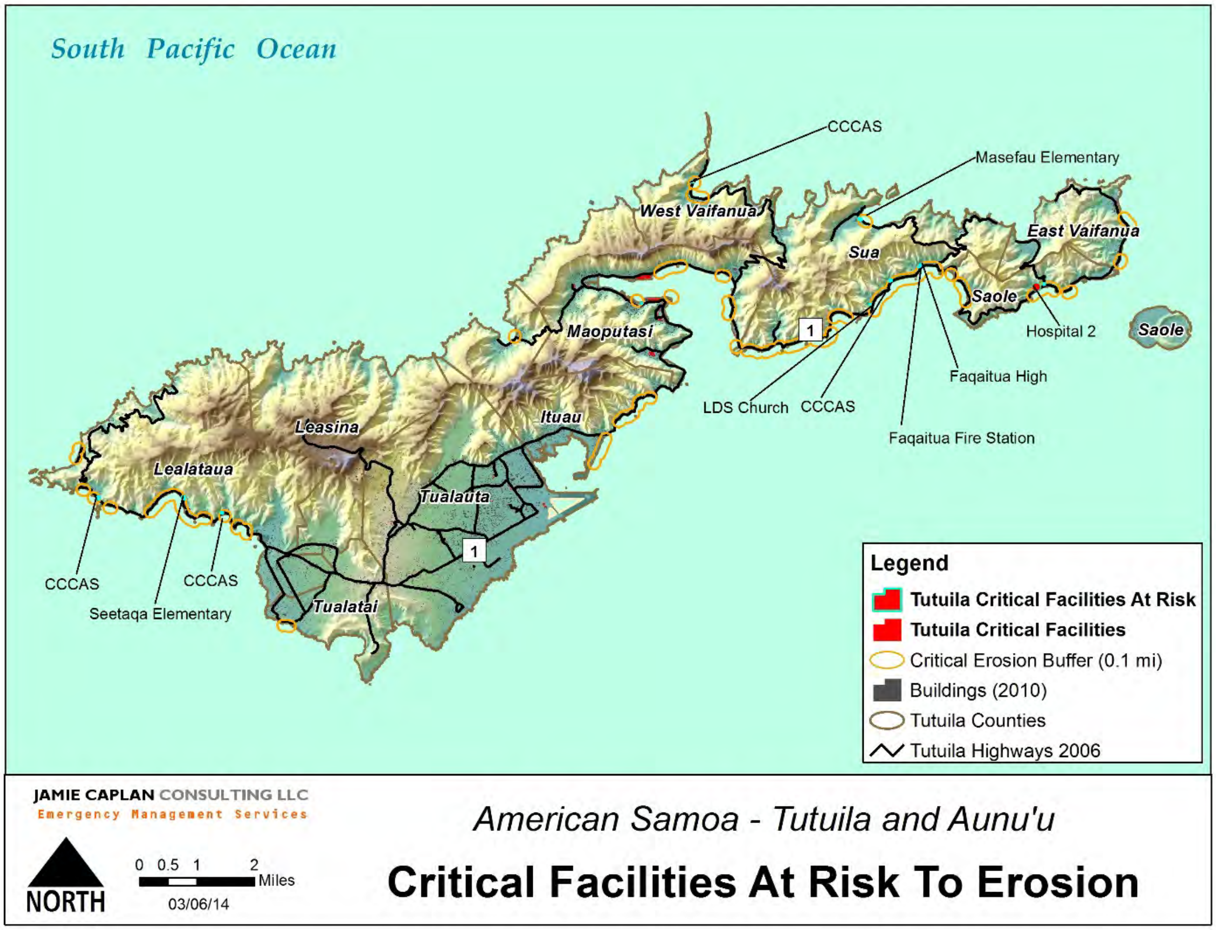

Figure 23: Critical Facilities at Greatest Risk to Coastal Erosion

4.3 Drought

4.3.1 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 16 below:

Table 16: 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 groundwater 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 groundwater supply.

According to NOAA, precipitation totals below eight inches of the normal median amount are considered a critical threshold in the Pacific Islands.[45] The U.S. Drought Monitor, also records drought in the U.S. and categorizes drought into five categories as shown in Table 17 below. 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.

[45] NOAA (2014). *State of the Climate –Drought.* https://www.ncdc.noaa.gov/sotc/drought/2014/1#det-reg-pacis

Table 17: U.S. Drought Monitor Categories

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.

4.3.2 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.

4.3.3 Previous Occurrences

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 the figure below.

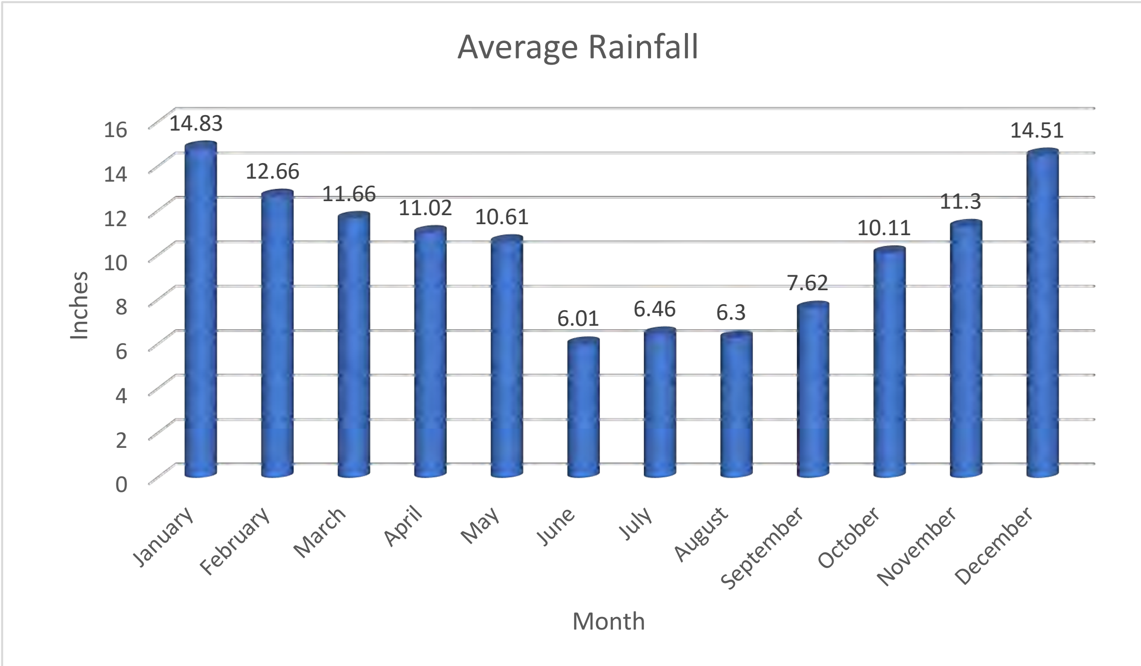

Figure 24: Average Rainfall in American Samoa (NOAA, Pago Pago Station)

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.[46] 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 18 below shows a summary of significant droughts through 2020. No significant drought impacts were experienced in American Samoa since the previous plan update. However, below average rainfall did occur as a result of the El Nino year in 2016 which resulted in severe drought impacts throughout the Pacific.

The USGS has indicated that as long as the Territory receives steady rainfall, at least 16 million gallons of water seeps into the freshwater 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.[47] The old underground pipes of Pago Pago and Fagatogo areas were notorious for leaks before recent mitigation efforts.

[46] (1998, June 7). American Samoa Governor Declares State of Emergency. *The Samoa News.* Retrieved from https://www.samoanews.com/

[47] (1998, June 1). Water Department Officials Take Water Conservation to the Schools. *The Samoa News.* Retrieved from https://www.samoanews.com/

Table 18: Summaries of Significant Droughts

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 one week. Cannery closed for six 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	Three 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.[48] Four to five months without rain during the Territory's usually drier wintertime depleted underground water sources. From April to August, only 24.28 inches of rainfall was recorded at the airport weather station in Tutuila. Above groundwater was unavailable, and sediment in groundwater 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

[48] (1998, June 1). Water Department Officials Take Water Conservation to the Schools. *The Samoa News.* June 1, 1998. Retrieved from https://www.samoanews.com/

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 six months, with major impacts on the Territory, causing water rationing and closure of schools for one week. One cannery closed for six months, coincident with renovations. American Samoa's Governor arranged for the 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.[49]

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."[50] 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 five-month period was 18.52 inches in 1983. In contrast, another major drought year in 1974 recorded 24.28 inches during the same five-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."[51] 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 four month period in 1996, and that January through April 1998 rainfall had decreased by almost 60% compared to the same period in 1997.[52] 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

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[49] (1998, June 7). American Samoa Governor Declares State of Emergency. *The Samoa News.* Retrieved from https://www.samoanews.com/

[50] (1998, September 17). ASPA Director Says This is American Samoa's Worst Drought. *The Samoa News.* Retrieved from https://www.samoanews.com/

[51] (1998, May 18). Drought Conditions Remain in American Samoa." *The Samoa News.* Retrieved from https://www.samoanews.com/

[52] (1998, May 18). Drought Conditions Developing in American Samoa. *The Samoa News.* Retrieved from https://www.samoanews.com/

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.

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%, 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."[53] American Samoa was not the only Pacific island to experience very dry conditions that year. Record droughts had been forecasted for Guam, Commonwealth of Northern Mariana Islands (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

[53] University of Guam (UOG) Water and Energy Research Institute (WERI), Pacific El Niño-Southern Oscillation (ENSO) Applications Center (PEAC). 1998. Update to Newsletter Issued 1st Quarter 1998, Vol. 4 No. 1. *Pacific ENSO Update – Special Bulletin, March 27, 1998.* National Oceanic and Atmospheric Administration (NOAA) Office of Global Programs.

cycle and its relationship to drought in *Understanding ENSO and Forecasting Drought,* https://drought.unl.edu/Education/DroughtIn-depth/ENSO.aspx.

Figure 25 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,[54] and identifies American Samoa's significant drought events. The various phases of the Pacific 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. Generally, these cycle approximately every seven years.

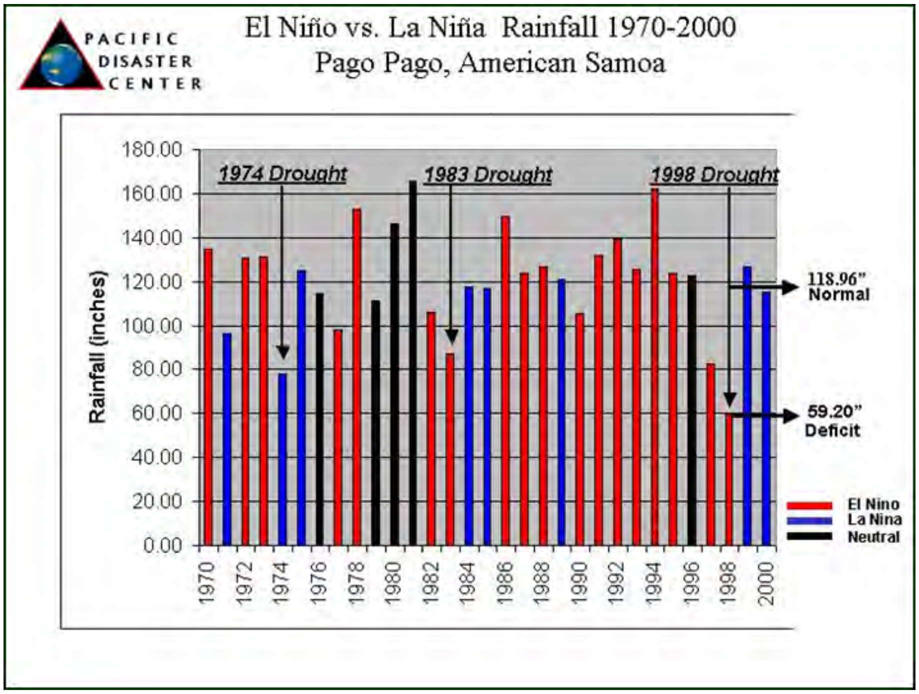


Figure 25: Comparison of Rainfall Amounts, Drought Occurrence and ENSO

4.3.4 Extent

While reported drought events in American Samoa are not categorized by the U.S. Drought Monitor, 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 Table 17: U.S. Drought Monitor Categories.

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% to 80% of normal rainfall is received can also trigger severe drought. The 1998 drought was severe when just

[54] National Oceanic and Atmospheric Administration (1985). *Local Climatological Data Annual Summary with Comparative Data.* NOAA Tafuna Weather Station.

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 24: Average Rainfall in American Samoa (NOAA, Pago Pago Station).

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

4.3.5 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 long-lasting or exceptionally severe, prompting water conservation.

When considering future probability, drought location will remain island wide. The island is expected to become wetter overall due to climate change (Section 4.3.6.1), likely resulting in less drought. However, when drought does occur, it may be more severe and intense, especially if driven by climate-influenced extreme El Niño episodes.

Using available historical data reporting from 1976 to 2014, four events were reported of which three were severe in nature. Based on this information, the probability of drought occurrence is between 7% and 11% annually.

With consideration to past and potential future hazard events, the annual probability can be summarized as possible, between 1% and 10% annually. Of note, this probability is aligned with drought events that may result in widespread impacts or water conservations measures, rather than localized events.

4.3.6 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. Imported food is much more expansive than locally grown food.

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 shortage, 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.

4.3.6.1 Climate Change Considerations

American Samoa is expected to become wetter overall as a result of climate change. However, climate change is also expected to increase temperature change and could exacerbate existing droughts or accelerate presence of a drought.

4.3.6.1 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.

4.4 Earthquake

4.4.1 Description

The earth is made up four major layers and several sub layers (Figure 26): 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.

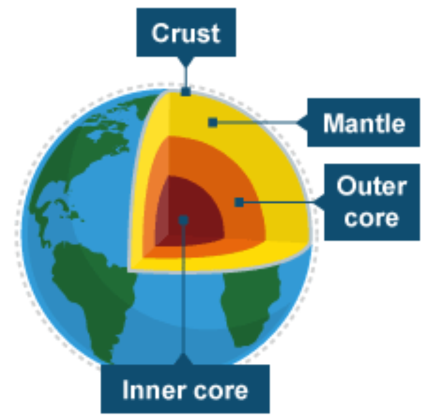


Figure 26: Earth's Sub Layers

There are approximately twelve major plates and several dozen more minor plates on the earth's crust, as shown in

Figure 27. 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.

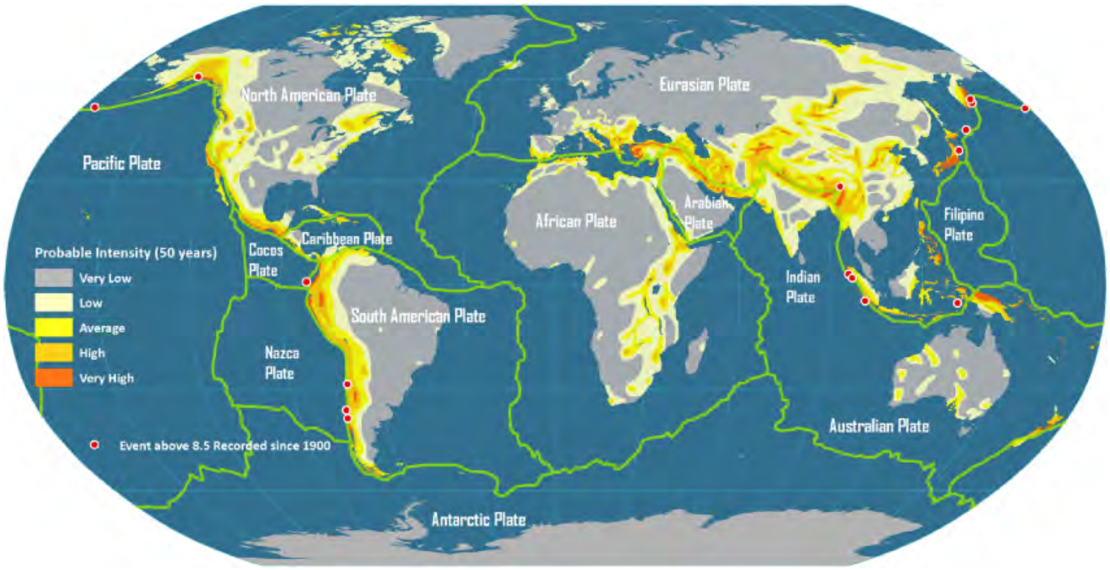


Figure 27: Global Plate Tectonics and Seismic Activity[55]

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.[55] 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 19: 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 MMI

[55] Hofstra University. Geography of Transport Systems. Retrieved 5/19/20: https://transportgeography.org/?page_id=6411

Scale of earthquake intensity and its correspondence to the Richter Scale is given in Table 20: Modified Mercalli Intensity Scale for Earthquakes.

Table 19: Richter Scale[56]

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.

Table 20: Modified Mercalli Intensity Scale for Earthquakes[57]

SCALE	INTENSITY	DESCRIPTION OF EFFECTS	CORRESPONDING RICHTER 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	SLIGHTLY 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

[56] USGS. *Richter scale*. Retrieved from https://earthquake.usgs.gov/learn/glossary/?term=Richter%20scale.
[57] Magnitude/Intensity Comparison. USGS. Retrieved from http://earthquake.usgs.gov/learn/topics/mag_vs_int.php Retrieved March 3, 2015.

SCALE	INTENSITY	DESCRIPTION OF EFFECTS	CORRESPONDING RICHTER MAGNITUDE
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 21: Moment Magnitude Scale shows the Moment magnitude scale, and The table below shows a few examples of how the Moment Magnitude Scale compares to the Richter Scale.

Table 21: Moment Magnitude Scale

SCALE VALUES	EARTHQUAKE EFFECTS
<3.5	Very weak; unlikely to be felt.
3.5 - 5.4	Generally felt; rarely causes damage.
5.4 - 6.0	Will not cause damage to well-designed buildings; will damage poorly designed ones.
6.1 - 6.9	Considered a "major earthquake" that causes a lot of damage.
7.0 - 7.9	Large and destructive earthquake that can destroy large cities.
8 or >	Large and destructive earthquake that can destroy large cities.

Table 22: Richter v. Moment Magnitude Values

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

4.4.2 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 of historic occurrences with many earthquakes occurring in the Tonga Trench, more than 100 miles southwest of the islands (Figure 28: Tonga Trench Location).

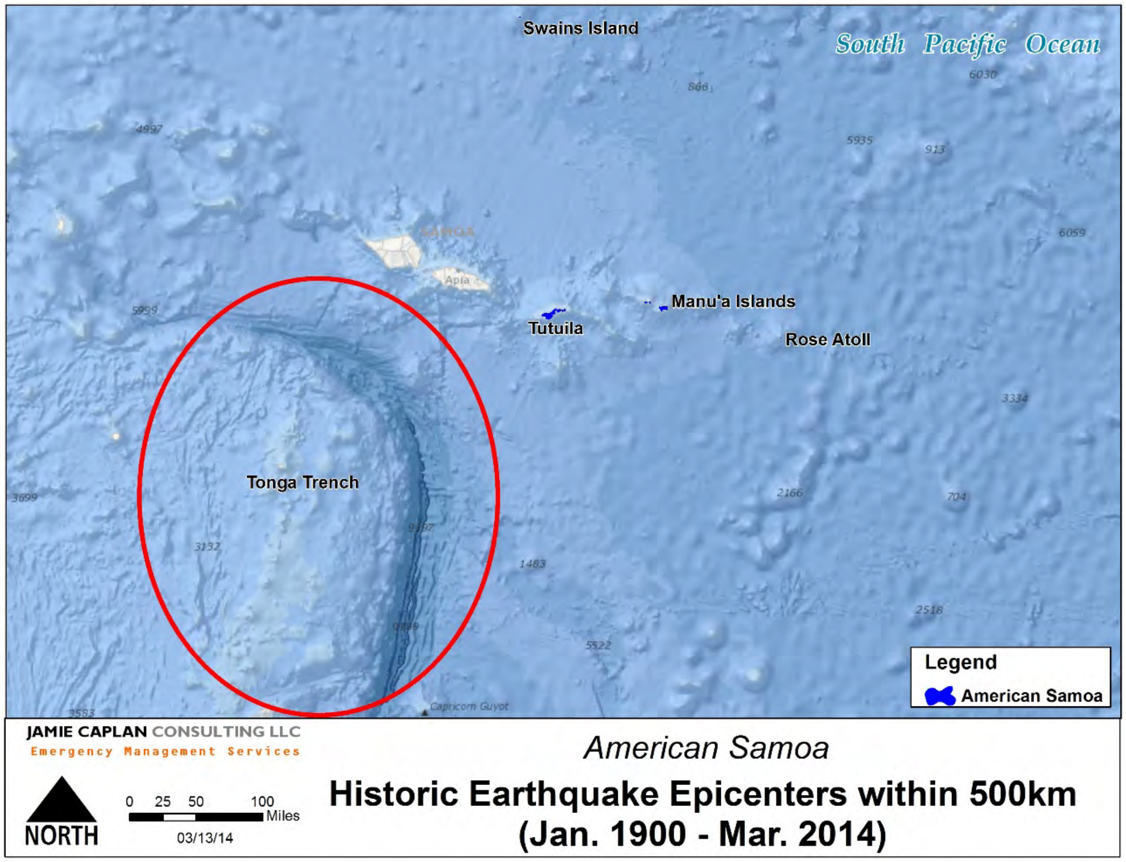


Figure 28: Tonga Trench Location

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 29 and Figure 30 show fault lines on the islands Tutuila/Aunu'u Islands and the Manu'a Islands, respectively. For Tutuila Island and Aunu'u Island (Figure 29), 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.

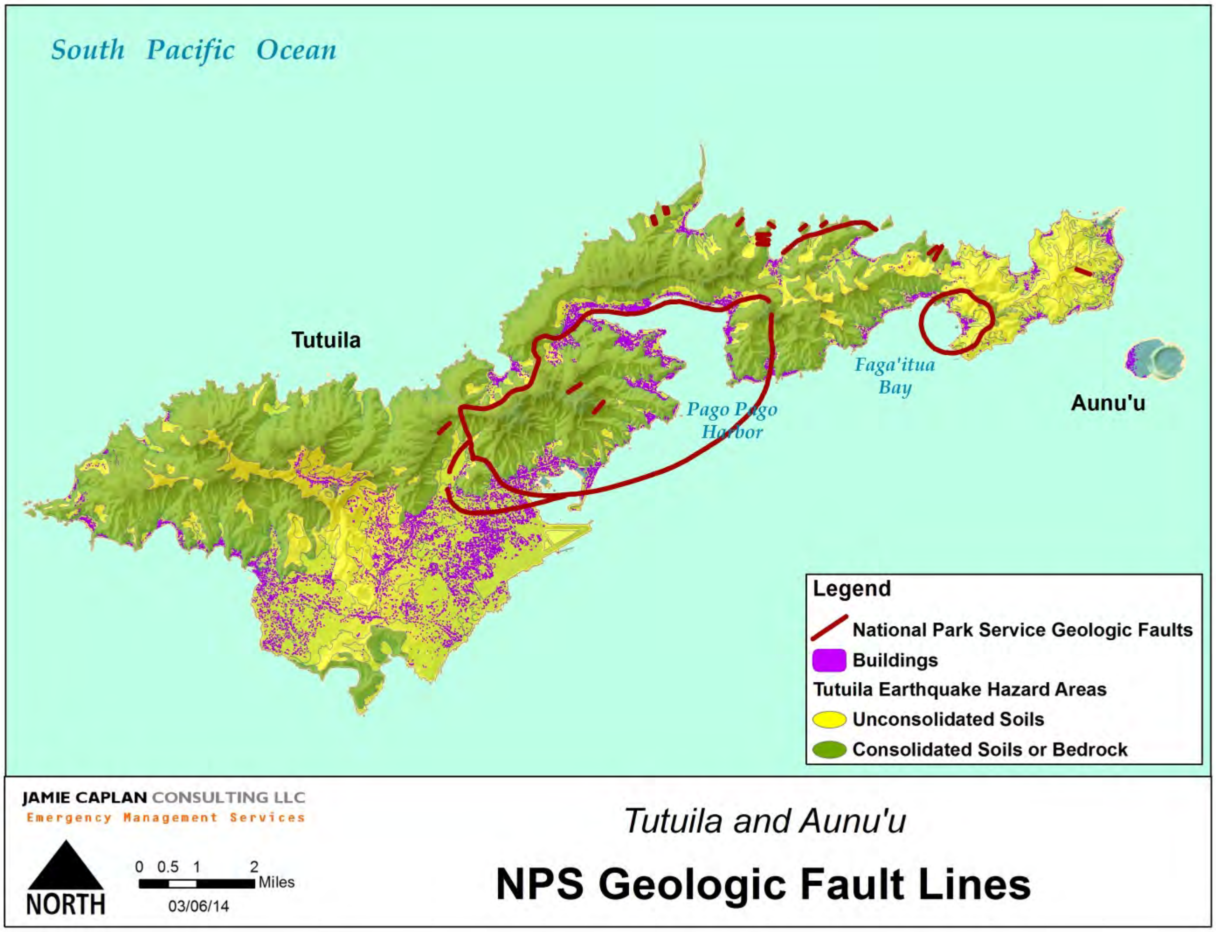


Figure 29: Tutuila Island and Aunu'u Island Earthquake Fault Lines and Hazard Areas

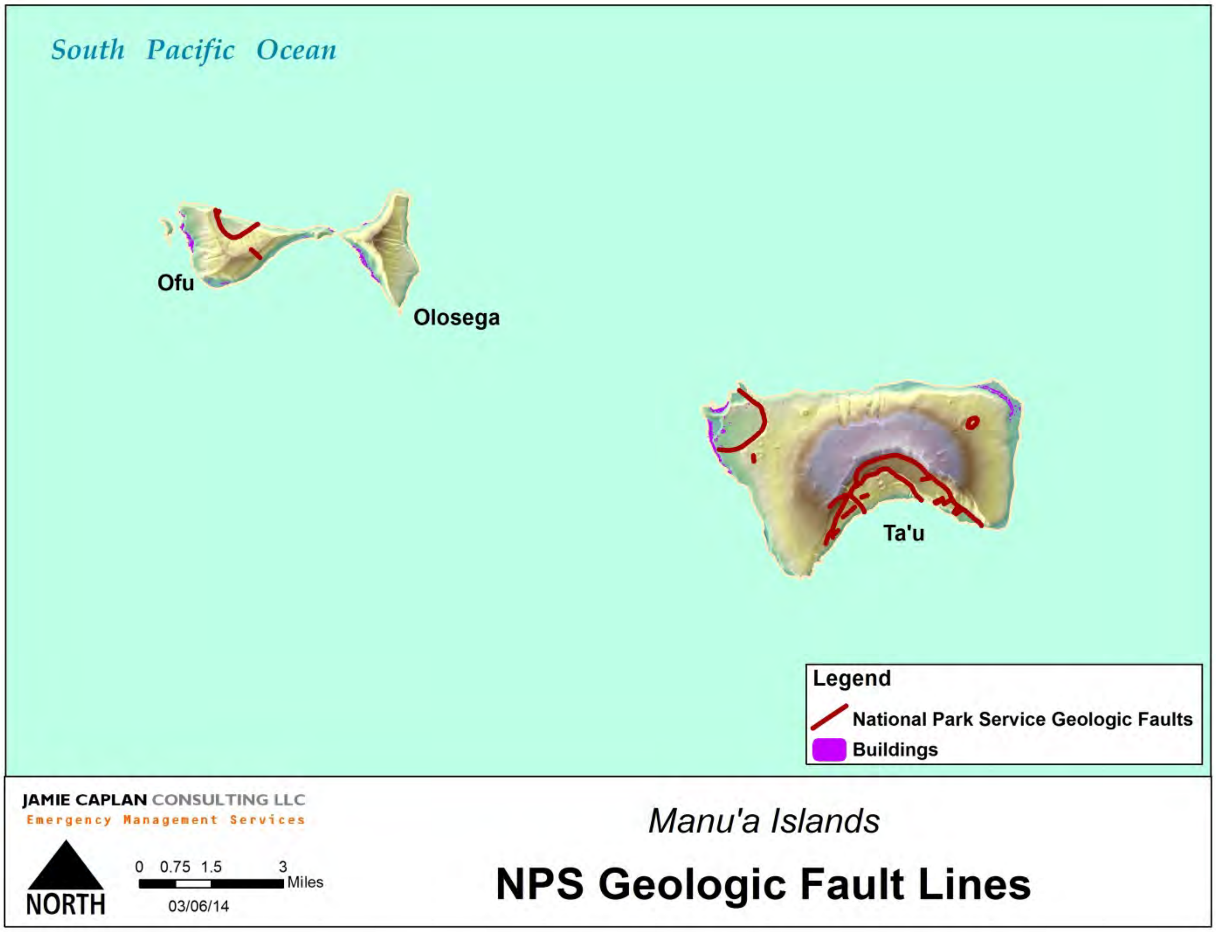


Figure 30: Manu'a Islands Earthquake Fault Lines

4.4.3 Previous Occurrences

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)."[58] 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 28). 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

[58] http://pubs.usgs.gov/of/2012/1087/OF12-1087.pdf page 2

Figure 27 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 31 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.

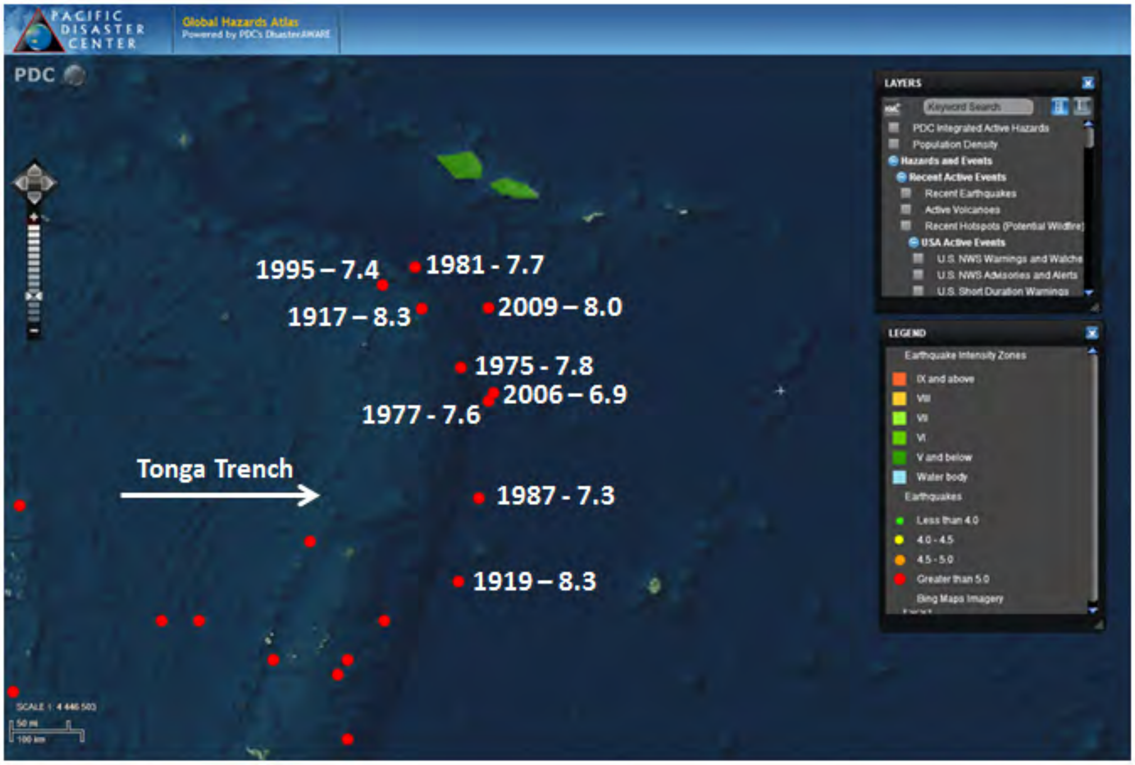


Figure 31: Historic Earthquakes over 7.0 and the Tonga Trench[59]

[59] PDC. http://atlas.pdc.org/atlas/

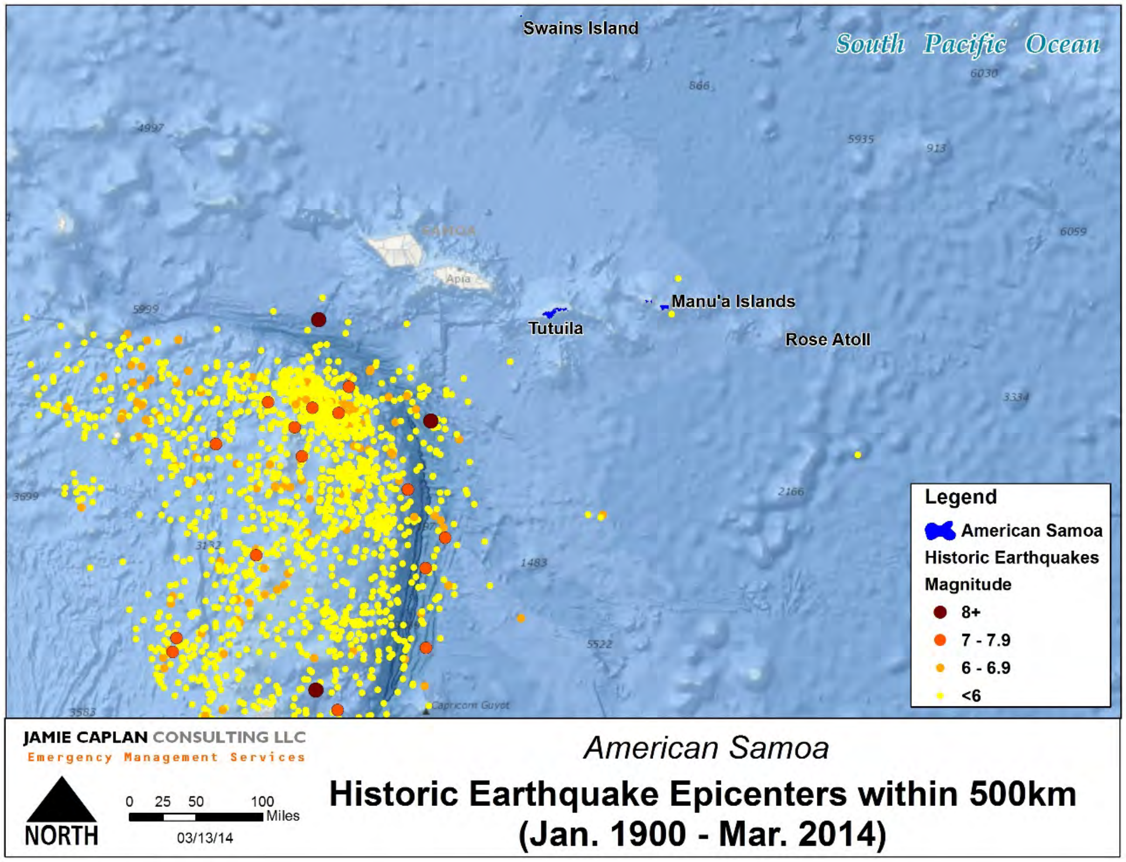


Figure 32 shows data from the United States Geological Survey from the Comprehensive Earthquake Catalog.[60] The map includes earthquakes from January 1900 to March 2014 with a magnitude 5.0 or greater. These are earthquakes that occurred within 500 kilometers of American Samoa and include the Tonga 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). This information was refreshed for the 2020 plan from 2014 – May 2020. An additional 286 events were reported over 5.0 magnitude. However, none were over 7.0.

[60] http://earthquake.usgs.gov/earthquakes/search/

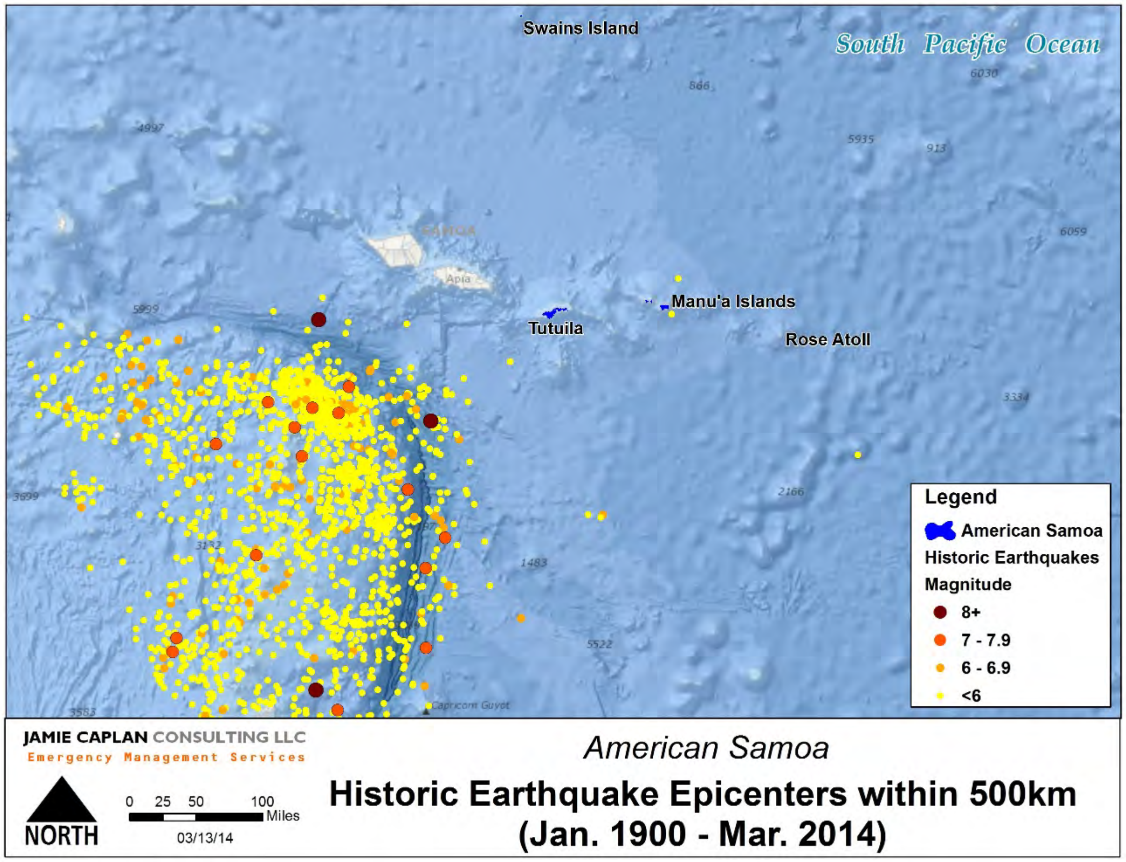


Figure 32: Historic Earthquakes near American Samoa

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.

4.4.4 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 USGS calculates and publishes the probabilities of ground shaking hazard for each Territory by conducting an in-depth seismic hazards analysis

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% probability of exceedance in 50 years. (A 10% chance of exceedance means that is there 90% chance that the shaking will NOT exceed the value, thus indicating probable upper bounds (magnitude) of shaking.[61] Magnitude in terms of %g varies across islands as shown in the figures below. In addition, Table 24 shows the associated damage level by percent acceleration force of gravity (% g).

Table 23: Peak Horizontal Acceleration (% g) 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)

[61] USGS (2020). Earthquake Hazards. Retrieved from http://earthquake.usgs.gov/hazards/about/basics.php

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)

Table 24: 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.

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.

4.4.5 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."[62] This fact is based on previous occurrences from several different sources. Of note, these events historically do not originate in American Samoa and do not typically cause extensive damage. However, such events are capable of causing damage, or a tsunami.

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 32). The data ranges from 1906 to 2020 and includes 22 earthquakes over 7.0. This results in a probability of 0.2% or 20% probability each year.

[62] http://pubs.usgs.gov/of/2012/1087/OF12-1087.pdf, page 2

Future earthquakes in American Samoa in terms of location, extent, intensity, and frequency are expected to remain generally the same. While several earthquakes are felt each year, few earthquakes result in damage in American Samoa. However, intense events resulting in damage are possible. With consideration to past event and potential events, a categorization of "likely," (between 10% and 90% annually) was assigned.

4.4.6 Vulnerability Assessment

In the extent section, data indicated a range of 0.01-0.2%g with 10% 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 29) 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, which increases vulnerability. 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 33).

Earthquakes in American Samoa have the potential to cause damage to buildings, and infrastructure including roads and pipes. An earthquake could result in deaths, injuries, property damage, environmental damage, and disruption of normal services and business activities. It is also common for fires to follow earthquakes, as a result of ruptured gas lines. The effects of an earthquake could be aggravated by collateral emergencies such as fires, flooding, tsunamis, landslides, hazardous material spills, utility disruptions, and transportation emergencies. Aftershocks to major earthquakes could also be large enough to cause damage.

While earthquakes are possible and shaking will likely be felt occasionally, the damage is generally minor in American Samoa. However, it should be noted that extremely strong earthquakes are capable of causing widespread damages on the islands, particularly when buildings reside on unconsolidated soil or are not built to more recent building code standards. Further, all earthquake occurrences should be an indication to stay alert for a possible tsunami. For these reasons, earthquakes are a moderate hazard for the islands.

4.4.6.2 Climate Change Considerations

While a changing climate is not thought to affect the seismicity of a region, seismic occurrence may accelerate climate change impacts. Recent research suggests that the tectonic movement of American

Samoa during the 2009 magnitude 8.2 earthquake and tsunami is resulting in accelerated subsidence and sea level rise across the Territory.[63]

4.4.6.2 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.

Newer buildings will likely be constructed to a higher building code, which will increase the likelihood of building survival and minimal damage. 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 25 below and several figures that follow.

Table 25: 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
Ituaa (East District)	1,075	1,008	94%	1 402 type 2 government 12 church 32 commercial 959 residential
Lealataua (East District)	2,026	1,589	78%	6 school 7 commercial 14 churches 37 not listed 1525 residential
Leasina (East District)	474	460	97%	1 commercial 5 church 6 government 448 residential
Maoputasi (East District)	2,246	1969	88%	1 school 1 Tedi of Samoa

[63] Han, S. C.; Sauber, J. M.; Pollitz, F. F.; Ray, R. D. *Sea level rise in the Samoan islands escalated by viscoelastic relaxation after the 2009 Samoa-Tonga earthquake.* American Geophysical Union. *Dec 2018. Retrieved from:* https://ui.adsabs.harvard.edu/abs/2018AGUFMOS44B..10H/abstract

County (District)	Total Number of Buildings	Total Number of Buildings in Unconsolidated Soil Area	Percent	Type
				1 new 6 unlisted 13 church 32 commercial 68 government 1847 residential
Saole (East District)	364	363	69%	1 business 2 unknown 260 residential
Sua (East District)	938	823	88%	4 unlisted 4 commercial 3 church 812 residential
Tualatai (West District)	903	901	98%	48 not listed 12 church 5 commercial 856 residential
Tualata (West District)	7,441	7,373	99%	12 not listed 1 832 73 church 107 commercial 88 government 7,092 residential
West Vaifanua (East District)	172	166	97%	166 residential
Tutuila Island Total	16,136	13,858	85%	--
AUNU'U ISLAND				
Saole (East District)	179	N/A	--	--
Aunu'u Island Total	179	N/A	--	--
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	133	N/A	--	--

County (District)	Total Number of Buildings	Total Number of Buildings in Unconsolidated Soil Area	Percent	Type
(Manu'a District)				
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 26 and Table 27 and Figure 33 through Figure 36 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 C.

