US Army Corps of Engineers
Honolulu District

Appendix B - ECONOMICS

Tafuna Flood Risk Management Study
American Samoa

January 2022

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Appendix B - ECONOMICS

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1. INTRODUCTION

1.0 Purpose

The National Economic Development (NED) analysis for the Tafuna Flood Risk Management Study (TFRMS) focuses on economic damages and benefits to structures and their contents, vehicles. The HEC-FDA software (v1.4.2) is the analytical tool being used to estimate damages and benefits. The economic framework and the results of the without-project and with-project alternatives analysis presented below. The main engineering and economic HEC-FDA inputs, along with the methods, techniques, assumptions, and data underpinning those inputs, and the results of the analyses, are described in this report. Additionally, two additional assessments will be presented in the draft report: 1) a Regional Economic Development (RED) assessment, which was performed using the U.S. Corps of Engineers (USACE)-certified RECONS (Regional Economic System) software, and 2) a Life Safety Assessment, which was performed using the USACE-certified Life-Sim 2.0 software.

1.1 Study Area

The study area is located on the main island of Tutuila, along the Tafuna plain within Tualauta county and includes the villages of Malaeimi, Tafuna, and Nuuuili. The Tafuna-Leone Plain is the largest area of Tutuila in acreage with relatively flat slopes. Several watersheds contribute to flows to and/or are contained within the Tafuna-Leone Plain. The upper watershed portions (upstream of Route 1 Highway) that drain the mountainsides and have well defined stream cross- sections, while the lower watersheds (downstream of Route 1 Highway) drain the drier alluvial plains and have poorly defined drainageways. The study area has a total drainage area of approximately 8.5 square miles.

The central portion of the Tafuna-Leone Plain, located in the lower alluvial plains, is an area of focus for many government agencies due to the increasing rate of development in the area and the potential for aggravated flood problems. Intense rainfall and the lack of well-defined stream channels attribute to the flooding experienced in the Tafuna study area. A greater potential for flooding exists in the village areas where the streams are incapable of supporting small flood events such as a 10 percent annual exceedance probability (AEP) flow. Flooding is intensified due to small channel sizes obstructed by thick vegetation, flat areas, constrictions from bridges and culverts, and encroaching development into the flood plain areas.

None of the streams within the study area are considered perennial and only Vaitele, Taumata, Mapusagatuai and Leaveave streams have clearly defined main streams within the upper watershed (upstream of Route 1 Highway) with characteristic riffle and pool systems. The six remaining streams originate in the lower alluvial coastal plains (downstream of Route 1 Highway), lack defined stream channels, and sheet flow overland due to relatively flat topographic elevations, heavy vegetative growth, and development encroachments.

The study area boundary consists of a small subset of waterways within the Tafuna-Leone Plain. Per ER-1165-2-21, urban water damage problems associated with a natural stream or modified natural waterway may be addressed under the flood risk management authorities downstream from the point where the flood discharge of such a stream or waterway within an urban area is greater than 800 cubic feet per second (cfs) for the 10-percent flood. The current study area boundary includes portions of the watershed, including the following streams:

- Leaveave Stream
- Taumata Stream
- Vaitele Stream

Figure 1 shows a map of the study area.

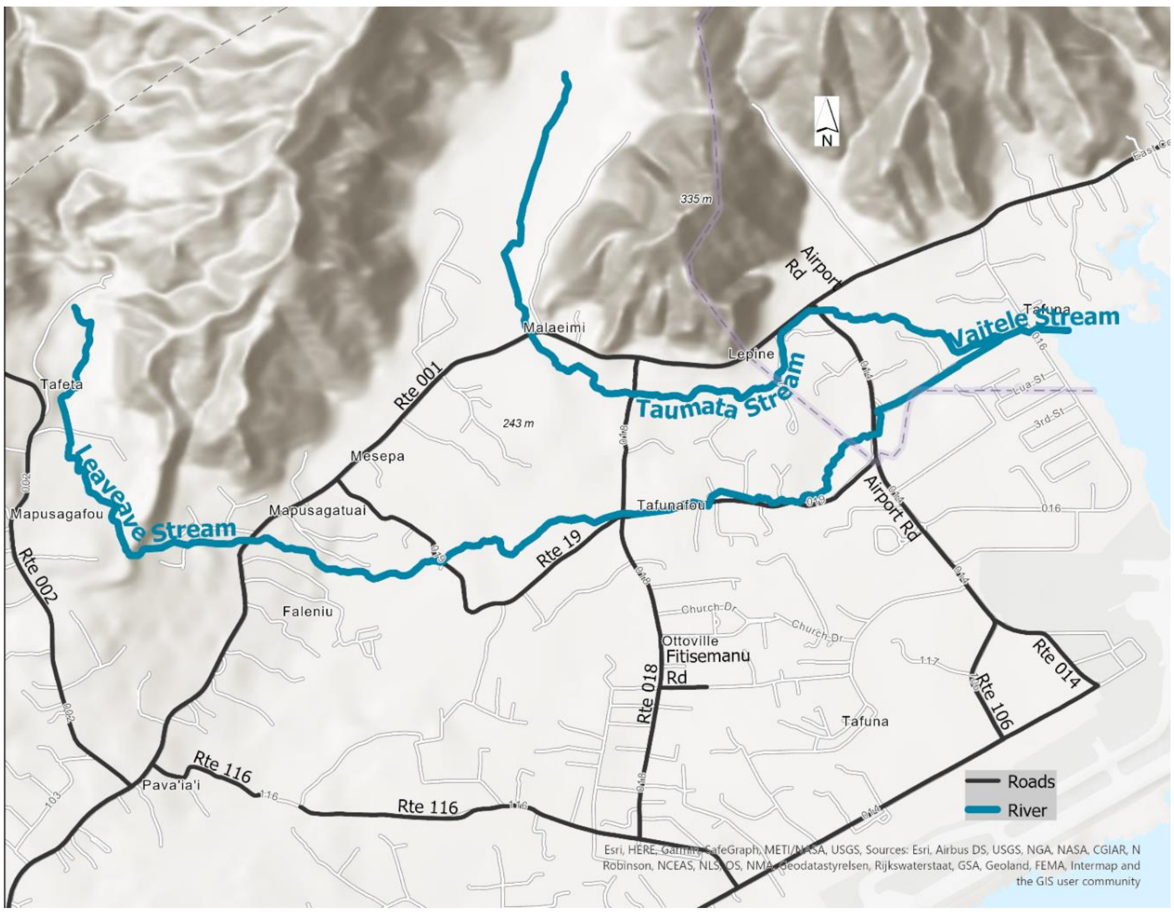


Figure 1. Tafuna Risk Management Study Area

1.2 Flooding in the Study Area

Flood Issues: Intense rainfall and the lack of well-defined stream channels contribute to the flooding experienced in the Tafuna study area. A greater potential for flooding exists in the village areas where the streams are incapable of supporting small flood events such as a 10 percent AEP flow. Flooding is intensified due to small channel sizes obstructed by thick vegetation, flat areas, constrictions from bridges and culverts, and encroaching development into the flood plain areas.

The Tafuna area has a history of flooding issues as population continues to develop and live on the alluvial plain beneath steep mountains that receive significant rainfall.

- Tropical Cyclone Gita caused significant flooding throughout numerous villages in American Samoa. Rainfall exceeded 6 inches in Pago Pago and more than 800 people were displaced from their homes throughout the islands. Damage estimate across the Territory was $7 million. A Presidential Disaster Declaration was issued on March 2, 2018.
- Torrential rainfall of greater than 21 inches during July 29 -Aug. 03, 2014 caused overflowing of streams, severe flooding in low lying areas and roadways, and caused landslides along mountainous areas throughout the Island of Tutuila.
- In January 2004, Tropical Cyclone Heta's high winds, high surf, and heavy rainfall caused flooding, mudslides, and landslides throughout the territory. Approximately 13.03 inches of rainfall caused an estimated $25.9M in damages. A presidential Disaster Declaration was issued on Jan. 13, 2004 (DR-1506).
- Typhoon Esau caused flooding, landslide, and mudslides in May 2003. American Samoa received more than 23 inches of rainfall and nearly 4,500 individuals required assistance. Damage across the territory was estimate at $12M. A presidential Disaster Declaration was issued on June 6, 2003.