Table 26: Number of Critical Facilities (CFs) Potentially at Risk to Earthquakes

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 27 below.

Table 27: 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

County (District)	Total Number of Buildings	Total Number of CFs in Unconsolidated Soil Area	Type	Value
Lealataua (East District)	23	21	7 churches 13 schools (Leona High & Seetaga) 1 fire	$4,818,000
Leasina (East District)	7	7	7 churches	$4,818,000
Maoputasi (East District)	77	75	1 commercial 2 processing 39 school (Aua Elementary, Pago Pago Elem, Samoana High) 4 hospital 3 church 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 Elem) 3 church 1 hospital	$9,206,000
Sua (East District)	27	27	6 church 1 fire 1 police 19 school (Faqaitua High, Laulii Elementary and Elementary)	$23,283,000
Tualatai (West District)	3	3	3 church	$2,164,000
Tualata (West District)	62	61	27 school (Ili ili Elementary and Pavaiai Elementary) 9 fuel storage (tank farm) 7 transportation (Pago Pago airport) 10 utility (APSA Tafuna plant) 5 church 1 communication 1 government	$784,361,640

County (District)	Total Number of Buildings	Total Number of CFs in Unconsolidated Soil Area	Type	Value
			1 fire	
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 36). 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 C.

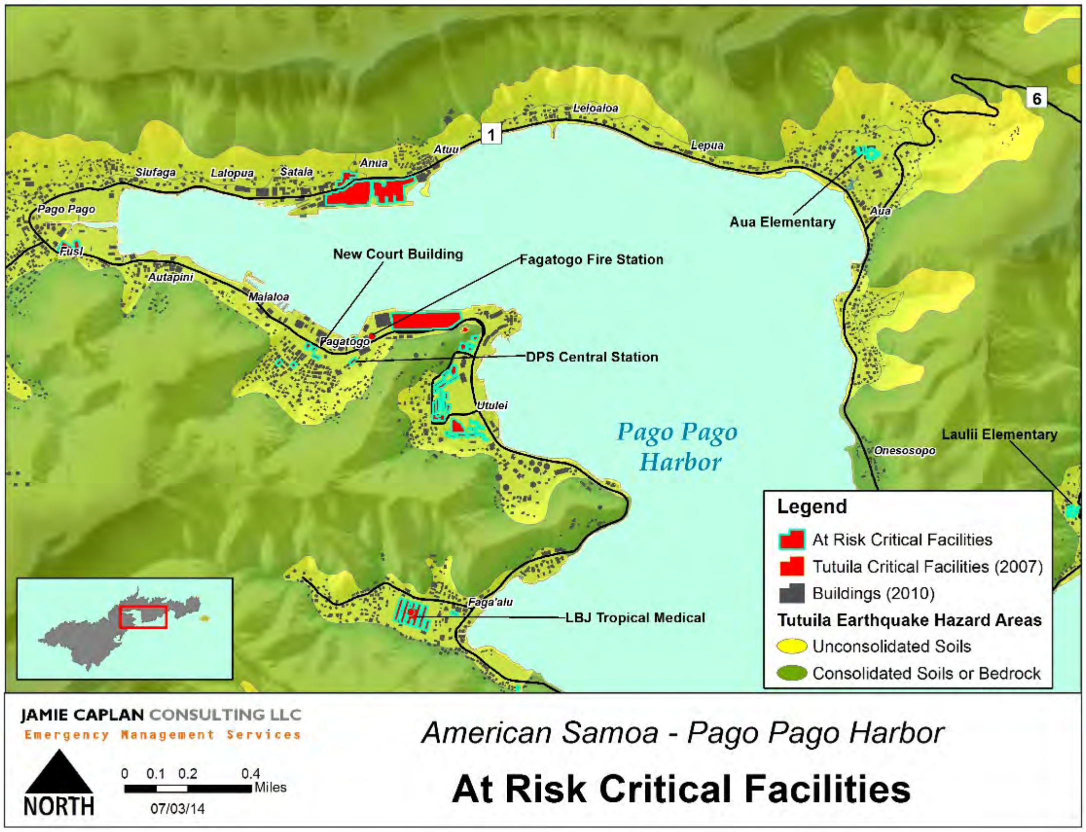


Figure 33: Critical Facilities Potentially at Risk to Earthquake (Pago Pago Area)

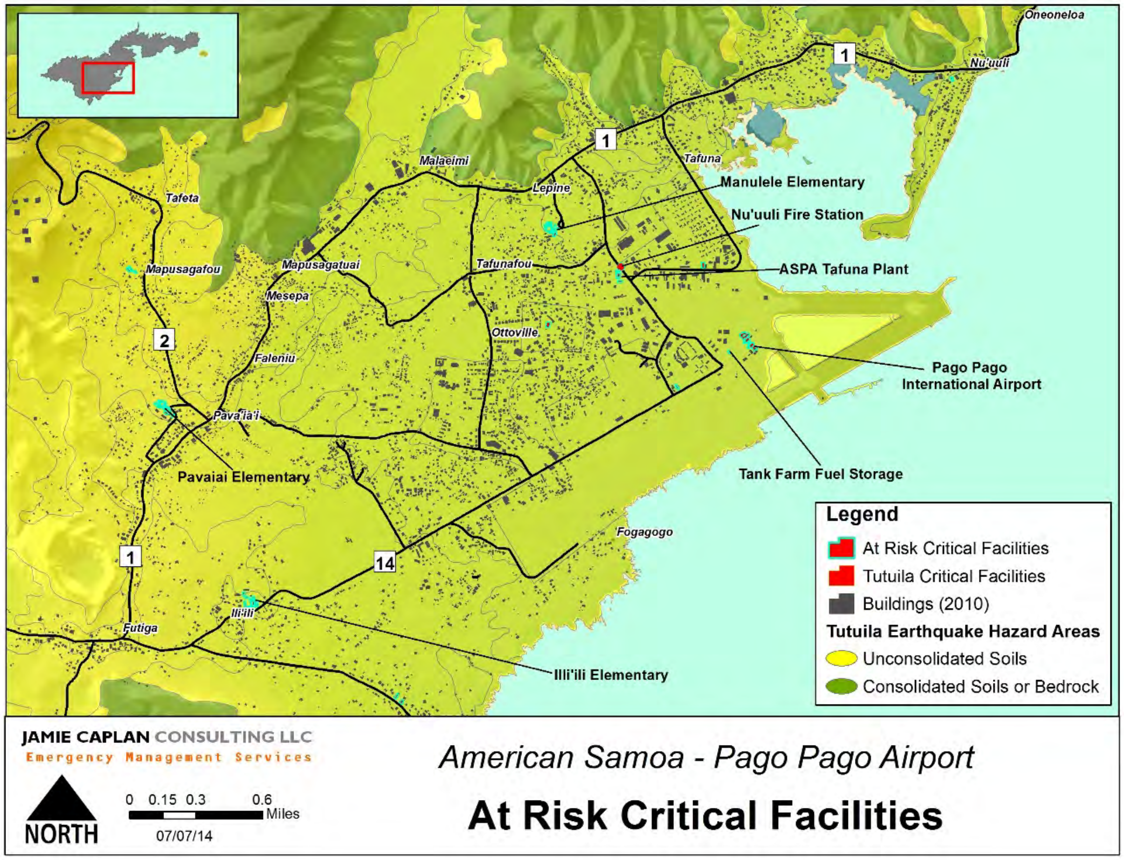


Figure 34: Critical Facilities Potentially at Risk to Earthquake (Tafuna Plain/Pago Pago Airport Area)

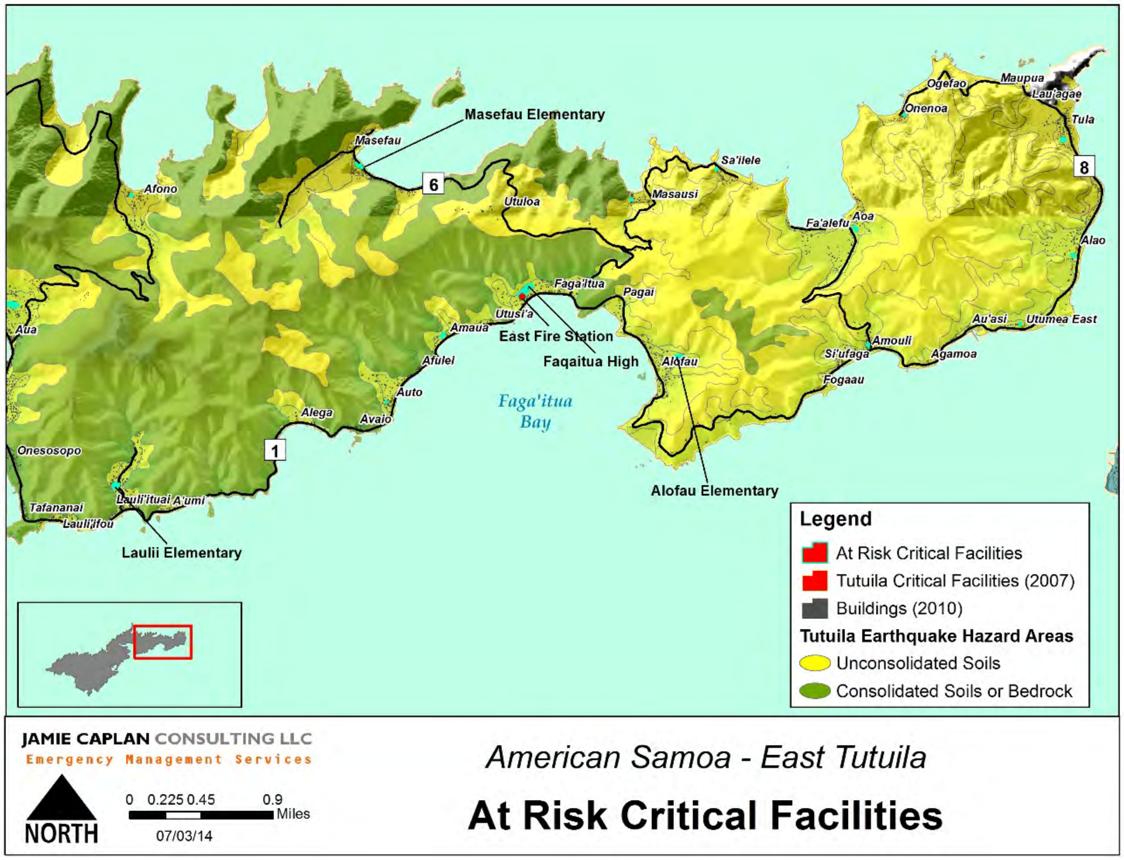


Figure 35: Critical Facilities Potentially at Risk to Earthquake (East Tutuila)

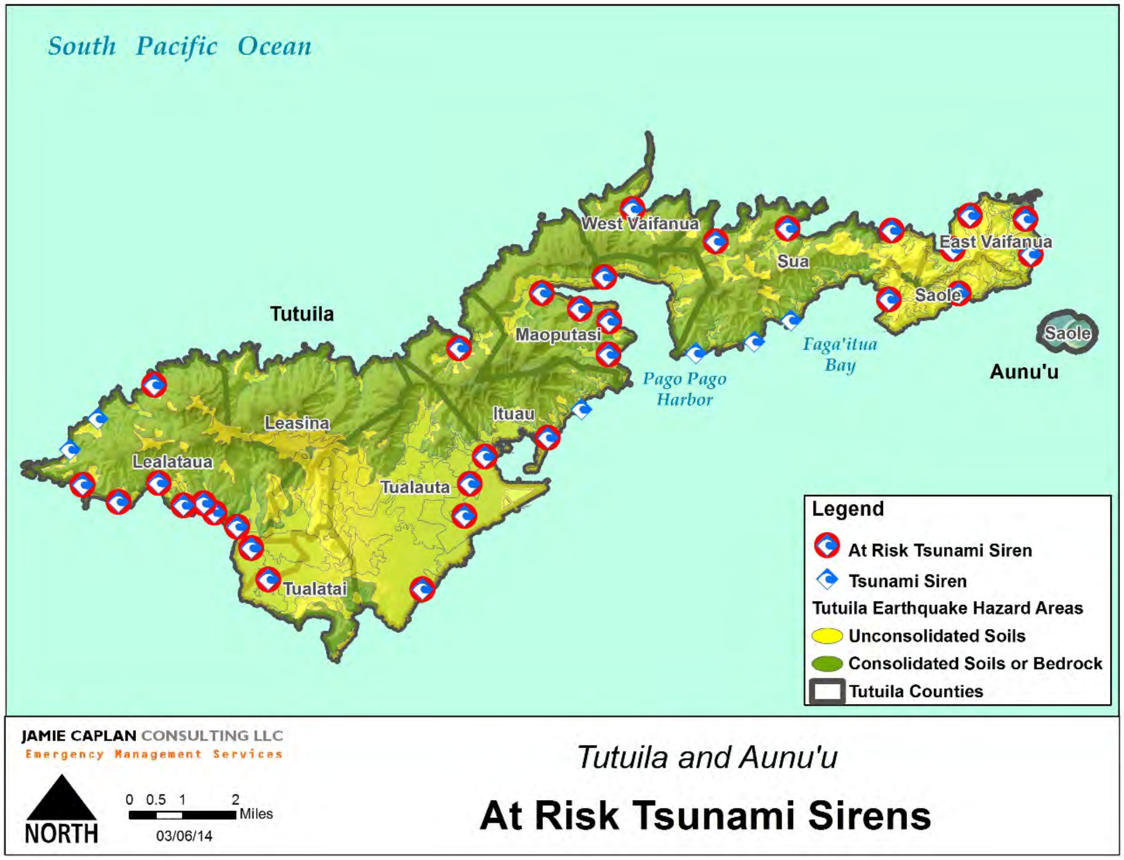


Figure 36: Tsunami Sirens in Unconsolidated Soil Areas (sirens at risk)

4.5 Extreme Heat

4.5.1 Description

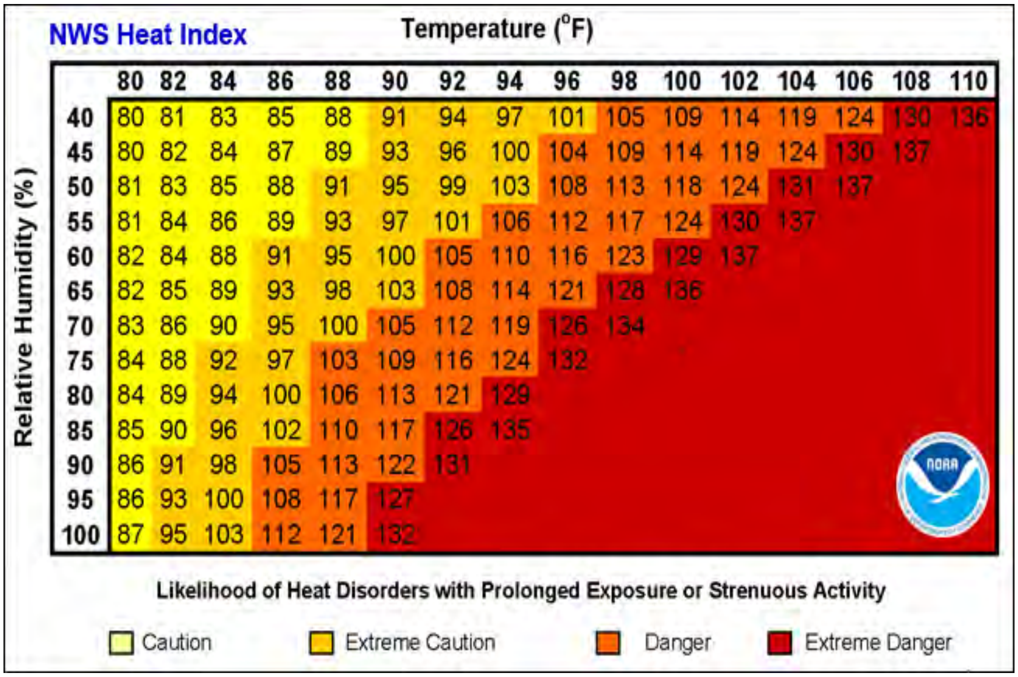
Extreme heat is generally defined as temperatures that hover 10° or more above the average high temperature for the region and last for an extended period. A heat wave may occur when temperatures hover 10° or more above the average high temperature for the region and last for an extended period. The actual temperature threshold depends on norms for the region.[64]

Extreme heat events are usually a result of both high temperatures and high relative humidity. (Relative humidity refers to the amount of moisture in the air.) The higher the relative humidity or the more moisture in the air, the less likely that evaporation will take place. This becomes significant when high relative humidity is coupled with soaring temperatures. On hot days, the human body relies on the evaporation of perspiration or sweat to cool and regulate the body’s internal temperature. Sweating

[64] University of Washington Emergency Management (2017). *Extreme heat*. Retrieved from https://www.washington.edu/uwem/preparedness/know-your-hazards/extreme-heat/

does nothing to cool the body unless the water is removed by evaporation. When the relative humidity is high, then the evaporation process is hindered, robbing the body of its ability to cool itself.

NOAA's NWS devised the Heat Index as a mechanism to better inform the public of heat dangers. The Heat Index Chart, shown in Figure 30, uses air temperature and humidity to determine the heat index or apparent temperature.[65] In addition, information regarding the health dangers by temperature range is presented.



RH (%)	80	82	84	86	88	90	92	94	96	98	100	102	104	106	108	110
40	80	81	83	85	88	91	94	97	101	105	109	114	119	124	130	136
45	80	82	84	87	89	93	96	100	104	109	114	119	124	130	137	
50	81	83	85	88	91	95	99	103	108	113	118	124	131	137		
55	81	84	86	89	93	97	101	106	112	117	124	130	137			
60	82	84	88	91	95	100	105	110	116	123	129	137				
65	82	85	89	93	98	103	108	114	121	128	136					
70	83	86	90	95	100	105	112	119	126	134						
75	84	88	92	97	103	109	116	124	132							
80	84	89	94	100	106	113	121	129								
85	85	90	96	102	110	117	126	135								
90	86	91	98	105	113	122	131									
95	86	93	100	108	117	127										
100	87	95	103	112	121	132										

Extreme Danger	Heat stroke or sunstroke highly likely
Danger	Sunstroke, muscle cramps, and/or heat exhaustion likely
Extreme Caution	Sunstroke, muscle cramps, and/or heat exhaustion possible
Caution	Fatigue possible

Figure 37: NWS Heat Index Chart

Some populations, such as the elderly and young, are more susceptible to heat danger than other segments of the population.

Heat Disorders

Heat disorders are illnesses caused by prolonged exposure to hot temperatures and are characterized by the body's inability to shed excess heat. These disorders develop when the heat gain exceeds the level the body can remove or if the body cannot compensate for fluids and salt lost through perspiration. In either case, the body loses its ability to regulate its internal temperature. All heat disorders share one common feature: the individual has been overexposed to heat, or over exercised for their age and physical condition on a hot day. The following describes the symptoms associated with the different heat disorders.

[65] NOAA (n.d.). *NWS Heat Index*. Retrieved from https://www.weather.gov/safety/heat-index

Sunburn

Sunburn is characterized by redness and pain of skin exposed too long to the sun without proper protection. In severe cases it can cause swelling, blisters, fever, and headaches. It can significantly retard the skin's ability to shed excess heat.

Heat Cramps

Heat cramps are characterized by heavy sweating and painful spasms, usually in the muscles of the legs and possibly the abdomen. The loss of fluid through perspiration leaves the body dehydrated resulting in muscle cramps. This is usually the first sign that the body is experiencing trouble dealing with heat.

Heat Exhaustion

Heat exhaustion is characterized by heavy sweating, weakness, nausea, exhaustion, dizziness, and faintness. Breathing may become rapid and shallow and the pulse weak. The skin may appear cool, moist, and pale. Blood flow to the skin increases, causing blood flow to decrease to the vital organs. This results in a mild form of shock. If not treated, the victim's condition will worsen.

Heat Stroke (Sunstroke)

Heat stroke is a life-threatening condition characterized by a high body temperature (106°F or higher). The skin appears to be dry and flushed with very little perspiration present. The individual may become mentally confused and aggressive. The pulse is rapid and strong. There is a possibility that the individual will faint or slip into unconsciousness. If the body is not cooled quickly, then brain damage and death may result.

Studies indicate that, all things being equal, the severity of heat disorders tend to increase with age. Heat cramps in a 17-year-old, heat exhaustion in someone 40, and heat stroke in a person over 60. Elderly persons, small children, chronic invalids, those on certain medications and persons with weight or alcohol problems are particularly susceptible to heat reactions.

4.5.2 Location

The entirety of American Samoa is considered at risk to extreme heat events.

4.5.3 Previous Occurrences

In order to understand extremes, monthly averages are reviewed. As shown in Figure 38 below, March is typically the warmest month, and temperatures stay consistent year-round given American Samoa's equatorial location.[66] High temperatures rarely deviate above the mid-to-upper 80s degrees Fahrenheit (*°F)* for high temperatures and mid-to-upper 70s for low temperatures.

[66] Weather Atlas (2020). Retrieved from https://www.weather-us.com/en/american-samoa-usa/pago-pago-climate#temperature

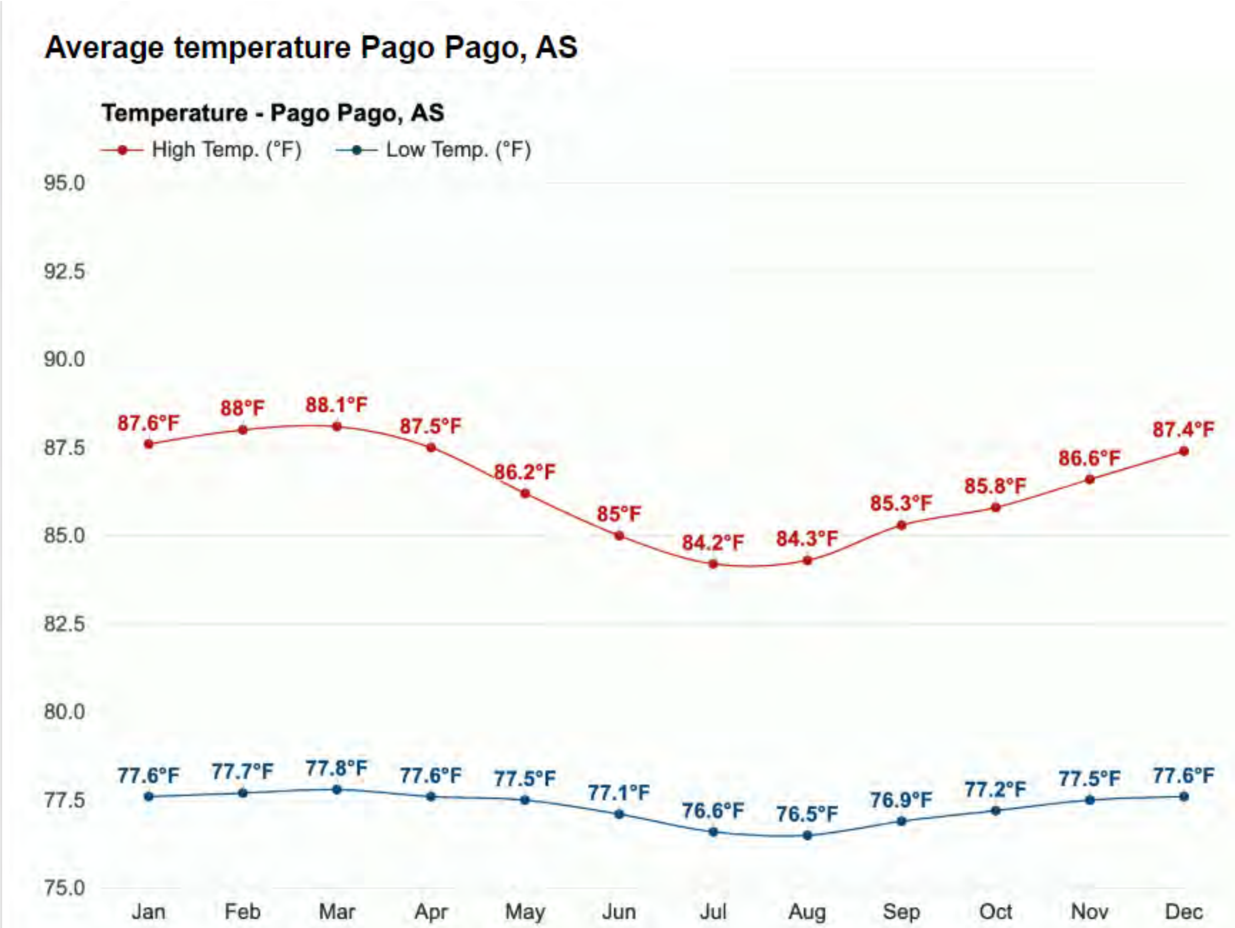


Figure 38: Monthly Temperature Averages (Weather Atlas)

Limited information on previous extreme heat and heat wave events in American Samoa were located. However, the Territory experienced two days of record heat on March 9th and March 10th, 2020. The temperatures were 92°F.[67] Another record was broken on May 10, 2020 with an 89°F temperature.

4.5.4 Extent

Malaeloa / Aitulagi recorded the highest temperature in American Samoa of 99°F on April 27, 1972.[68]

4.5.5 Probability of Future Events

While American Samoa's equatorial location has generally moderated temperature year-round, climate change impacts may be leading to increased extreme heat conditions as described below in Section *4.5.6.1 Climate Change Considerations*. The following conclusions were drawn when considering future extreme heat events:

[67] Record High Temp for American Samoa. *Samoa News.* (2020, March 3). Retrieved from https://www.samoanews.com/local-news/record-high-temp-american-samoa-two-days-row
[68] Weather Atlas (2020). Monthly weather forecast and climate American Samoa, USA. Retrieved from https://www.weather-us.com/en/american-samoa-usa-climate

- Location: The entire Territory will continue to be impacted by heat events. Areas of higher elevation, typically less subject to extreme heat, will experience extreme heat more frequently.
- Extent/Intensity: The severity of this hazard is projected to increase in alignment with rising greenhouse gas conditions, which will lead to more record heat and heat waves.
- Frequency/Duration: American Samoa is expected to experience more frequent extreme heat conditions. Specific Information on duration was not located but will updated as information becomes available.

With consideration to recent record-breaking occurrences, limited historical data, and potential future events, a probability of "possible," (between 1% and 10% annually) was assigned based on known information and trends.

4.5.6 Vulnerability

As the extreme heat hazard is atmospheric and does not have a geographic boundary, all current and future populations and structures, including critical facilities and cultural sites, are considered at risk. Extreme heat events generally have limited impact on buildings. However, in some rare cases extreme heat can cause structures to collapse or buckle. Power consumption for air conditioning can increase during heat events, causing blackouts or brownouts. Loss of power during an extreme heat event can necessitate evacuations and rescues, cause schools to close, and impact tourism. Aside from the potential for damages, there are serious health risks to the population due to heat.

Vulnerable populations, such as the elderly, young children, mentally ill, disabled, or homeless persons are at greatest risk to the impacts of extreme heat. Another population vulnerable to extreme heat events includes outdoor laborers. In addition, families or individuals living in housing without air conditioning or proper ventilation are at higher risk during heat events.

Higher temperatures also increase evaporation, reducing water supply and increasing water demand. This can put economic strains on low income or fixed income households, in addition to straining water utilities.

The environment, too, suffers from increased temperature such as changes in flora and fauna, rising sea temperatures which can bleach coral reefs, and poor air quality.

4.5.6.1 Climate Change Considerations

Sources agree that temperatures are rising and will continue to rise as a result of climate change in American Samoa. However, the magnitude of temperature rises varies across sources.
According to EcoAdapt, between 1950 and 2009, each decade:[69]

- Average annual temperatures increased +0.25°F (+0.14°C)

[69] EcoAdapt (2016). American Samoa Chliamte Change Trends and Projections. Retrieved from http://ecoadapt.org/data/documents/AmericanSamoaClimateChangeTrendsandProjections7-5.pdf

- Average maximum air temperatures increased +0.4°F (+0.22°C)
- Average minimum air temperatures increased +0.07°F (+0.04°C)

Further, based on low/high emissions scenarios, temperatures are projected to increase (compared to 1971-2000) by 2030:

- +1.1-1.3°F (+0.61- 0.72°C) > By 2050:
- +1.9-2.5°F (+1.06- 1.39°C) > By 2090:
- +2.5-4.8°F (+1.39- 2.67°C)

This is anticipated to lead to more extreme heat days in the future.

4.5.6.2 Potential Losses

Dollar losses due to extreme heat events are difficult to quantify as most are indirect impacts, thus a specific dollar value has not been quantified. Potential losses include lost work and productivity due to illness or unfavorable working conditions and lost Territorial gross domestic product (GDP) as residents stay indoors rather than patronizing businesses.

4.6 Flood

4.6.1 Description

Flooding is a very frequent, dangerous and costly hazard. It is the most common disaster, accounting for 40% of all natural disasters. Globally, flooding results in an average of over 6,500 deaths annually.[70] In the U.S., flooding resulted in an average of 89 deaths annually over the last 30 years.[71] Nearly 90% of all presidential disaster declarations result from natural events where flooding was a major component. This holds in American Samoa where 12 out of 14 disaster declarations (86%) are assumed to have flood impacts (Table 11, page 53). 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.

The severity of a flooding event is typically determined by a combination of several 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. Flooding events can be brought on by severe (heavy) rain, which is a frequent occurrence in American Samoa, tropical storms, or tsunamis. There are several types of flooding which are possible in American Samoa:

Flash Flooding

[70] Prevention Web (1980-2008). Retrieved from http://www.preventionweb.net/english/hazards/statistics/?hid=62

[71] NOAA (n.d.). Weather Related Fatality and Injury Statistics. Retrieved from http://www.nws.noaa.gov/om/hazstats/resources/weather_fatalities.pdf

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, intense rain events often, 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. Notably, sea level rise, an increased by of coastal flood, is addressed in a separate hazard profile given the severity.

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. Flood frequencies such as the 100-year flood (or 1.0% annual chance 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% chance of occurring in any given year, and the 500-year flood decreases to a 0.2% chance of occurring in any given year. Therefore, they are commonly referred to as the 1.0% annual chance flood and 0.2% annual flood, respectively. It should be noted that flooding is possible every year and even multiple times each year. Further, flooding can occur outside of these boundaries.

The USACE and FEMA have a role in defining floodplain. The USACE 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.[72] FEMA develops FIRMs to indicate areas where mandatory flood insurance requirements apply within the 100-year flood zone, and to demonstrate other areas of flood risk, such as the 500-year flood. They are also used for planning purposes to identify hazard areas. In May 1991, FIRMs were published by FEMA for American Samoa in support of the National Flood Insurance Program (NFIP) designating zones according to potential risk and impact due to flooding. The FIRM, a paper document, has been digitized to permit mapping. The most recent Flood Insurance Study (FIS) reports and FIRM panels are July 2006. Although

[72] North Carolina Division of Emergency Management. *Flooding.* Online. Available: http://www.dem.dcc.state.nc.us/mitigation/flood.htm [June 2003].

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 FIS 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

Zones AE and A1-A30 are the flood insurance rate zones that correspond to the 100-year floodplains determined in the FIS 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 flooded historically should not be considered immune from such an event.

4.6.2 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 FIS can be used to determine the location of floods.[73]

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 (Figure 39 to Figure 46) 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 39).
- Pago Pago (Figure 40): 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 41): 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 42): 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 43): 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 44): 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.

[73] The American Samoa FIS is dated as revised July 17, 2006.

- Olosega (Figure 45): 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 46): 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 below.

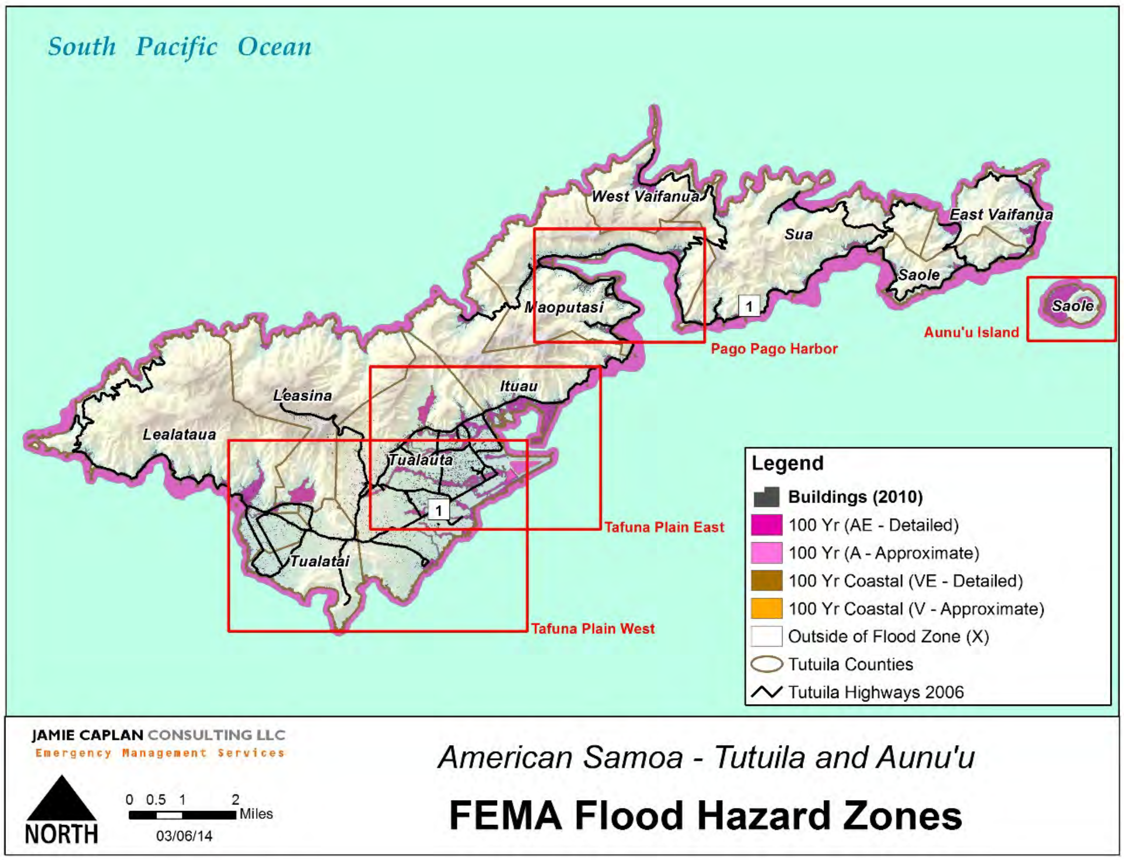


Figure 39: FEMA Flood Hazard Areas for Tutuila and Aunu'u Island

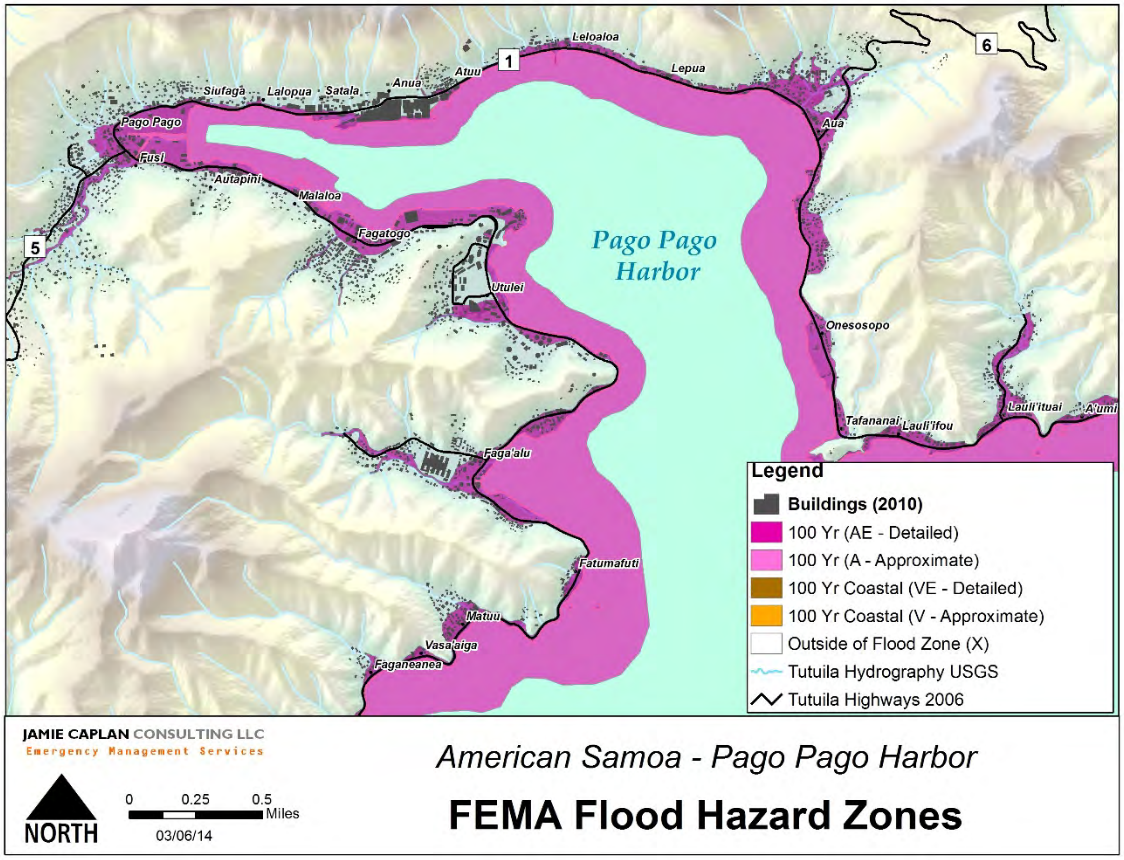


Figure 40: FEMA Flood Hazard Areas for greater Pago Pago

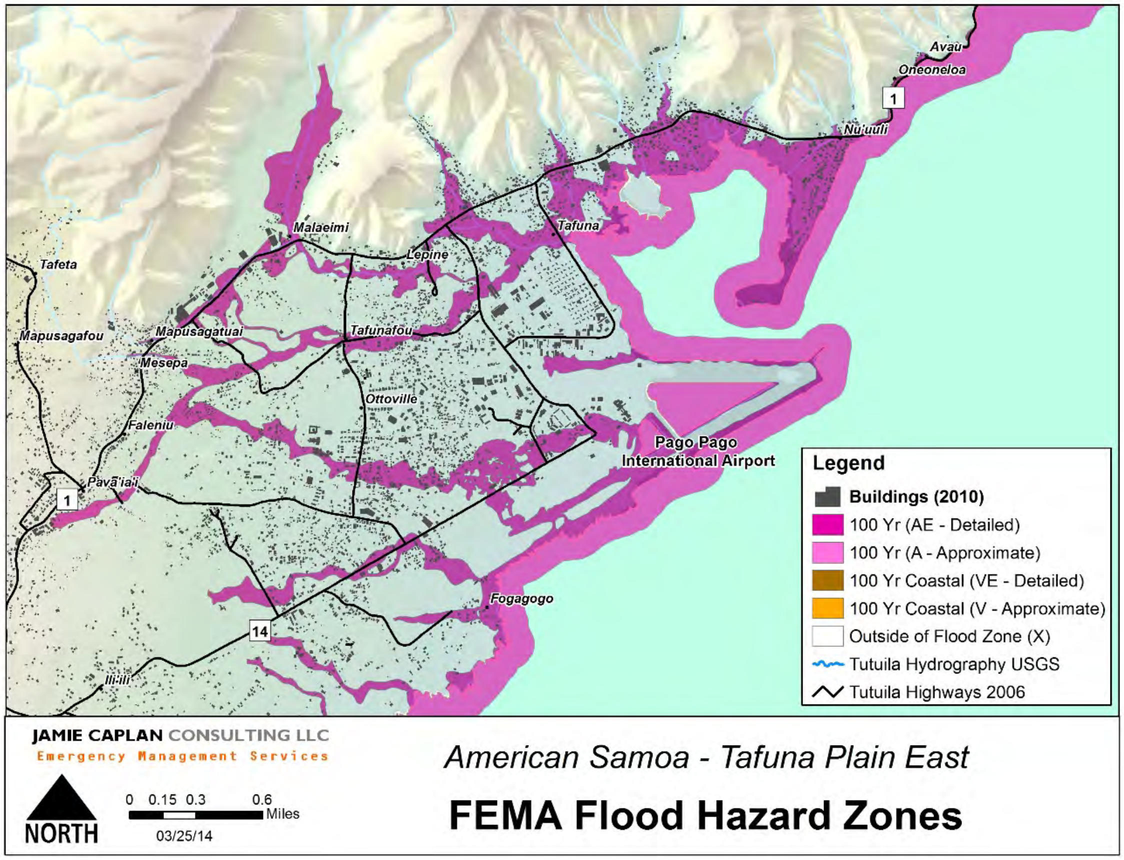


Figure 41: FEMA Flood Hazard Areas for Tafuna Plain East

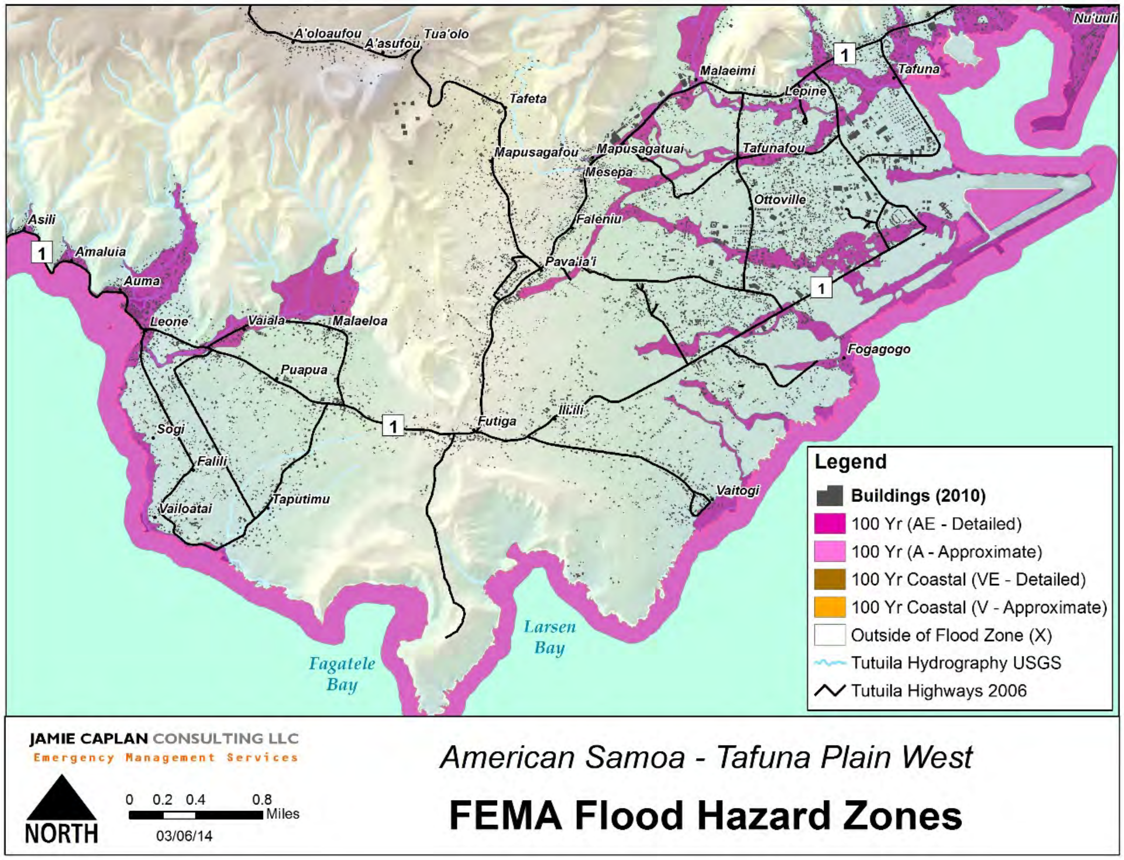


Figure 42: FEMA Flood Hazard Areas for Tafuna Plain West

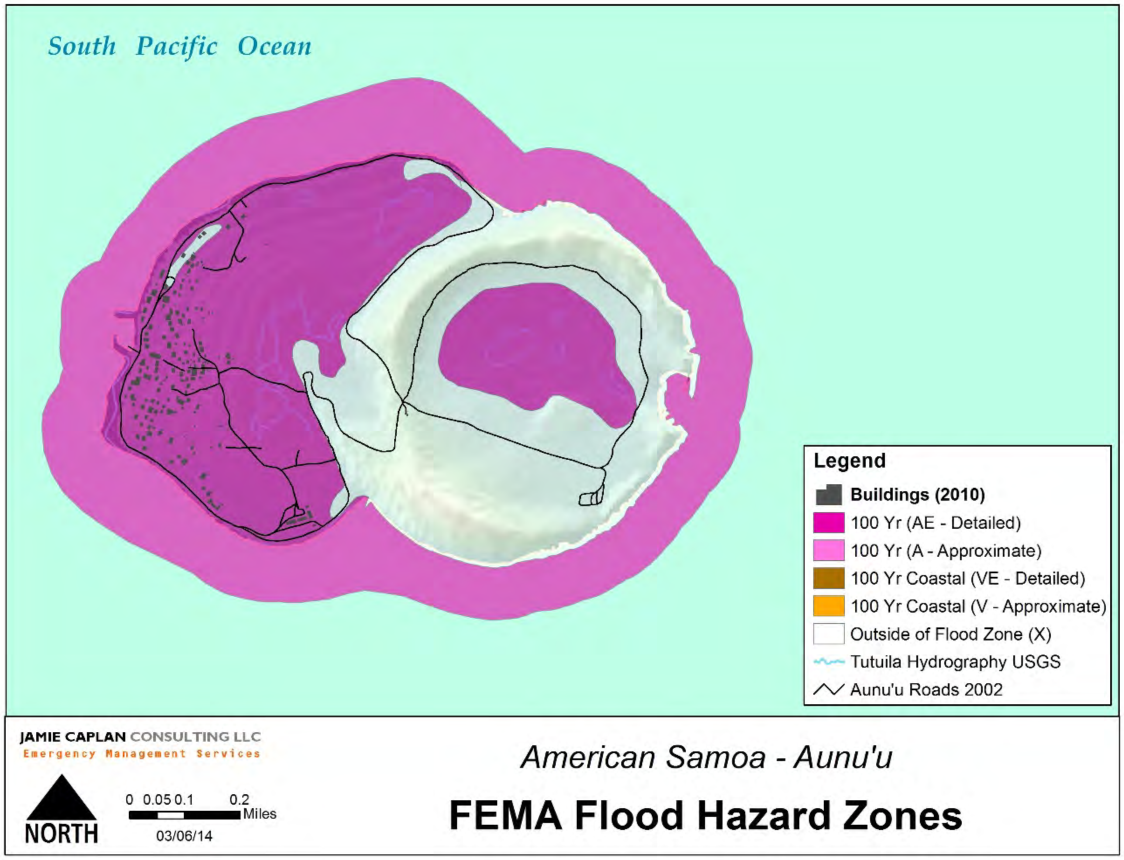


Figure 43: FEMA Flood Hazard Areas for Aunu'u

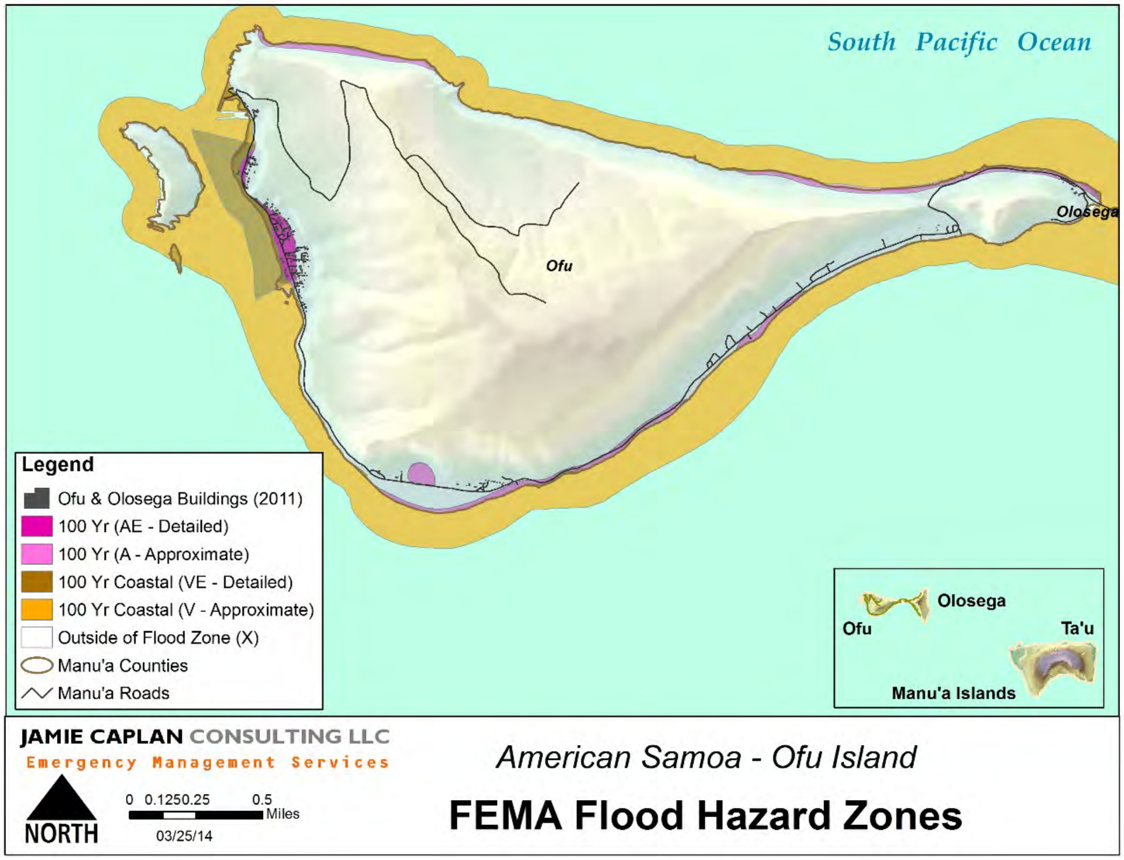


Figure 44: FEMA Flood Hazard Areas for Ofu

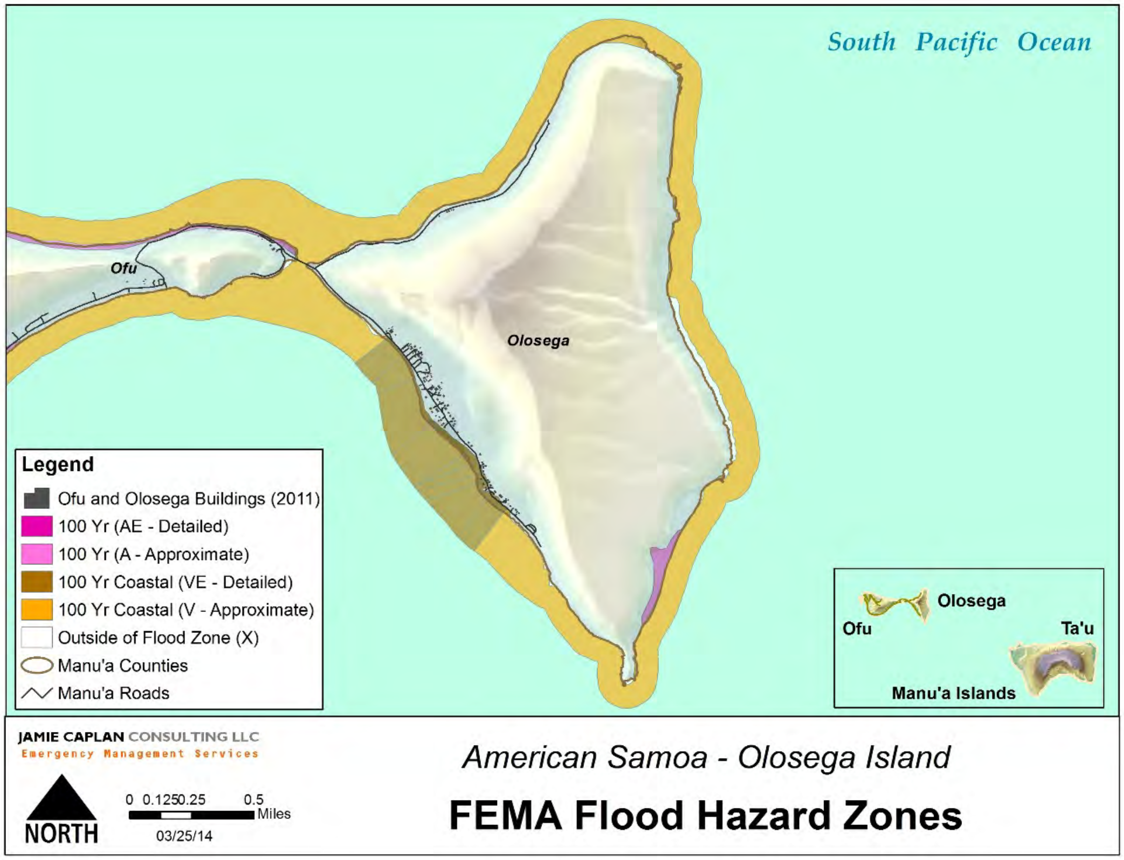


Figure 45: FEMA Flood Hazard Areas for Olosega

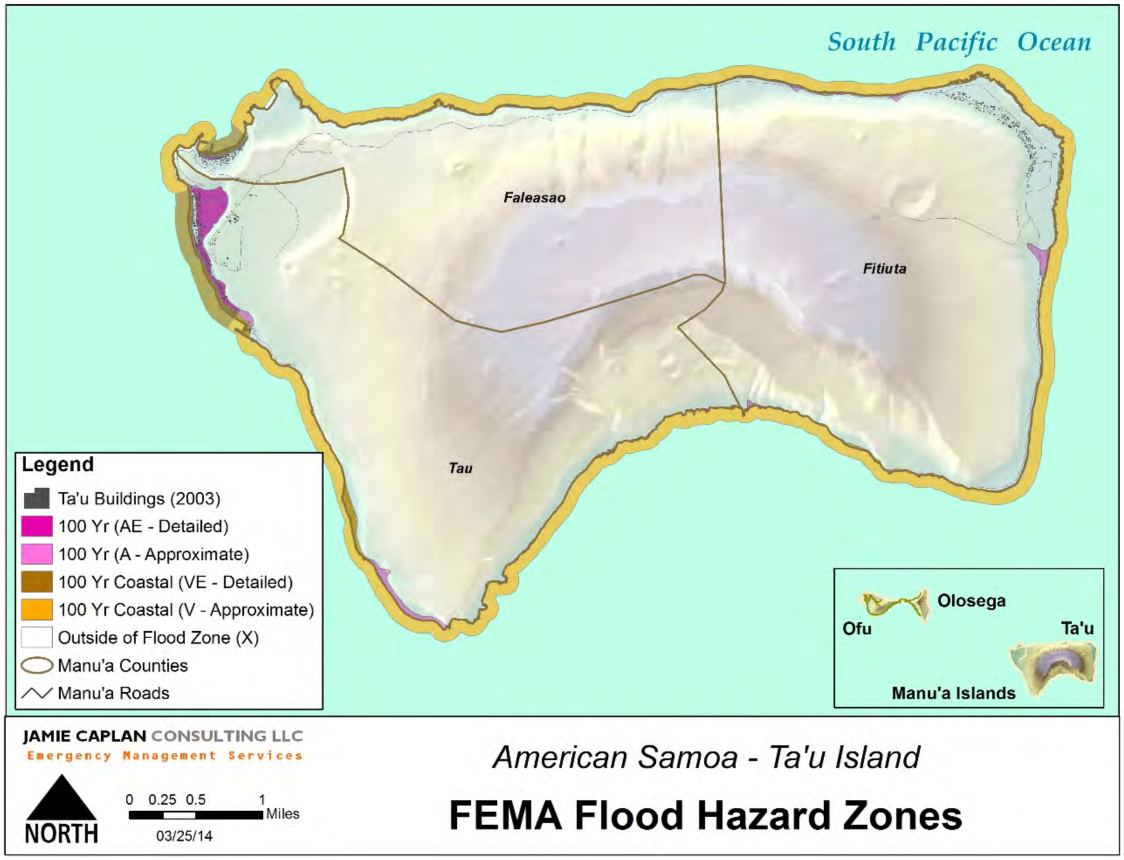


Figure 46: FEMA Flood Hazard Areas for Ta'u

Table 28: Amount of Floodplain by County in American Samoa

County	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 (East District)	9.22	0.41	0
Leasina (East 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

County	Size of County (Sq. Mi.)	Size of A, AE Floodplain (Sq. Mi.)	Size of V, VE Floodplain (Sq. Mi.)
Tualata (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 (Table 28), 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.

4.6.3 Previous Occurrences

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, tsunamis, and La Niña cycles. More recently climate change impacts are also impacting rainfall. 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.

Previous occurrences were collected from NOAA's Storm Event's Database (1994-2020) and additional sources (web research, previous American Samoa Hazard Mitigation Plans). A total of 17 flood events in the Manu'a Islands (7 flood, 7 flash flood, 3 heavy rain) and 105 flood events in Tutuila (39 flood, 50 flash flood, 16 heavy rain). These events resulted in over $63.5 million in damages reported in Tutuila (including a $50 million flood event with associated landslide damage and $8 million associated Tropical Cyclone Tuni). One death was reported due to flooding, and five deaths resulted due to landslides associated with flooding. A listing of previous occurrences can be found in Appendix C.

Disaster Declarations Due to Flood

Eleven federal disaster declarations potentially had flood impacts including all declarations from tropical storms and hurricanes. The following declarations specifically list flood as a hazard. Related declarations such as tropical storms are shown in their respective profiles.

November 9, 1979: Flooding, Mudslides, Landslides (DR-610)
Unfortunately, little information could be found on this event. It was the second declaration made in American Samoa and the first due to flooding.

May 19-21, 2003: Heavy Rainfall, Flooding, Landslides, and Mudslides (DR- 1473)
FEMA Disaster #1473. 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. FEMA declared American Samoa a disaster area on June 6, 2003. Estimated FEMA assistance is $1.5 million for public building and nearly $9.6 million for individuals. NOAA's National Climatic Data Center estimated over $50 million (2003 dollars) in total damages.

The declaration covers damage to private and public property from heavy rains, flooding, and mud and landslides that occurred between May 19-21.

After the declaration, FEMA designated the island of Tutuila eligible for federal aid to stricken residents that can include grants to help pay for temporary housing, home repairs and other serious disaster-related expenses. Low-interest loans from the U.S. Small Business Administration were also available to cover residential and business losses not fully compensated by insurance.

In addition, FEMA said federal funds would be provided for the territory and affected local governments on the island of Tutuila to pay 75% of the approved costs for debris removal, emergency services related to the disaster, and the restoration of damaged public facilities.

Under the declaration, cost-shared funding will be available to the territorial government for approved projects that reduce future disaster risks, FEMA said. President Bush indicated that additional areas may be designated for aid later if requested by the Territory and warranted by the results of further damage assessments.

Over 1,300 residents have registered for disaster assistance since President Bush declared the disaster. Almost 1,900 residents have visited the Disaster Recovery Center (DRC) located at the Lee Auditorium. The rain and mudslides claimed four lives and left several other people severely injured.

September 29-October 6, 2009: Earthquake, Tsunami, and Flooding (DR- 1859)

NOTE: This event is also related to the 2009 Tsunami and will be detailed further in the tsunami profile section.

A series of waves from the tsunami disabled the local power plants; destroyed 248 homes and 28 rental units; and damaged another 2,750 dwellings. One school was destroyed and another four suffered substantial damage (over 50% destroyed). Roads, bridges, churches, and everything in the waves' paths were damaged to varying degrees. The small island and its 65,000 residents were left to rebuild their property and their lives.[74] Over $140 million in relief and rebuilding money was provided by FEMA and other federal agencies.

July 29-August 3, 2014: Severe Storms, Flooding and Landslides (DR- 4192)[75]

This event brought heavy rain, winds, flooding and landslides to the area. High surf of 14 to 16 feet impacted south facing shores and wind gusts of 50 miles per hour were reported. July was a particularly wet month for the territory. Typically, it receives around 6 inches of rain but received over 18 inches in 2014, making it the second wettest July on record. Given the inundation of rain, the terrain was saturated making it highly susceptible to landslides.

Damage across Tutuila was extensive. Governor Lolo Matalasi Moliga requested (and was granted) a disaster declaration due to these events. In his letter, the governor said the flooding, associated runoff and resulting landslides produced serious and extensive damage to both public and private property,

[74] http://www.fema.gov/news-release/2010/03/17/disaster-assistance-american-samoa-tops-33-million
[75] http://www.samoanews.com/content/en/lolo-asks-presidential-disaster-declaration-over-flooding-and-landslides

and directly caused injuries and one death. The fatality occurred in Fagaalu Bay, when a female high school student was swept out to sea while swimming in the heavy rains.

The weather events left many residents homeless. Dozens of people were required to evacuate to temporary shelters, and over 100 homes were destroyed. Three shelters were opened at Samoana High School, CCCAS Gataivai and the Catholic Hall, which accommodated over 100 displaced residents. Those housed at the two shelters are residents of both Utulei and Gataivai, where a landslide destroyed at least three homes and damaged the church.

Several government departments were also impacted by flooding including Territorial Registrar's office, the Department of Education, the E-Rate Office, and the Department of Public Safety. The Territorial Registrar saw water seep into the building and ordered staff to clear out cabinets to avoid damage to records. The building sustained nearly 2 feet of water, but no records were impacted. The roof of the old Veteran's Affairs building was also partially torn off by strong winds. In addition to structural damage, several banana trees were blown down. This was of particular concern as the bananas were near mature stage for picking and slated to be sold to schools. The photo below demonstrates some of the severe flooding experienced around the island.

Photo 1: 2014 Flooding[76]

4.6.4 Extent

Extent can be measured by reviewing the mapped hazard areas and previous occurrences. The FEMA DFIRMs indicate areas of the 1.0% (100-year) annual chance flood areas. In addition, more severe floods, such as the 0.2% (500-year) annual chance flood or greater, urban/flash flooding, and sea level rise impacts, are possible in the planning area. In these cases, additional land will be submerged, and higher

[76] FijiTV. Retrieved from http://fijione.tv/disaster-declaration-for-american-samoa/

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 events 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.

4.6.5 Probability of Future Events

The probability of flooding was largely determined using the number of historical occurrences and consideration of future events. Flooding is a regular occurrence, and the Territory is expected to become wetter overall due to climate change (Section 4.6.7.1). Extreme rain events (greater intensity) are also expected to increase which could result in more extreme flooding. In general, areas subject to flooding are expected to increase in both coastal and inland areas, and the extent, intensity and frequency are also expected to rise.

El Niño years tend to be drier but are often marked by intense rainfall events, which may cause localized flooding. Increased probability of flooding can be expected in La Niña phase of ENSO as these tend to be wetter, rainier months. Rainfall due to climate change is also expected to increase over the next century in the Territory.

The probability of flooding with the arrival of any tropical cyclone system is also likely. As previously mentioned, slow-moving storms with high moisture can wreak havoc on the islands, even with lower wind speeds, due to flooding impacts. While weak tropical storms are projected to decrease, more intense tropical storms are projected to increase, which can lead to more intense rainfall and more severe flooding.

FEMA Digital Flood Insurance Rate Maps (DFIRMs) provide a method to account for a statistical probability. It can be assumed that areas located in the base flood area on the DFIRMs have a one-percent annual chance of flood occurrence. This area is likely increasing in area and depth and future FEMA flood studies will be included in this plan as they become available. However, flooding can occur outside of these areas and often does in American Samoa with heavy rain and tropical cyclone events. Historic events are also investigated to better a more definitive estimate of probability.

According to NOAA's Storm Events Database, there were 105 flood events reported in Tutuila and 17 flood events reported in the Manu'a Islands since 1994, a 26-year reporting period. Many events have likely gone unreported. Based on these events, there is 100% annual probability of a flood event in Tutuila (highly likely) and a 65% annual probability (likely) of a flood event in Manu'a.
With consideration to past event and potential future events, a probability of highly likely (90% or greater) was assigned for the flood hazard.

4.6.6 National Flood Insurance Program Participation

American Samoa participates in the NFIP. There are two repetitive loss properties and no severe repetitive loss properties. Claims data from August 1970 – May 17, 2020 indicates 10 claims and three claims that were closed with pay. Total payouts were $36,086, averaging $12,029 per claim payment. There was a surge in policies following the 2009 Tsunami when there were over 460 policies. However, most have lapsed and were not renewed. There are a total of 51 policies as shown in

Table 29.

Table 29: NFIP Policies in American Samoa as of May 17, 2020

Flood Zone	Number of Policies
AE	20
A	19
VE	8
X	4
Total	51

4.6.7 Vulnerability Assessment

Flooding is an increasing issue 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 groundwater 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 may 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.

4.6.7.1 Climate Change Considerations

According to the Fourth Annual National Climatic Assessment, rainfall is projected to increase by up to 10% by mid-century compared with the present, with additional increases by the end of the century.[77] Some sources note an increase of up to 25% by the late 21st century with more frequent extreme rainfall events.[78] This is likely to increase flooding. Weaker tropical storms are expected to decrease while stronger tropical storms are expected to increase.

4.6.7.2 Potential Losses

A GIS analysis of buildings that are potentially at risk to flooding was conducted. This analysis was not updated for the 2020 plan given no new building or flood hazard data. 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 in the Territory are not elevated given older construction and local knowledge of the islands.

Tutuila has buildings at risk to flooding along a majority of the 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 for Tutuila and Aunu'u can be found on the proceeding pages starting with Figure 47 and in Table 30 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 53 below. On Ta'u, development is concentrated in the northeastern and northwestern portions of the island (Figure 54). However, only the northwestern portion has buildings at risk. This information is reinforced in the table and figures below.

Table 30 below highlights the approximate number of buildings in the A and V flood zones on Tutuila, Aunu'u and Manu'a Group islands.

[77] Fourth National Climate Assessment (2018). *U.S. Global Change Research Program*. Retrieved from https://nca2018.globalchange.gov/chapter/27/

[78] Project Explorer (2016). 21st Century High-Resolution Climate Projections for Guam and American Samoa. Retrieved from https://cascprojects.org/#/project/4f8c650ae4b0546c0c397b48/50118ddce4b0d78fd4e59ba3

Table 30: 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 in Zones
TUTUILA ISLAND						
East Vaifanua (East District)	497	298	60%	0	0%	60%
Ituau (East District)	1,075	592	55%	0	0%	55%
Lealataua (East District)	2,026	612	30%	0	0%	30%
Leasina (East District)	474	78	16%	0	0%	16%
Maoputasi (East District)	2,246	756	34%	0	0%	34%
Saole (East District)	364	356	98%	0	0%	98%
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	16,136	4,250	42%	0	0%	42%
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						
TA'U 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)	--	--	--	--	--	--
Ofu Island Total	133	40	30%	4	3%	33%

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 in Zones
OLOSEGA ISLAND	--	--	--	--	--	--
Olosega (Manu'a District)	--	--	--	--	--	--
Olosega Island Total	101	0	0%	7	7%	7%
TOTAL	17,018	4,427	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 to determine buildings in the floodplain. For the 2020 plan, eight additional critical facilities were identified as being in the floodplain. These were added to previous plan totals. 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 85 critical facilities, including the district court building, schools, fire stations, shipyard office and a museum were reported as in the A/AE floodplain in Tutuila. These structures have an approximate combined value of $320,032,311 (this value does not include new 2020 critical facilities as new values were not available). 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 31, highlights the results. Several figures also note the location of these critical facilities beginning with Figure 55.

Table 31: Number of Critical Facilities (CFs) in the Floodplain hazard Area

County (District)	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	256	87	$320,032,311	6	N/A
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 location 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 C.

ASTCA Infrastructure

- Eleven ASTCA infrastructure items were including two ASTCA stores, four cell sites, two microwaves towers, one cell tower, and two 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 C.

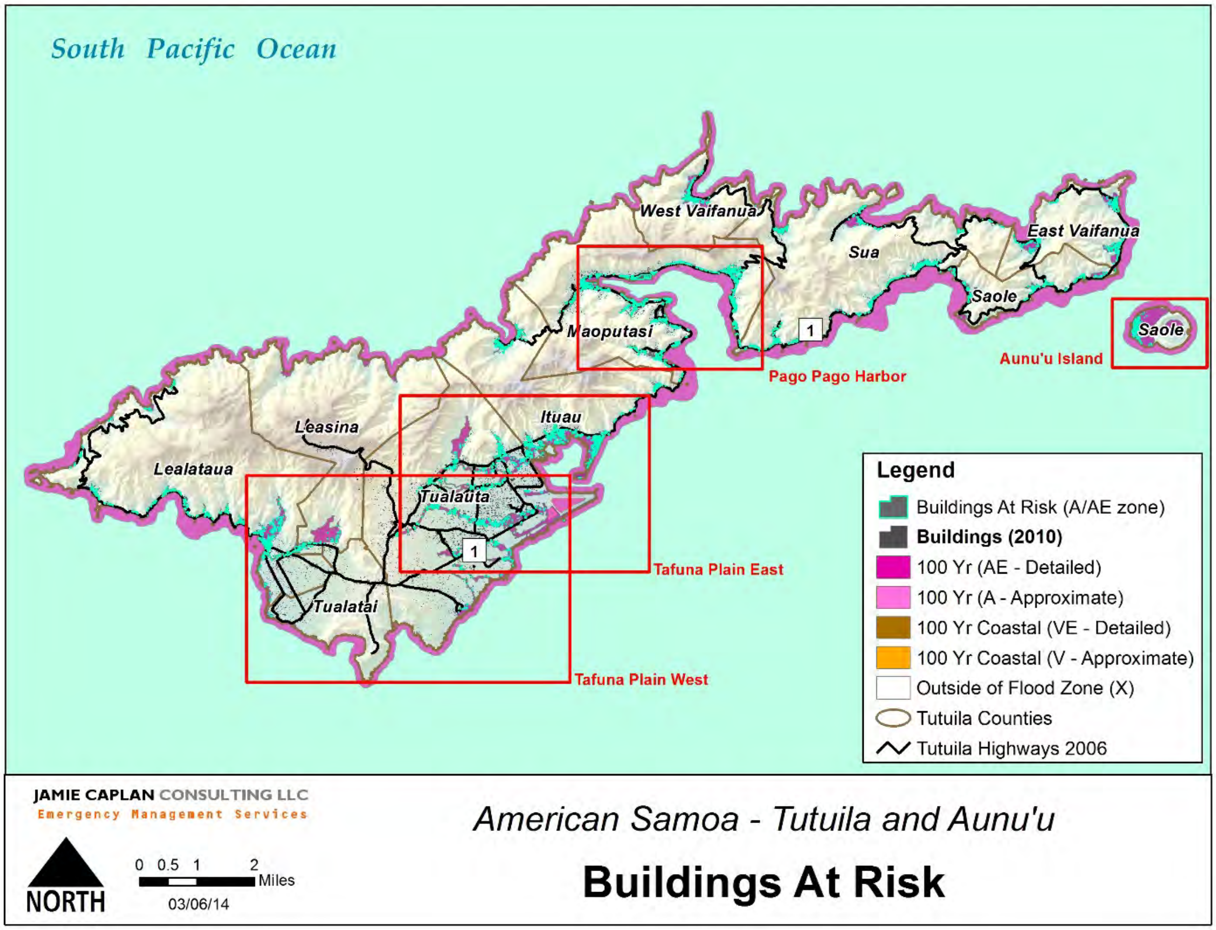


Figure 47: Buildings Potentially at Risk to Flooding on Tutuila and Aunu'u Islands