1.3 Study Guidance

The following references were used to guide the economic analysis:

- Engineer Regulation (ER) 1105-2-100, Planning Guidance Notebook, 22 April 2000.
- Engineer Regulation (ER) 1105-2-101, Risk Assessment for Flood Risk Management Studies, 17 July 2017.
- Engineer Regulation (ER) 1105-2-100 Appendix D, Economic, Social and Regional Considerations, 1 April 2019.
- Engineer Regulation (ER) 1110-2-1302, Civil Works Cost Engineering, 30 June 2016.
- Economic Guidance Memorandum (EGM) 01-03, Generic Depth-Damage Relationships, 4 December 2000.
- Economic Guidance Memorandum (EGM) 04-01, Generic Depth-Damage Relationships for Residential Structures with Basements, 10 October 2003.
- Economic Guidance Memorandum (EGM) 09-04, Generic Depth-Damage Relationships for Vehicles, 22 June 2009.
- Engineer Manual (EM) 1110-2-1619, Risk-Based Analysis for Flood Damage Reduction Studies, 1 August 1996.
- Institute for Water Resources (IWR) Report 96-R-12, Analysis of Nonresidential Content Value and Depth-Damage Data for Flood Damage Reduction Studies, 1 May 1996.
- ER 1110-2-1302
- Incorporating Life Safety into Flood and Costal Storm Risk Management Studies, PB 2019-04, 20 June 2019

2. STUDY AREA SOCIOECONOMIC & DEMOGRAPHIC INDICATORS

Describing the social landscape of the area provides an understanding of who lives in the study area, who has a stake in the problem or issue, and why it is important to them. A demographic profile of the area was performed using social statistics, and the information served as input into the Other Social Effects (OSE) analysis, which is presented in Section 8. It is important to note that the demographic profile itself is not an OSE analysis but rather a data collection step that provides a basic level of understanding about the social conditions in the area; the data provides input into a more in-depth analysis that targets areas of special concern or relevance to the water resources issue at hand. The basic social statistics discussed below are indicators used to portray basic information about the social life and the processes of the study area.

2.0 Population and Housing

Historic and current population estimates for the study area are summarized in Table 1. From 2010 to 2020, the overall population of American Samoa declined by 10.5%. During the same time period, the population of the Tafuna village remained very stable, rising by only 43. Tualauta County, where Tafuna village is located, was the only division of American Samoa to experience positive growth over the 2010s, with a total population increase of 9.4%. Table 1 shows the total population counts. Table 2 shows the racial and ethnic breakdown of the population in the study area, as well as that of the American Samoa to provide context. Table 3 summarizes existing housing and household data for the study area. Because many areas of American Samoa actually lost housing units, the Tafuna Village alone was responsible for over half of net growth in housing units. The overall vacancy rate for Tualauta County was 12.0% in 2010, with a vacancy rate for rental units of only 5.4%. Tafuna had the highest average occupants per room, for both owners and renters, within Tualauta County.

Table 1. Historic and Current Population Estimates

Area	Population		Total Change	Annualized Change over Decade
	2010	**2020**	2020-2010	
Tafuna	7,945	7,988	43	+0.05%
American Samoa	55,519	47,710	-5,809	-1.1%

Source: 2018 American Samoa Statistical Yearbook and 2020 US Census

Table 2. Race and Ethnicity in the Project Area by Percentage of Population (2010)

Race or Ethnicity	Tafuna Study Area		American Samoa	
	Population	% of Population	Population	% of Population
Samoan	6,743	84.9%	49,333	88.9%
Tongan	228	2.9%	1,614	2.9%
Other Pacific Islander	179	2.3%	456	0.8%
Asian	356	4.5%	1,994	3.6%
White	152	1.9%	493	0.9%
All Other Single Ethnicities	31	0.4%	150	0.2%
Two or more ethnic origins	256	3.2%	1,479	2.7%
Total	7,945	100%	55,519	100%

Source: 2018 American Samoa Statistical Yearbook

Table 3. Estimated Occupied and Vacant Housing Units

Area	Total Housing Units		New Units	% Change
	2010	2020		
Tafuna	1,428	1,914	486	+34.0%
Tualauta County	4,080	5,304	1,224	+30.0%
American Samoa	10,963	11,807	844	+7.7%

Source: 2020 U.S. Census

2.1 Employment, Key Industries, Education, and Income

The total labor force age 16 and older, divided into employed and unemployed categories is shown in Table 4. Employment data by industry for American Samoa and Tualauta County are summarized in Table 5. Social services, government, and manufacturing are the three largest industries within the County. The figures show that the breakdown of industries is very similar between the County and the Territory, and that Tualauta County is incredibly important to the American Samoa economy, with more than 35% of all employment and nearly 50% of employment in several industries.

Table 4. Labor Force and Unemployment

Area	Total Labor Force	Employed		Unemployed	Not in Labor Force
		Private	Government		
Tualauta County	6,776	4,030	2,277	469	6,128
American Samoa	18,387	10,508	6,195	1,684	16,380

Source: U.S. Census (2010)

Table 5. Employment by Industry for American Samoa

Industry	Tualauta County	Percent	American Samoa	Percent
Agriculture, Fishing, Mining	102	1.6%	501	3.0%
Construction	461	7.3%	1,096	6.6%
Manufacturing	1,034	16.4%	2,753	16.5%
Wholesale	171	2.7%	335	2.0%
Retail	713	11.3%	1,614	9.7%
Transportation	444	7.0%	1,100	6.6%
Information	151	2.4%	385	2.3%
Finance, Insurance, Real Estate	192	3.0%	391	2.3%
Management, Administration	157	2.5%	330	2.0%
Education, Health, Social Services	1,213	19.2%	3,324	19.9%
Arts, Entertainment, Food Service, Tourism	420	6.7%	932	5.6%
Other Services	321	5.1%	626	3.7%
Public Administration	898	14.2%	3,229	19.3%
Military	30	0.5%	87	0.5%
Total	6,307	100.0%	16,703	100.0%

Source: 2018 American Samoa Statistical Yearbook

Low-income populations in the study area were identified by several socioeconomic characteristics, including median household income, educational attainment, and poverty status. Table 7 displays these economic characteristics for the Project area based on 2010 U.S. Census Bureau data.

Table 6. Educational Attainment (Population 25 Yrs and Older)

Area	Less than HS/GED	HS Grad/ GED	Assoc. Degree	Bachelor's Degree	Graduate Degree
Tafuna	511	1,735	1,031	342	226
Tualauta County	1,718	4,425	2,354	727	429
American Samoa	4,642	12,512	6,179	1,668	906

Source: 2018 American Samoa Statistical Yearbook

Table 7. Income and Poverty

Area	Individuals in Poverty [1]	Families in Poverty	% Living in Poverty		2010 Median Household Income [1]
			Individual [1]	Family	
Tafuna	-	615	-	12.8%	-
Tualauta County	11,840	1,718	57.6%	37.0%	$25,062
Amer. Samoa	31,809	4,810	57.8%	54.4%	$23,892

Source: 2018 American Samoa Statistical Yearbook. Not all data is available at the village level.

2.2 Traffic & Road Network

There are two major routes from the western-most villages of Tuituila to Pago Pago in the central part of the island, with several alternate paths available on larger roads through the interior of Tualauta County. Two such routes run through the study area, Route 1 being the main thoroughfare and Route 19 being a common alternative. Both routes are somewhat susceptible to flooding, with Route 19 being more frequently affected. See Figure 2.