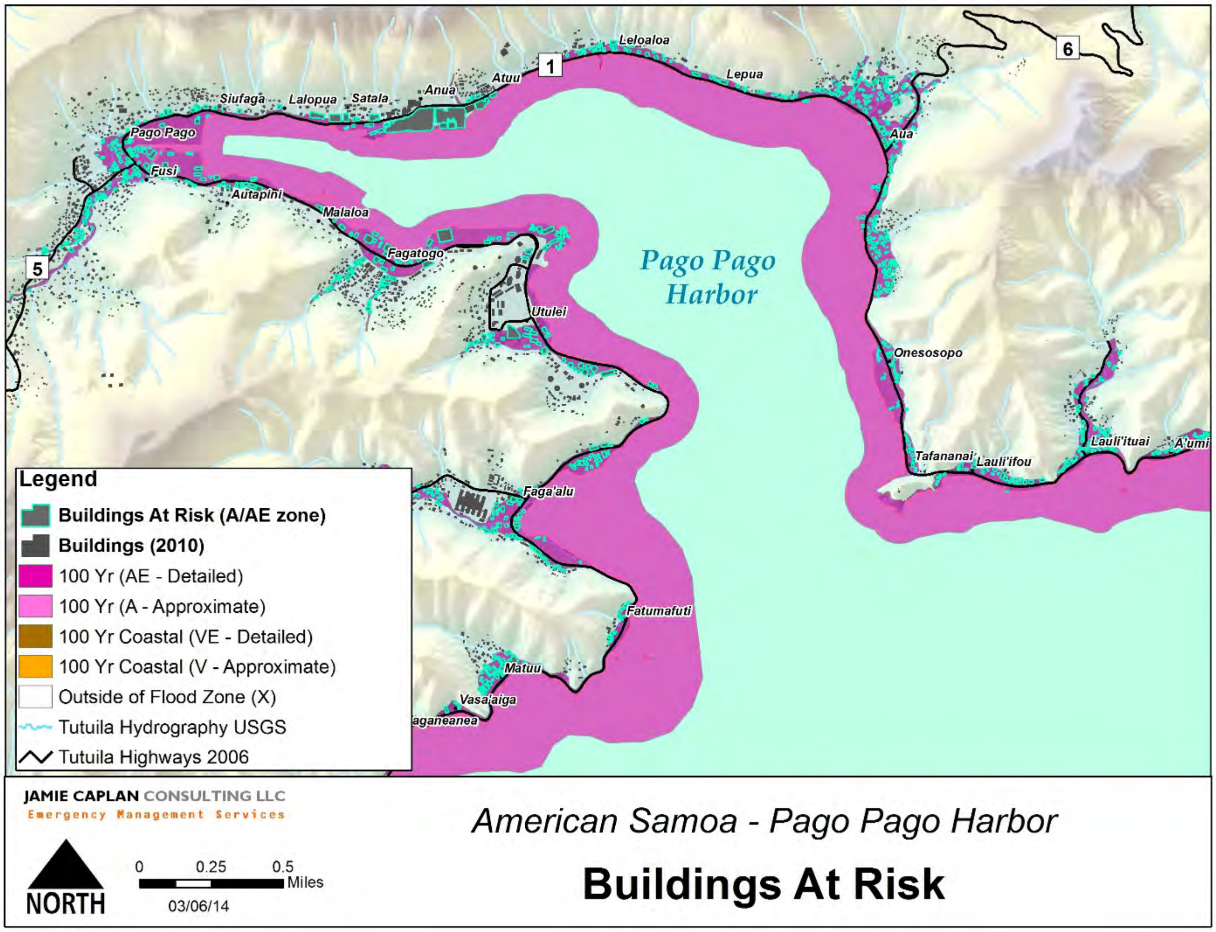


Figure 48: Buildings Potentially at Risk to Flooding in Greater Pago Pago

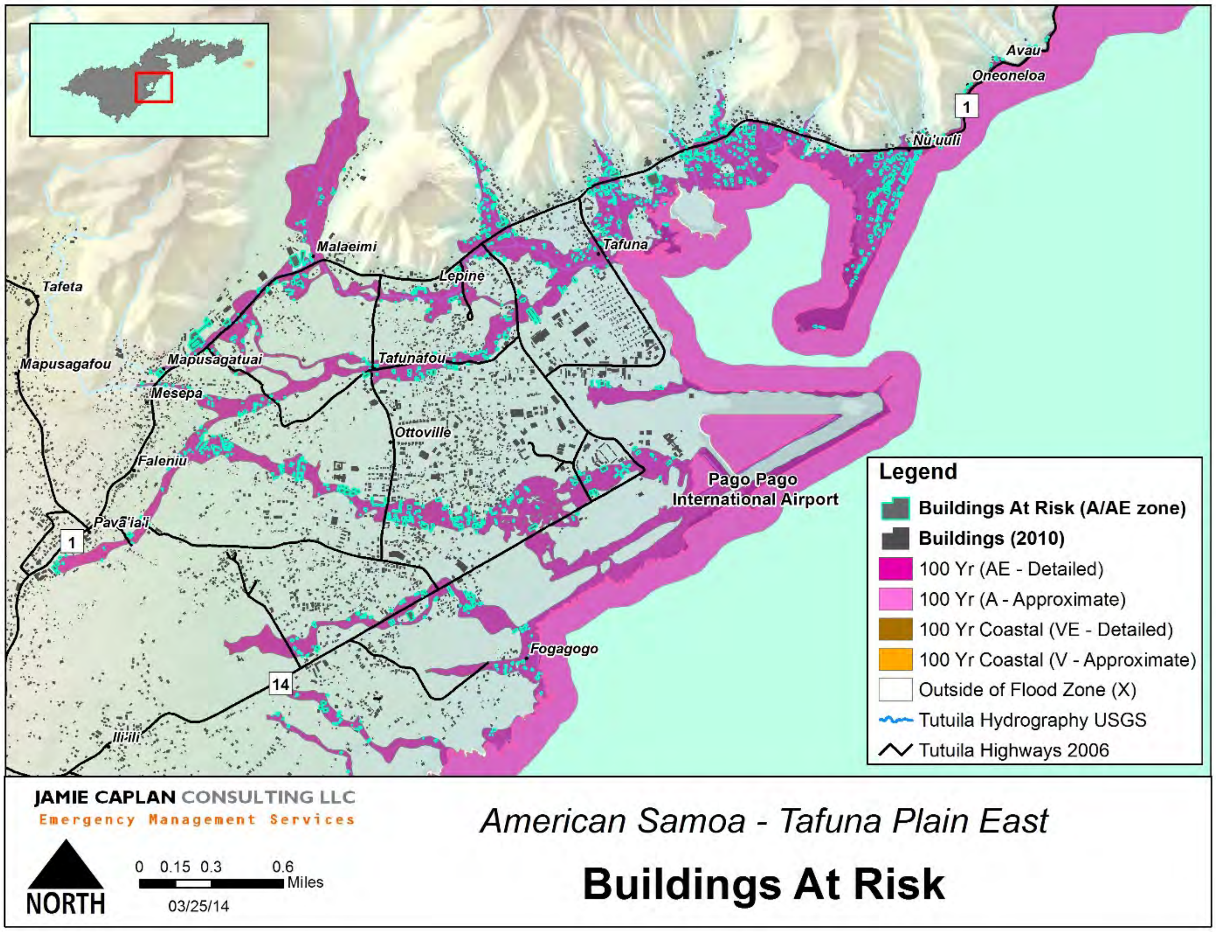


Figure 49: Buildings Potentially at Risk to Flooding in Tafuna Plain East

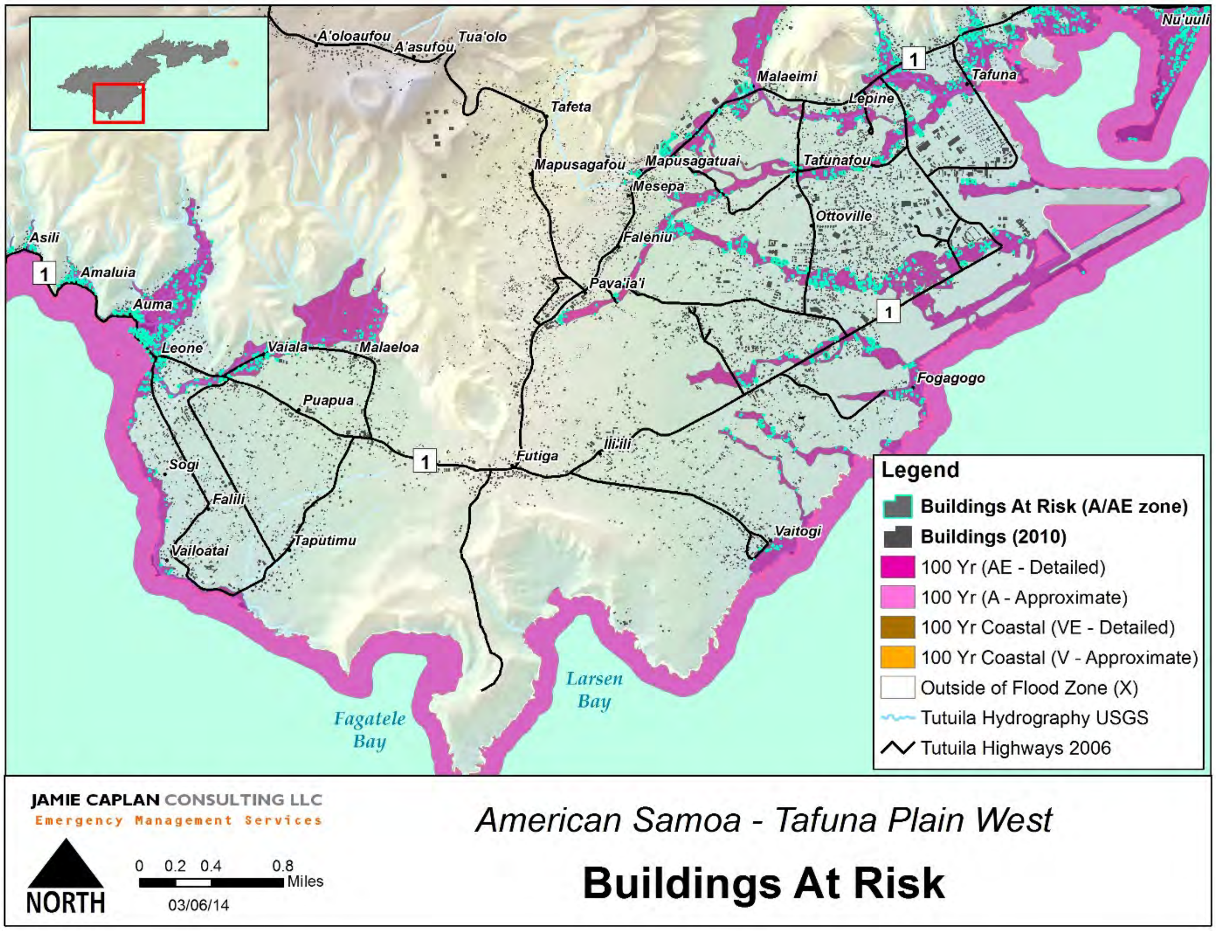


Figure 50: Buildings Potentially at Risk to Flooding in Tafuna Plain West

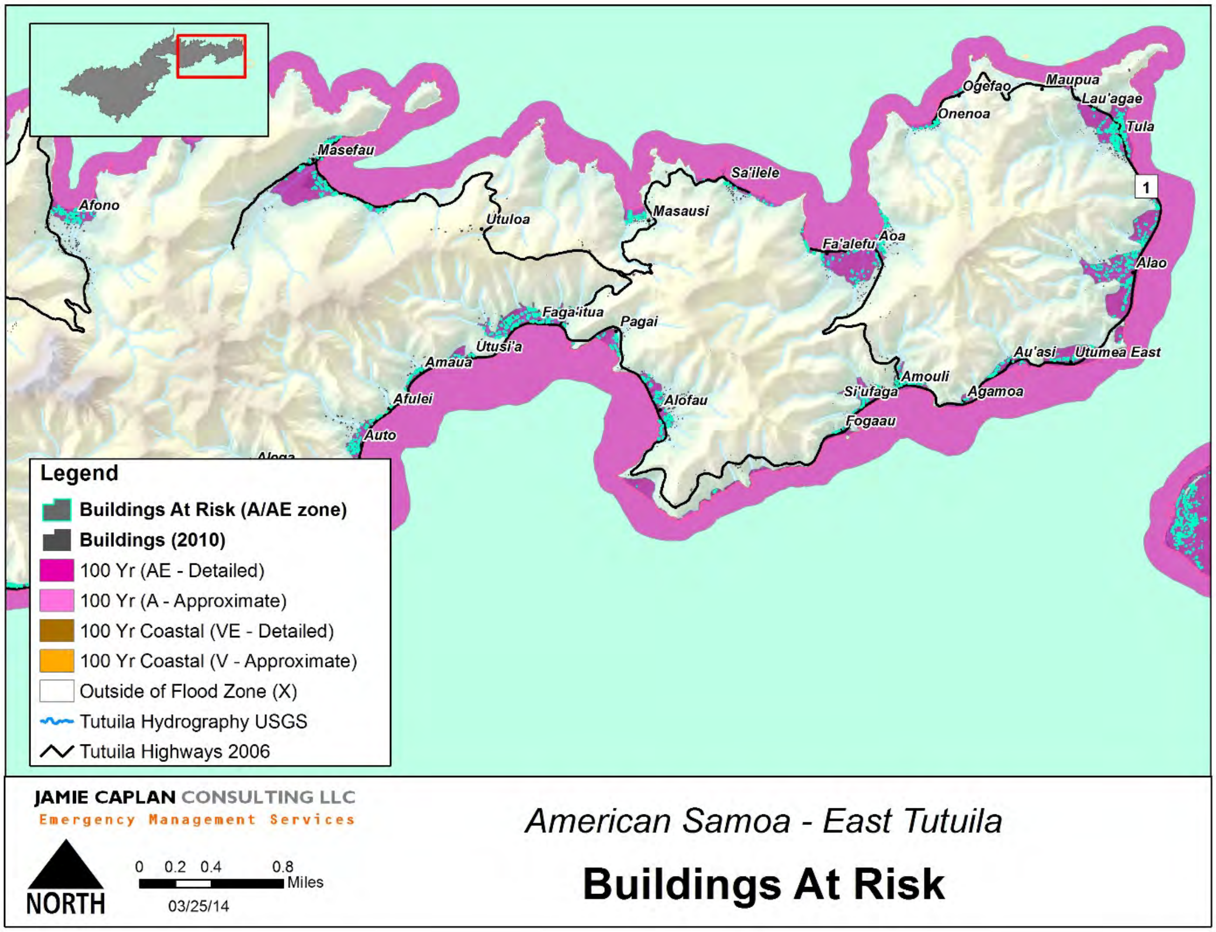


Figure 51: Buildings Potentially at Risk to Flooding in East Tutuila

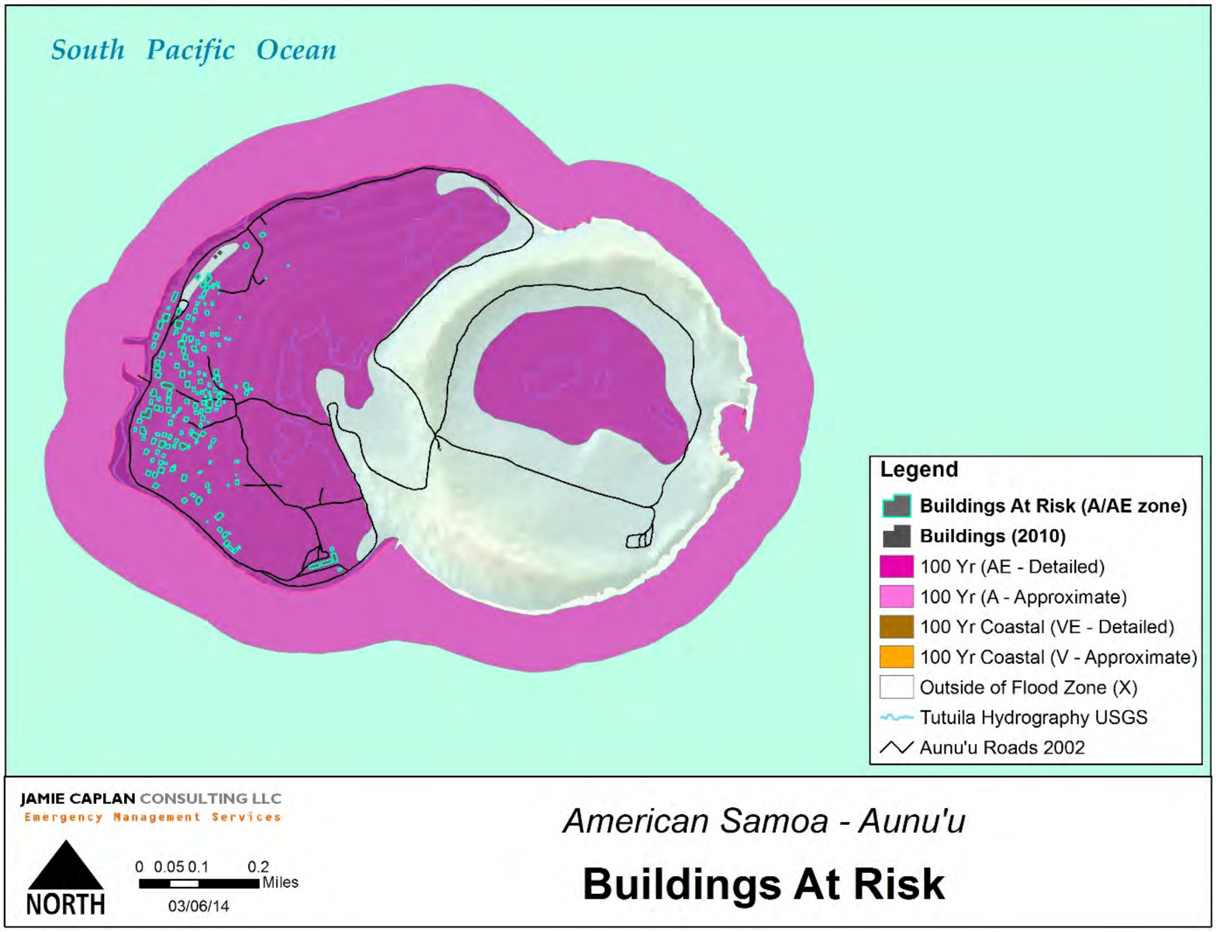


Figure 52: Buildings Potentially at Risk to Flooding on Aunu'u Island

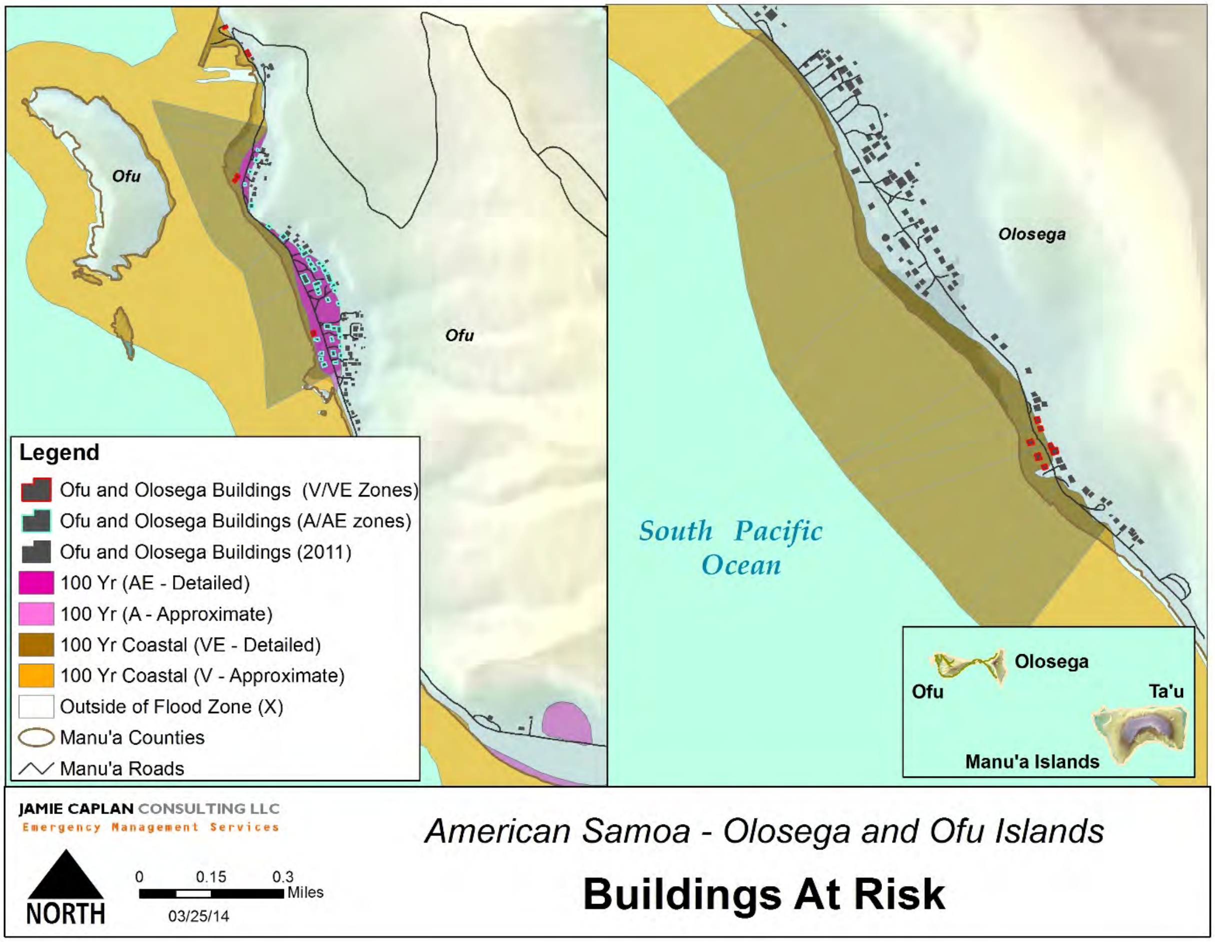


Figure 53: Buildings Potentially at Risk to Flooding on Olosega and Ofu Islands

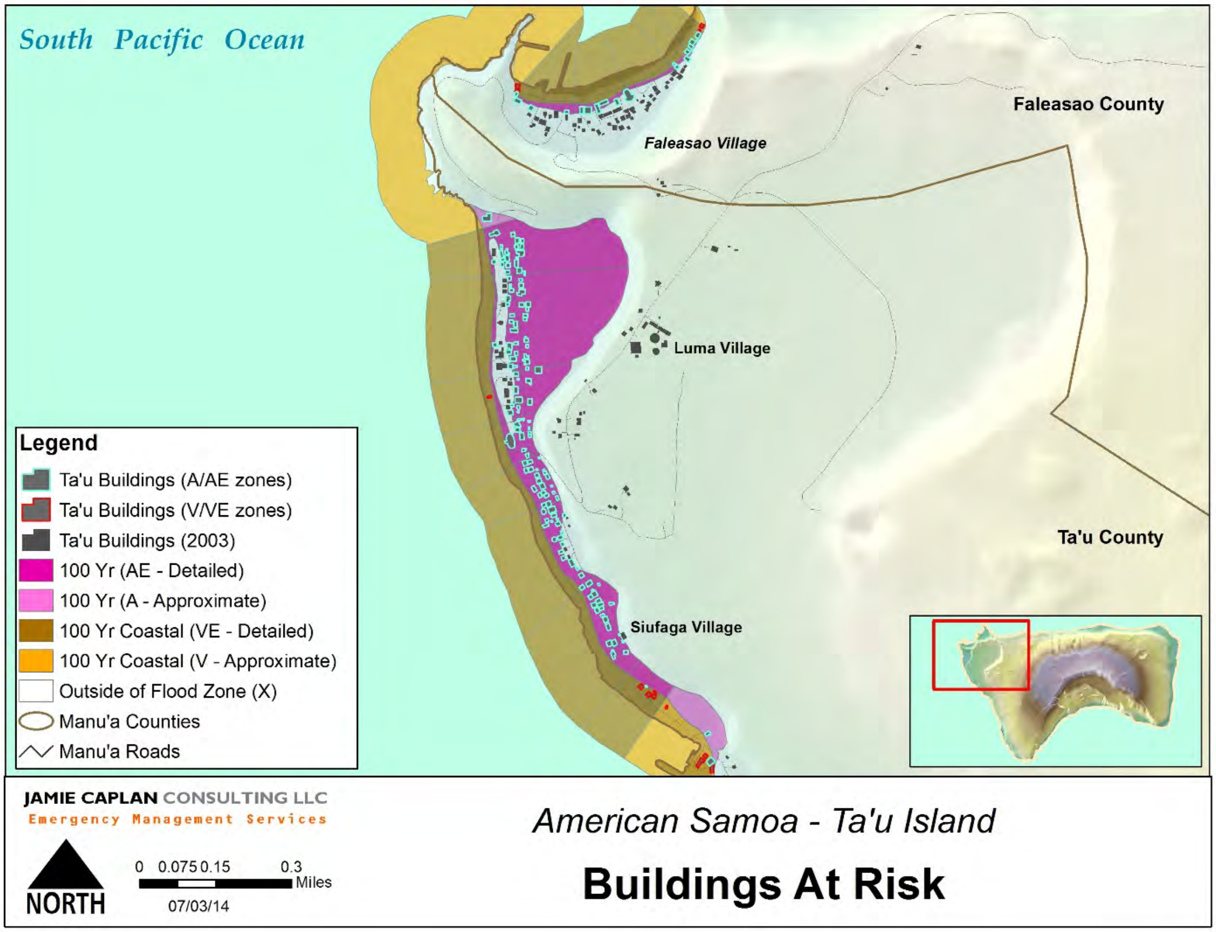


Figure 54: Buildings Potentially at Risk to Flooding on Ta'u Island

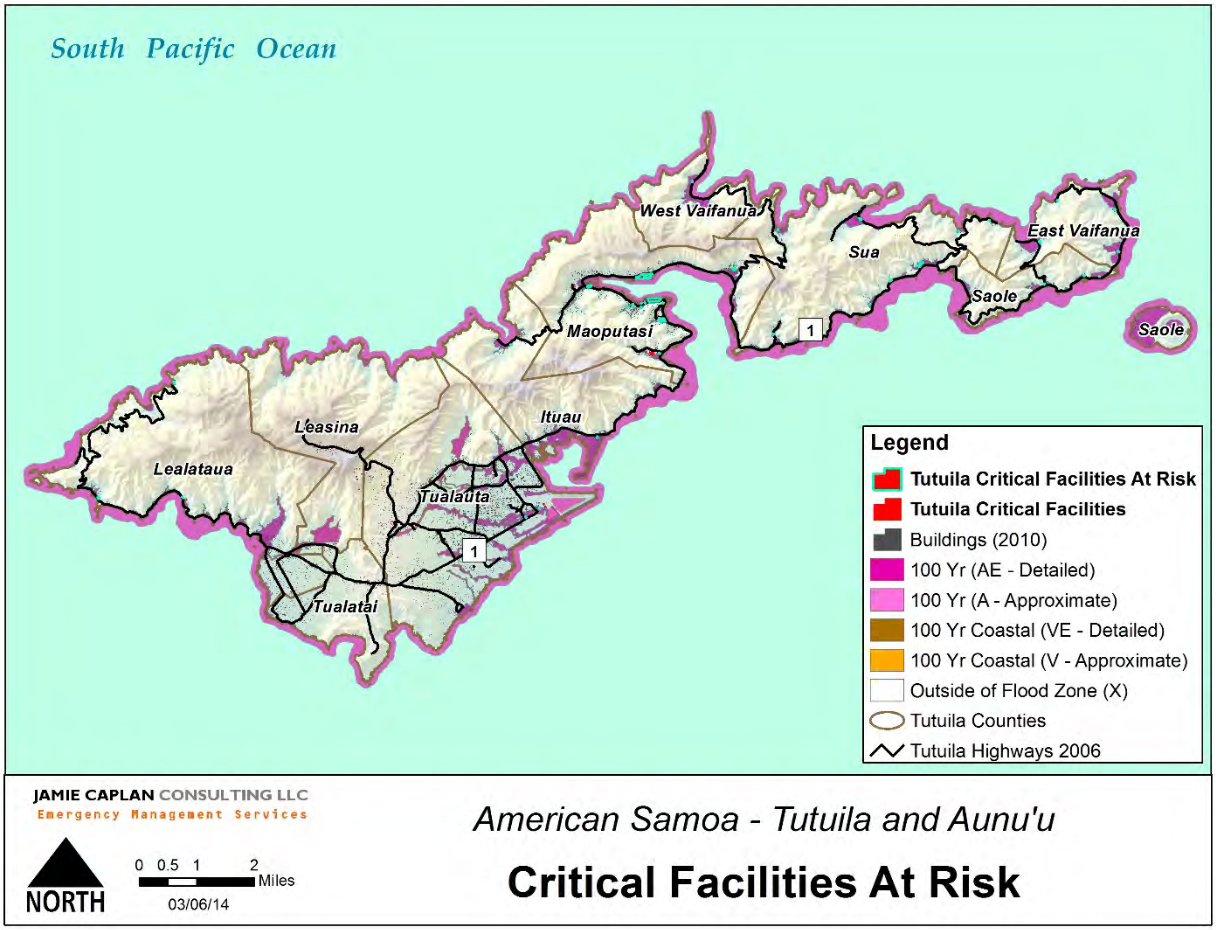


Figure 55: Critical Facilities Potentially at Risk to Flooding in Tutuila

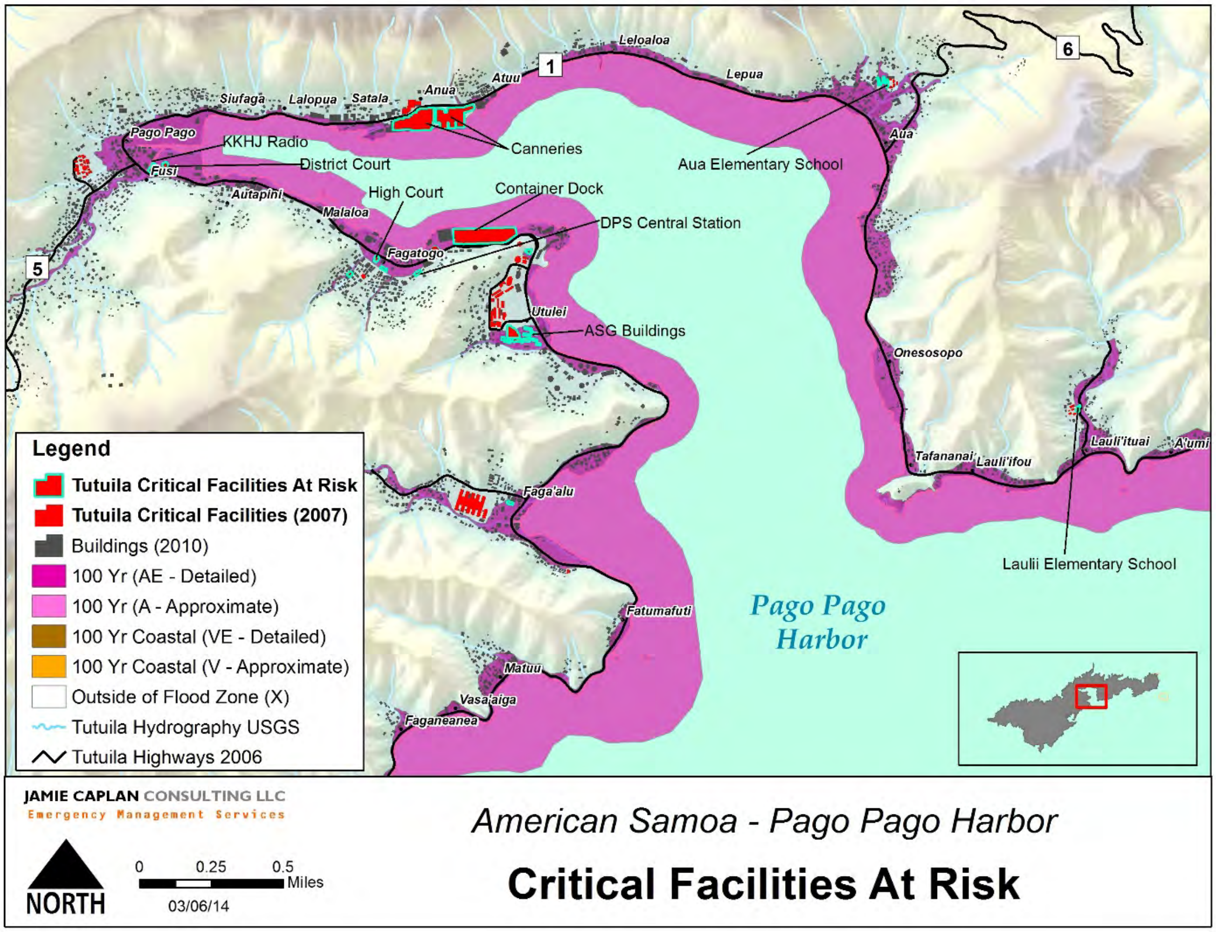


Figure 56: Critical Facilities Potentially at Risk to Flooding in Greater Pago Pago

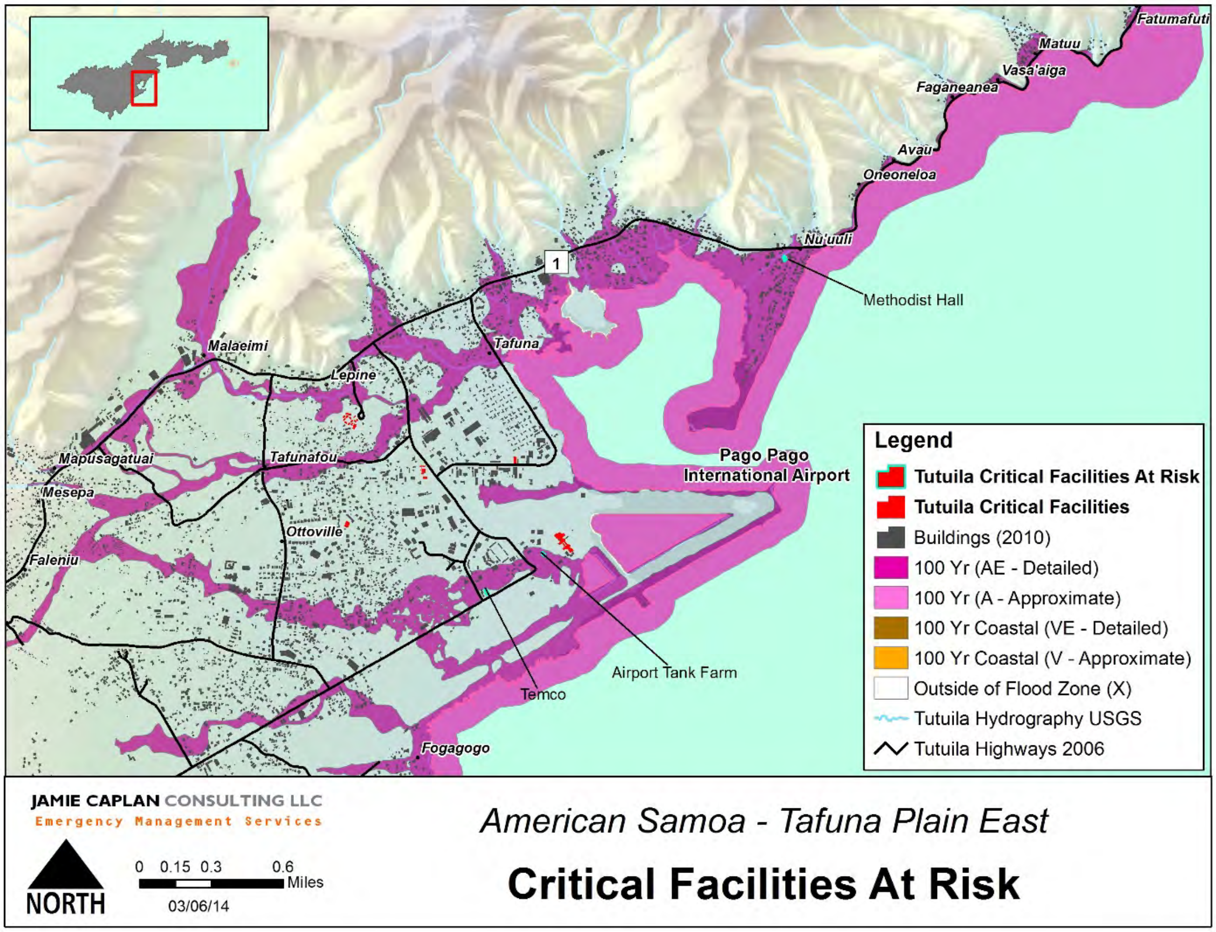


Figure 57: Critical Facilities Potentially at Risk to Flooding in Tafuna Plain East

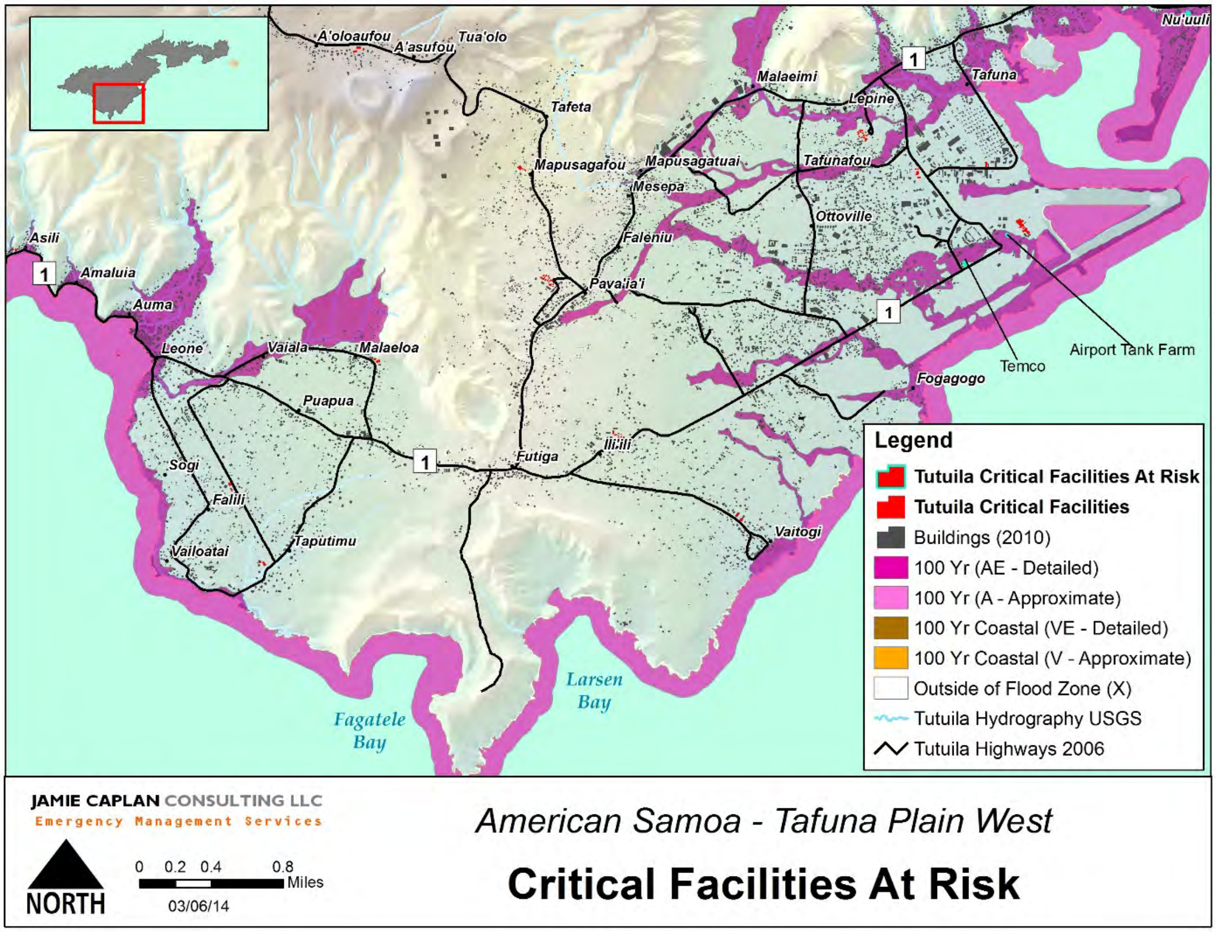


Figure 58: Critical Facilities Potentially at Risk to Flooding in Tafuna Plain West

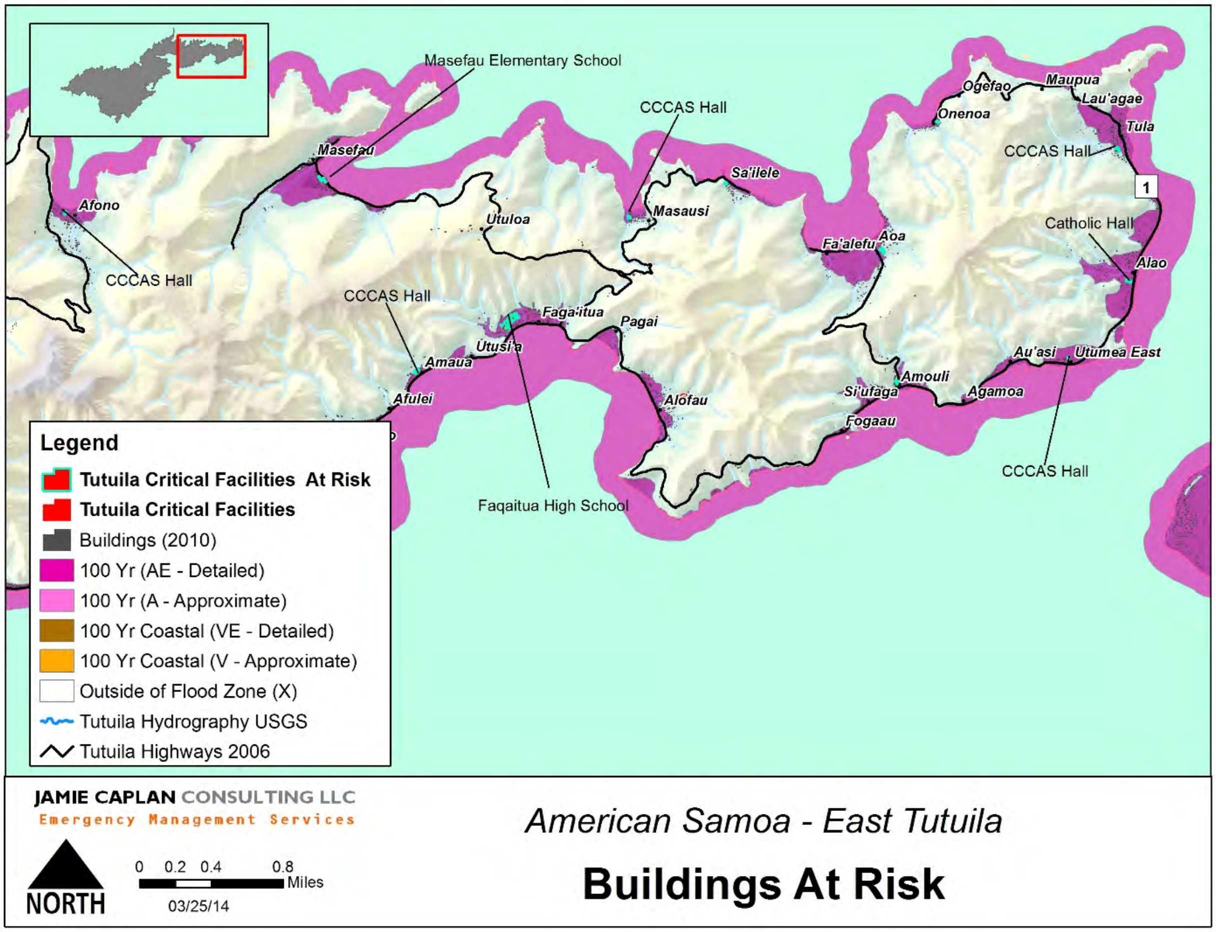


Figure 59: Critical Facilities Potentially at Risk to Flooding in east Tutuila

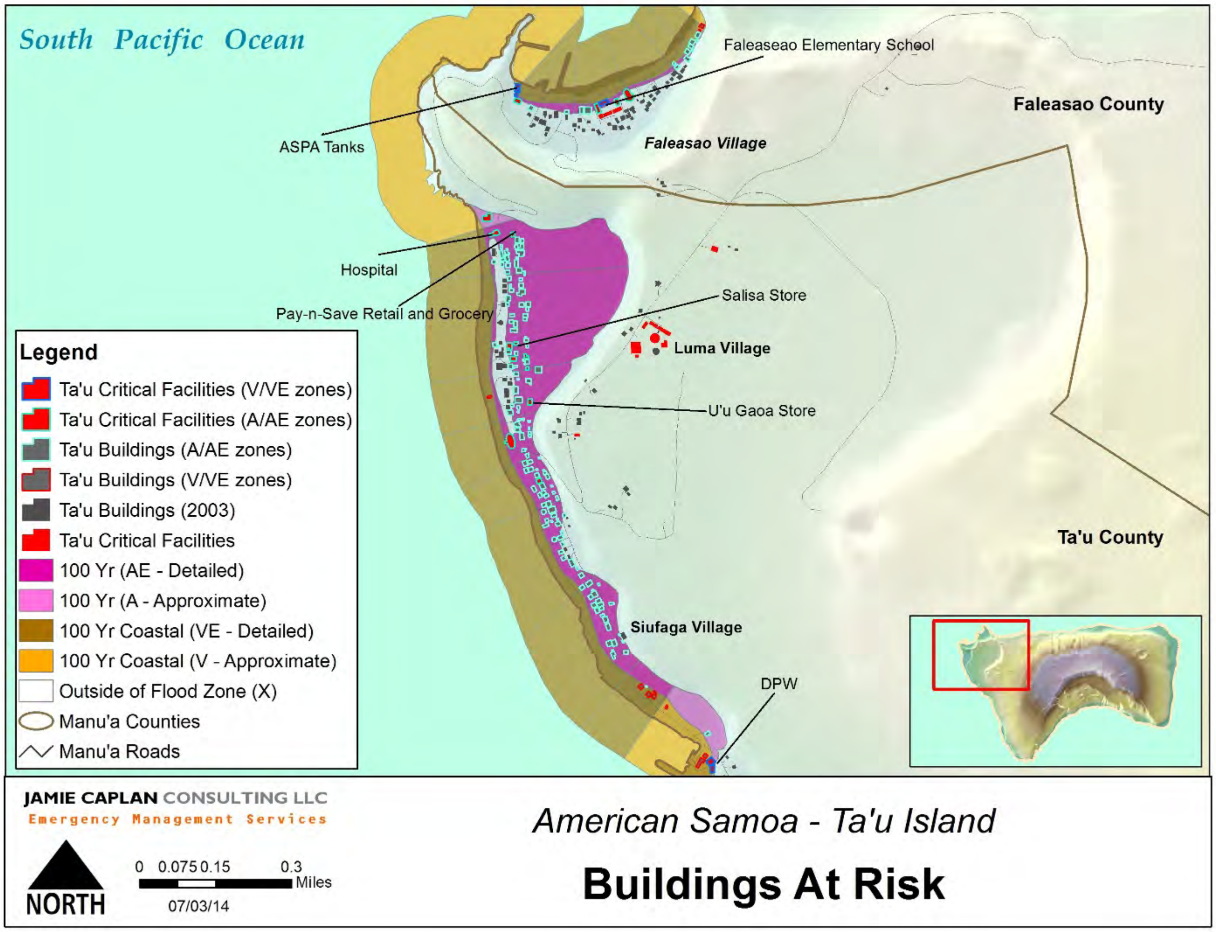


Figure 60: Buildings and Critical Facilities Potentially at Risk to Flooding on Ta'u Island

4.7 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 (HAZMAT) 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 the quality of life if they are not applied, handled and stored properly in accordance with the label.
The ASEPA often disposes of abandoned hazardous materials/waste by using different types of neutralizing/diluting methods. On some occasions, USEPA has provided assistance 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 the Department of Education compliance assistance on properly managing quantity and volume of purchased laboratory chemicals. In the past three to four years, ASEPA, with the assistance of USEPA 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 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.[79]

4.8 High Surf

4.8.1 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 and may cause seiche as well. 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

[79] Non-Transportation Related Facility Response Plan, January 2007 p.36.

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.

4.8.2 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.

4.8.3 Previous Occurrences

A total of 68 high surf events were reported in American Samoa between 1994 and 2020 NOAA's Storm Event Database. (Notably, there is a gap in reporting from 2008 – 2014, though high surf events continued to impact the island.) Of the 68 events, 37 were reported across all islands, 18 were reported on Tutuila, and six were reported for the Manu'a Islands, and two on Swains. Unfortunately, there have been five fatalities since 2019 for recreational swimmers and veteran fisherman. A listing of previous occurrences can be viewed in Appendix C.

4.8.4 Extent

Previous occurrences of high surf indicate conditions ranging from 3 to 30 feet. Further fatalities have been reported. 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 12 feet were calculated.

4.8.5 Probability of Future Events

A total of 68 high surf events were reported in American Samoa between 1994 and 2020, a 26-year reporting period. Future high surf are not expected to increase in frequency but likely will increase in terms of intensity, severity, and location impacted as highlighted in *Section 4.8.6.1 Climate Change Considerations*.

The overall probability of any high surf in American Samoa, with consideration to past and future events is highly likely (greater than 90% annual probability). The probability of strong events (waves greater than 12 feet), is likely (between 10% and 90% annual probability).

4.8.6 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 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 six reported fatalities to date and several in the last two years. High surf and riptides caused by high surf may injure or kill swimmers or fishermen in the ocean waters.

4.8.6.1 Climate Change Considerations

La Niña events are likely to result in a higher vulnerability as these cycles are characterized by strong wind events and are projected to more extreme as a result of climate change impacts. Climate change research projects fewer yet more intense large tropical storms which are likely to bring high surf conditions.

4.8.6.2 Potential Losses

No spatial data could be located to conduct a quantitative analysis. 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 change and increased hazard occurrence may lead to greater impacts in the future.

4.9 Landslide

4.9.1 Description

According to the USGS, each year landslides cause $5.7 billion (2014 dollars) in damage and between 25 and 50 deaths in the United States.[80] 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.

[80] United States Geological Survey (USGS). United States Department of the Interior. "Landslide Hazards – A National Threat." 2005.

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.

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.

4.9.2 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 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 61.

- 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.
- 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.
- 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.

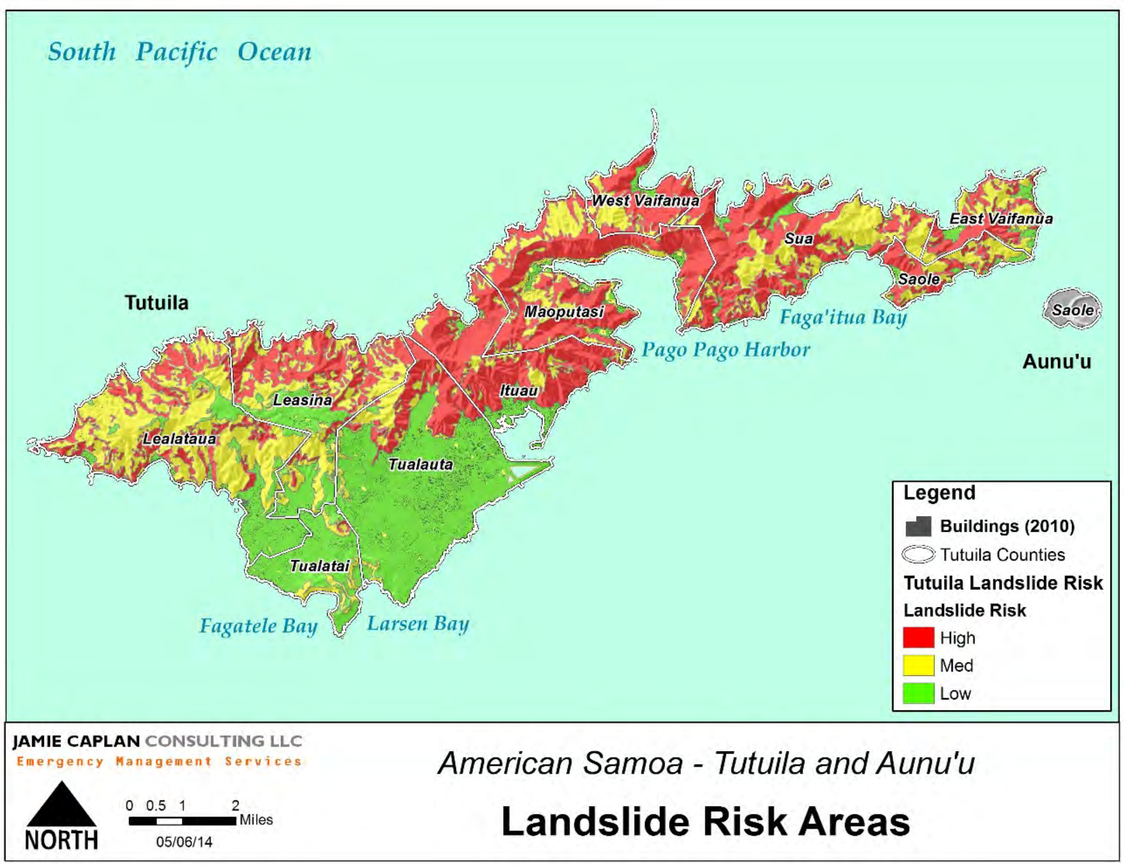


Figure 61: Landslide Risk Areas on Tutuila

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% is a flat surface, while a calculated value of 100% is a 45-degree angle of slope. As the surface becomes steeper, the percent rise becomes increasingly larger. The values reached 584% in Manu'a. This information was then arbitrarily grouped into low, medium and high-risk ranges based on slope as follows:

- Low: 0% to 25% (approximately 20-degree slope)
- Medium: 25%+ to 100% (20 degree to 45-degree slope)
- High: greater than 100% (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 *62* & Figure 63, show slope levels to indicate landslide risk on the Manu'a Islands.