Figure 2. Tafuna Major and Minor Traffic Routes

3. DAMAGE ANALYSIS METHODOLOGY

3.0 Structure Inventory Development

Currently, geospatially referenced parcel data for American Samoa does not exist and the National Structure Inventory Version 2.0 (NSI2) does not include the Pacific Territories. Given the DOD and American Samoa travel restrictions that have been in place for over a year, with no foreseeable date when travel to American Samoa will be authorized, it was necessary to develop the Tafuna FRM Study structure inventory remotely, with assistance from local study partners.

The imagery features of ArcPro and Google Earth Pro (GE) were used to help identify and assign georeferenced information to structures in the study area. To determine the extent of which structures to include in the inventory, a shapefile derived from a previously developed 500-year floodplain, with a 500-foot buffer, was overlaid onto an aerial image of the study area. If a structure appeared in the base map imagery of ArcPro within the buffered shapefile boundary and was confirmed to also appear in GE, then the ArcPro “Add Feature Tool” was used to create a point in a georeferenced database. This process was completed for each structure that appeared in the imagery, approximately 2,450 structures. It should be noted that the number of structures that are included in the structure inventory is greater than the number of structures that are within in the most recent 500-year without floodplain that was developed for this study.

The Google Earth measuring tool was used to estimate structure square footages based on the aerial view of a structure’s overall footprint. The non-square footage related attributes (NSFRA) of sampled structures, which include a) construction quality, b) condition, c) occupancy type, d) damage category, e) construction class, and f) foundation height were collected to help identify the type of structure (house, store, school, etc.), depreciated replacement value, and first floor elevation.

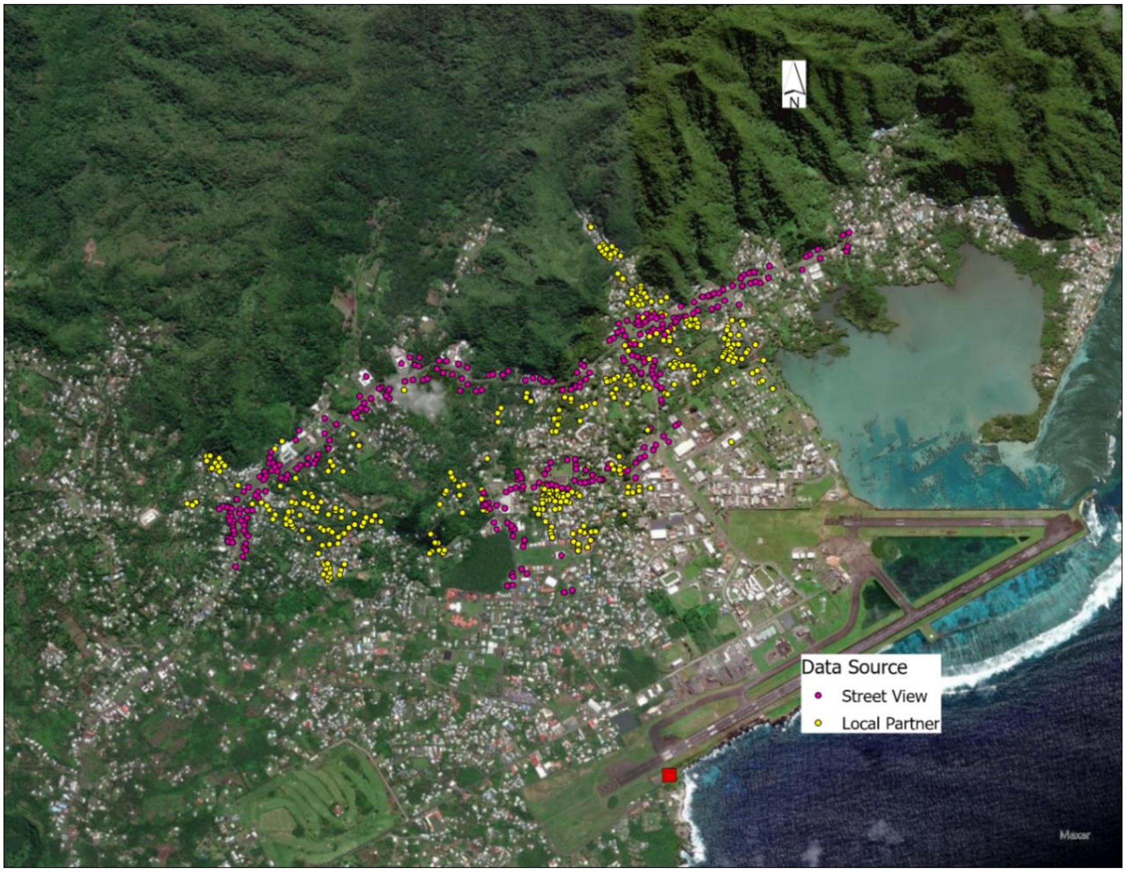
3.0.0 Sampled and Non-Sampled Structures

The structure inventory contains two categories of structures, 1) *sampled structures* and 2) *non-sampled structures*.

<u>Sampled Structures:</u> Sampled structures are structures whose NSFRA were identified by Google Earth Street View (SV) or by local partner input. Although there approximately are 2,450 structures in the study area, only about 300 can be seen well enough on SV to determine the NSFRA. In addition to these roughly 300 structures, the local study partners provided approximately 350 photos of different structures. The set of sampled structures is then made up of the structures seen on SV and of those shown in the study partner provided photos.

<u>Non-Sampled Structures:</u> Non-sampled structures are structures that do NOT appear in SV or seen in photos provided by the local study partner, however their NSFRA were assigned based on the statistical characteristics of the sampled structures, see Sections 3.0.1 and 3.0.2. The set of non-sampled structures is made of all the remaining structures that cannot be seen in SV or in study partner photos.

Figure 3 shows the location of the sampled structures, the yellow points represent the locations of structures that have photos provided the local partner while the purple points represent structures that were able to be seen in Google Street View.



[7]

Figure 3. Tafuna Study Sampled Structures Data Points

The NSFRA information observed from sampled structures was used to assign the NSFRA for the approximately 1,700 non-sampled structures that cannot be seen on SV or in local partner provided photos. All NSFRA for non-sampled structures were assigned using the Excel Data Analysis Tool- Random Number Generator (RNG). The derivation of the input data for the RNG that will be covered in Sections 3.0.1 and 3.0.2. Figure 4 shows non-sampled structures (green points) and sampled structures (yellow and purple points).

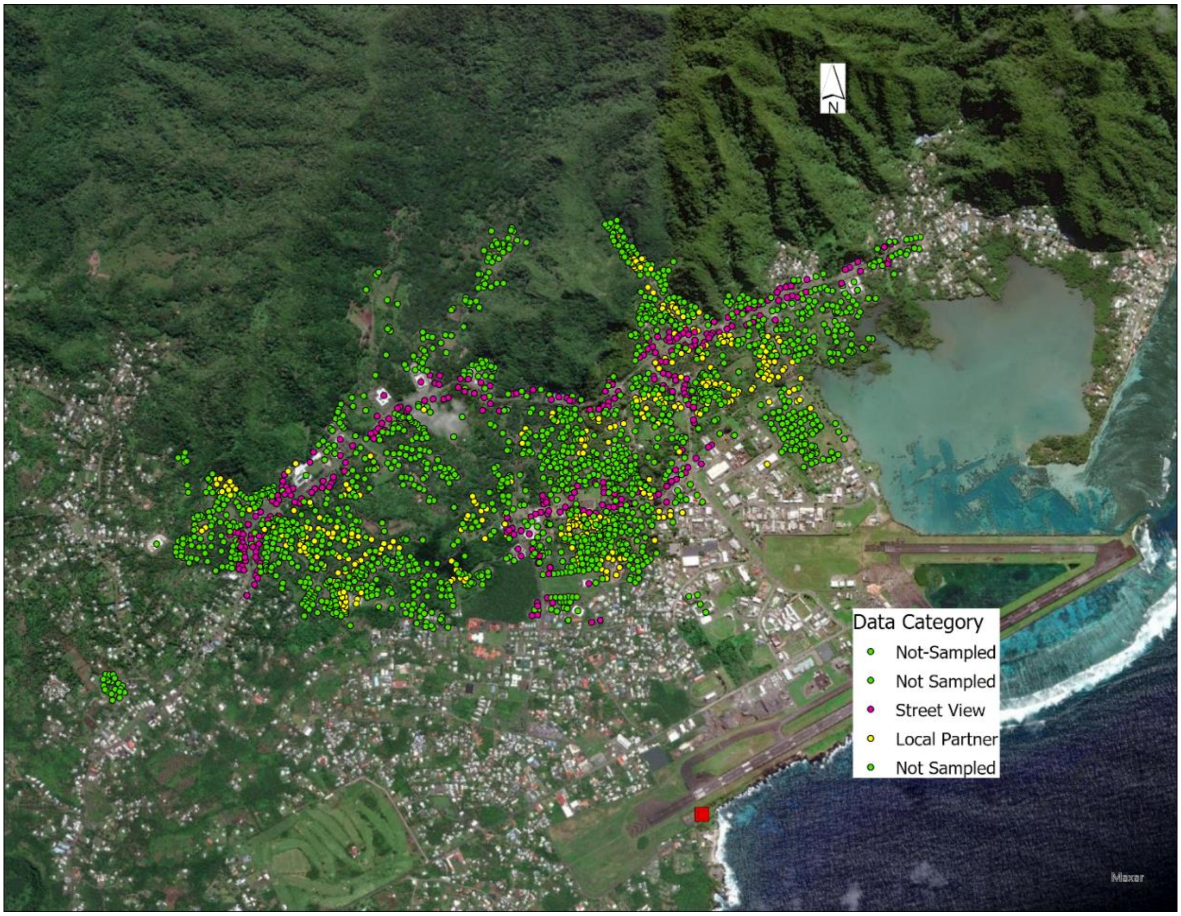


Figure 4.Tafuna-Study Sampled and Non-Sampled Structure Data Points

3.0.1 NSFRA Assignment for the Non-Residential Non-Sampled Structures

The following sections review the methodology of assigning NSFRA to the non-sampled structures and the derivation of the input data for the RNG.

<u>Occupancy Type:</u> The occupancy type RNG input assignments, that is the assignments that describe the type of structure (*e.g.*, single or multi-family house, retail business, office building, etc.), are based on the actual observed occupancy type distribution. The occupancy type data input table for the RNG is shown in Table 8.

Table 8: Observed Occupancy Type Distribution

Occupancy Type	Occupancy Type Observed Distribution	Damage Category
Auto Shop/Garage	0.79%	Commercial
Convenience Market/Groceries	2.37%	Commercial
Motel	0.79%	Commercial
Office	1.74%	Commercial
Restaurant	0.95%	Commercial
Retail	8.36%	Commercial
Shopping Center	0.16%	Commercial
Warehouse	1.89%	Industrial
Light Industrial	1.26%	Industrial
Church	1.42%	Public
Government Office	0.95%	Public
Recreation	1.10%	Public
Schools/Colleges	1.89%	Public
Multi-Family Residence	5.21%	Residential
Single Family Residence	71.14%	Residential

Damage Category: The damage category for all sampled structures is based on occupancy type aggregations from Table 1 above:

- Residential – Includes single unit such as detached single-family homes, multi-family homes, apartment complexes, condominiums, and multiplex units.
- Commercial – Includes retail, service stations, office buildings, restaurants, and shopping centers.
- Industrial – Includes warehouses, light, and heavy manufacturing facilities.
- Public – Includes both public and semi-public uses such as post office, fire department, hospitals, government buildings, schools, and churches.

Aggregating the occupancy types from Table 1, the total sampled and unsampled structure damage category percentages are:

- 76.3 percent residential
- 15.1 percent commercial
- 3.2 percent industrial
- 5.4 percent public

Non-Residential Construction Quality and Structure Condition: The RNG input assignments for non-residential construction quality and condition were made using similar methodology to that used for occupancy type, however the input table date for the RNG inputs was based on multinomial distribution (MD) estimates of construction quality and condition using observed data on non-residential construction type and condition. These multinomial distributions were estimated using Palisades @Risk Distribution Fitting Tool. Palisade @Risk is a risk and decision analysis software that runs in Microsoft Excel and uses Monte-Carlo simulation to see a range of possible outcomes. The Palisades @Risk Best Fitting Distribution Tool uses historical (or observed) data to fit data to various distributions and provides “goodness of fit” statistics to help the user select an appropriate distribution.

The non-residential RNG input data and MD estimates for condition and construction quality are shown in Figure 5 and Figure 6, respectively. For non-residential structures condition and construction quality, the estimated distribution parameters, or the percentages associated with the red bars, were used as input data for the RNG. The red bars indicate the estimated discrete parameter estimates while the blue bars show the distribution of the observed data. Table 9 displays the structure condition and construction quality names along with their corresponding codes that are used in Figure 5, Figure 6, Figure 8, and Figure 9.

Table 9. Structure Condition and Construction Quality Codes

Condition	Code	Construction Quality	Code
Dilapidated	1	Cheap	1
Poor	2	Low Cost	2
Fair	3	Fair	3
Average	4	Average	4
Good	5	Good	5
Excellent	6	Very Good	6
New	7	Excellent	7

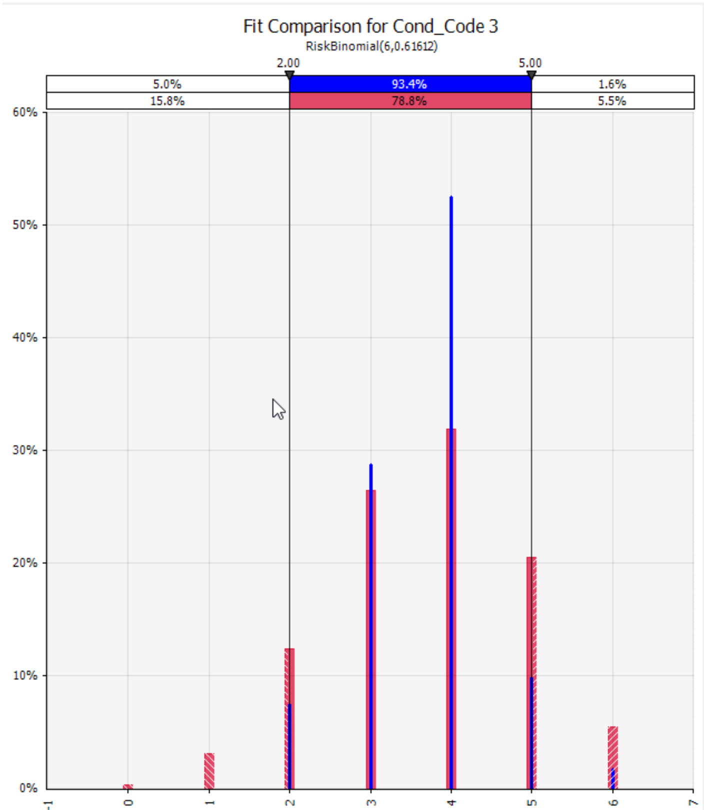


Figure 5. Non-Residential Condition Codes and Multinomial Distribution Parameters