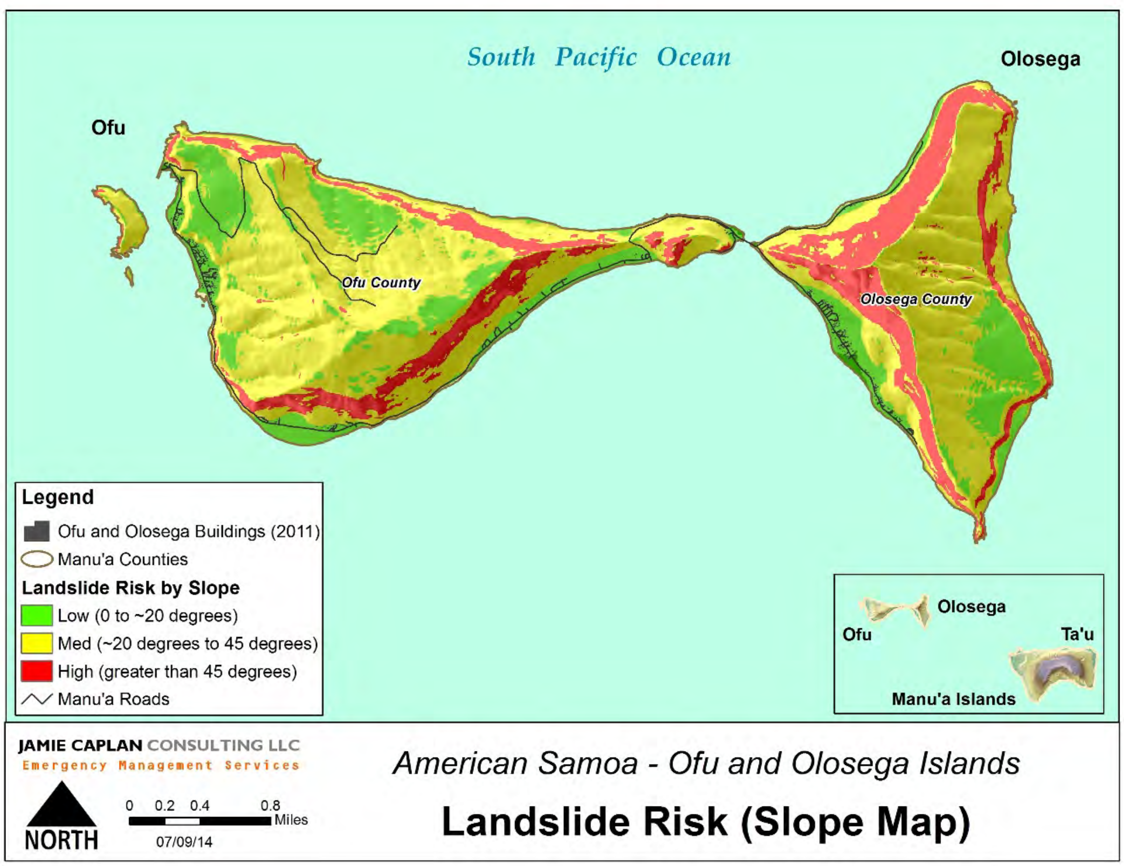


Figure 62: Landslide Risk on Ofu and Olosega Islands

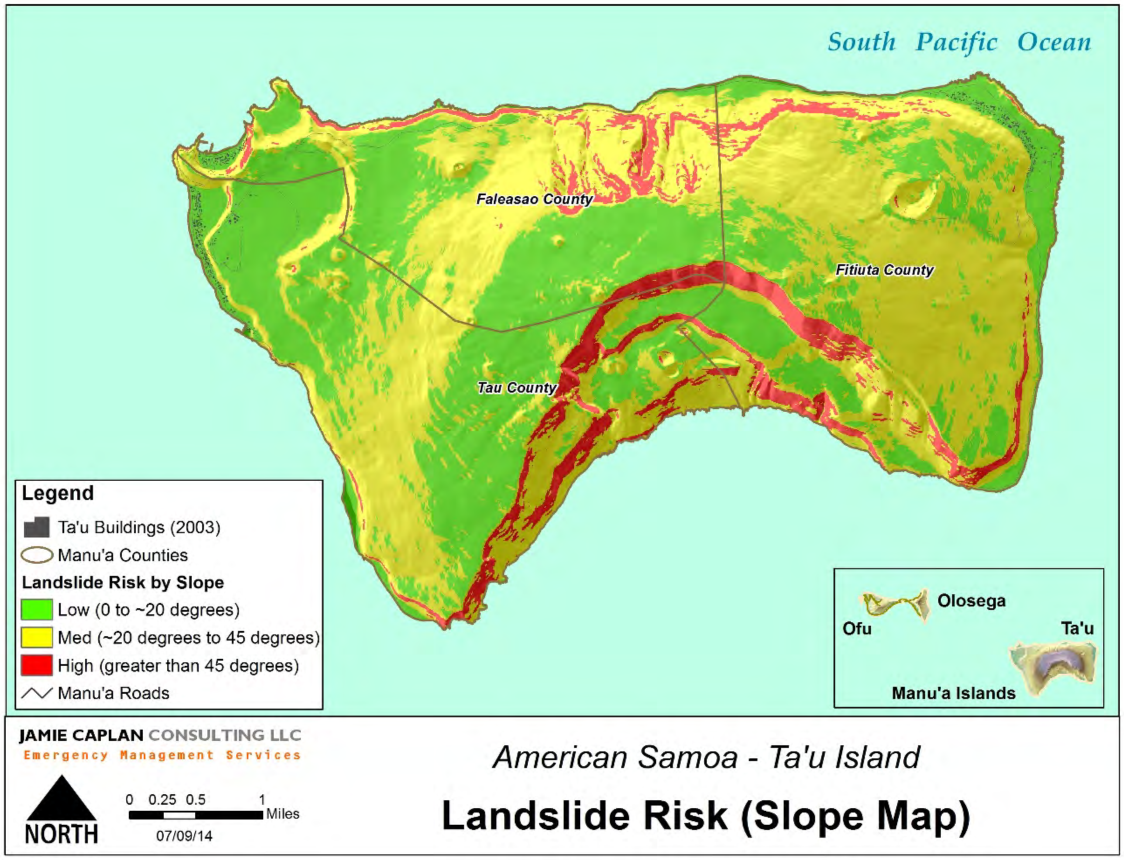


Figure 63: Landslide Risk on Ta'u Island

4.9.3 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. Records from NOAA's Storm Event Database noted 14 landslide events between 2014 and 2020 associated with flood and hurricane events. Further records from American Samoa officials indicated over 100 events, some of which caused fatalities. Events with details are outlined below. A full listing of recorded events can be found in Appendix C. It should be noted that these events are based on available data only, and there are likely several more that have gone unreported. Conditions are favorable for landslides and rock falls on the Manu'a Islands as well.

Landslide (1979)

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

Landslide (1985)

In 1985, a school building was destroyed in Nua, Tutuila.[81]

[81] US Soil Conversation Service and American Samoa Coastal Management Program (1990). *Landslide Hazard Mitigation Study.* Retrieved from http://www.botany.hawaii.edu/basch/uhnpscesu/pdfs/sam/White1990AS.pdf

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 below in Figure 64. However, these landslides are dated 1979, 1989, and 2001. Since the timeframe is so limited, they likely show frequent hot spots for landslide activity rather than all activity. Unfortunately, no information on historic landslides was located for the Manu'a islands.

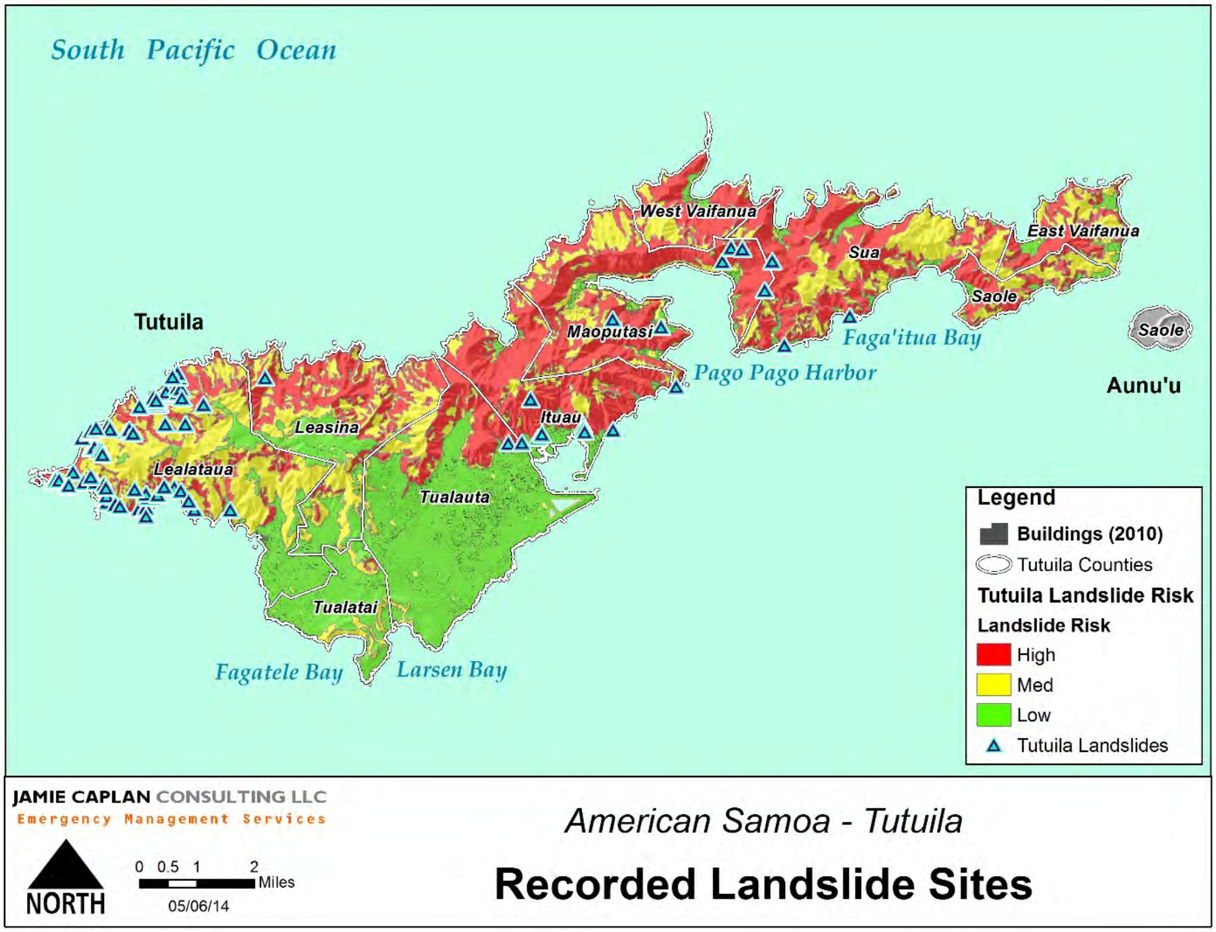


Figure 64: Recorded Landslide Sites in Tutuila

4.9.4 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.

4.9.5 Probability of Future Events

Determining a statistical probability for landsliding was challenging given the lack of recorded events but known high frequency given anecdotal and related hazard information. 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 61, Figure *62* and Figure 63). When considering future landslide events, increased rainfall and flooding will likely results in more frequent landslides in more locations. They may also increase the severity of landslide impacts as more population and built environment is impacted, as well as the intensity as more rainfall may lead to larger events.

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. Further, landslides are known to be a regular occurrence which will likely increase will changing climate conditions. Local input indicates that landslides (including rockfalls) 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.

4.9.6 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 61 through Figure 64.

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 including tropical storm/hurricanes.
- 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 place. 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.

4.9.6.1 Climate Change Considerations

American Samoa is projected to experience an increase in precipitation and strong tropical storms over the next century, which will increase vulnerability to landslides. La Niña ENSO cycles also bring rainier weather to American Samoa which increases the probability of landslides.

4.9.6.2 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 (Table 32). This analysis was not revised for the 2020 plan no new data was available. This information should be used to determine areas where the greatest vulnerability occurs.

Table 32: 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 (East District)	2,026	135	7%	1 church 3 schools 131 residential
Leasina (East District)	474	1	0%	1 residential
Maoputasi (East District)	2,246	879	39%	2 not listed 4 church 6 commercial 16 government 851 residential

County (District)	Total Number of Buildings	Total Number of Buildings in High Risk Landslide Areas	Percent of Buildings	Type
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	16,136	2,046	13%	
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
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 landslide risk 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 33. Specific buildings are also highlight in Figure 65. No critical facilities were determined to be located on the Manu'a islands.

Table 33: 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

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

Safe Zones

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

Tsunami Sirens

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

ASTCA Infrastructure

- Eleven ASTCA sites and towers were determined to be located in high-risk landslide areas including six cell sites, two towers, one DCO, and one 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 C.

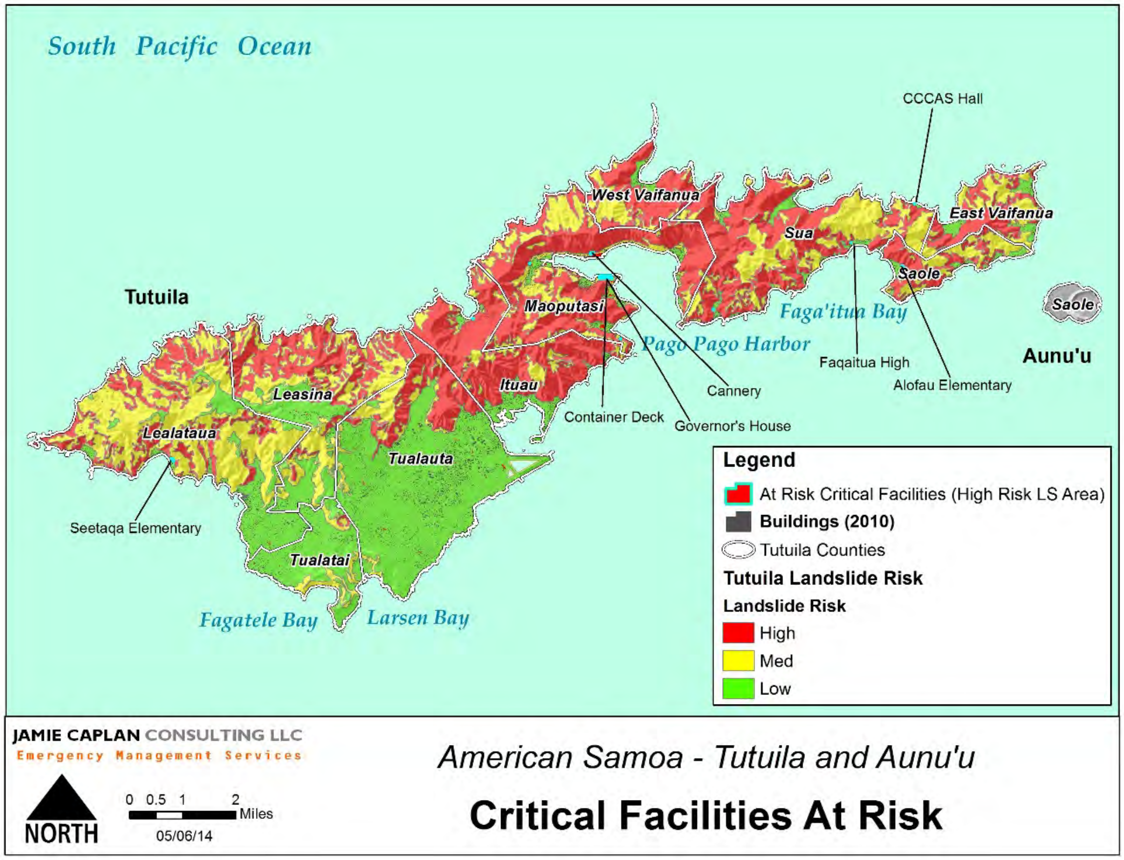


Figure 65: Critical Facilities Located in High Risk (higher likelihood) Landslide Areas

4.10 Lightning

4.10.1 Description

Lightning, a hazard typically associated with thunderstorm, was added to this update of the mitigation plan. According to NOAA, 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°F. 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.

4.10.2 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 66 below, which shows both extent and location of previous occurrences of lightning strikes globally, exemplifies this point.

4.10.3 Previous Occurrences

Previous occurrences were researched through a variety of mechanisms including local news sources and online weather reports. Only three reported strikes were found. According to NOAA's Storm Event Database, three lightning strikes were reported between 1996 and 2020. A lightning strike on April 4, 2006 caused a death and an injury. The second event reported caused damages to electronics, and the third event did not specific the cause of damages. All reported events are reported in Table 34 below. It is likely that additional events have occurred but were not reported.

Table 34: Reported Lightning Occurrences in American Samoa[82]

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
Tutuila	Pago Pago	8/3/2018	0	0	$1,000

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.

4.10.4 Extent

Figure 66 below was compiled with NASA data from 1998 to 2012 to show the frequency of lightning strikes per square kilometer per year.[83] This can be used to measure extent. American Samoa appears to receive approximately one 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.

[82] NOAA National Climatic Data Center (2020). Storm Events Database. Retrieved from https://www.ncdc.noaa.gov/stormevents/

[83] Wikipedia (2020). Distribution of Lightning. Retrieved from http://en.wikipedia.org/wiki/File:Global_lightning_strikes.png

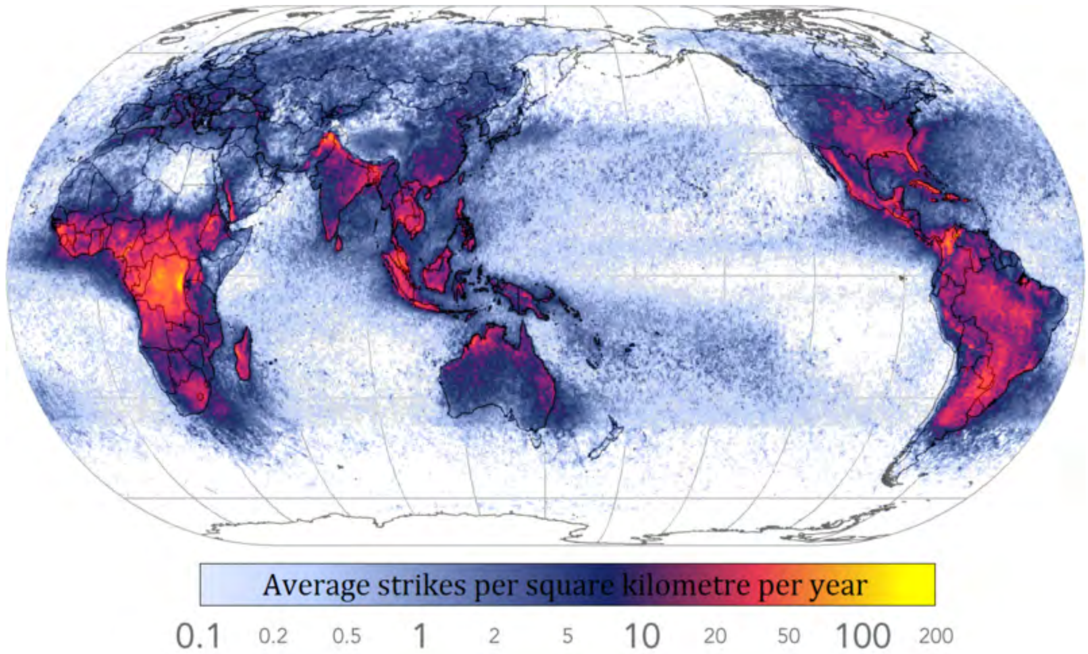


Figure 66: Average Lightning Strikes per square kilometer per year (1998-2012)

4.10.5 Probability of future events

Based on three events reported between 1996 and 2020, there is a 13% annual probability of a lightning strike. As noted in *Section 4.10.6.2 Climate Change Considerations*, research is still emerging on lightning in terms of future impacts. In general, future lightning events may increase but are expected to be unchanged in terms of location, severity, intensity. With consideration to past and potential future events, a probability categorization of likely (between 10% and 90% annually) was assigned.

4.10.6 Vulnerability assessment

This atmospheric hazard has the potential to impact the entire planning area including all islands in American Samoa. 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.

4.10.6.2 Climate Change Considerations

Research is still emerging on the topic of lighting and climate change connections. Some research indicates that lightning may be a strong indicator of where climate change impacts are increasing as lightning is a measure of storminess.[84] It may also exacerbate climate changes as it produces high levels

[84] Eos (2020). *Lightning. A New Essential Climate Variable.* Retrieved from https://eos.org/science-updates/lightning-a-new-essential-climate-variable

nitrogen oxide, which is a greenhouse gas. Increased precipitation and thunderstorm events associated with climate change may also result in more lightning activity.

4.10.6.2 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.

4.11 Public Health Risks (including Infectious Disease)

4.11.1 Description

Public health risks, such as those presented by infectious diseases, vector-borne illnesses, water-borne illnesses, and chronic diseases, are present within every community. They include commonly occurring illnesses like the common cold and influenza, as well as less common inflictions such as bacteria-caused *Escherichia coli* ("E. coli") and mosquito-transmitted Zika virus.

The degree to which communities are susceptible to or actively experiencing public health issues can impact a community's vulnerability to natural hazards, as well as its ability to respond to disasters. For instance, an infectious disease outbreak may complicate evacuations or/and mass sheltering required due to a natural hazard. Similarly, high incidents of chronic diseases may decrease mobility within a community, and natural disasters may reduce access to vital healthcare services needed by the ill. History reveals that in the absence of information about a public threat, treatments, and vaccines, infectious diseases can be extremely deadly. For example, the 14th-century bubonic plague killed about 50 million people in Europe at a time well before modern medicine or an understanding of contagion existed. The plague did not submit for nearly 10 years, even then, continued to reemerge every decade or so for nearly 400 years.[85] The plague was largely managed through trial and error and ultimately controlled through quarantine measures, the first use of it in history. Tuberculous is considered the world's deadliest infectious disease today despite available vaccines and treatments. Although it is nearly eliminated from the U.S., less developed areas of the world such as Southeast Asia and Africa see high infection rates and have limited capacity to manage the disease.

While major outbreaks are uncommon, public health emergencies can become stand-alone disasters that compound the threat of other natural hazards and exceed local and state capacity. There is precedent for federal assistance due to public health emergencies including West Nile Virus (2000), a mosquito-borne disease, for which a federal emergency declaration was made in New York and New Jersey[86], and the COVID-19 pandemic, which resulted in a major disaster declaration in all states, territories, and the District of Columbia.

The list below highlights some of the public health risks, including infectious disease, which may impact American Samoa. It is not intended to be a complete list of potential public health threats.

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[85] Ishack, Natasha. "The Black Death Was The Worst Pandemic In Human History, So How Did It Finally End?" All That is Interesting. 8 Apr 2020. Retrieved from: https://allthatsinteresting.com/how-did-the-black-plague-end.
[86] FEMA (2000). *President Authorizes Emergency Funds For New Jersey Virus Threat.* Retrieved from: https://www.fema.gov/news-release/2000/11/01/president-authorizes-emergency-funds-new-jersey-virus-threat.

Vector-borne Diseases

A vector-borne disease is a disease transmitted to humans from living organisms or animals.

Angiostrongyliasis (Rat Lungworm Disease)

Rat Lungworm Disease is caused by a parasitic nematode, also known as a roundworm parasite. In humans, rat lungworm affects the brain and spinal cord, impacting the brain and nervous system. Infected rats can pass larvae of the roundworm in their feces to intermediate hosts, such as slugs, snails, and freshwater crustaceans. Humans can become infected by:

- Eating raw or undercooked snails, slugged, freshwater shrimp, land crabs, frogs, or crayfish;
- Accidently eating produce with slugs, snails, or slime; or
- Drinking improperly filtered catchment water with slugs or snails.

Symptoms of rat lungworm include severe headache, stiff neck, tingling skin, low-grade fever, and nausea or vomiting.[87]

Chikungunya

According to the Centers for Disease Control and Prevention (CDC), the Chikungunya virus is spread by mosquitos. The most common symptoms of infection are fever and joint pain, but it may also cause headache, muscle pain, joint swelling, or rash. Currently, there is no vaccine to prevent or medicine to treat chikungunya virus infection.

Dengue

Dengue fever is transmitted to humans by Aedes aegypti and Aedes albopictus mosquitoes. Symptoms include headache, body aches, fever, and rash. In several cases, blood clotting problems can occur. Symptoms typically last one to two weeks. About half of cases present no symptoms. Prevention actions include avoiding mosquito bites (repellant and covering skin), as well as reducing mosquitos by emptying standing water.[88] Dengue is endemic in American Samoa, meaning outbreaks are somewhat common (typically occurring every couple of years).

Leptospirosis[89]

Leptospirosis can be contracted when a person has contact with water, soil, or urine from an infected animal. Multiple animals may be infected including dogs, horses, pigs, wildlife, and rodents. Symptoms generally include a combination of fever, diarrhea, muscle aches, vomiting, red eyes, and jaundice.

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[87] MauiReady (n.d.). Emergency Preparedness Information for Maui Residents and Visitors. Retrieved from https://mauiready.org/ratlungworm/.

[88] Hawaii Department of Health Disease Outbreak Control Division (2016). *Dengue Outbreak 2016-15*. Retrieved from https://health.hawaii.gov/docd/dengue-outbreak-2015/

[89] Centers for Disease Control and Prevention (2018). *Hurricanes, Floods and Leptospirosis.* Retrieved from https://www.cdc.gov/leptospirosis/exposure/hurricanes-leptospirosis.html

Without treatment, Leptospirosis can lead to kidney damage, meningitis (inflammation of the membrane around the brain and spinal cord), liver failure, respiratory distress, and even death. According to the CDC, people should avoid floodwater as water may contain infected animal urine. The following factors increase risk to Leptospirosis:

- Drinking from potentially contaminated water sources, including floodwater, streams, rivers, or unsafe tap water.
- Bathing or wading in floodwater or contaminated fresh water, especially when putting your head under water or if you have an open wound or scratch.
- Eating food that has been exposed to contaminated water or potentially urinated on by rodents.

Zika Virus

Zika virus is spread by *aedes* mosquitoes. Zika virus is also considered an infectious disease, as it can be sexually transmitted. Symptoms of Zika infection can include a fever, joint pain, rash, headache, and conjunctivitis ("pink eye"). Only about 20% of people with Zika infection have symptoms. When symptoms occur, they can last several days to a week. Human fetuses are susceptible to severe birth defects if the mother is infected with Zika virus.

Infectious Diseases

Infectious diseases are caused by pathogens that can be spread, directly or indirectly, from person to person. Such diseases may be seasonal (seasonal influenza) or result, in the case of new diseases, in a global pandemic.

Coronavirus (COVID-19)

COVID-19 is a novel, highly contagious, viral upper-respiratory illness that was first detected in China in late 2019. The virus quickly spread throughout the world and has resulted in a global pandemic ongoing at the time of this plan. As of May 7, 2020, there were just under 3.7 million cases of COVID-19 globally, resulting in over a quarter million deaths. COVID-19 symptoms include cough, difficulty breathing, fever, muscle pain, and loss of taste or smell. Severe cases may result in death, especially in individuals over the age of 65 or with underlying medical conditions, such as diabetes, lung disease, asthma, obesity, or those who are immunocompromised. COVID-19 spreads from person to person through respiratory droplets in the air or on surfaces.[90] Currently, there are no viable treatments or vaccines for the disease. To prevent the continued spread of the virus, many communities around the world issued stay-at-home orders, in which residents must remain home except to utilize essential services, such as grocery stores and health care services. Many schools have closed, and workers have switched to teleworking. Business closures have caused major economic losses in many countries.

[90] Centers for Disease Control and Prevention (2020). *Coronavirus disease 2019 (COVID-19)*. Retrieved from https://www.cdc.gov/coronavirus/2019-ncov/faq.html

Hepatitis B

Hepatitis B is an infectious liver disease caused by the hepatitis B virus. Hepatitis B infections can be acute (short-term illness occurring with six months of contraction) or chronic (long-term illness in which serious health problems can develop). About 90% of infants infected with Hepatitis B will develop a chronic infection, compared to only about 5% of adults. Symptoms can include fever, fatigue, loss of appetite, nausea, vomiting, joint pain, and jaundice. Hepatitis B is transmitted from person to person through bodily fluids. There is no cure for Hepatitis B, but a vaccination is available to prevent against the virus.[91]

Measles[92]

Measles is a highly contagious respiratory disease caused by the Rubeola virus. Symptoms include high fever, rash, and cough. The virus is spread through the air, primarily from coughing and sneezing. It can result in numerous complications including pneumonia and encephalitis (swelling of the brain) that can lead to seizures, deafness, brain damage, or death. Approximately one in five people who contract measles will be hospitalized. Young children under the age of 5, pregnant women and those with compromised immune systems are most at risk to complications.

Prior to a vaccination, an estimated 3 to 4 million Americans were infected each year. A vaccine was developed in 1963, and most kids are vaccinated by the age of 15. The measles vaccine is usually combined with mumps and rubella, and commonly referred to as the "MMR," or combined with mumps, rubella and varicella ("MMRV"). Measles was declared eliminated (absence of continuous disease transmission for greater than 12 months) from the United States in 2000. However, in recent years the rate of vaccinations has dropped leading to a reemergence of the disease. According to the CDC, since 2010, cases reported have ranged between 55 cases in 2012 to 1,282 cases in 2019, including a December 2019 outbreak in American Samoa (Figure 67).[93]

[91] Hawaii Department of Health Disease Outbreak Control Division (2020). *Hepatitis B*. Retrieved from https://health.hawaii.gov/docd/disease_listing/hepatitis-b/

[92] Centers for Disease Control and Prevention (2020). Measles. Retrieved from https://www.cdc.gov/measles/symptoms/complications.html

[93] Centers for Disease Control and Prevention (2020). Measles Outbreaks. Retrieved from https://www.cdc.gov/measles/cases-outbreaks.html

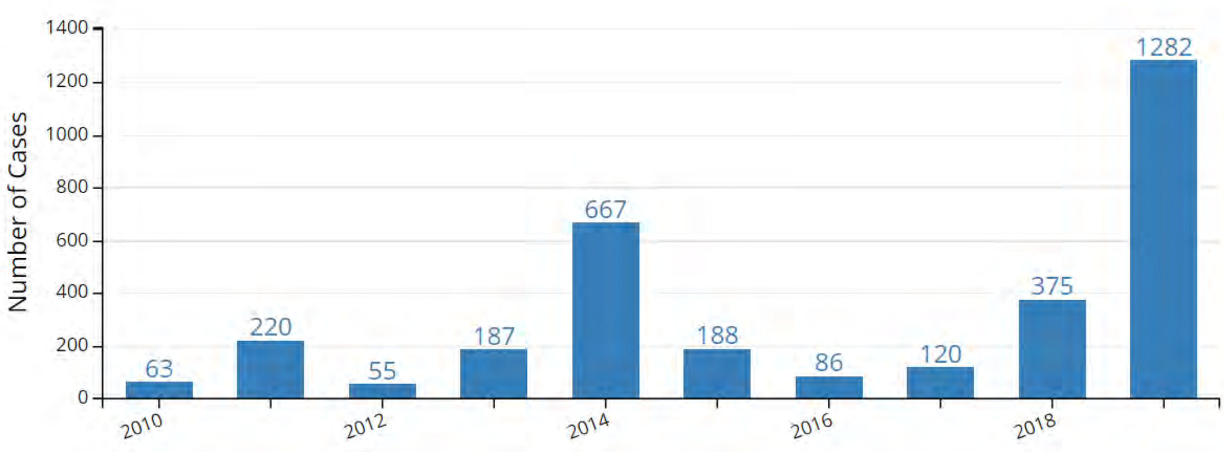

Figure 67: U.S. Measles Cases from 2010 – 2020 (as of May 7, 2020)

Tuberculosis

Tuberculosis (TB) is a bacterial infection that usually attacks the lungs but can also affect other parts of the body such as the spine, kidneys, or brain. Symptoms include a cough, fever, and weight loss. There are two types of tuberculosis – latent TB infection (LTBI), in which no symptoms are presented, and TB disease. TB disease can be infectious and is spread from person to person through droplets in the air, whereas LTBI is not infectious. Most cases of TB disease are treatable and curable but can be fatal if not properly treated. In some cases, TB infections are resistant to drugs, which is referred to as drug-resistant TB.[94] A vaccine exists but is rarely administered in the U.S., given a low rate of incidence. The national incidence rate was 2.8 cases per 100,000 persons (1.3% decrease from 2017), which has been declining since tracking started in the 1930s. However, rate of incidence is declining at a lower rate in recent years.

Water-borne Diseases

Waterborne diseases are illnesses caused by viruses and bacteria ingested through contaminated food, water, or by coming in contact with feces.

Typhoid Fever

Typhoid Fever is a bacterial illness resulting in high fevers, weakness, stomach pains, headache, and loss of appetite. Typhoid is present in American Samoa. A vaccine for typhoid fever exists, though may not be 100% effective.[95] Other preventative measures include eating cooked foods, only eat raw fruits and

[94] Centers for Disease Control (2020). *Basic TB facts*. Retrieved from https://www.cdc.gov/tb/topic/basics/default.htm

[95] Centers for Disease Control (2020). *Typhoid Fever Prevention*. Retrieved from https://www.cdc.gov/typhoid-fever/prevention.html

vegetables that you can peel yourself and washing your hands prior to eating. If left untreated, mortality rates can reach up to 20%.[96]

Non-Communicable Diseases (NCDs)
NCDs are diseases that are not transmissible directly from one person to another such as autoimmune diseases, diabetes, chronic kidney disease, Alzheimer's disease, cataracts, and others.

Other public health risks faced by the Territory of American Samoa include chronic diseases, such as diabetes, hypertension, asthma, and substance abuse.

4.11.2 Location
The entirety of American Samoa is considered to be uniformly exposed to public health risks.

4.11.3 Previous Occurrences
The following presents a summary of previous occurrences of the public health impacts in American Samoa. Notably, American Samoa was one of the few places in the world to emerge from the 1918 pandemic without any flu deaths. In more recent years, the Territory has been faced with 2017/2018 Dengue outbreak and a 2019 Measles outbreak. The measles event likely helped to prepare the Territory to deal with the impacts of the 2020 COVID-19 global pandemic as measures for school closures and social distances were put into place to control the spread.

Angiostrongyliasis/Rat Lungworm Disease: A Rat Lungworm Disease outbreak occurred in American Samoa in 1980 among a group of Korean fishermen aboard a boat docked in American Samoa, following ingestion of raw giant African snails.[97] No other incidents were located through records research.

Zika Virus: Zika was first detected in American Samoa in January 2016.[98] An outbreak was declared in February 2016 and end in March 2017. While the outbreak was initially contained, by early 2017, suspected cases had escalated to over 1,000.[99] According to Aifili John Tufa, PhD, MPH, ASDOH Epidemiologist (email communication on May 26, 2020), there were a total of 592 cases of which 289 were pregnant women. ASDOH is following 273 children born to mothers with laboratory evidence of Zika infection, and over $1 milllion was granted to the Territory by the US Centers for Medicaid and Medicare to combat spread and treat conditions.

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[96] Index Mundi (2019). *American Samoa Major Infectious Diseases.* Retrieved from: https://www.indexmundi.com/american_samoa/major_infectious_diseases.html
[97] Cowie, Robert H. Hawaii J Med Public Health. 2013 Jun; 72(6 Suppl 2): 70–74. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3689478/
[98] Chitnis, Deepak. Obgyn News. 17 March 2017. Retrieved from https://www.mdedge.com/obgyn/article/134183/zika/american-samoa-could-be-model-responding-zika-outbreaks
[99] Samoa News. *Over $1M Going to AS DOH to Combat Zika Virus.* Retrieved from https://www.samoanews.com/local-news/over-1mil-going-doh-combat-zika-virus

Dengue Fever: Dengue is endemic to American Samoa and noted as common by the CDC. A dengue serosurvey conducted in 2010 following an outbreak of dengue in 2009 demonstrated that 96% of residents of American Samoa had been previously infected with dengue.

On 13 July 2015, the American Samoa Department of Health requested assistance from CDC to organize a response to an ongoing dengue outbreak associated with a high mortality rate (~3%). There were less than 9 cases/week in April, when the outbreak began, but those rose to nearly 50/week by June. The event peaked in July as 179 suspected cases/week. A total of 898 suspected cases were identified and four deaths were reported with the outbreak.[100]

According to the Aifili John Tufa, PhD, MPH, ASDOH Epidemiologist (email communication on May 26, 2020), a dengue outbreak was declared in March 2017 and ended November 2018. During this outbreak, there were a total of 1,009 confirmed cases and no deaths.

It is not uncommon to have dengue outbreaks following tsunami, tropical storm or hurricane events. For example, cases doubled in the month following the September 29, 2009 tsunami from 27 in September to 62 in October.[101,102] Additionally, at least five cases were reported following the 2018 Tropical Storm Gita. All testing must be sent off island for confirmation.

Measles: According to Aifili John Tufa, PhD, MPH, ASDOH Epidemiologist (email communication on May 26, 2020), a measles outbreak was declared on November 13, 2019 and ended March 9, 2020. There were a total of 16 confirmed cases and no fatalities. Schools and day care centers were closed from December through March and the Territory implemented social distancing measures.[103] While measles vaccines are mandatory, not all students receive vaccinations and the vaccine cannot be administered until after 12 months of age. Further, many adults are not vaccinated, and several residents come from neighboring Samoa where vaccinations are not mandatory. (Samoa experienced thousands of cases and death toll over 100 during the outbreak).[104] American Samoa is now requiring arriving travelers born in or after 1957 to show proof of measles vaccination.

COVID-19: As of May 6, 2020, there were no confirmed cases of COVID-19 in the Territory of American Samoa.[105] The Territory moved swiftly to "lock down" including no incoming/outgoing flights or ships

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[100] CDC (2015). *Dengue Outbreak Response in American Samoa, 2015.* Retrieved from https://files.asprtracie.hhs.gov/documents/dengue-outbreak-response-in-american-samoa-2015-final-508.pdf
[101] Stuff (2009). Tsunami aftermath brings disease. Retrieved from http://www.stuff.co.nz/world/south-pacific/3044166/Tsunami-aftermath-brings-disease
[102] Añez, G., & Rios, M. (2013). Dengue in the United States of America: a worsening scenario? BioMed research international, 2013, 678645. Retrieved from https://doi.org/10.1155/2013/678645
[103] The New York Times (2020). *A Place in the US with no Covid-19? Look to American Samoa*. Retrieved from https://www.nytimes.com/2020/05/06/us/coronavirus-american-samoa.html
[104] Associated Press (2020). *American Samoa Declares Measles Outbreak. Closes School. Retrieved from* https://apnews.com/5b1a0d99558431d85e5023a5afce59c9
[105] The New York Times (2020). *Hawaii Coronavirus Map and Case Count*. Retrieved from https://www.nytimes.com/interactive/2020/us/hawaii-coronavirus-cases.html#county.

with the exception of one cargo flight with food and medical supplies each week. People were still permitted to gather in some social spaces, such as bars, but were limited to no more than 10 customers. Other social gatherings like bingo halls and churches, were shutdown. The COVID-19 global pandemic may still impact the island territory as it is projected to continue for several years. American Samoa received a major disaster declaration for COVID-19 in April 2020 and has received $35 million in relief funding (which can be used for preparedness) from the US Treasury as of April 22, 2020.

Tuberculosis: According to the World Health Organization, the Incidence of tuberculosis (per 100,000 people) in American Samoa has fluctuated between 12.00 in 2005 and 0.00 in 2018.[106]
Pink eye (Conjunctivitis): This can be caused by a virus or a bacteria. In 2014, a pinkeye outbreak resulted in over 5% of the population infected. This resulted in at least 28 school closures as upwards of 3,000+ students contracted the highly contagious infection. Travelers coming to and from the island were also monitored for symptoms.
NCDs: According to the Advanced Evaluation Team report following Tropical Storm Gita (2018):
NCD has been declared a public health emergency in American Samoa by the Pacific Island Health Officers Association, who call it "a serious impediment to effective emergency preparedness and response". American Samoa has very high rates of NCDs, including some of the highest rates of obesity and diabetes in the world. Approximately one in three people in American Samoa has type 2 diabetes. LBJ Tropical Medical Center has 32 dialysis chairs- a disproportionately high number in relation the population of around 60,000.[107]

Chikungunya and Leptospirosis are also present in the Territory, though specific information was on past events.

4.11.4 Extent

The severity of health risks is difficult to determine given the varying impacts associated with different viruses, diseases, and other public health conditions. Tuberculous and measles are considered to be the deadliest infectious diseases worldwide but have a low incidence rate in the U.S., are curable, and a vaccine exists for both (Figure 68). In addition, unknown viruses and diseases may bring unforeseen severity, such as that brought on by the novel coronavirus in 2020.

COVID-19, despite no confirmed cases to date in American Samoa, has resulted in a global pandemic and has no vaccine or viable treatments to date. The infection rate and mortality rates are also largely undetermined given the early stages of the tracking and limited testing. However, it is a deadly, highly infectious disease that is also resulting in significant economic and social impacts in American Samoa

[106] Index Mundi. Incidence of Tuberculosis. Retrieved from: https://www.indexmundi.com/facts/american-samoa/incidence-of-tuberculosis
[107] FEMA (2018, May 24). *Advanced Evaluation Team (AET) Report.* American Samoa

and across the globe.

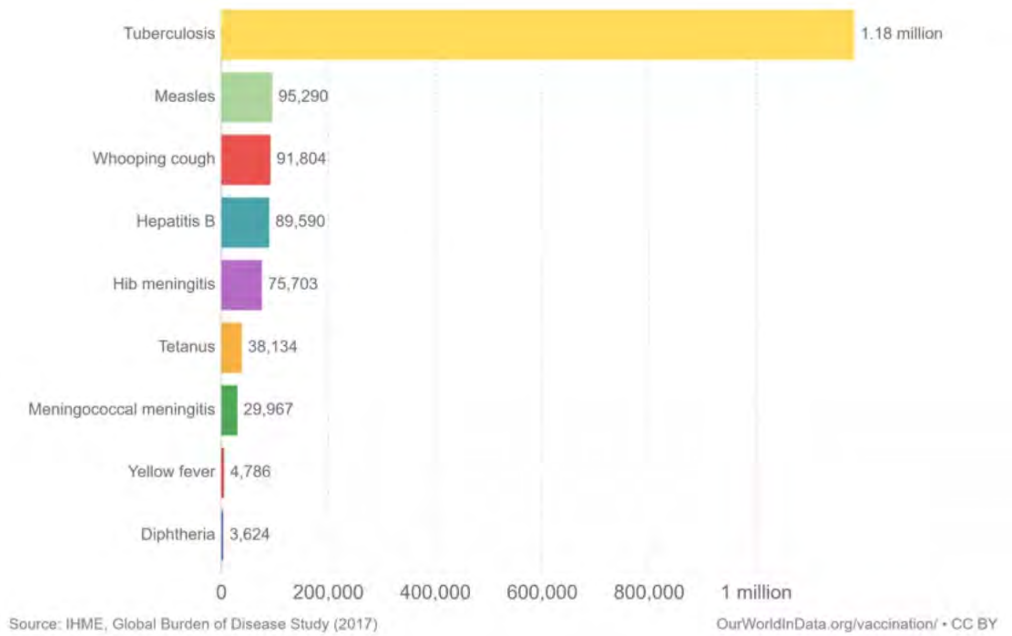

Figure 68: Deaths Causes by Vaccine-Preventable Diseases Worldwide[108]

4.11.5 Probability of Future Events

Probability of public health emergencies is variable based on conditions. Many public health risks occur seasonally and are ongoing, such as the common cold and influenza. Severe outbreaks, such as the current COVID-19 pandemic or measles outbreaks, are less common. When considering future public health risks, there are numerous factors that can impact the risk level.