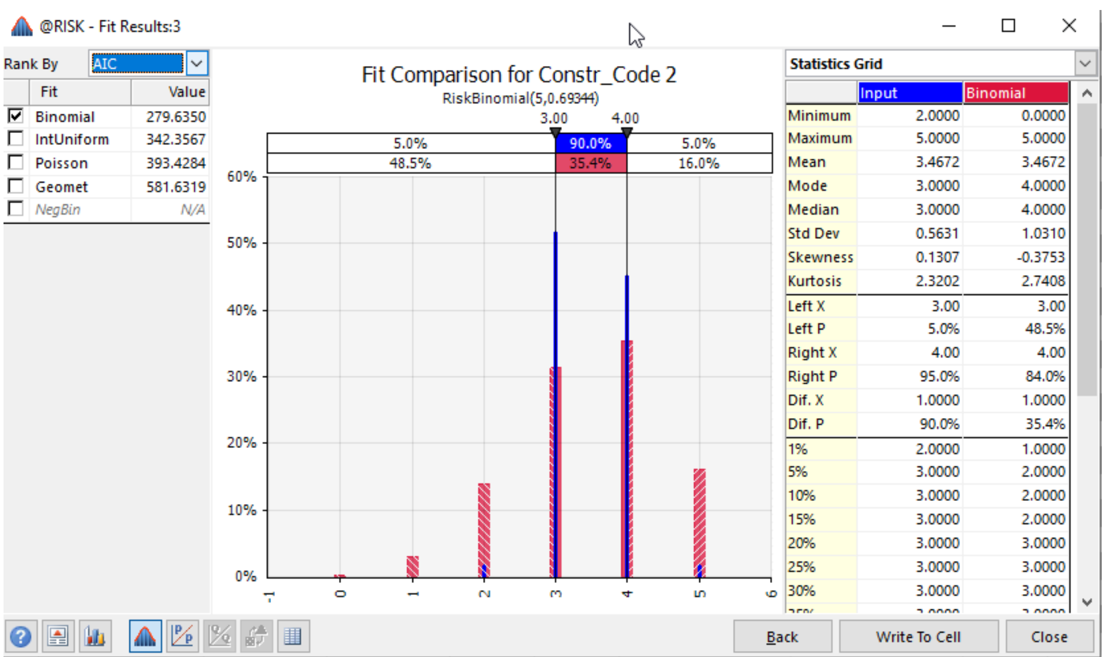


Figure 6. Non-Residential Construction Quality Codes and Multinomial Distribution Parameters

<u>Non-Residential Foundation Height</u>: Foundation height assignments for non-residential structures were made based on the same methodology for condition and construction mentioned above. Figure 6 shows the MD estimated RNG input data for non-residential foundation heights. Again, as was the case for the condition and construction assignments, RNG input parameters were based on the estimated MD parameters (red bars).

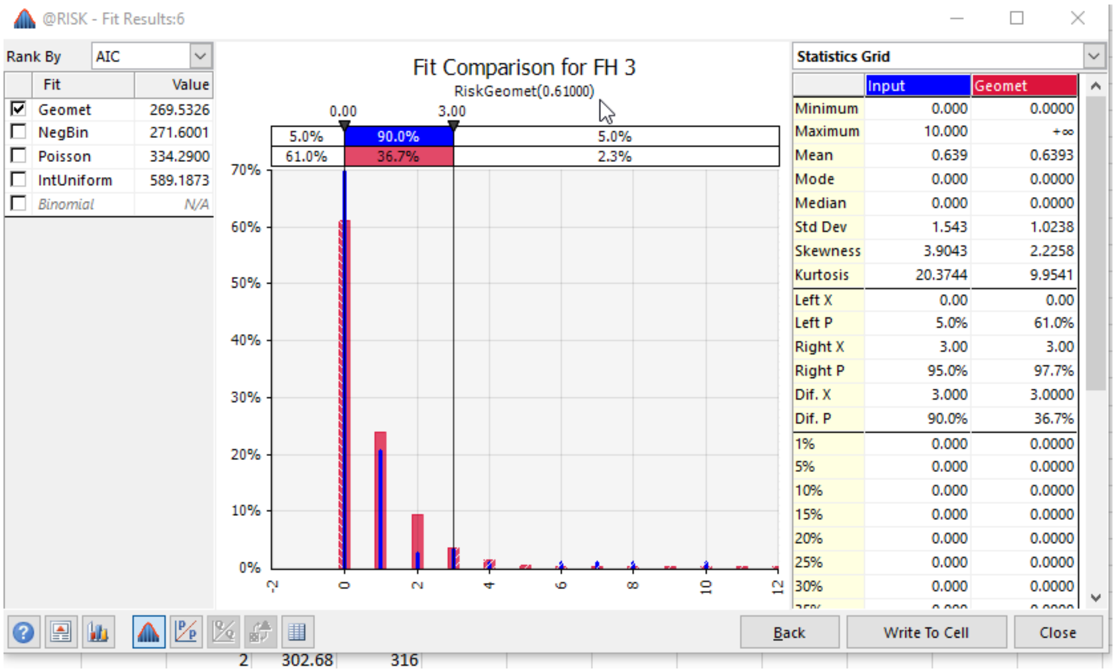


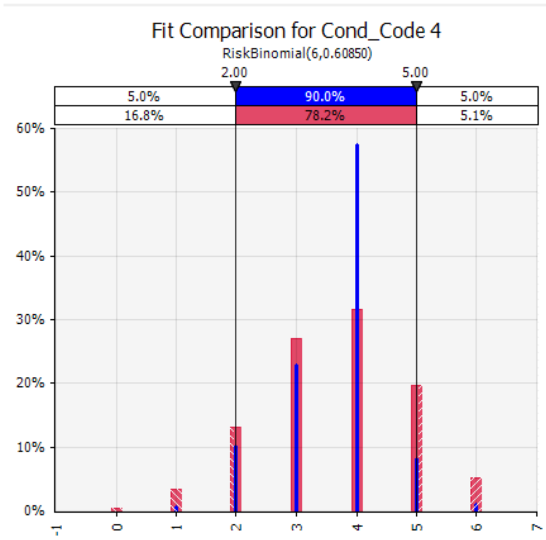
Figure 7. Non-Residential Foundation Heights Multinomial Distribution Parameters

<u>Construction Types:</u> Given the level of uncertainty of determining construction type remotely, for structure valuation purposes, it is assumed that all structures, including non-residential and residential, are wood frame (Type-D) unless it can be determined with certainty via Google Earth Street View or local partner photos, in those cases, the appropriate construction type will be used.

3.0.2 NSFRA Assignment for Structures NOT seen in Google Earth Street View

<u>Residential Damage Category and Occupancy Type:</u> The assignments for residential structures are very similar to the non-residential assignment methodology. The RNG data input tables for category and occupancy type assignments are based on observed data and not MD parameter estimates. It was assumed that most of the structures located off the main roads, Routes 001 and 018, are residential.

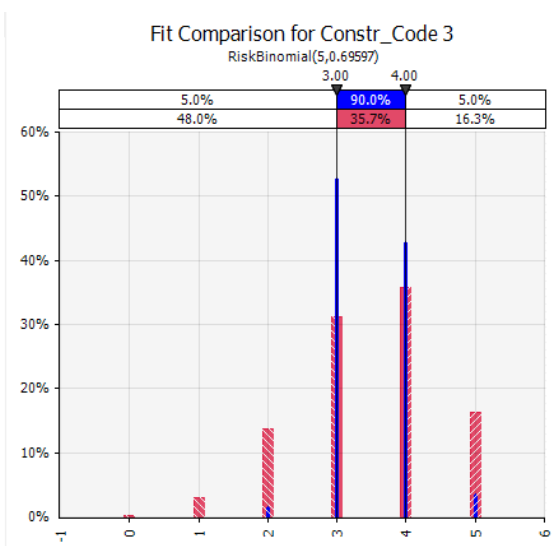
<u>Residential Construction Quality and Condition:</u> The assignments for residential construction quality and condition were made using the RNG. The input table data for the RNG inputs are based on multinomial distribution estimates using observed data on residential construction quality and condition. The residential RNG input data and MD estimates for condition and construction are shown in Figure 8 and Figure 9, respectively. As was the case for non-residential structures, the estimated distribution parameter (red bars) for residential structures were used as input data for the RNG. The red bars indicate the estimated MD estimates while the blue bars show the actual distribution of the observed data.



Statistics Grid

	Input	Binomial
Minimum	1.0000	0.0000
Maximum	6.0000	6.0000
Mean	3.6510	3.6510
Mode	4.0000	4.0000
Median	4.0000	4.0000
Std Dev	0.8322	1.1956
Skewness	-0.5055	-0.1815
Kurtosis	3.6024	2.6996
Left X	2.00	2.00
Left P	5.0%	16.8%
Right X	5.00	5.00
Right P	95.0%	94.9%
Dif. X	3.0000	3.0000
Dif. P	90.0%	78.2%
1%	2.0000	1.0000
5%	2.0000	2.0000
10%	2.0000	2.0000
15%	3.0000	2.0000
20%	3.0000	3.0000
25%	3.0000	3.0000
30%	3.0000	3.0000

Figure 8. Residential Condition Quality Codes and Multinomial Distribution Parameters

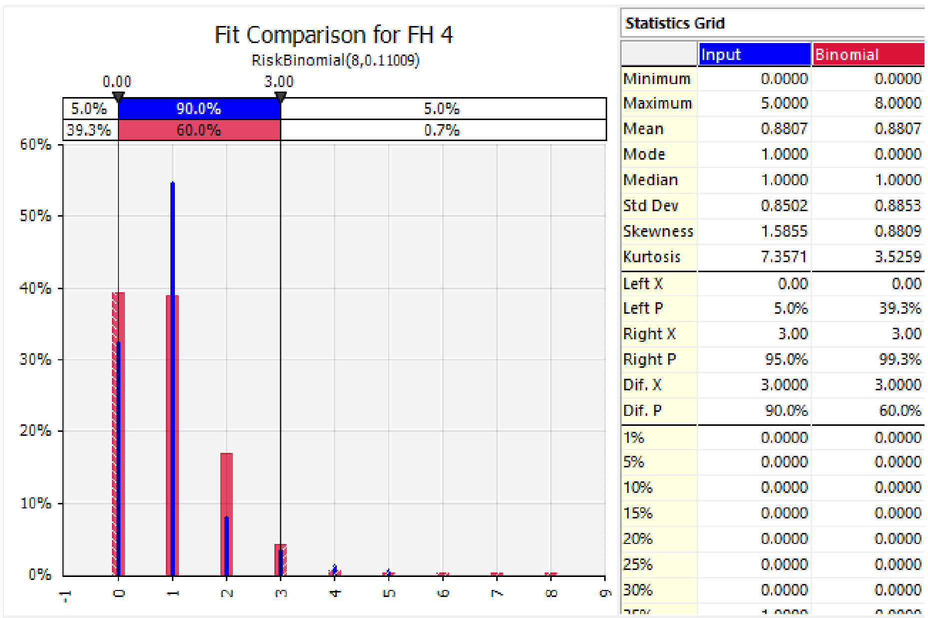


Statistics Grid

	Input	Binomial
Minimum	2.0000	0.0000
Maximum	5.0000	5.0000
Mean	3.4799	3.4799
Mode	3.0000	4.0000
Median	3.0000	4.0000
Std Dev	0.5871	1.0286
Skewness	0.3800	-0.3810
Kurtosis	2.5776	2.7452
Left X	3.00	3.00
Left P	5.0%	48.0%
Right X	4.00	4.00
Right P	95.0%	83.7%
Dif. X	1.0000	1.0000
Dif. P	90.0%	35.7%
1%	2.0000	1.0000
5%	3.0000	2.0000
10%	3.0000	2.0000
15%	3.0000	2.0000
20%	3.0000	3.0000
25%	3.0000	3.0000
30%	3.0000	3.0000

Figure 9. Residential Construction Quality Codes and Multinomial Distribution Parameters

Residential Foundation Height: Foundation height assignments for residential structures were made based on the same methodology as the non-residential structures. Figure 10 shows the MD estimated RNG input data for residential foundation heights. The RNG input parameters were based on the estimated MD parameters (red bars).



	Input	Binomial
Minimum	0.0000	0.0000
Maximum	5.0000	8.0000
Mean	0.8807	0.8807
Mode	1.0000	0.0000
Median	1.0000	1.0000
Std Dev	0.8502	0.8853
Skewness	1.5855	0.8809
Kurtosis	7.3571	3.5259
Left X	0.00	0.00
Left P	5.0%	39.3%
Right X	3.00	3.00
Right P	95.0%	99.3%
Dif. X	3.0000	3.0000
Dif. P	90.0%	60.0%
1%	0.0000	0.0000
5%	0.0000	0.0000
10%	0.0000	0.0000
15%	0.0000	0.0000
20%	0.0000	0.0000
25%	0.0000	0.0000
30%	0.0000	0.0000

Figure 10. Residential Foundation Heights Multinomial Distribution Parameters

3.1 Structure Valuation

Corps planning guidance requires property to be valued in terms of depreciated replacement value (DRV). To estimate DRV the following equation was used:

DRV= Dollars Per Square Foot x Structure Square Footage x (1-Depreciation)

Where:

Dollars Per Square Foot: Dollar per square foot values were estimated by using the methodology described above regarding assignments of NSFRA to sampled and non-sampled structures and applying the construction quality, construction type, and occupancy type assignments to look up the appropriate July 2020 Marshall and Swift Valuation Service Handbook's replacement cost per square foot estimate. The Marshall and Swift Valuation Service is a nationwide building valuation service.

Structure Square Footage: As mentioned in Section 3.0, the Google Earth measuring tool was used to estimate structure square footages based on the aerial view of a structure's overall footprint.

Depreciation: Depreciation was estimated by the structure *condition* assignments.

Per guidelines published in the Marshall & Swift Valuation Handbook, a locality or regional cost multiplier needs to be applied the dollar per square foot estimates to account for regional differences in material pricing or other related costs. However, since no locality multipliers are published for American Samoa, the Guam multiplier was used as a proxy, it was determined to be the most representative of the Tafuna Study Area. The Guam locality multiplier ranged between 1.23 and 1.31 depending on the construction type.

3.2 Elevations and Stationing

First floor elevation is defined as a structure's ground elevation plus structure foundation height. Each structure point was overlaid onto raster files from two-dimensional (2-D) HEC-RAS modeling to assign each structure a station that associates with a set of eight water surface elevation profiles. To calculate depth of flooding at each structure, first floor elevations are subtracted from flood depths within HEC-FDA, this depth is then applied to the appropriate depth damage curve to estimate structure damage. The first-floor elevations for each type of structure are assigned an uncertainty factor expressed as a standard deviation around a normally distributed variable.

3.3 Contents Valuation

Residential contents are not valued separately in the damage analysis since users of standard residential depth-damage functions issued by IWR in 2000 and 2003 are directed to enter 100 percent as the residential content-to-structure value ratio (CSVR), see Section 3.4 for discussion regarding depth-damage curves. For non-residential structures, a CSVR was based on the specific type of use of the structure. CSVRs developed as part of the *2008 American River Economic Reevaluation Report* (*2008 ERR*) completed by Sacramento District were utilized for this study and ranged from 25 percent to 213 percent of the structure value. As a part of the *2008 ERR*, Sacramento completed an expert elicitation to develop CSVRs and content damage functions that better reflect the land use. The outputs from the *2008 ERR* expert elicitation have been used extensively in Corps planning studies throughout the United States and were determined to be appropriate for the Tafuna study area as no better data was available and a sensitivity analysis, see next section, determined that using content valuation methodologies do not significantly impact expected annual damages.

3.4 Depth-Damage Curves

The depth of flooding is the primary factor in determining potential damages to structures, contents, and automobiles. Depth-percent damage functions were used in the HEC-FDA models to estimate the percent of value lost for these categories.