- Frequency: Climate change impacts project wetter weather which may increase mosquito-borne infections given favorite mosquito breeding conditions. The duration of public health events is largely dependent on available treatment and management which is dependent on the specific public health incident. There is some evidence that outbreaks are generally increasing.
- Location: The location of public health risk will remain Territory-wide.
- Extent/Intensity: The severity of some public health risk may increase such increased presence of novel viruses. However, modern technology general allows for the prevention, detection, control and treatment of public health risk.

Based on the information available regarding historic and current events, as well as future considerations, this hazard was assigned a probability of likely (10% to 90% annual chance).

[108] World Economic Forum (2020). *5 of the World's Deadliest Infectious Diseases.* Retrieved from https://www.weforum.org/agenda/2020/04/covid-19-infectious-diseases-tuberculosis-measles-malaria/

4.11.6 Vulnerability Assessment

All current and future populations, critical facilities and infrastructure in the Territory of American Samoa are considered at risk to public health risks. This includes the potential for fatalities. The Territory has a strong history of managing infectious diseases including the 1914 Flu and COVID-19. However, as an island chain, American Samoa is susceptible to outsiders bringing in new contagious diseases. It is also vulnerable to on island outbreaks. In either case, an outbreak could result in significant impacts given limited on island resources. While each outbreak and threat is different, below are potential vulnerabilities and impacts due to public health threats:

Limited medical capacity – There is one hospital on the island (LBJ Tropical Medical Center) which has 150 beds. During COVID-19, the hospital reported capacity to manage approximately 10 patients without further supplementation. A 2017 reported noted that LBJ had just 2/3 of the necessary doctors and nurses at LBJ.[109] While additional staff could be flown in to assist, any outsiders present a risk and would require a quarantine period. Further, outside resources may be strained in widespread events, limiting the ability to support. There is also no access to cardiology, oncology, neurology, nephrology, or diagnostic imaging (MRI) in the Territory. The medical system could be easily overwhelmed in severe public health emergencies.

Limited supplies – While resources can generally be flown or shipped to the island, given the Territory's remoteness, there can be shortages and high shipping costs. Public health emergencies may exacerbate this or limit this option. In addition, as experienced with COVID-19, public health emergencies can also disrupt the supply chain for a wide range of products, food, and equipment. This applies to several areas including:

- Medical supplies - Whether the threat can be combatted through disinfectant measures, personal protective equipment (PPE), or mosquito repellant, the island may not have the immediate resources on hand. Further, there is limited food grown on the island.
- Food – American Samoa grows food on the island but is highly dependent on Samoa and the U.S. for food imports. It is also subject to regular fresh food shortages, even in blue-sky condition, given its remoteness. The COVID-19 event has demonstrated that public health emergencies can disrupt the food supply resulting in shortages and price fluctuations. There is a current movement to increase food security through subsistence farming at households and farmer support to grow certain foods such as tomatoes, and lettuce.[110] There is vulnerability not only in the ability to get food to the island, but the possibility of new diseases brought in by outside food.
- Equipment and other necessitates – In any emergency, equipment and basic necessities are needed. Such resources may be challenges to obtain in timely manner.

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[109] There is limited or no access to cardiology, oncology, neurology, nephrology, or diagnostic imaging (MRI) in the Territory.

[110] Samoa News (2020). *American Samoa's remote location is a challenge for food security.* Retrieved from https://www.samoanews.com/local-news/american-samoas-remote-location-challenge-food-security

Managing compounded disasters – Infectious diseases, such as COVID-19, create added complexity to emergency response including evacuation, sheltering and managing events from a typically crowded Emergency Operations Centers (EOC). Public health emergencies may has strain capacity of emergency personnel time and budgets to manage multiple disasters.

Closure of Schools – Public health emergencies may result in school closures which is disruptive to education. While some options for remote learning exists, it all requires equipment such as a laptop and access to broadband. Such events are also disruptive to parents, as young children will need supervision. In addition, schools provide access to multiple services, such as free or reduced cost lunch and counseling, the absence of which can have cascading impacts on students and families.
Closure of Business – In severe public health emergencies, businesses may need to be closed which will have economic implications. The closures may be limited certain geographic areas to contain an event or to specific sectors (e.g. restaurants), though they may also be wide-spread such as the COVID-19 events.

4.11.6.1 Climate Change Considerations

Increases in temperature, precipitation, humidity and tropical storm events (anticipated to see less frequent but more severe events) which are expected in American Samoa all have impacts on public health. The impacts are dependent on each type of public health risk. For instance, warmer and wetter conditions create a more favorable environment for the growth and spread of some infectious diseases and vectors, such as mosquito-borne viruses. Insects also have a limited range of temperatures where they can live, which may bring new insects to the Territory or lead to the decline of others. Conversely, warmer and more humid weather generally weakens the spread of respiratory illnesses. Changing climate conditions may also lead to virus mutations and adaptation leading to a rise in emerging diseases.[111] It will also shift habitats for wildlife and livestock, which may bring animals, and their diseases, closer to humans. Beyond disease, more extreme heat days and more precipitation may also deter people from outdoor exercise which may increase NCDs, such as diabetes.

4.11.6.2 Potential Losses

In general, public health emergencies will not result in significant dollar losses. They may however, result in the need for significant capital to manage the event. In severe situations, such as the COVID-19 event, widespread closures may be necessary in an effort to slow the rate of infection. In these cases, depending on the length of the closure, the economic conditions could be extreme. As we are experiencing with COVID-19, the immediate impacts include significant job loss. This not only impacts the individual and family directly, it has cascading impacts on the overall economic multiplier as people reduce spending. Similar to natural hazard events like hurricanes, economic disruptions, even when temporary in nature, can have significant impacts on the Territory’s Gross Domestic Product (GDP) for years to come. While it is too soon to understand the direct economic losses for COVID-19, most

[111] Medical News Today (2020). *How might climate change affect the spread of viruses?* Retrieved from https://www.medicalnewstoday.com/articles/how-might-global-warming-influence-the-spread-of-viruses#A-taste-of-things-to-come

economists agree that we are currently in a recession and without continued federal intervention, more severe impacts are possible.

Given the unpredictable nature of this threat, additional vulnerabilities, impacts and losses are feasible.

4.12 Sea Level Rise

4.12.1 Description

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 and ice sheets resulting in a greater amount of water in the oceans. Regardless of the cause, rising oceans means that greater areas of coastal shorelines can be inundated by water associated with nuisance flooding ("high tide flooding") and coastal storms. 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.[112] However, according to NOAA data, the rate of sea level rise is accelerating: it has more than doubled from 0.06 inches (1.4 millimeters) per year throughout most of the twentieth century to 0.14 inches (3.6 millimeters) per year from 2006–2015.[113] Even with low emission scenarios used, the sea is projected to rise at least 12 inches above 2000 levels over the next century. In higher emission scenarios, the sea could rise as high as 8.5 feet globally.

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 and assets reside near coastal areas. In neighboring Samoa, nearly one in four homes are below four meters elevation according to reinsurance company Swiss Re.; similar conditions are likely in American Samoa though this could not be verified.[114]

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, and increase nuisance flooding during high tides. When these hazards are combined with sea level rise, more water will inundate the land further inland. Salinization, when saltwater encroaches into fresh groundwater aquifers, is also a

[112] EPA (n.d.). Retrieved from http://www.epa.gov/climatechange/impacts-adaptation/coasts.html#adapt
[113] NOAA (2019). *Climate Change: Global Sea Level.* Retrieved from: https://www.climate.gov/news-features/understanding-climate/climate-change-global-sea-level
[114] SwissRe (n.d.). Retrieved from http://www.swissre.com/rethinking/climate_and_natural_disaster_risk/Samoa_South_Pacific_Facing_the_risks_of_rising_sea_levels.html

concern. This may contaminate drinking water supplies. Shoreline erosion, loss of developable land, loss of cultural sites, and loss of ancestral connections to the 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, coral dye-offs, and changes in coastal biodiversity.

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.[115] 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, 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. Sea level rise impacts in American Samoa are notable and projected to continue.

4.12.2 Location

NOAA has created a hypothetical sea level rise viewer, the Digital Coast Sea Level Rise Viewer, which can be used at: https://coast.noaa.gov/slr/.

Static maps from the Digital Coast are below (Figure 69 to Figure 74; 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.

[115] Adams, John (2007, May 3). Rising Sea Levels Threaten Small Pacific Island Nations. *New York Times.* Retrieved from https://www.nytimes.com/

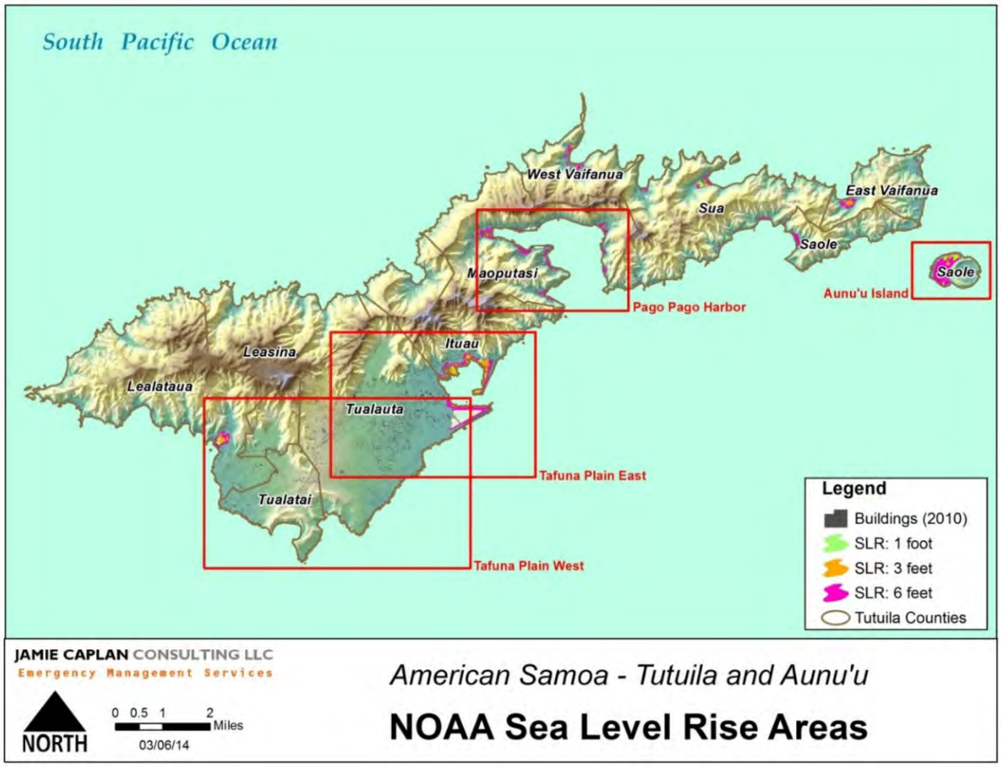

Figure 69: Tutuila Island Hypothetical Sea Level Rise Areas

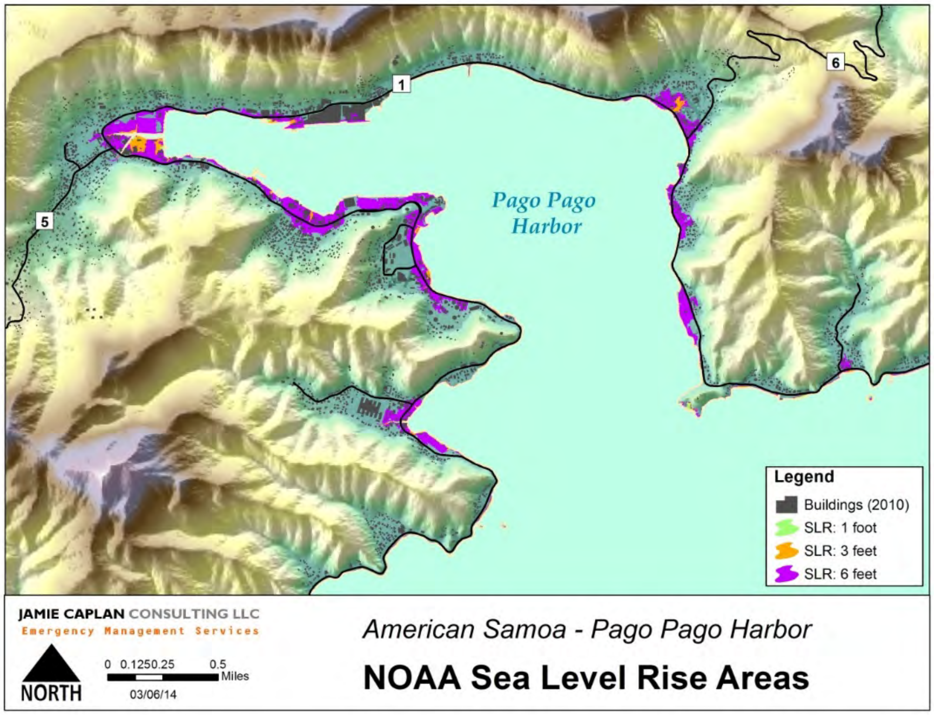

Figure 70: Pago Pago (Tutuila Island) Hypothetical Sea Level Rise Areas

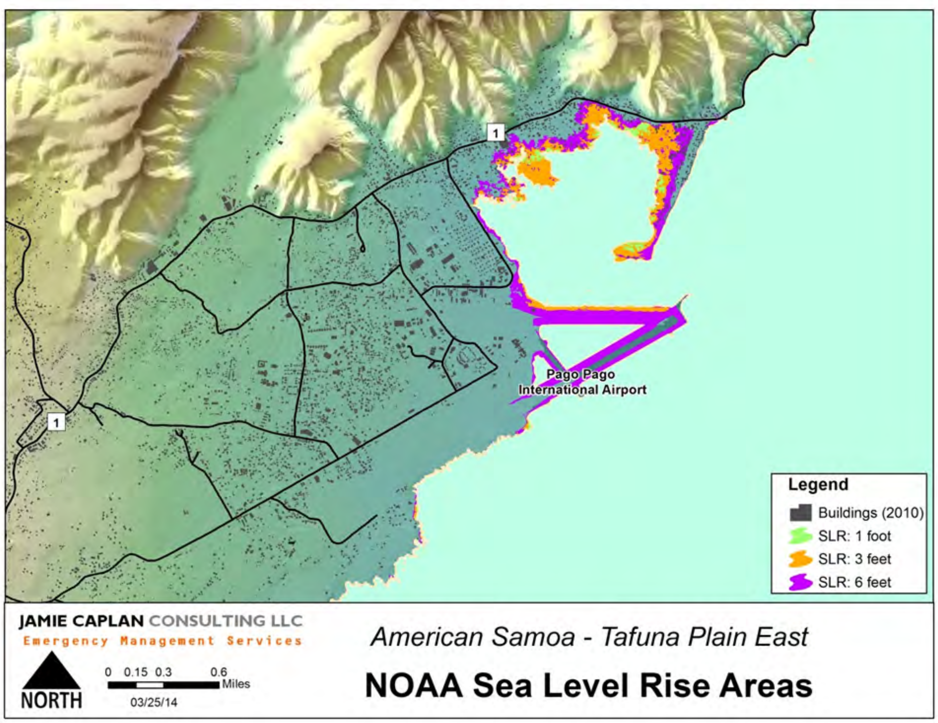

Figure 71: Tafuna Plain East (Tutuila Island) Hypothetical Sea Level Rise Areas

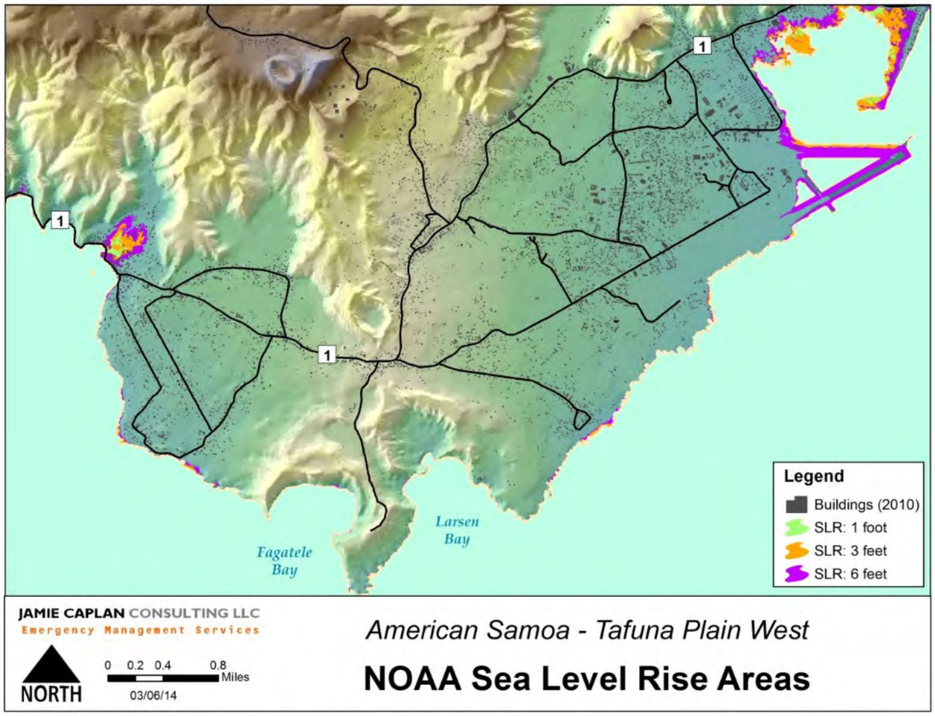

Figure 72: Tafuna Plain West (Tutuila Island) Hypothetical Sea Level Rise Areas

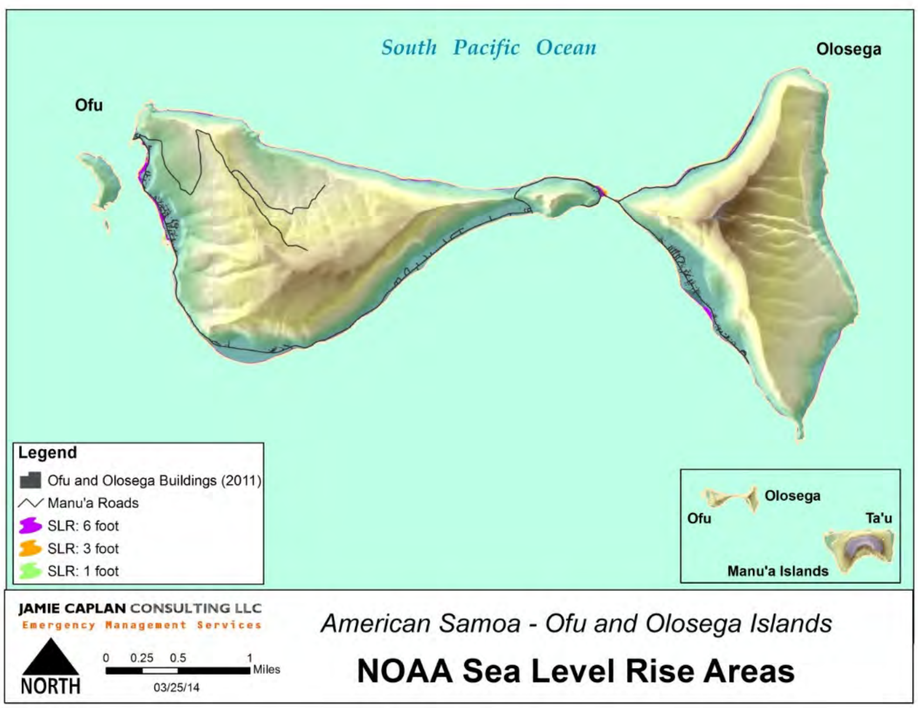

Figure 73: Ofu and Olosega Islands (Manu'a Group) Hypothetical Sea Level Rise Areas

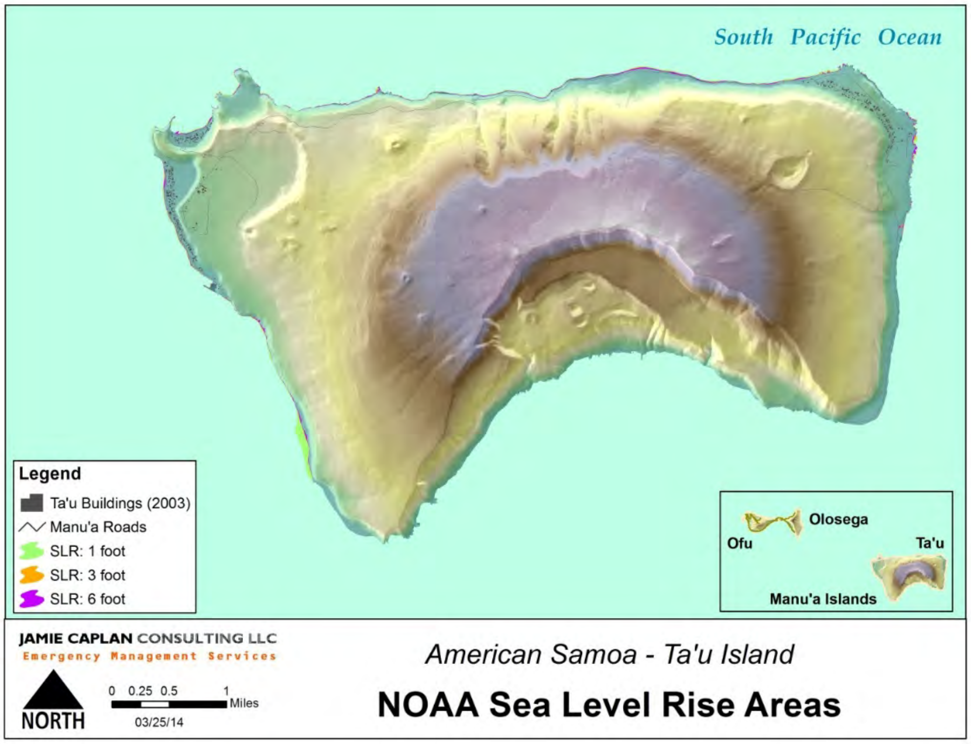

Figure 74: Ta'u Island (Manu'a Group) Hypothetical Sea Level Rise Areas

4.12.3 Previous Occurrences

Multiple sources were research to triangulate the trends of sea level rise previous occurrences. In general, sea level rise has not been tracked extensively until recent decades.

The USGS conducted a 2005 assessment on sea level rise. Its data indicated a rate of sea level rise of 1.48 millimeters per year (0.06 inches), which is equivalent to 0.49 feet (5.88 inches) in 100 years.[116] It found that the National Park of American Samoa, Island or Ofu and southern coast of Ta'u fall within the very low vulnerability category based on the water elevation alone. However, a more detailed and recent assessment by USGS, called the Coastal Vulnerability Index (CVI), shows varied risk along the shoreline of the National Park of American Samoa. The 2014 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 section below. 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 2.41 millimeters (0.10 inches) per year based on data from 1948 -2009, which is equivalent to 0.79 feet in 100 years.[117] Of note, this value has increased since the

[116] USGS (2005). *Physical process variables.* Retrieved from http://pubs.usgs.gov/of/2005/1055/html/ppvariables.htm
[117] NOAA (2020). *Tides and currents Relative Sea level trend 1770000 Pago Pago, American Samoa.* Retrieved May 16, 2020 from http://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=1770000

2014 plan, which indicated a trend of 2.07mm/year and a rise of 0.69 feet in 100 years. The rise has since declined but is still above the mean sea level rising trend line as shown in Figure 75 below.

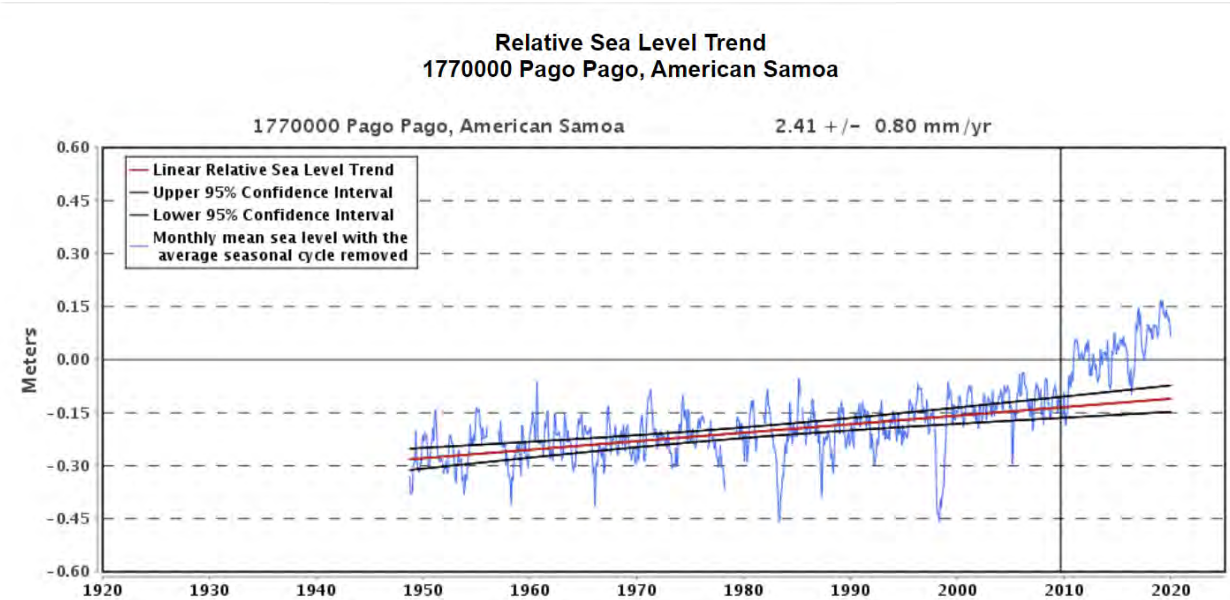

Figure 75: NOAA Annual Sea Level Rise Records

Data indicates a sharp increase in sea levels following 2010. This was initially thought to be a result of a strong La Niña in 2010-2011, but it is now thought to be a result of the 2009 magnitude 8.0 earthquake and tsunami according to new research from the American Geophysical Union (AGU).[118] Prior to the earthquake and tsunami, sea level rise in American Samoa was generally aligned with global averages of 2-3 millimeters (0.08 – 0.12 inches) each year. Following the earthquake, sea level rise rates are now roughly five times that. This 2019 research indicates that ongoing subsidence as a result of the seismic activity has greatly accelerated to 8-16 mm/yr. Coupled with rising temperatures, this has exacerbated sea level rise in American Samoa. This research indicated a projected sea level rise of 30-40 centimeters (12-16 inches) in American Samoa throughout this century.

The Samoa News also noted that many residents experienced King Tide impacts June 30-July 6, 2019 and July 31-August 2, 2019. Areas on the south and east-facing portions of the Territory's islands experienced the worst flooding in early July because of the strong winds and large waves from the east and south.[119]

[118] Han, S. C.; Sauber, J. M.; Pollitz, F. F.; Ray, R. D. *Sea level rise in the Samoan islands escalated by viscoelastic relaxation after the 2009 Samoa-Tonga earthquake.* American Geophysical Union. *Dec 2018.* Retrieved from *https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018JB017110*

[119] Sea level rise - A growing threat here in American Samoa*. Samoa News* (2019, August 7). Retrieved from https://samoanews.com/local-news/sea-level-rise-growing-threat-here-american-samoa

4.12.4 Extent

There is high confidence that sea level rise in American Samoa will continue. However, the magnitude of the trend varies considerably based on emissions scenarios and even seismic events. Sources from the USGS, NOAA, and AGU predict sea level rise between 6 inches, 8.9 inches, and 16 inches over the next century in American Samoa. Additionally, a 2016 study by EcoAdapt found sea level rise in American Samoa by 2100 will range between 7.2 inches (low emissions), 19.2 inches (moderate emissions) and 48 inches (high emissions).[120]

4.12.5 Probability of Future Events

As noted above, there is high confidence that sea level rise in American Samoa will continue and will result in gradual, annual impacts to the Territory. Nuisance flooding caused by sea level rise is also projected to be a regular occurrence by 2026. The location is expected to increase with areas further inland being impacted. The extent, intensity, and frequency are also projected to rise as described in *Section 4.12.6.1 Climate Change Considerations.* With consideration to past occurrences and future hazard events, a probability assignment of highly likely (between 90% and 100% annually).

4.12.6 Vulnerability Assessment

Sea level rise is projected to continue, likely at an accelerated rate. This means sea level rise will flood areas further inland as a result of tidal flooding, high surf, and coastal storms. This has wide-reaching impacts on Territorial assets in low lying coastal areas. All current and future populations and structures, including critical facilities, are at risk to sea level rise. Some of the potential impacts include:

- *Transportation* - America Samoa has "ring road" that borders the coast around most of the island. As sea levels rise, this threatens the road and Samoans' ability to traverse the island for business or emergencies.
- *Land* - As an island, land is very limited. Rising seas degrade landmass and shoreline on island for new construction opportunities and beach activities.
- *Water Supply* – Rising sea levels threaten salinization of aquifers and the ability to easily treat drink water.
- *Environmental* – Low lying ecosystems, fauna, and flora, such as mangroves that offer coastal protection, will be inundated.
- *Business* – Businesses along the coast, including hotels and restaurants, will be impacted.
- *Cultural/Spiritual* – Loss of seaside cultural sites and the potential need to relocate populations will result in a loss of spiritual connect to land that families have occupied for centuries[121]

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[120] EcoAdapt (2016). Climate Change Trends and Projections for National Marine Sanctuary of American Samoa Rapid Vulnerability Assessment and Adaptation Planning Project. Retrieved from http://ecoadapt.org/data/documents/AmericanSamoaClimateChangeTrendsandProjections7-5.pdf

[121] ASEPA (2007). *An order recognizing the importance of the American Samoa Government's commitment to ameliorate global climate change and its negative effects on the territory; setting forth ASF's short and long-term commitments to this worthy effor*t (American Samoa Executive Order 0101A-2007). Retrieved from http://www.epa.as.gov/sites/default/files/documents/climate_change/2007climatechangeeo.pdf

In addition, the USGS indicates areas of vulnerability via the Relative Coastal Vulnerability Assessment shown in Figure 76.**Error! Reference source not found.**[122] 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.

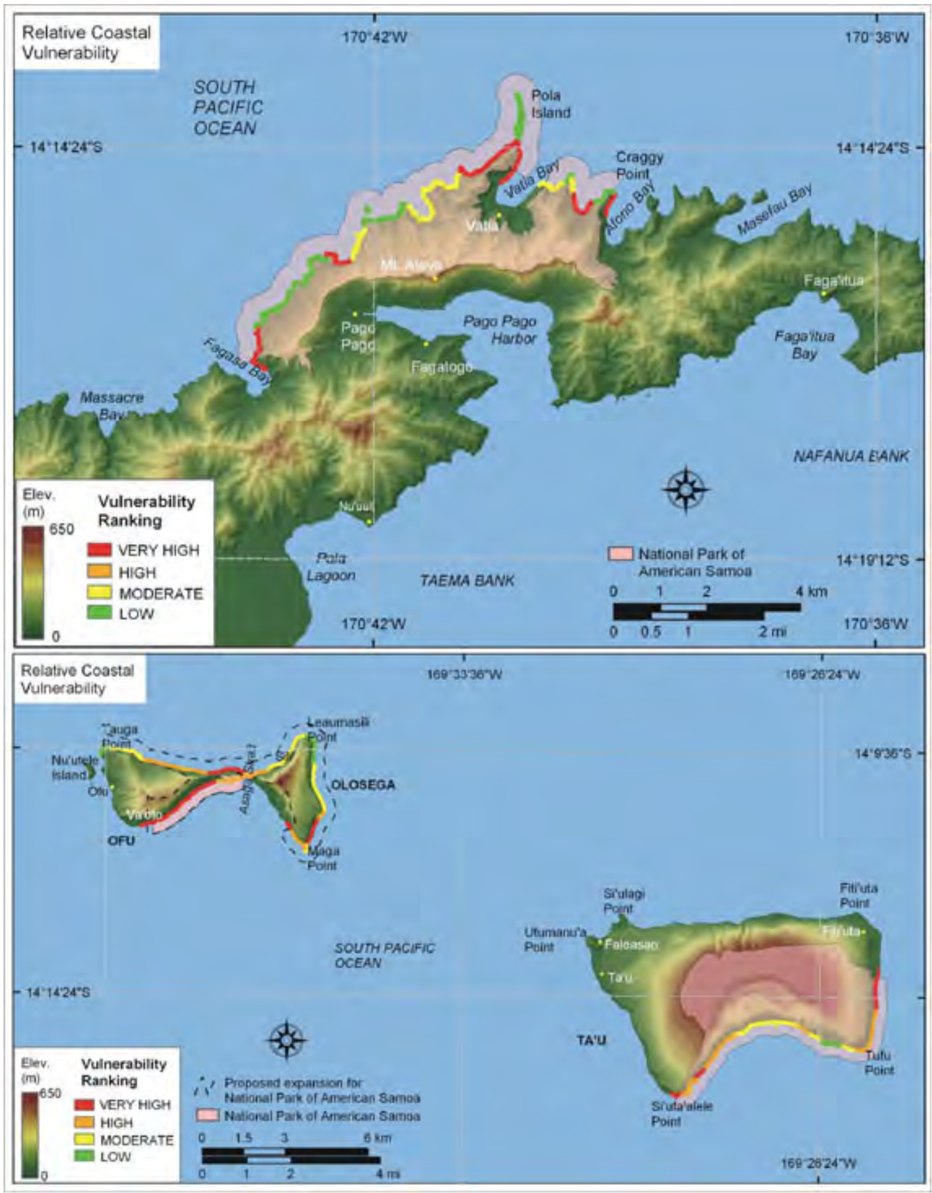

Figure 76: NOAA CVI Future Sea Level Rise Vulnerability

[122] USGS (n.d.). Retrieved from http://woodshole.er.usgs.gov/project-pages/nps-cvi/parks/npsa.htm

4.12.6.1 Climate Change Considerations

El Niño or La Niña events can also have an impact on sea level rise vulnerability and the ENSO phases are projected to more intense due to climate change.[123] During El Niño cycles, winds tend to calm, and the air is dry, leading to less flooding. Conversely, during La Niña cycles, strong winds push water further inland during storms and tidal flooding, including king tides (the highest tides of the year). Further, climate change predictions include fewer small coastal storms, but more frequent severe coastal storms. Each of these factors increase the vulnerability, severity of impacts, intensity and frequency of sea level rise of American Samoa.

4.12.6.2 Potential Losses

In order to better estimate potential sea level risk and potential losses in American Samoa, areas of hypothetical sea level rise 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. Of note, this analysis was conducted for the 2015 plan and was not updated for the 2020 plan given data limitations. The results are summarized in Table 35 below.

Table 35: Buildings Potentially at Risk to Sea Level Rise

County (District)	Total Number of Buildings	Total Number of Buildings in the 1-foot SLR Area	Type	Total Number 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 2 residential	61	1 402 1 church 59 residential
Lealataua (East District)	2,026	3	3 residential	36	36 residential
Leasina (East District)	474	0	-	0	-
Maoputasi (East District)	2,246	11	1 commercial 10 residential	30	1 govt (FONO) 3 commercial 26 residential
Saole (East District)	364	0	-	2	2 residential
Sua (East District)	938	0	-	0	-
Tualatai (West District)	903	0	-	0	-

[123]Pacific Island Climate Education Partnerships (2014). *Climate Change in American Samoa.* Retrieved from http://www.soest.hawaii.edu/coasts/publications/AmSamoa%20Climate%202016.pdf

County (District)	Total Number of Buildings	Total Number of Buildings in the 1-foot SLR Area	Type	Total Number of Buildings in the 3-feet SLR Area	Type
Tualata (West District)	7,441	0	-	1	1 residential
West Vaifanua (East District)	172	0	-	5	5 residential
Tutuila Island Total	16,136	16	-	141	-
AUNU'U ISLAND					
Saole (East District)	179	0	-	0	-
Aunu'u Island Total	179	0	-	0	-
MANU'A ISLANDS					
TA'U ISLAND					
Faleasao (Manu'a District)	81	0	-	0	-
Fitiuta (Manu'a District)	180	0	-	0	-
Ta'u (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, the island's key commerce area, 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 (three 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 the table below. In addition, assembly areas, safe zones, tsunami sirens, and ASTCA communication infrastructure were analyzed for vulnerability. The results are reported in Table 36 below.

Table 36: 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 C. While some new critical facilities identified for 2020 are located in flood hazard areas, no structures are thought to be at risk to sea level rise as those in coastal areas are elevated.

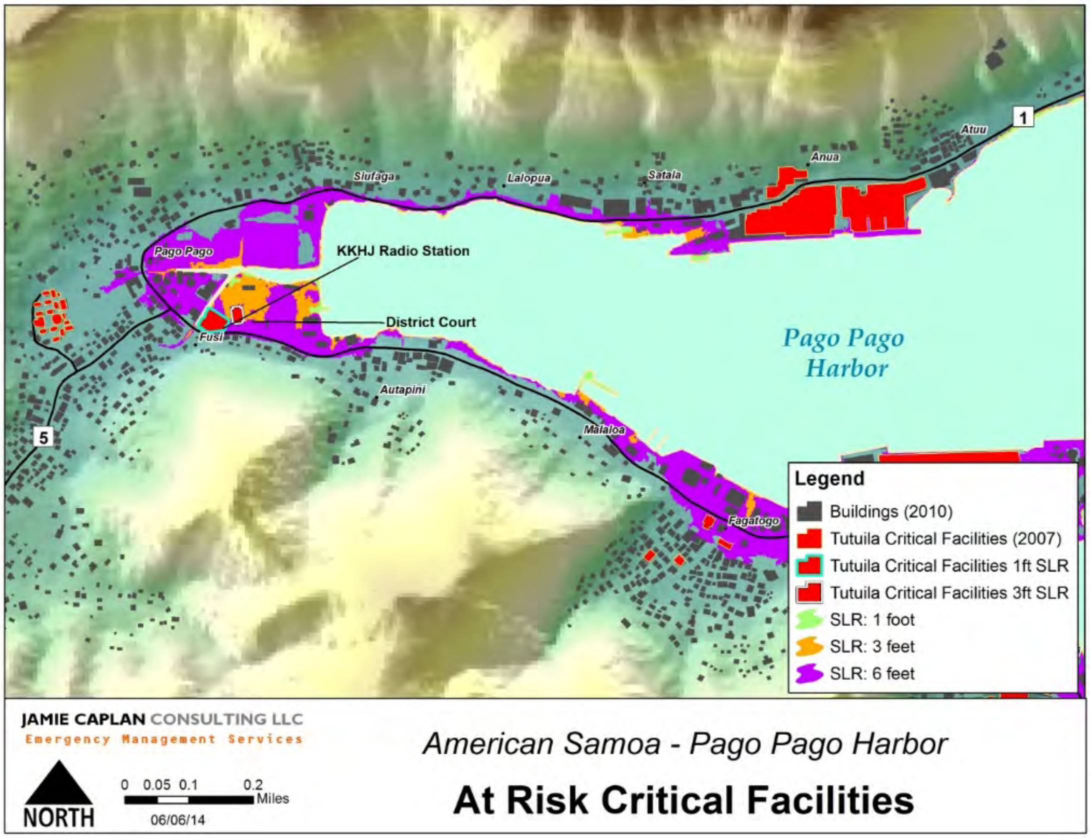

Figure 77: Critical Facilities Potentially at Risk to Sea Level Rise (Greater Pago Pago)

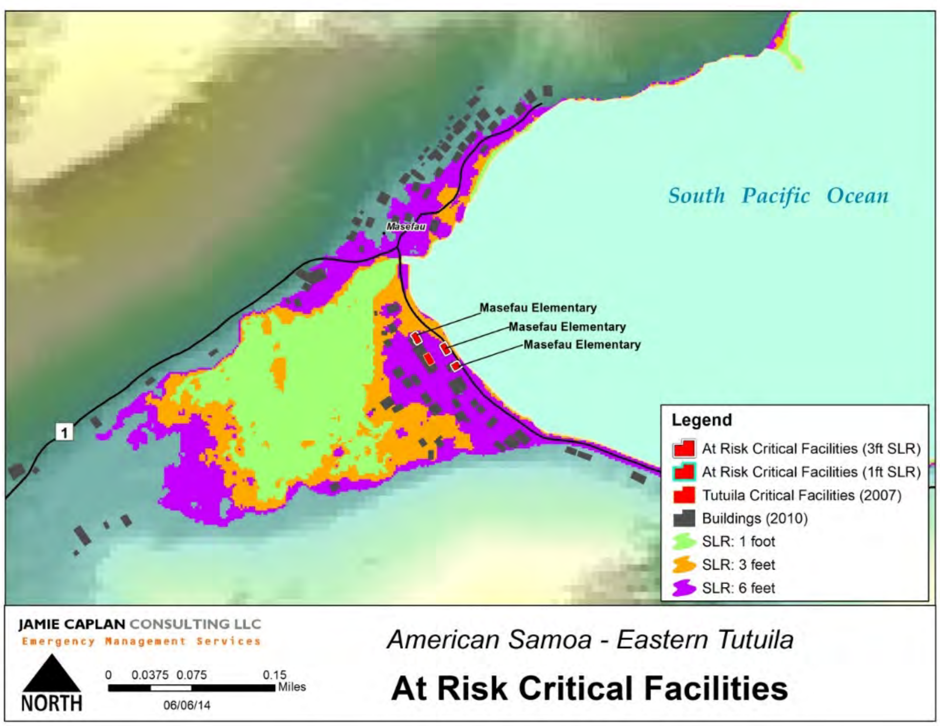

Figure 78: Critical Facilities Potentially at Risk to Sea Level Rise (Eastern Tutuila)

4.13 Soil Hazards (Expansion and Sinkhole)

4.13.1 Description

Soils hazards are defined here as soil expansion and sinkholes. Subsidence may also be considered a soil hazards. It was made a stand-alone hazard for the 2020 plan update. 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%.