- Residential depth-damage curves (structures and contents) were taken from Economic Guidance Memorandum (EGM) 01-03, Generic Depth-Damage Relationships, and EGM 04-01, Generic Depth-Damage Relationships for Residential Structure with Basements, for use on both single-family and multi-family residential structures. Structures were identified as 1-story, 2-story, or split-level.
- Non-residential structure depth damage curves were based on revised FEMA Flood Insurance Administration (FIA) curves.
- Depth-percent damage functions for automobiles were based on weighted average from curves developed by the Institute for Water Resources (IWR) and provided in EGM 09-04, Generic Depth-Damage Relationships for Vehicles.

The economic modeling for the Tafuna FRM Study included several sensitivity analyses to test the sensitivity the overall results are to the selection of depth damage curves and/or non-residential CSVR assumptions. One sensitivity analysis included the use of the depth damage curves and CSVR developed by the Hawaii district. The results of the all the sensitivity analysis indicate the overall results are not sensitive to changes in the choice of depth damage curves or non-residential CSVR assumptions.

3.5 Economic Uncertainty:

Structure Value and Occupancy Type Uncertainty: In the estimation of structure value, three variables were considered to have a possible range of values: 1) construction quality, 2) building square footage, and 3) percent of estimated depreciation. Using triangular or normal distributions to describe the range of these three variables, an @Risk simulation was run on all structures to estimate a most likely structure value. To obtain estimates of occupancy type uncertainty, pooled occupancy type standard deviations were calculated by aggregating the standard deviations of two structure value estimates, deterministic and most likely, for each occupancy type. The deterministic value was estimated without uncertainty and the most likely value was estimated assuming the uncertainty distributions. Structure value uncertainty by occupancy type were entered in HEC-FDA as coefficients of variation (standard deviation/mean).

Content Value Uncertainty: Per Economic Guidance Memorandum 01-03 (EGM 01-03), residential contents are not valued separately in the damage analysis as this guidance advises users to set the residential content to structure value ratio (CSVR) to 100 percent which forces the correct usage of the residential content depth-damage curve. Content value uncertainties for non-residential structures were based on CSVR coefficient of variation estimates from the ERR expert elicitation mentioned previously. The program Best Fit was used to determine what would be a reasonable distribution, and using the model data, it was determined that a normal distribution best described uncertainty in the residential structure and content valuation. These uncertainty parameters for valuation were imported into the HEC-FDA program.

Automobile Uncertainty: Several factors contributed to the uncertainty associated with automobile damages. These factors include the average unit value, the number of vehicles per residence, and the evacuation rate. It was assumed that the average number or automobiles per residential unit was two and the evacuation rate was 50%. While uncertainty in these variables was not considered, uncertainty in the percent damage by depth (as reflected in the depth-percent damage curve) was considered.

First Floor Uncertainty: Uncertainty in first floor elevation (FFE) was also included in the model. Since field visits were not undertaken for the study, Table 6-5 from EM-1110-2-1619 (1619) was referenced to obtain FFE standard deviations. Per 1619 for field survey- stadia methods, all structures were assigned a 0.4-foot FFE standard deviation.

The uncertainty associated with the percent damages at specific depths of flooding for structures and contents were entered into the HEC-FDA model. Residential structure and content depth-percent damage curves are normally distributed and include standard deviations of percent damages by depth of flooding. Non-residential structure depth damage curves were assumed to be normally distributed with a standard deviation of 5 percent for flood depth stages of zero feet stages and lower and a standard deviation of 10 percent for stages greater than 0.5 feet. Non-residential content depth-percent damage curves are triangularly distributed and include a minimum, most likely, and maximum percent damage by depth of flooding. All depth damage uncertainty values were taken from the respectively source for the depth damage curve (see section above).

3.6 Structure Counts

There are approximately 545 structures within the 0.2 percent AEP event floodplain. Table 10 displays the number of structures by damage category and study reach within the 0.2 percent AEP event floodplain and Figure 11 shows the locations of structures

Table 10. Number of Structures by Damage Category in 0.2% AEP Floodplain by Reach

Study Reach	Commercial	Industrial	Public	Residential	Total
1	1	2	1	18	22
2-E	3	0	3	14	20
2-W	1	2	0	26	29
3	25	2	2	133	162
4	2	0	1	40	43
5-N	3	0	1	42	46
5-S	1	2	1	26	30
6-E	2	0	0	27	29
6-W	0	3	4	3	10
7	1	3	2	48	54
8	13	4	2	81	100
Total	52	18	17	458	545

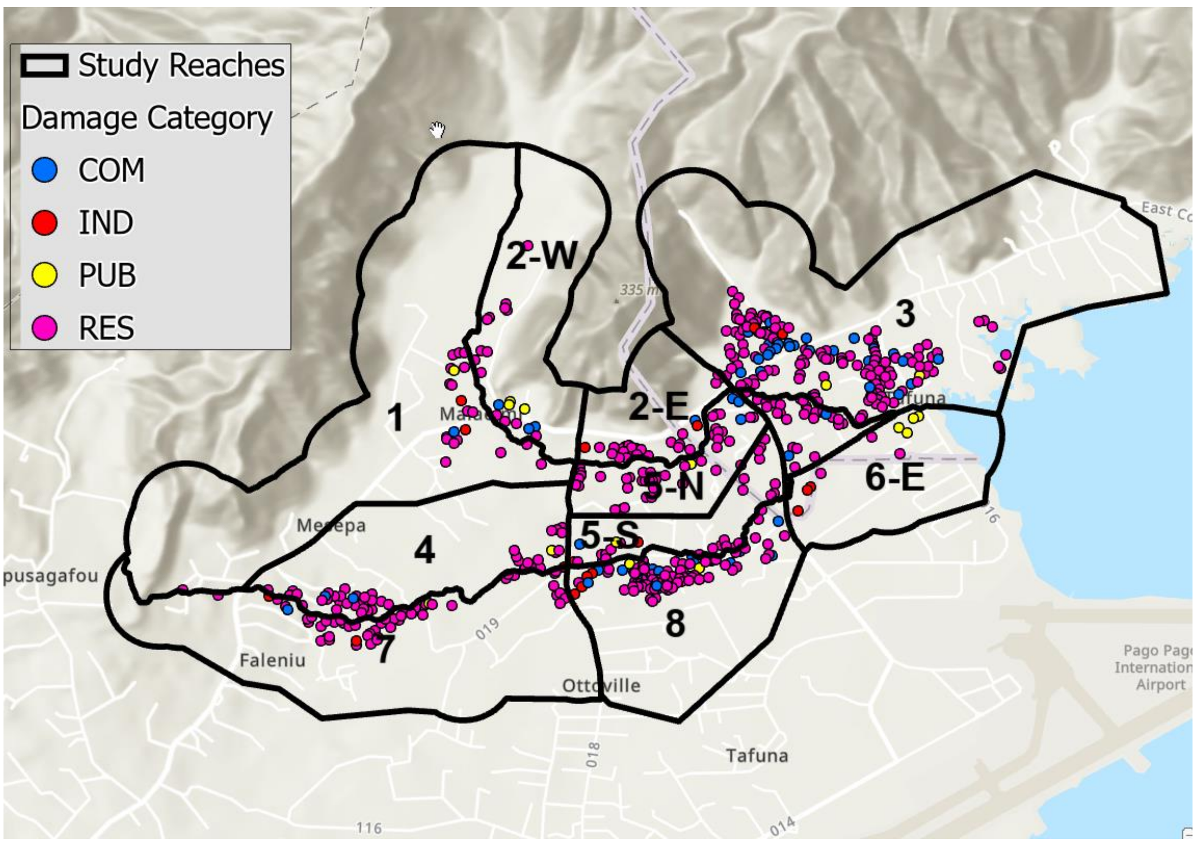


Figure 11. Structures in 0.2 Percent AEP Event Floodplain by Damage Category.

3.7 Damageable Property

Tables 11 through 13 display the value of damageable property within the 0.2 AEP event floodplain for structures, contents, and totals, respectively, by study reach. The total value of damageable property, structures, and contents, within the 0.2 percent AEP floodplain is approximately $210.5 million.