According to the USGS, sinkholes are common with limestone, carbonate rock, salt beds, or rocks that can naturally be dissolved by groundwater circulating through them. They typically occur when karst terrain is present (or 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.

4.13.2 Location

Soil expansion is possible throughout American Samoa where soil is present.
Sinkholes are possible throughout American Samoa. As noted above, they are most likely to be formed due to leaky pipes and other human causes.

4.13.3 Previous Occurrences

Limited information on previous soil hazards was found. As additional information is available, this profile will be updated.

4.13.4 Extent

Soil Expansion

The combination of the shallow depth of soil and the soil composition in American Samoa limits 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% of their original composition. Given the limited documentation of this hazard, extent is assumed to be limited.

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 relatively small (less than 10 feet wide and 10 feet deep and likely a result of human activities).

4.13.5 Probability of future events

When considering future soil expansion or sinkhole events, the following conclusions were drawn: Frequency: There are limited records on past occurrence but both soil expansion and sinkholes could increase in frequency and locations impacted given changes in climate include temperature swings and more precipitation which increase sinkhole occurrence. Given these assumptions, it is also feasible that the severity and impacts of these hazards may increase in alignment with increased frequency and locations.

Given the limited information on these soil hazards and consideration of future events a, probability of unlikely (less than 1% annual chance) was assigned.

4.13.6 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

Sinkholes

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

4.13.6.1 Climate Change Considerations

American Samoa is expected to experience extreme rising temperatures which may lead to more hot days. This may also result in more varied temperature swings which can impact soil expansion. The projections for increased wet weather may also increase the occurrence of sink holes.

4.13.6.2 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.

4.14 Subsidence

4.14.1 Description

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."[124] 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.

4.14.2 Location

Land subsidence is a threat across all of American Samoa, particularly in coastal areas, according to the territory's Coastal Management Plan.[125] At presence there are no data or maps to indicate specific locations of subsidence, or differences in severity.

4.14.3 Previous Occurrences

Although limited research has been conducted, recent sources indicate land subsidence is a growing threat to American Samoa. The rate of subsidence is currently about 0.63 inches/year, though more accelerated subsidence is possible.

4.14.4 Extent

As referenced in the Sea Level Rise hazard, subsidence is thought to be increasing significantly following the 2009 earthquake and tsunami as a result of tectonic changes. This 2019 research indicates that ongoing subsidence on American Samoa has accelerated to 8-16 mm/yr (0.31 - .63 inches/year). The Samoa News also noted that American Samoa has subsiding approximately five inches since the earthquake.[126]

4.14.5 Probability of Future Events

Future subsidence events are expected to be more severe and more frequent. The entire island is subject to subsidence and coastal areas generally see more pronounced impacts. As subsidence continues to occur, it may be more pronounced in inland areas as well. A future earthquake event, similar to the 2009 event that likely resulted in the recent rise in subsidence rates, could also exacerbate the intensity of subsidence. Given new information on subsidence and consideration of future events, probability is assumed to be highly likely (greater than 90% annual chance).

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[124] USGS (n.d.). *Land Subsidence.* Retrieved from http://water.usgs.gov/edu/earthgwlandsubside.html
[125] American Samoa Department of Commerce (2011). *Section 309 Assessment and Strategy for the American Samoa Coastal Management Program*. Retrieved from http://coastalmanagement.noaa.gov/mystate/docs/as3092011.pdf
[126] Sea level rise - A growing threat here in American Samoa. Samoa News (2019, August 7). Retrieved from https://samoanews.com/local-news/sea-level-rise-growing-threat-here-american-samoa

4.14.6 Vulnerability Assessment

Vulnerability to subsidence is island-wide, though will be notable in coastal areas, particularly due to increased sea level rise impacts. Lower elevations mean greater coastal flood impacts. Subsidence can also result in displaced foundations on structures and cracks in roads. As a result, all current and future structures, critical facilities, and populations are considered at risk to subsidence.

4.14.6.1 Climate Change Considerations

While project changes in climate (increased hot days, increased precipitation, fewer large but more intense tropical storms) are not anticipated to directly impact subsidence vulnerability, the impacts of flooding associated with climate change will impact the islands. Coupled with subsidence, low lying areas will experience greater flood impacts.

4.14.6.2 Potential Losses

Limited information exists to determine a reliable potential loss estimate for the subsidence hazard. As subsidence continues, it is likely that impacts will be more pronounced. As more information becomes available, this profile will be updated.

4.15 Tropical Cyclone

4.15.1 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.[127] 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 counterclockwise 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 1 to April 30, 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.[128] The most predominant and destructive hazards associated

[127] NOAA (2020). *What is the difference between a hurricane and a typhoon?* Retrieved from http://oceanservice.noaa.gov/facts/cyclone.html
[128] US Department of State (2011). *Travel Alert: South Pacific Cyclone Season.* Retrieved from https://www.osac.gov/Country/Palau/Content/Detail/Report/bbb1789e-8190-4606-b3a1-15f4ad127d70

with hurricanes include high winds, heavy rain, and storm surge. These whether events are possible outside of a hurricane or tropical cyclone events but are typically most severe when part of a tropical system.

High Winds

Hurricane winds can reach speeds up to 155 miles per hour in the eyewall 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, flying debris is primary wind-related cause of death, destruction, and injury.

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.

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 proximity to Australia/New Zealand, information comes from their weather agencies as well. Also, since American Samoa is a U.S. Territory, NOAA and the 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 37 below.

Table 37: Cross-comparison of Tropical Cyclone Categories[129]

<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>Tropical 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 rowspan="2">Severe Tropical Storm</td><td rowspan="2">Severe Cyclonic Storm</td><td rowspan="2">Severe Tropical Storm</td><td rowspan="2">Category 2 tropical cyclone</td></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>Category 1 hurricane</td><td>Typhoon</td></tr>
</table>

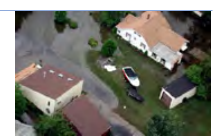
[129] Wikipedia (2020). Tropical Cyclone. Retrieved from http://en.wikipedia.org/wiki/Tropical_cyclones

<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>72–82 knots (83–94 mph; 133–152 km/h)</td><td>64–72 knots (74–83 mph; 119–133 km/h)</td><td></td><td rowspan="6"></td><td rowspan="8">Typhoon</td><td rowspan="6">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="3">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 rowspan="3">Category 4 hurricane</td></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="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. [130]

Table 38 and Table 39 show the damages expected from the Saffir-Simpson scale and the Australian Cyclone Severity Scale, respectively.

Table 38: Hurricane Damage Classification on the Saffir-Simpson Scale[131]

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).	

[130] NOAA (n.d.). Retrieved from http://www.aoml.noaa.gov/hrd/tcfaq/A3.html
[131] NOAA (n.d.). Beaufort Wind Scale. Retrieved from http://www.spc.noaa.gov/faq/tornado/beaufort.html

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).	

Table 39: Australian Cyclone Severity Scale [132]

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

4.15.2 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.

[132] NOAA (2011). *Frequently asked questions. How are Australian tropical cyclones ranked?* Retrieved from http://www.aoml.noaa.gov/hrd/tcfaq/D2.html

4.15.3 Previous Occurrences

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, such as 2018 Tropical Storm Gita.

Figure 79 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. An additional 27 storms were reported within 75 miles of the islands, and distance where tropical cyclones tend to impact. However, extremely large events may impact the islands from even greater distances. Such events, such 2005 Category 5 Hurricane Heta, were included in the previous occurrences list.

During the last 50+ years, nine major hurricanes have impacted American Samoa. They have been fairly uniform in frequency and more or less evenly distributed during this period. Details are significant events are presented below. Combined losses are totaled at more than $300 million. A complete listing of previous occurrences can be found in Appendix C.

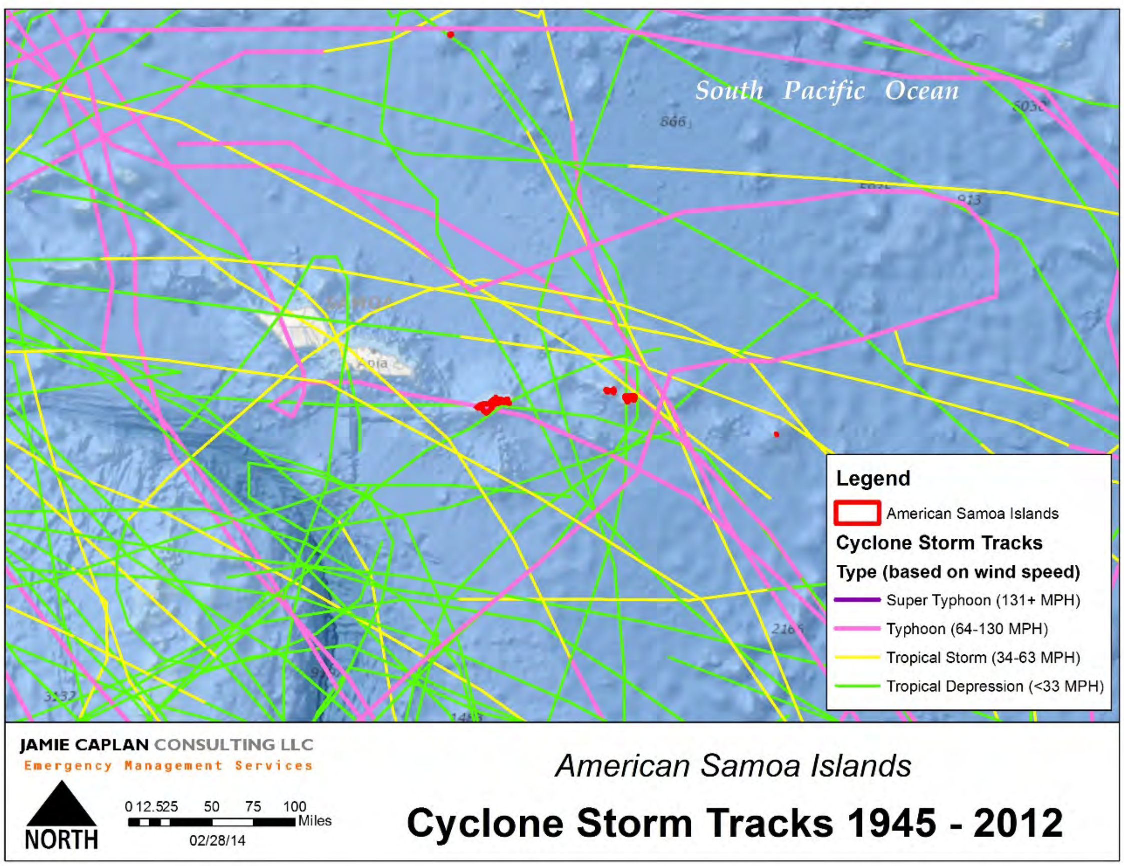


Figure 79: Historic Hurricane Tracks

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.[133] 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.

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."[134]

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.

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133 American Samoa Government (2003). *American Samoa.* Online. Retrieved from http://www.asg-gov.com/islandinfo.htm

134 Robert L. Webb. *Hurricane Ofa – American Samoa.* 2000. Retrieved from http//www.motivation-tools.com/hunky-dory/feb27-90.htm

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.[135]

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.[136]
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.[29]

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.[137]
Both the cannery and the airport were heavily impacted by storm surge on the southern shore of the island. Neither of these facilities had backup power, making both particularly vulnerable.

Tropical Cyclone Heta (2004)
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.

[135] PPG Consultants, American Samoa Flood Mitigation Plan, PPG Consultants. January 10, 2003.
[136] Federal Emergency Management Agency, Hazard Mitigation Strategies, Hurricane Val. DR-927-AS. FEMA, December 22, 1991.
[137] Seugogo Ben Schirmer, Director of the Port Authority. Pago Pago Harbor. Personal Interview. Pago Pago, American Samoa. April, May 2003.

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.[138]

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 (2005)

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 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% 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.

[138] Wikipedia (2020). *Cyclone Heta* (see note 12). Retrieved from http://en.wikipedia.org/wiki/Cyclone_Heta

Tropical Cyclone Tam (2006)

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.[139] 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 (2010)

On January 26, 2010 Tropical Cyclone Nisha was centered at its closest point to American Samoa, about 175 miles southeast of Tutuila.[140] The storm was not a major cyclone but was of significance because many people were still sheltering in tents following the 2009 tsunami.[141] 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.

Tropical Storm Gita (DR-4357) (2018)

Tropical Storm Gita impacted American Samoa during the period of February 7-12, 2018 and resulted in a presidential disaster declaration. Gita was a tropical storm upon impact, but it caused significant damage to residences, power, water, and telecommunications in the American Samoa. Fortunately, there were no reports of injuries or fatalities.

In the two days leading up to impact, Tropical Storm Gita brought torrential rain to the American Samoa, totaling 17 inches in some areas, and resulting in flooding and landslides.[142] Flooding was reported in Pago Pago and Malaeloa, and landslides were reported in the Villages of Avau, Amanave, and Poloa, though actual impacts were likely widespread across the island.[143] The storm left 90% of the island without power and water, and one day into recovery just 30% of the island had operable power and water.

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[139] NOAA's Storm Events Database. *Tropical Cyclone Tam.* Retrieved from https://www.ncdc.noaa.gov/stormevents/

[140] NOAA's Storm Events Database. *Tropical Storm Nisha.* Retrieved from https://www.ncdc.noaa.gov/stormevents/

[141] RNZ (2010). *Cyclone Nisha buffets American Samoa.* Retrieved fromhttp://www.radionz.co.nz/international/pacific-news/188421/cyclone-nisha-buffets-american-samoa

[142] RNZ (2018). *Depression heading towards Samoa expected to become cyclone.* Retrieved from https://www.rnz.co.nz/international/pacific-news/350051/depression-heading-towards-samoa-expected-to-become-cyclone

[143] RNZ (2018). *Homes evacuated amid flooding in American Samoa.* Retrieved from https://www.rnz.co.nz/international/pacific-news/349922/homes-evacuated-amid-flooding-in-american-samoa

Notably, the American Samoa Weather Service Office (WSO) lost power and telecommunications the morning of February 9, when the peak of the storm impacted the Territory.[144] The WSO is located at the airport in Tafuna and had backup power via a generator. However, the generator was inoperable shortly after losing power and could not be repaired given the needs for off-island parts. The Honolulu Forecast Office assumed the role of issuing weather reports for American Samoa for the remainder of the event (the WSO noted it was a lesson learned to regularly service and test their generator prior to an event). Approximately 1,000 homes were impacted by Tropical Storm Gita, most of which were uninhabitable. FEMA's Preliminary Damage Assessment (PDA) report indicated the following damages to households (Table 40): [145]

Table 40: Household Damage due to Tropical Storm Gita

Damage	Description	Households Affected
Destroyed	Total loss of structure and is not economically feasible to repair.	56
Major Damage	Substantial failure to structural elements of residence.	180
Minor Damage	Damaged and uninhabitable but may be made habitable in short period of time with repairs.	632
Affected	Some damage to the structure and contents, but still habitable.	82

Of the homes damaged, 9% had insurance and 38% were low income households. A total of 6,082 FEMA individual assistance applications were approved, totaling over $20.5 million. Figure 80 indicates some of the impacts. Additionally, FEMA distributed over 500 tents and 400 cots on Tutuila and Aunu'u, and more than 20 tents and 60 cots in Manu'a. At the peak, the Territory opened over 24 shelters and sheltered over 1,000 persons.

The PDA also indicated the greatest impact to utilities. Over $7.2 million in FEMA public assistance applications were obligated including $5.2 million for permanent work. Additional infrastructure, including the LBJ Medical Center were also impacted and received FEMA repair and recovery funding. The October 4, 2018 American Samoa Governor's Authorized Representative (GAR) update, noted the following impacts as shown in Table 41.

Table 41: Tropical Storm Gita Impacts

Affected Area	Impacts
Communication	• 2 tower sites damaged

[144] Samoa News (2018). *Weather service says they are taking lessons learned from Gita to heart*. Retrieved from https://www.samoanews.com/local-news/weather-service-says-they-are-taking-lessons-learned-gita-heart
[145] FEMA (2018). Retrieved from https://www.fema.gov/media-library-data/1522770993552-1a9d5e8947e6bc440c21f88471a32671/FEMA4357DRAS.pdf

Affected Area	Impacts
	• 3 remote sites damaged • 6 remote sites inoperable due to power issues
Utilities	• 9,600 without water (8 days to restore) • 12,000 without power (19 days to restore to 98%; unable to reach 100% due to structure damage)
Health, Social Services, Special Needs & Elderly	• 2,100+ patients treated/50 Gita-related • 4 medical teams deployed • 5 cases of dengue
Food Safety & Security Impact	• $260,000-$2,000,000 in crop damage • Damage to subsistence farming but did not receive funding support • $164,000+ in USDA loans for 32 farmers

The 2019 American Samoa Economic Forecast (ASEF) report noted that Tropical Storm Gita "caused as much as $186 million in direct and indirect damages across the territory," leaving a long recovery for the island.[146]

A Long Term Recovery (LTR) Task Force was established to help guide the recovery. It includes multiple task force teams for recovery of housing, economy, infrastructure, community planning, and health and social services and is supported by multiple Territorial agencies and non-Territorial partners to restore normalcy across the islands.

Figure 80: ASG/FEMA Preliminary Damage Assessments conducted immediately after Tropical Storm Gita. Source: GAR Report

4.15.4 Extent

As the previous occurrences show, powerful Category 5 cyclones, such as Hurricane Olaf and Hurricane Heta, are possible in American Samoa. Such events can bring winds in excess of 140 miles per hour.

[146] Relief Web (2018). *Tropical Storm Gita has some significant effects on American Samoa's GDP and economic forecast.* Retrieved from https://reliefweb.int/report/american-samoa/tropical-storm-gita-has-some-significant-effects-american-samoas-gdp-and

4.15.5 Probability of Future Events

Previous occurrences, ENSO cycle impacts, and future considerations were reviewed to estimate probability. The previous occurrences indicated 31 events within 75 miles of the planning area over a 75-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 41%. However, when we investigate these events based on major cyclones (category 3; 111 mile per hour winds or greater), just six events apply. This results in an approximate annual probability of 8%, for category 3 or above events. Of note, even less severe events, such as Tropical Storm Gita, can have significant impacts on the Territory.

The ENSO cycle also appears to have bearing on the probability of occurrence. As Figure 81 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. Typically, La Niña cycles bring stronger winds and wet weather and are associated with tropical storm activity. However, El Niño events mean storms form closer to the islands, which may increase the probability of impact.[147]

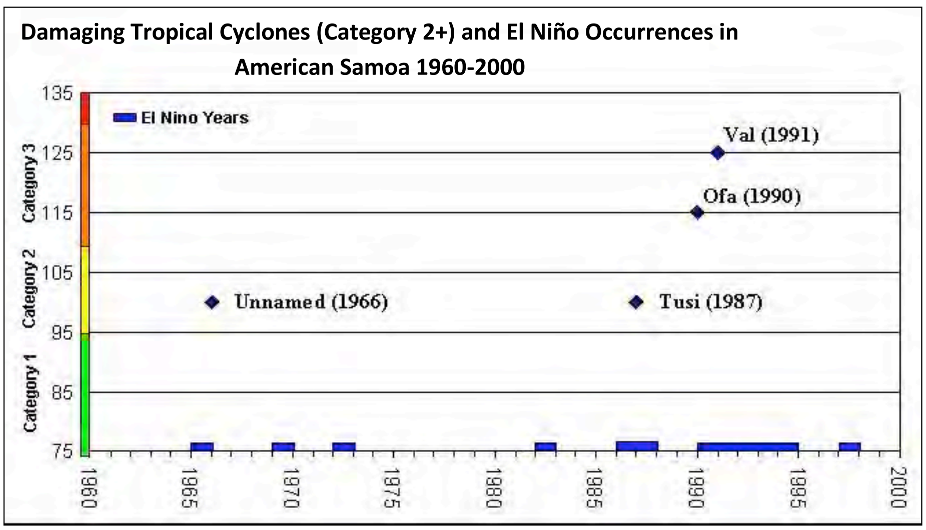

Figure 81: Tropical Cyclone Concurrence with El Niño

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

[147]NOAA (2015). *El Niño and its Impacts on American Samoa.* Retrieved from https://www.pacificrisa.org/wp-content/uploads/2015/11/Pacific-Region-EL-NINO-Fact-Sheet_ASamoa_2015-FINAL-v2.pdf

- 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

The ENSO cycle is expected to see more extremes as future of climate change.

Further described in Section 4.15.6.1, future tropical storm events are projected to decrease for small events but increase for large, more intense events. While the entire Territory is generally at risk, larger storms may mean more severe impacts across larger areas of the Territory.

With consideration to historic and future events, a probability of likely was assigned.

4.15.6 Vulnerability 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 FIRMs, coincident with areas vulnerable to wave action resulting from tsunamis. However, impacts would likely be territory wide. Development and population 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. Even less severe events, such as Tropical Storm Gita, can have major impacts on the island. 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
- Evacuations
- Downed utility lines/power outages
- Harbor closure
- Increase in mosquito-born diseases
- Injury, death

4.15.6.1 Climate Change Considerations

ENSO El Niño and La Niña phases, which may be more pronounced due to climate change, have a bearing on hurricane vulnerability. During El Niño phases, there is increased risk as storms form closer to the islands. During La Niña phases, winds typically bring more wind and wet weather.

In general, tropical activity is expected to decrease for American Samoa as storm tracks shift toward the Central North Pacific. Specifically, climate change is expected to decrease the frequently of weak tropical storms while increasing that of strong tropical storms. However, in high emission scenarios, American Samoa is likely to see a decrease in both weak and strong events.[148]

[148] Wang, Yuqing (2016). Final Report - 21st Century High-Resolution Climate Projections for Guam and American Samoa
PICSC Final Report Wang DD_Guam&Tutuila 2016 11 17.pdf. Retrieved from https://www.sciencebase.gov/catalog/item/583331f6e4b046f05f211ae6

4.15.6.2 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. Specific losses could be estimated for this hazard given limited data.

4.16 Tsunami

4.16.1 Description

In the last two decades 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.

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.[149] 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 of 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.[150] 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."[151] Observing this phenomenon is a clear indication to go to higher ground away from the shoreline.

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[149] NOAA (n.d.). *NOAA Tsunami Program*. Retrieved from http://www.tsunami.noaa.gov/

[150]Australian Government Bureau of Metrology (n.d.). *Tsunami facts and information.* Retrieved from http://www.bom.gov.au/tsunami/info/index.shtml

[151] National Geographic (n.d.). Retrieved from http://environment.nationalgeographic.com/environment/natural-disasters/tsunami-profile/

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.[152]

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.

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

[152] Pacific Tsunami Warning Center (n.d.). *Frequently asked questions.* Retrieved from http://ptwc.weather.gov/faq.php

generation mechanism, and a non-seismic event, such as a landslide, meteorite impact, or sub-marine volcanic eruption can also generate a tsunami.[153]

4.16.2 Location

The entire coastline of American Samoa is a risk to a tsunami event. 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

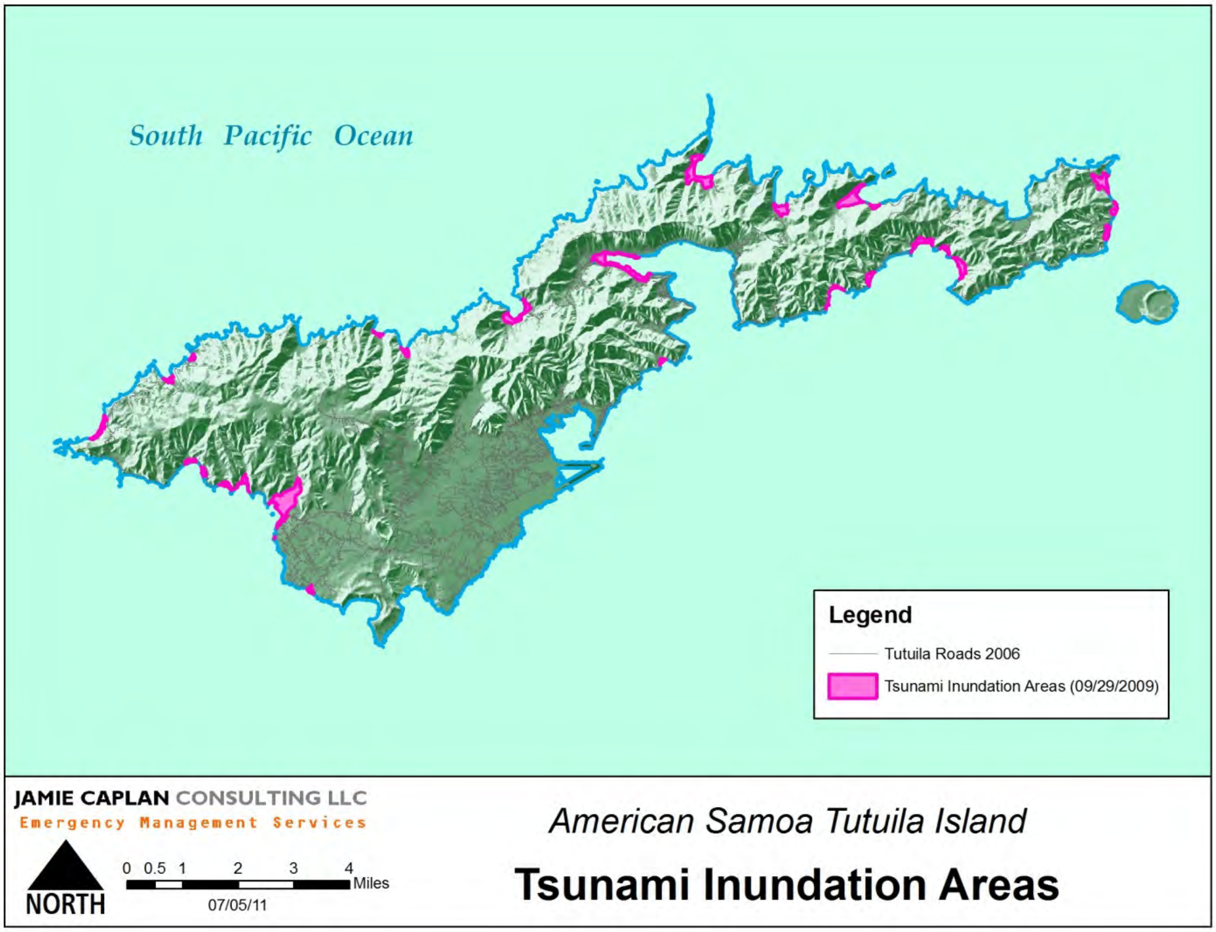

Figure 82. While this was a catastrophic event, future tsunamis may impact areas beyond those impacted in 2009. Tsunamis are often associated with wave action making the FEMA maps one tool of identifying areas A/AE and V/VE along the coast can be considered at risk. However, there are no areas of V/VE identified on Tutuila from the FEMA maps. Figure 83 shows the flood zones and corresponding

[153] Australian Government Bureau of Metrology (n.d.). *Tsunami facts and information.* Retrieved from http://www.bom.gov.au/tsunami/info/index.shtml

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.

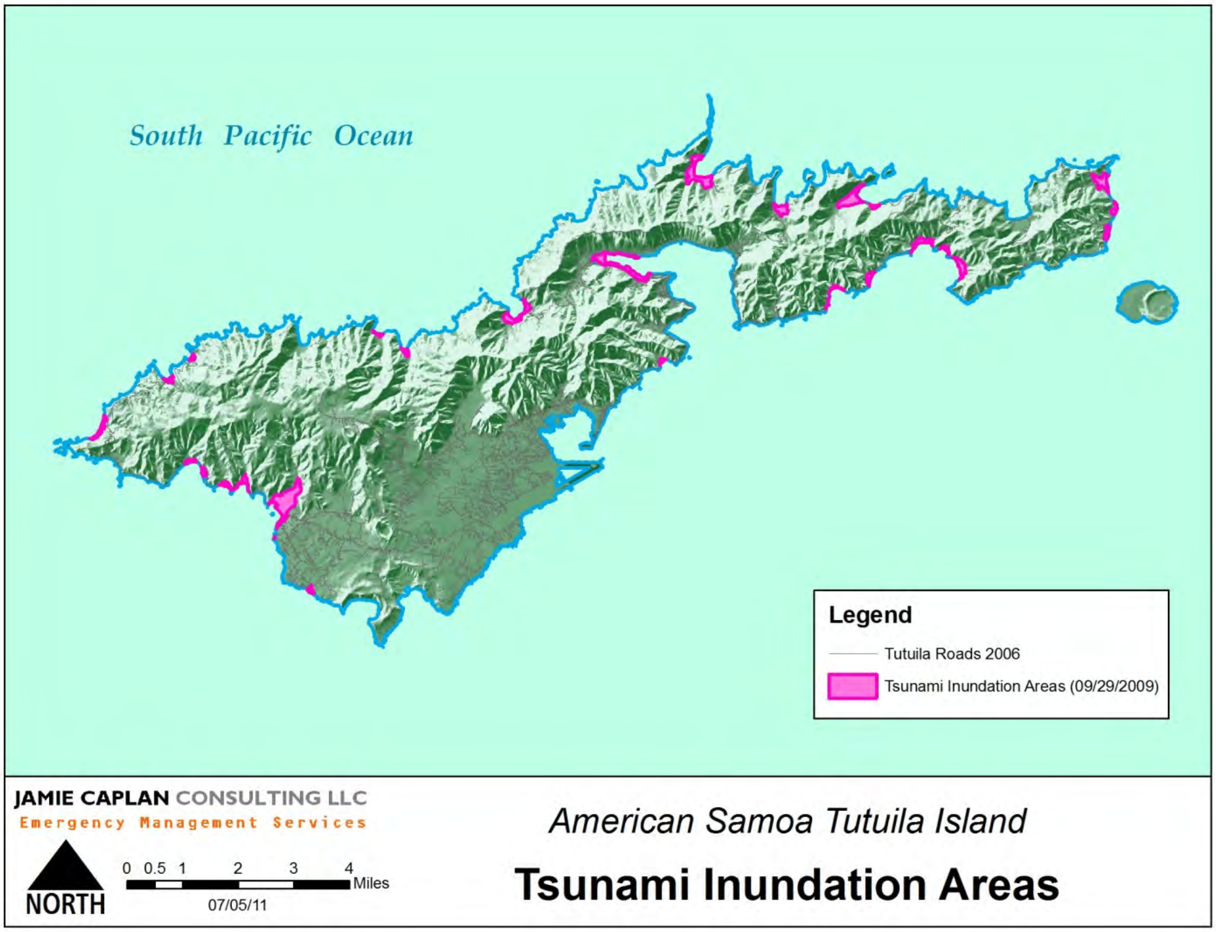

Figure 82: 2009 Tsunami Inundation Levels

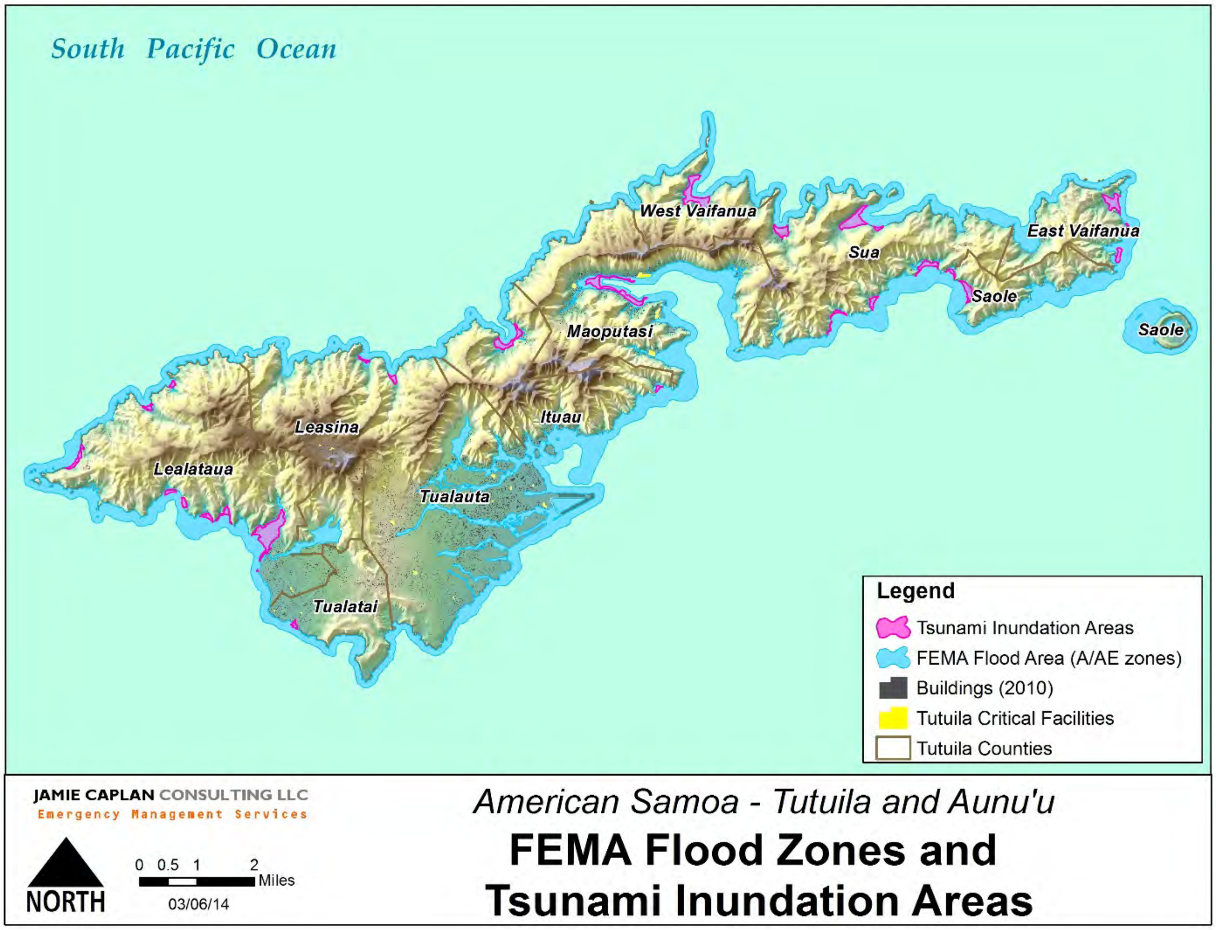

Figure 83: FEMA Flood Zones and 2009 Tsunami Inundation Areas Comparison

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.

4.16.3 Previous Occurrences

Between 1837 and 2020, there were 98 tsunami events reported for American Samoa from NOAA's National Geophysical Data Center (NGDC) Historical Tsunami Database.[154] One additional event was reported in April 2014 due to the Chilean earthquake; however waves were less than 1 foot.[155] When

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[154] NOAA's National Geophysical Data Center (NGDC). *Historical Tsunami Database*. Retrieved from http://www.ngdc.noaa.gov/nndc/struts/form?t=101650&s=167&d=166

[155] Accuweather (2014). Retrieved from http://www.accuweather.com/en/weather-news/breaking-magnitude-80-quake-st/25144298

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. For events from 1937 to 1980, details and impacts were provided from the "Catalog of Tsunamis in the Samoan Islands."[156] A narrative for the 2009 Tsunami that impacted American Samoa is provided below.

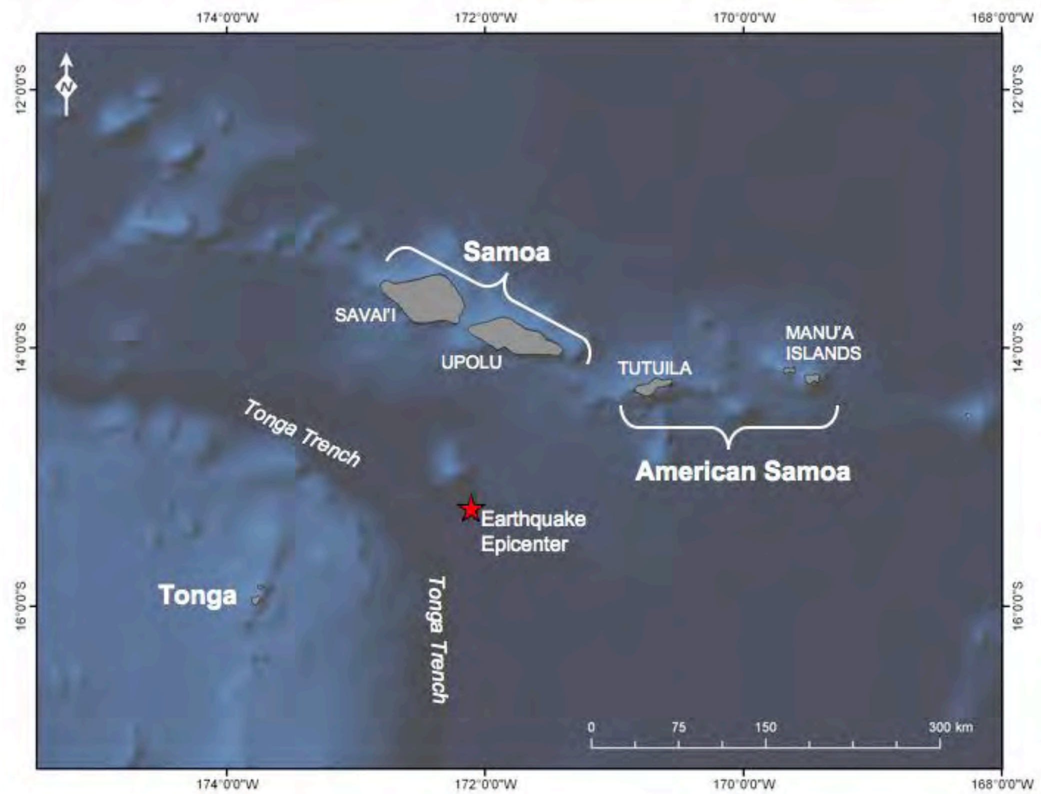

Figure 84: Location of Earthquake Epicenter in Relation to American Samoa[157]

TSUNAMI SEPTEMBER 29, 2009

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

[156] Pararas-Carayannis, George and Bonnie Dong. International Tsunami Information Center. *Samoa Islands Tusunami Catalog.* Retrieved from http://www.drgeorgepc.com/TsunamiSamoaIslandsCatalog.pdf

[157] THE LIMIT OF INUNDATION OF THE SEPTEMBER 29, 2009, TSUNAMI ON TUTUILA, AMERICAN SAMOA BY BRUCE E. JAFFE, GUY GELFENBAUM, MARK L. BUCKLEY, STEVE WATT, ALEX APOTSOS, ANDREW W. STEVENS, AND BRUCE M. RICHMOND USGS INUNDATION REPORT, USGS OPEN FILE REPORT, P.3

others sustained substantial damage. The tsunami rather than the earthquake caused most of the damage.[158]

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 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 84). 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.[159]

Figure 85: Tsunami Damage from 2010

FEMA's Post-Tsunami Disaster Assistance[160]

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. 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.

[158] FEMA After Action Report for 2009 Tsunami (no further information)
[159] USGS (n.d.). *Tsnami and earthquake research.* Retrived from http://walrus.wr.usgs.gov/tsunami/samoa09/index.html
[160] FEMA After Action Report for 2009 Tsunami (no further information)

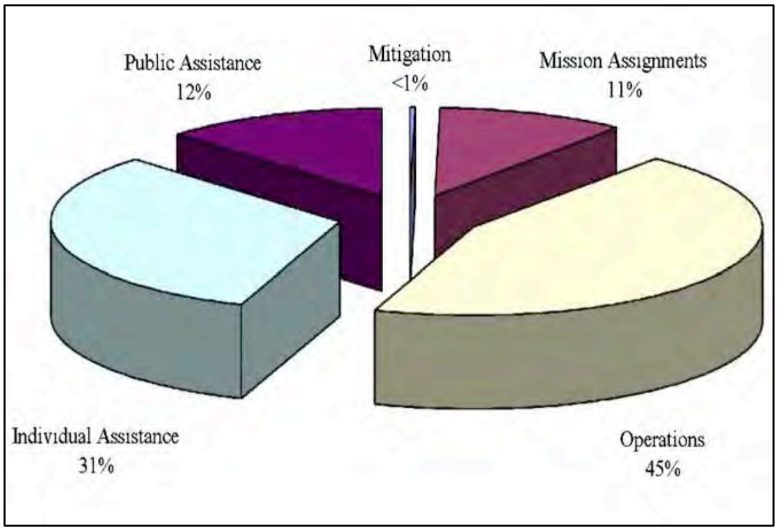

Figure 86 FEMA Disaster Assistance after Tsunami

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.

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 (see breakdown of assistance spending in graphic above). 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 were 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.

4.16.4 Extent

The 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.

4.16.5 Probability of Future Events

Between 1837 to 2020, a 183-year period, a total of 78 events were reported. This results in an approximate annual probability of 43%. It should be noted that a majority of these events did not result in damage. Data also suggests the probability of a potentially destructive tsunami impacting the Territory 2 to 3 times every 50 years (4% to 6% annual chance). Future events more be pronounced in terms of location and severity given rising subsidence rates and sea levels, but levels of frequency and durations are not expected to be impacted. A probability categorization of possible (between 1% and 10% annual probability) was assigned for tsunamis that are likely to cause damage.

4.16.6 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. [161]

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 be planned for. Continued public education to remind residents of the 2009 impacts and ongoing danger is recommended to prevent “disaster amnesia,” which increases

[161] Geological Society of Australia. Retrieved from http://www.gsa.org.au/resources/factites/factitesTsunami.pdf

vulnerability. Additional measures such as installing more seismic sensors to detect for locally generated tsunamis are also encouraged.

4.16.6.1 Climate Change Considerations

While tsunamis are most closely correlated to earthquake, climate change impacts can increase the impacts of tsunami through rising seas. Coupled with accelerating subsidence rates, future events may reach areas further inland.

4.16.6.2 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 analysis was not refreshed for the 2020 plan update given no new tsunami data.) 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 87). However, it does provide a potential estimate for an event even more devastating than the 2009 tsunami event.

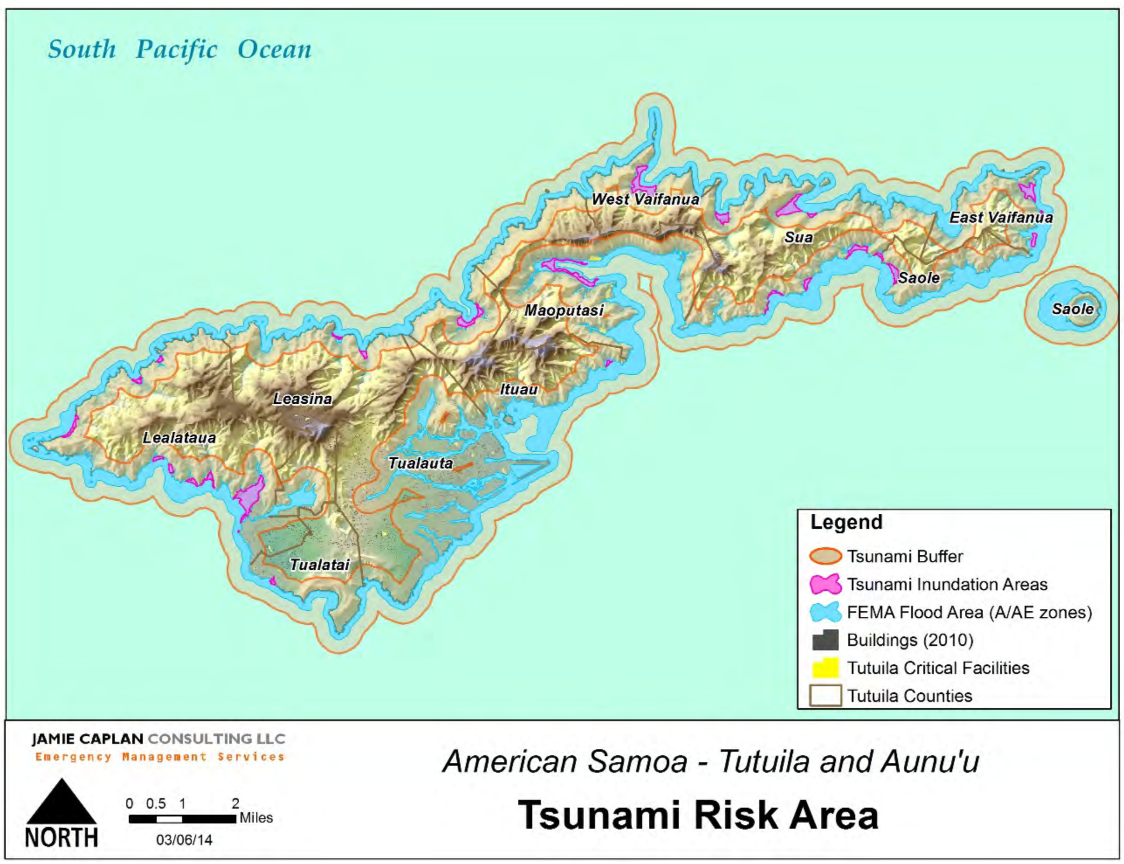

Figure 87: Tsunami Risk Area Based on Calculated Buffer

Table 42: 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
Ituau (East District)	1,075	1,075	100%	1 402 2 government 12 church 32 commercial 1,028 residential
Lealataua (East District)	2,026	1,473	73%	13 church 22 unknown 4 commercial 6 schools 1,432 residential
Leasina (East District)	474	161	34%	1 church 160 residential
Maoputasi (East District)	2,246	2,185	97%	1 community hall 1 new 1 school 1 Tedi 6 unknown 13 church 33 commercial 77 government 2058 residential
Saole (East District)	364	360	99%	1 business 359 residential
Sua (East District)	938	902	96%	4 church 4 commercial 5 unknown 889 residential
Tualatai (West District)	903	467	52%	2 commercial 7 church 28 unknown 430 residential
Tualata (West District)	7,441	6,082	82%	1 832 type 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 1 church
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				
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 43 highlights the results. Several figures also note the location of these critical facilities beginning with Figure 88 on page 225.

Table 43: 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

- Forty 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

- Sixty 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 C.

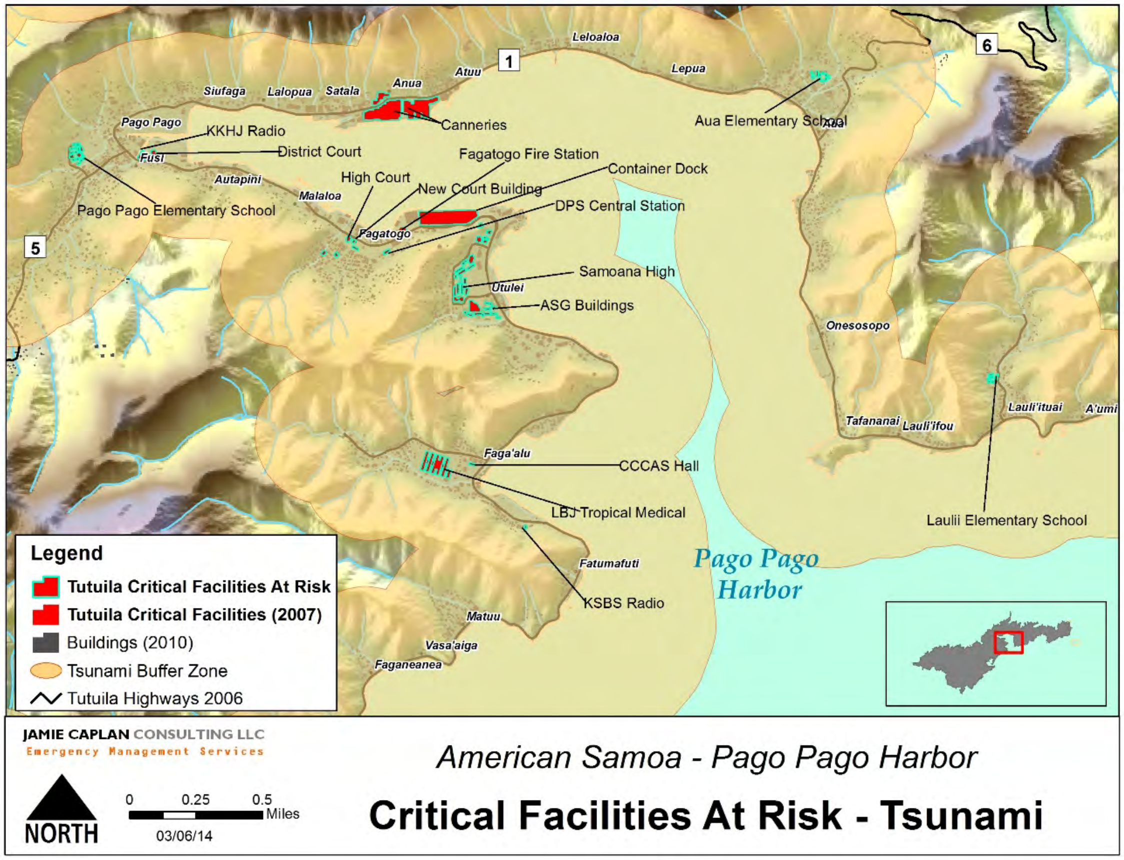

Figure 88: Critical Facilities Potentially at Risk to Tsunami– Greater Pago Pago Harbor

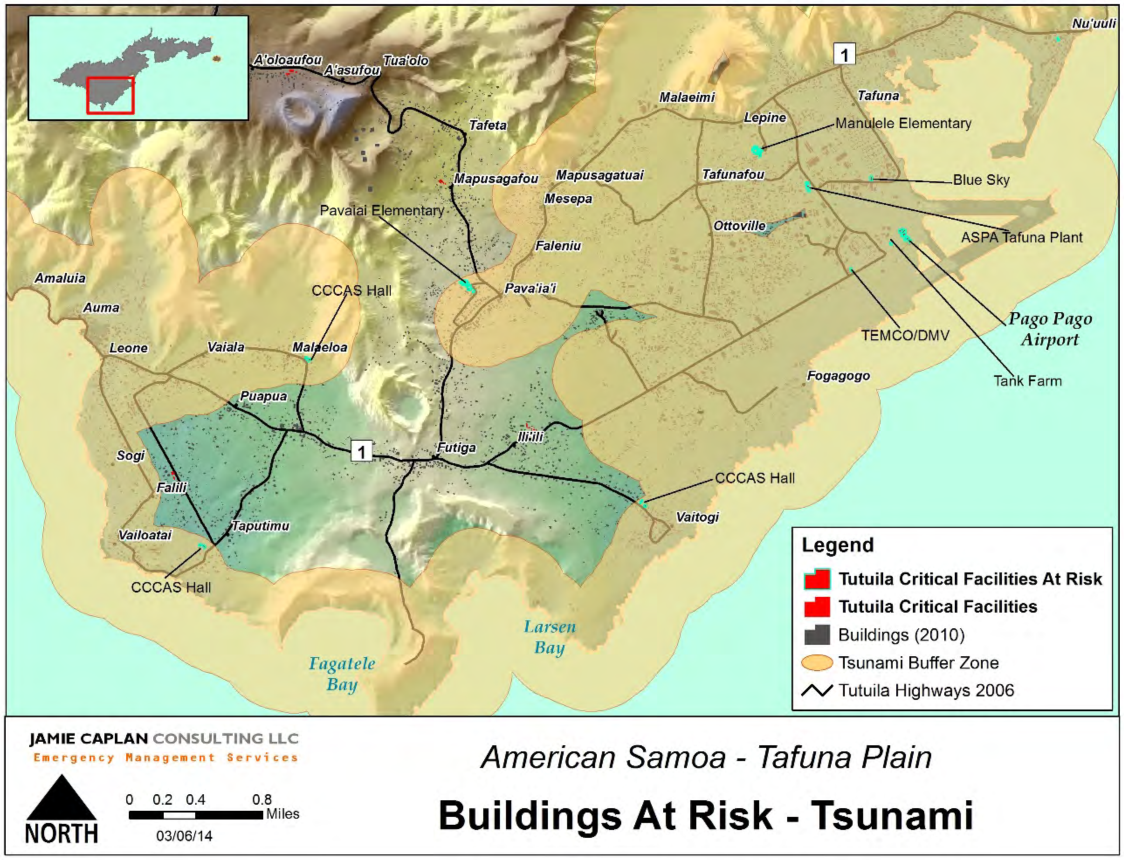

Figure 89: Critical Facilities Potentially at Risk to Tsunami– Tafuna Plain

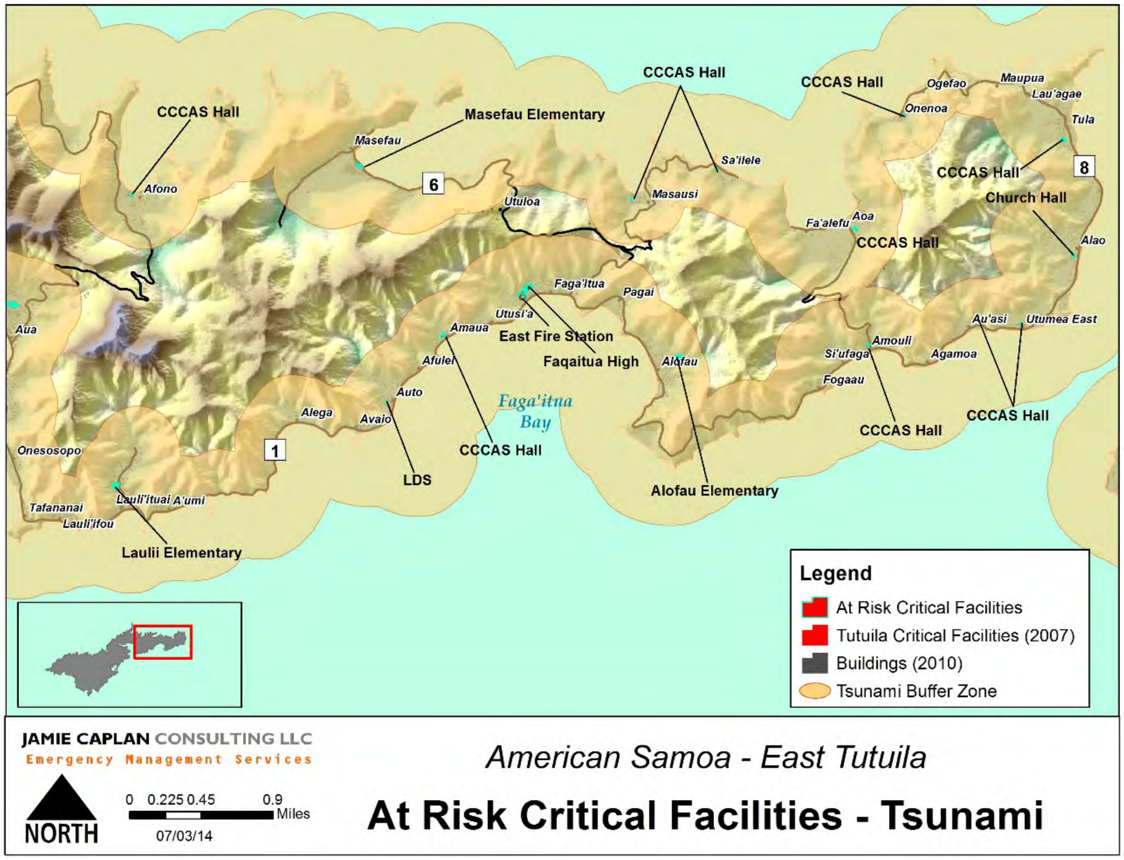

Figure 90: Critical Facilities Potentially at Risk to Tsunami– East Tutuila

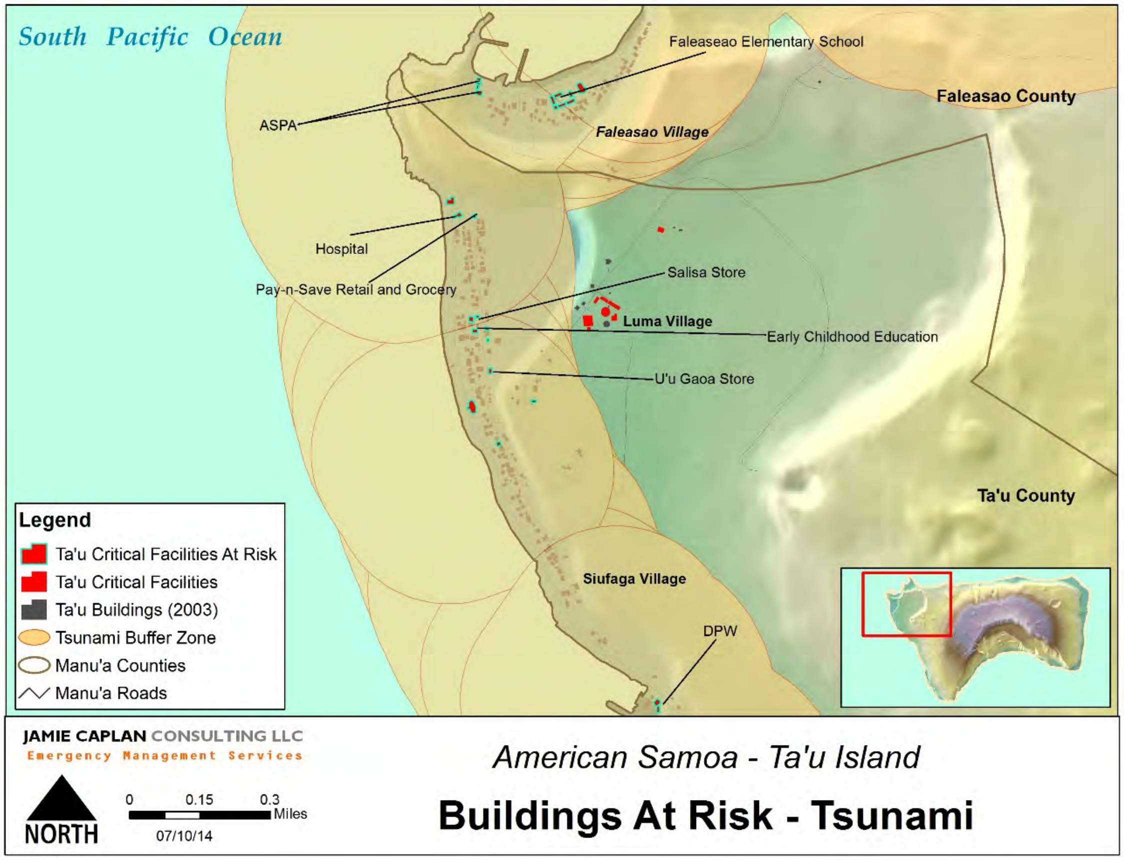

Figure 91: Ta'u Critical Facilities Potentially at Risk to Tsunami

4.17 Volcano

4.17.1 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.
There are three main types of volcanoes as described below. Volcanoes may be visible above the surface or submarine on the ocean floor:[162]

[162] USGS (2011). *Principal types of volcanoes.* Retrieved from http://pubs.usgs.gov/gip/volc/types.html

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.

Stratovolcanoes – (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 when magma rises from below the earth's crust (the mantle). The mantle rock melts, becoming liquid magna. It has a temperature of 700-1300°C. 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 44 below.

Table 44: Volcanic Explosivity Index (VEI) (based on global observations)[163]

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

[163] Oregon State University (2020). *How big are eruptions?* Retrieved from http://volcano.oregonstate.edu/how-big-are-eruptions

VEI	Description	Plume Height	Volume	Classification	How often	Example
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."[164] 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 Hawaiian 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. 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. 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.

[164] NOAA (n.d.). *How did the Hawaiian islands form?* Retrieved from http://oceanservice.noaa.gov/facts/hawaii.html

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.

4.17.2 Location

Figure 92 below identifies the location of the four major volcano areas in American Samoa. The proceeding graphic, Figure 93, shows a geomorphologic interpretation of major volcanic structures within American Samoa and their associated rift zones.[165] The proceeding text describes each location. Just one volcano in American Samoa is active today - Vailulu'u. It is a subsurface volcano 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.

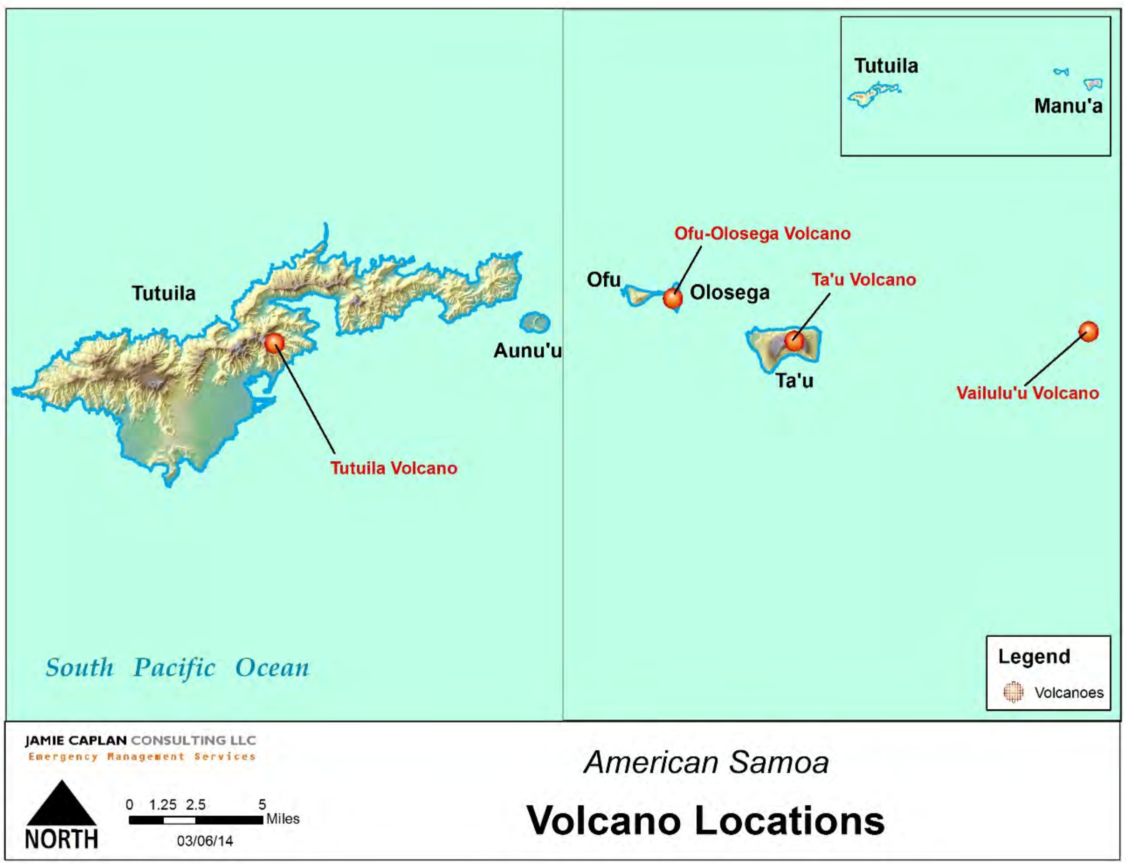

Figure 92: Volcano locations in American Samoa

[165] Wright, Dawn. Oregon State University.

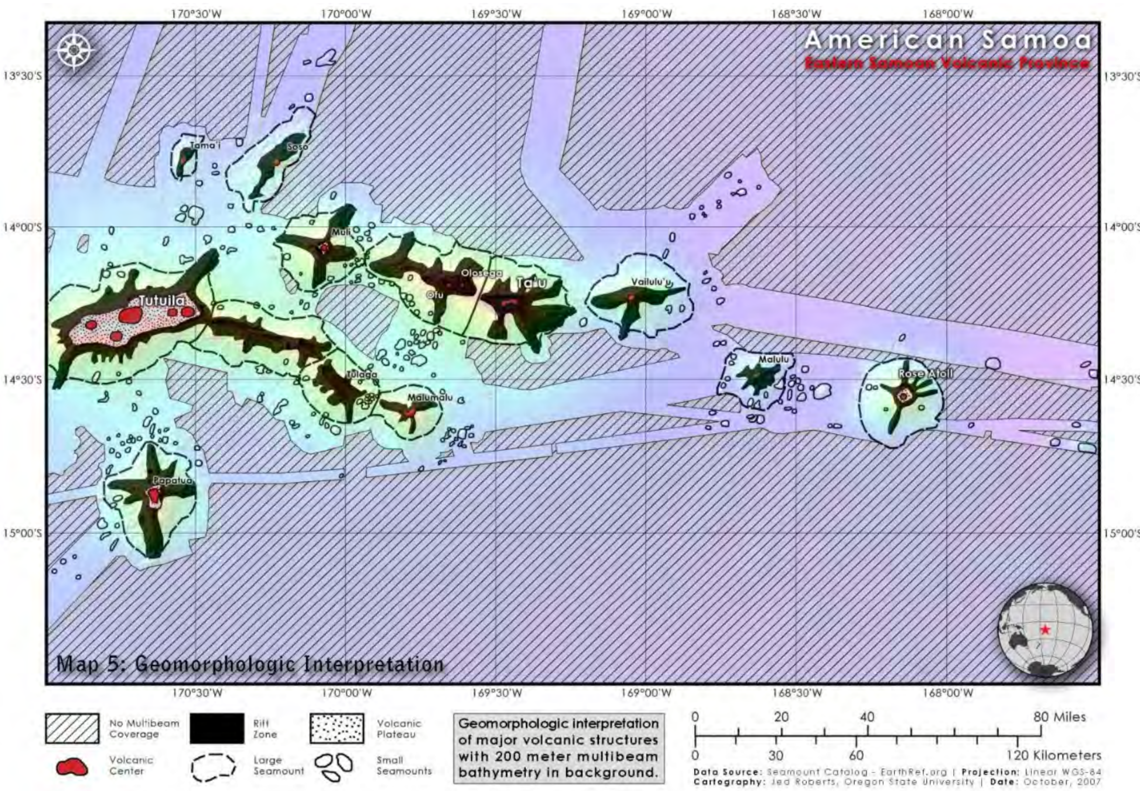

Figure 93: Volcanos and Rift Zones

Vailulu'u

A massive volcanic seamount not discovered until 1975, in Vailulu'u rises 4200 meters from the sea floor to a depth of 590 meters. It is about one-third of the way between Ta'u and Rose islands, at the eastern end of the American Samoa. Vailulu'u is considered to mark the current location of the Samoan hotspot. The summit of Vailulu'u contains a 2-km-wide, 400-meter-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. On July 10, 1973, explosions from Vailulu'u were captured by hydrophone recordings 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.[166] Turbid (muddy) water above the summit shows evidence of ongoing hydrothermal plume activity.[167] In 2005, researchers discovered a submarine 300-meter tall volcano cone growing in the summit crater of Vailulu'u, since named Nafanua, after the Samoan Goddess of War. The formation is growing so quickly (approximately 8 inches a day) that it may surface within decades.[168] Vailulu'u is considered to be a very

[166] Siebert, Lee, Tom Simkin, Paul Kimberly. (2010). *Volcanoes of the World (*Page 74). University of California Press.
[167] Smithsonian Institute (n.d.). *Global Volcanism Program.* Retrieved from https://volcano.si.edu/volcano.cfm?vn=273070&fbclid=IwAR3JjrGl1Xz9G-USaztW3loRD9-fICAU5iB-eSMVJur2mU1FnbjLujw6H44

[168] Hubert Staudigel, Stanley R. Hart, Adele Pile, Bradley E. Bailey, Edward T. Baker, Sandra Brooke, Douglas P. Connelly, Lisa Haucke, Christopher R. German, Ian Hudson, Daniel Jones, Anthony A. P. Koppers, Jasper Konter, Ray Lee, Theodore W. Pietsch, Bradley M. Tebo, Alexis S. Templeton, Robert Zierenberg, and Craig M. Young (2006).

active underwater volcano. Figure 94 shows a cross section and location orientation figure of the hotspot.

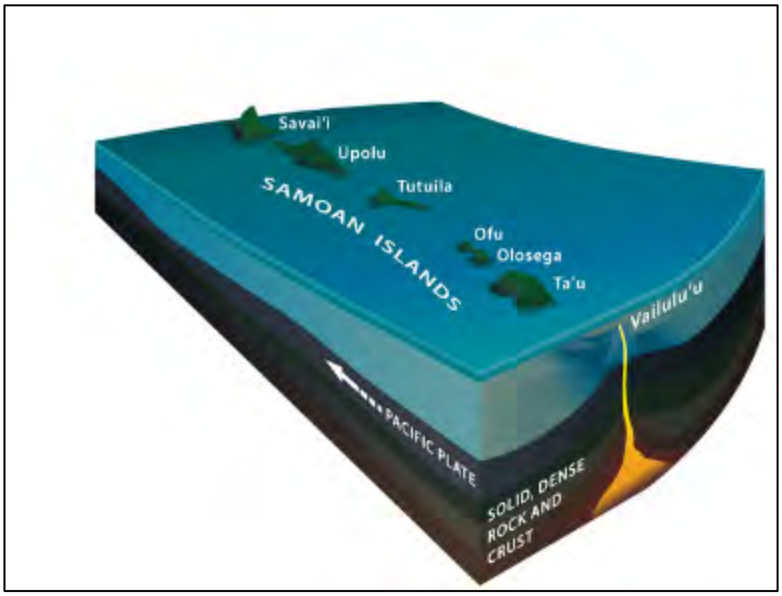

Figure 94: Illustration of Vailulu'u Samoan Hotspot[169]

Ta'u

Ta'u is the eastern most island in the Samoan Island chain and has an elevation of 3,054 feet (931 meters). The 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. Numerous Holocene post-caldera-aged (11,700 years ago to present) cones occur at the summit and flanks of the Lata shield volcano.[170] 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 kilometers. The islands are formed by two eroded, coalescing basaltic shield volcanoes whose slopes dip to the east and west. Steep cliffs up to 600-meters high truncate the northern and southern sides of the islands. The 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

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Vailulu'u Seamount, Samoa: Life and death on an active submarine volcano. National Academy of Sciences of the United States of America. Retrieved from http://www.pnas.org/content/103/17/6448.full

[169] Doucette, Jayne. Woods Hole Oceanographic Institution (Oceanus 2005).

[170] Smithsonian Institute (n.d.). *Global Volcanism Program.* Retrieved from https://volcano.si.edu/volcano.cfm?vn=273070&fbclid=IwAR3JjrGl1Xz9G-USaztW3loRD9-fICAU5iB-eSMVJur2mU1FnbjLujw6H44

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.[171]

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-kilometer-long island is truncated by an eroded, 9-kilometer-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.[172] No recent eruptions have been recorded at this location and it is considered dormant.

4.17.3 Previous Occurrences

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).[173] Eruptions from this volcano could impact air quality in American Samoa. Table 45 below shows the known eruptions for volcanoes on American Samoa.

Table 45: Recorded Eruptions on American Samoa's Islands[174]

Volcano Name	Primary Volcano Type	Last Eruption Year	Total Reported Eruptions	Elevation (m)	Population within 5 km	Population within 10 km	Population within 30 km
Ofu-Olosega	Shield(s)	1866	1	639	220	384	1387
Ta'u	Shield	Unknown	0	931	95	1154	1538

[171] Smithsonian Institute (n.d.). Global Volcanism Program. Retrieved from https://volcano.si.edu/volcano.cfm?vn=273070&fbclid=IwAR3JjrGl1Xz9G-USaztW3loRD9-fICAU5iB-eSMVJur2mU1FnbjLujw6H44

[172] Smithsonian Institute (n.d.). *Global Volcanism Program.* Retrieved from https://volcano.si.edu/volcano.cfm?vn=273070&fbclid=IwAR3JjrGl1Xz9G-USaztW3loRD9-fICAU5iB-eSMVJur2mU1FnbjLujw6H44, Volcano Discovery (n.d.). *Tutuila Volcano.* Retrieved from http://www.volcanodiscovery.com/tutuila.html

[173] Smithsonian Institute (2013). Global Volcanism Program. Retrieved from https://volcano.si.edu/volcano.cfm?vn=244040

[174] Smithsonian Institute (2013). Global Volcanism Program. Retrieved from https://volcano.si.edu/volcano.cfm?vn=244020

Volcano Name	Primary Volcano Type	Last Eruption Year	Total Reported Eruptions	Elevation (m)	Population within 5 km	Population within 10 km	Population within 30 km
Tutuila	Tuff cone(s)	Unknown	0	653	16653	49763	56239
Vailulu'u	Submarine	2003	3 (2003, 1995, 1973)	-592	0	0	0

4.17.4 Extent

One way to measure volcano extent is through the 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. Known eruptions from the Vailulu'u volcano were also non-explosive. 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.

4.17.5 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 in Samoa 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 three times over a 254-year period (0.01% annual chance)
- The Vailulu'u volcano (submarine) has erupted three times over a 41-year period (7% annual chance)
- The Ofu-Olosega volcano has erupted one time over a 148-year period (0.6% annual chance)

Combining these known eruptions over a 254-year period yields a 1% annual chance. When considering future impacts, it is possible that volcanoes can suddenly increase (or decrease) eruption activity which can impact the location impacts, severity, and intensity. However, estimation with these will occur is not possible to date.

With consideration to historic and potential future events, the estimated probably of an eruption is unlikely, less than a 1% chance per year.

4.17.6 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 and aggravate respiratory illness. Submarine eruptions may result in algae plums and fish and coral 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.

4.17.6.1 Climate Change Considerations

A 2017 study indicated that warmer air temperatures may lead to an increase in the frequency and severity volcanic eruptions.[175] The theory is that as glaciers melt, this releases pressure that was otherwise in holding magna in place. With limited glacial pressure, magma can more easily flow, resulting in increased volcanic activity. The study was conducted for areas in Iceland and focused on historic information. It is not yet known how this research will translate to our modern climate impacts, or if it will have impacts in areas where glaciers and volcanos do not interact, such as the South Pacific. This information will be updated as more data becomes available.

4.17.6.2 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.

4.18 Wildfire

4.18.1 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

[175] Scientific American (2017). *Get Ready for More Volcanic Eruptions as the Planet Warms.* Retrieved from https://www.scientificamerican.com/article/get-ready-for-more-volcanic-eruptions-as-the-planet-warms/

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 wildfire 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

4.18.2 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.

4.18.3 Previous Occurrences

No wildfire events were reported by the National Climatic Data Center. Several sources were investigated for wildfire data as noted in the Description section. Given limited occurrence, there are very few tracking mechanisms in place. A stakeholder meeting with fire officials during the 2014 plan update yielded insight fire events on the islands. 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 on island fire officials:

- Typically, there are five 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 a quarter 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.

4.18.4 Extent

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

4.18.5 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 (five brush fires per month in typical conditions). However, it is apparent that few wildfires have posed a risk to American Samoa people or structures. As described in *Section 4.17.6.1 Climate Change Considerations*, changing climatic conditions may have varying impacts on future brush fires in the Territory. Droughts are expected to decrease but may be more severe when they occur, increasing the probability of fires to impact greater locations and be more severe and intense. As ENSO cycles intensify, stronger winds may also lead to more brush fires burning out of control and requiring assistance. In general, increased precipitation will decrease wildfire risk.

With consideration to past and potential future events, probability can be categorized as highly likely (greater than 90% annual chance) for small brush fires or unlikely (less than 1% annual chance) for large, damaging fires.

4.18.6 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."[176]

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 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 are 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 or addressed (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 three minutes, but it is much longer.

Truck size

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

[176] 2011-2015 American Samoa Forest Assessment and Resource Strategy (June 2010). Division of Community and Natural Resources, American Samoa Community College. http://www.wflccenter.org/islandforestry/americansamoa.pdf

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.

4.17.6.1 Climate Change Considerations

ENSO El Niño phases, which are projected to be more pronounced due to climate change, have a bearing on wildfire vulnerability. During El Niño phases, there is increased risk for drought, which increases fire risk and may exacerbate impacts when drought occurs. However, drought in generally expected to decrease as American Samoa becomes wetter. The increased precipitation will encourage vegetation growth which is fuel for wildfires and increases risk.

4.17.6.2 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.

Figure 95: Debris Burning in American Samoa

4.19 Summary of Hazard Risk and Vulnerability

4.19.1 Summary of Jurisdictional Vulnerability by Hazard

This section provides a summary of the most at risk area, typically at the county level, based on available data.

Coastal Erosion

All coastlines in American Samoa are vulnerabile to coastal erosion. Sua and Itua Counties have the most critical shorelines in terms of miles, percentage, buildings in the critical shoreline areas based on a USACE study described in the coatal erosion Location subsection.

Drought

All counties and jurisdictions are vulnerabile to drought. However, those with a higher acerage of farm land may be more vulnearble to drought impacts. This is includes the counties of Tualauta, Lealataua, Maoputasi and Sua.

Earthquake

Counties with higher number of buildings likely have the greatest vulnerability to earthquakes. This is includes the counties of Tualauta, Lealataua, Maoputasi, Ituau, and Sua.

Extreme Heat
All counties are generally equally at risk to experiencing extreme heat. However, those with higher populations may experience greater impacts due to health impacts. These include Tualauta and Maoputasi counties.

Flood
All counties have flood risk, particularly in coastal areas. Tualauta has the most area of FEMA floodplain in terms of square mileage.

High Surf
South facing shores have the greatest vulnearbilty to high surf. This includes the south facing shores of Tutuila Island, Aunu'u Island and the Manu'a Islands.

Landslide
Steep slopes are most vulnerable to landsliding which are prevalent in the central part of Tutuila Island and the western edge of Lealataua County. Areas in the southwestern Sua County near Faga'itua Bay are also vulnerable to landslide and have several previous incidents.

Lightning
All areas are equally vulnerable to lighting. However, those areas with more built environment may be subject to greater impacts which includes the counties of Tualauta, Lealataua, Maoputasi, Ituau, and Sua.

Public Health Risks
All areas are equally vulnerable to public health risks which may vary by specific threats.

Sea Level Rise
All coastal areas vulnerable to sea level rise. Using available data, the counties of Itua, Lealataua and Maoputasi are most vulnerable to sea level rise on Tutuila Island. The counties of Ta'u and Ofu are most vulnerable in the Manu'a Islands.

Subsidence
Coastal areas in all counties are most vulnearble to subsidence.

Tropical Cyclone
Coastal areas in all counties are most vulnerable to tropical cyclones.

Tsunami
Coastal areas in all counties are most vulnerable to tsunamis. The counties of Ituau, Maoputasi, Lealata, and Tualata on Tutuila Island have the greatest tsunami vulnerability based on available data. The Manu'a Islands generally have equal vulnerability.

Volcano
Western counties on Tutuila Island (Lealataua, Tualatai, Leasina and Tualauta) may be considered most vulnerable to volcano impacts due to proximity to Samoa's Savai'I volcano.

Wildfire
The western district of American Samoa is more populated and that results in more fires and increased vulnerability.

4.19.2 Summary of Risk

Table 46 below provides a brief overall of the hazards that impact American Samoa. The table lists impacts, number of occurrences, spatial extent, probability and estimated 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 46: Summary of Hazards in American Samoa

Hazard Type	Potential Impacts	Count	Spatial Extent	Probability	Estimation of Accumulated Losses ($)	Critical Facilities at Risk?
Coastal Erosion	Loss of beach area; Loss of structures along coast/cliffs	N/A	Coast	Highly Likely	N/A	YES
Drought	Water rationing; Food shortage; Cannery closures; School closures; Groundwater depletion; Depletion of wells and catchment; Economic recession;	4	Territory-wide	Possible	Losses to agriculture crops and economy	NO

Hazard Type	Potential Impacts	Count	Spatial Extent	Probability	Estimation of Accumulated Losses ($)	Critical Facilities at Risk?
Earthquake	Damage to infrastructure and buildings; Injuries, loss of life;	22 over 7.0M	Territory-wide	Likely	Reported damage but not the amount	YES
Extreme Heat	Health impacts; economic impacts	2	Territory-wide (lower elevation will experience greater impacts)	Possible	N/A	YES
Flood	Damage to roads, homes, businesses; Loss of access to emergency services; Inundation of urban and low-lying areas Erosion; Landslides; Power failures; Death/injury	122	Territory-wide	Highly Likely	$63+ Million	YES
Hazardous Material	Water contamination; Fire	N/A	Territory-wide	Low	None reported	YES
High Surf	Debris; Road washout; Hindered fishing efforts; Death, injuries	68	Coastal areas	Likely	$4+ Million	NO
Landslides	Injuries, loss of life; Loss of access to emergency services; Property loss; Blocked or damaged roads, buildings;	1+ annually	Territory-wide (generally excludes flat plain areas such as Tualauta and Tualatui)	Highly Likely	Damage reported but not exact amount; loss of structures including homes, schools, churches	YES

Hazard Type	Potential Impacts	Count	Spatial Extent	Probability	Estimation of Accumulated Losses ($)	Critical Facilities at Risk?
	Liquefaction of fill soil types; Amplified ground shaking of unconsolidated soils.					
Lightning	Electrical damage; Electrical fire; Death, injury	2	Territory-wide	Likely	$41,000	YES
Public Health Risks	Death/illness; school/business interruption	N/A	Territory-wide	Likely	Undetermined	NO
Sea Level Rise	Loss of landmass and cultural sites; relocation of population; increased inland flood impacts	N/A	Coastal areas	Highly Likely	Undetermined	YES
Soil Hazards	Cracked foundation; Loss of structural integrity	0	Territory-wide	Unlikely	None reported	YES
Subsidence	Structure damage; increase sea level rise; land loss	N/A	Territory-wide (impacts more pronounced in coastal areas)	Highly Likely	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;	31	Territory-wide	Likely	$300+ million	YES

Hazard Type	Potential Impacts	Count	Spatial Extent	Probability	Estimation of Accumulated Losses ($)	Critical Facilities at Risk?
	Death, injury					
Tsunamis	Inundation of low-lying areas; Injuries, loss of life; Damage to buildings and infrastructure; Coastal erosion	78	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	Unlikely	None reported	NO
Wildfire	Loss of natural and manmade resources; Structure fire	Annual brushfire s	Territory-wide	Unlikely	None reported	YES

4.18.3 PRI Results and Hazard Ranking

The process of completing the hazard profiles above informed the PRI input. Table 47 shows the PRI results for American Samoa. These values were then categorized into high, moderate and low risk categories based on natural breaks in scoring and available information. The ranking of hazards can be found in the table below.

Table 47: Summary of PRI Results for American Samoa

Hazard	Category/Degree of Risk					PRI Score
	Probability	**Impact**	**Spatial Extent**	**Warning Time**	**Duration**	
Coastal Erosion	Highly Likely	Minor	Moderate	More than 24 hours	More than one week	**2.6**
Drought	Possible	Limited	Large	More than 24 hours	More than one week	**2.5**
Earthquake	Likely	Limited	Large	Less than 6 hours	Less than 6 hours	**2.8**

Hazard	Category/Degree of Risk					PRI Score
	Probability	Impact	Spatial Extent	Warning Time	Duration	
Extreme Heat	Possible	Limited	Large	More than 24 hours	Less than one week	2.4
Flood	Highly Likely	Critical	Moderate	6 to 12 hours	Less than 24 hours	3.0
HAZMAT	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
Lightning	Likely	Limited	Negligible	Less than 6 hours	Less than 6 hours	2.2
Public Health Risks	Likely	Critical	Large	More than 24 hours	More than one week	3.1
Sea Level Rise	Highly Likely	Critical	Moderate	More than 24 hours	More than one week	3.2
Soil Hazards	Unlikely	Minor	Small	More than 24 hours	More than one week	1.5
Subsidence	Highly Likely	Minor	Large	More than 24 hours	More than one week	2.8
Tropical Cyclone	Likely	Catastrophic	Large	More than 24 hours	Less than 24 hours	3.0
Tsunami	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, sea level rise, tropical cyclones, and public health risks 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.

Flooding impacts the islands frequently. Damage may be limited to catastrophic based on the amount and previous rainfall. Floods may also trigger landslides. Sea level rise is occurring at a faster rate due to increasing subsidence coupled with global warming trends. It is resulting in land loss which threatens coastal assets, including cultural resources, and may force population relocation in the future. Tropical cyclones often result in territory-wide impacts and devastating associated hazards such as high winds, storm surge, and extreme rainfall. Public health risks are an ongoing concern that threaten school closures, business interruptions, and fatalities across the Territory. While high hazards can help American Samoan officials guide resources and mitigation actions, all hazards should be considered to reduce future losses.

Table 48: Ranking of American Hazards

Ranking	Hazard
High	Landslides Tsunami Flood Public Health Risks Tropical Cyclone Sea Level Rise
Moderate	Earthquake HAZMAT Coastal Erosion Drought High Surf Subsidence
Low	Extreme Heat Lightning Wildfire Volcano Soil Hazards