Table 11. Value of Damageable Structure Values by Damage Category and Study Reach in 0.2% AEP Floodplain, October 2020 Price Level in $1,000's

Study Reach	Commercial	Industrial	Public	Residential[1]	Total
1	119	509	115	3,014	3,757
2-E	631	-	3,130	3,669	7,430
2-W	168	150	-	4,712	5,030
3	8,452	354	668	24,275	33,749
4	181	-	70	6,713	6,964
5-N	500	-	476	5,539	6,515
5-S	73	277	144	5,032	5,526
6-E	644	-	-	4,994	5,638
6-W	-	1,945	1,244	730	3,920
7	91	113	123	8,996	9,322
8	4,585	1,995	1,339	18,423	26,342
Total	15,445	5,342	7,309	86,097	114,193

1-Includes the value of automobiles.

Table 12. Value of Damageable Content Value by Damage Category and Study Reach in 0.2% AEP Floodplain, October 2020 Price Level in $1,000's

Study Reach	Commercial	Industrial	Public	Residential	Total
1	50	480	30	2,643	3,203
2-E	298	-	3,130	3,381	6,808
2-W	86	133	-	4,176	4,396
3	4,598	446	142	21,409	26,595
4	122	-	22	5,826	5,971
5-N	227	-	81	4,693	5,002
5-S	37	317	83	4,434	4,872
6-E	785	-	-	4,251	5,037
6-W	-	1,916	324	668	2,908
7	46	148	29	7,635	7,858
8	4,049	2,787	292	16,567	23,696
Total	10,300	6,228	4,133	75,685	96,346

Table 13. Total Value of Damageable Property (Structures and Contents) by Damage Category and Study Reach in 0.2% AEP Floodplain, October 2020 Price Level in $1,000's

Study Reach	Commercial	Industrial	Public	Residential[1]	Total
1	169	989	145	5,657	6,960
2-E	928	-	6,260	7,050	14,238
2-W	254	283	-	8,889	9,426
3	13,050	800	811	45,683	60,344
4	304	-	92	12,539	12,934
5-N	727	-	557	10,232	11,516
5-S	111	594	227	9,466	10,399
6-E	1,429	-	-	9,245	10,675
6-W	-	3,861	1,568	1,399	6,828
7	137	261	151	16,631	17,181
8	8,635	4,782	1,631	34,990	50,038
Total	25,744	11,570	11,442	161,782	210,539

1-Includes the value of automobiles.

4. FUTURE WITHOUT-PROJECT (FWOP)

4.0 National Economic Development (NED)

The following sections describe the economic analysis as it pertains to the National Economic Development (NED) planning account. The NED account is one of the four planning accounts that are used by the USACE to, quantitatively or qualitatively, determine the benefits in a comprehensive manner of an array of flood risk management (FRM) plans. From this comprehensive assessment of plans, a Tentatively Selected Plan (TSP) is identified.

The Federal objective of water resources planning is to contribute to national economic development, consistent with protecting the Nation's environment. The 1936 Flood Control Act established the nationwide policy that flood control on navigable waters and their tributaries is in the interest of the public welfare and is, therefore, a proper activity of the Federal government, in cooperation with the states and local entities. The Act provides that the Federal government may improve streams or participate in improvements for flood control purposes if the benefits to whomsoever they may accrue are more than the estimated costs, and if the lives and social security of people are otherwise adversely affected. Subsequent acts have enlarged the scope of the Federal interest to include consideration of all alternatives in controlling flood waters, by reducing the susceptibility of property to flood damage and relieving human and financial losses.

The current economic analysis assumes that any future development in the Tafuna study area would follow current laws and regulations pertaining to development in a floodplain. Therefore, any future development is expected to be outside of the 1% AEP floodplain and would be susceptible to only minimal damages, if any at all. Additionally, since there are no firm estimates on the number and types of structures that might be built in the future, the proposed future development in the Tafuna area was not included in the economic structure inventory.

4.1 Existing, Base Year, Future Without-Project, and Future Year Conditions

The *existing condition* is the structure inventory and engineering related conditions that exist now; for this analysis, the *base year*, which is the terminology used in HEC-FDA, is the year 2030 and is assumed to be the same as the *existing condition* in terms of both the engineering and economic related inputs.

The *most likely future year* (MLFY) condition in HEC-FDA is assumed to be 50 years out from the base year condition or the year 2079. In terms of the economic related HEC-FDA inputs, the without-project MLFY condition is assumed to be the same as the without-project *base year* condition. In terms of the engineering HEC-FDA inputs, the without and with-project MLFY conditions are different from the base year condition due to the expected impacts of sea level change (SLC).

A sea level change (SLC) analysis was completed for the hydrology and hydraulic engineering. The SLC analysis informed a Future Without-Project Condition (FWOP) that is 50 years out from today. Based on this FWOP, hydrologic and hydraulic engineering information and floodplains were developed for use in the HEC-FDA models. The future year hydrology and hydraulic engineering data were used to run a most likely *future year* in HEC-FDA to generate expected annual damages (EAD) for the year 2079 and equivalent annual damages over the 50-year period of analysis.

4.2 Basic Modeling

The structure inventory for the study area discussed above, including elevations, structure values, depth-damage functions, uncertainty factors, and depths of flooding for each AEP event were entered into HEC-FDA to estimate existing condition damages. Damages in this analysis consist of physical inundation damages to automobiles, commercial, industrial, public, and residential structures. Depth raster files produced from the HEC-RAS model output provide distinct water surface elevations at distinct locations throughout the study area.

4.3 Methodology and Key Assumptions

Unless stated otherwise, the price level is October 2021; the discount rate is 2.25% (FY 2022); the period of analysis is 50 years.

4.4 Study Reaches

Eleven study reaches were delineated based on the a) floodplain extents, b) a current understanding of the hydraulic engineering, c) with-project features, and d) the economic inventory.

4.5 Index Points

In total, twelve representative index points (IP) were selected for this analysis based on the location along the Taumata, Leaveave, and Vaitele streams where overtopping first takes place. These index points, highlighted in Table 14, were used in HEC-FDA to represent the connection between the depths of flooding in the study area and the in-channel hydrology and hydraulics (H&H) for all project conditions. The HEC-FDA software uses the index point locations and its associated engineering and economic inputs specific to an index point to compute aggregated economic stage-damage curves, expected annual damages, and engineering performance. Table 14 show the representative index point locations for the without project condition, Figure 12 shows the locations of the index points and the study reaches.

The selection of representative index points was guided by the following questions:

- Where does overtopping occur?
- Where does overtopping cause the greatest extent of flooding?
- Where does overtopping cause the greatest depth of flooding?
- Where does overtopping cause the greatest extent of flooding to structures?
- Where does overtopping occur that causes the greatest depth of flooding to structures?
- What is the number of index points and where would these index points be located to be able to reasonably characterize flood risk for the basin as a whole?
- What is the number of index points and where would these index points be located to be able to facilitate alternatives analysis and plan formulation?

Table 14. Representative Index Points, Station Numbers, Study Reach and Stream/Bank

Representative Index Point	Station Number	Study Reach	Stream/Bank
1	8898 R	Reach 1	Taumata/Left Bank
2	8898 L	Reach 2-W	Taumata/Right Bank
3	4550 L	Reach 2-E	Taumata/Left Bank
4	4550 R	Reach 5-N	Taumata/Right Bank
5	2114 L	Reach 3	Taumata/Left Bank
6	8412 L	Reach 4	Leaveave/Left Bank
7	3444 L	Reach 5-S	Leaveave/Right Bank
8	8412 R	Reach 7	Leaveave/Left Bank
10	1671 L	Reach 6-W	Leaveave/Left Bank
11	1671 R	Reach 6-E	Leaveave/Right Bank
12	3444 R	Reach 8	Leaveave/Right Bank

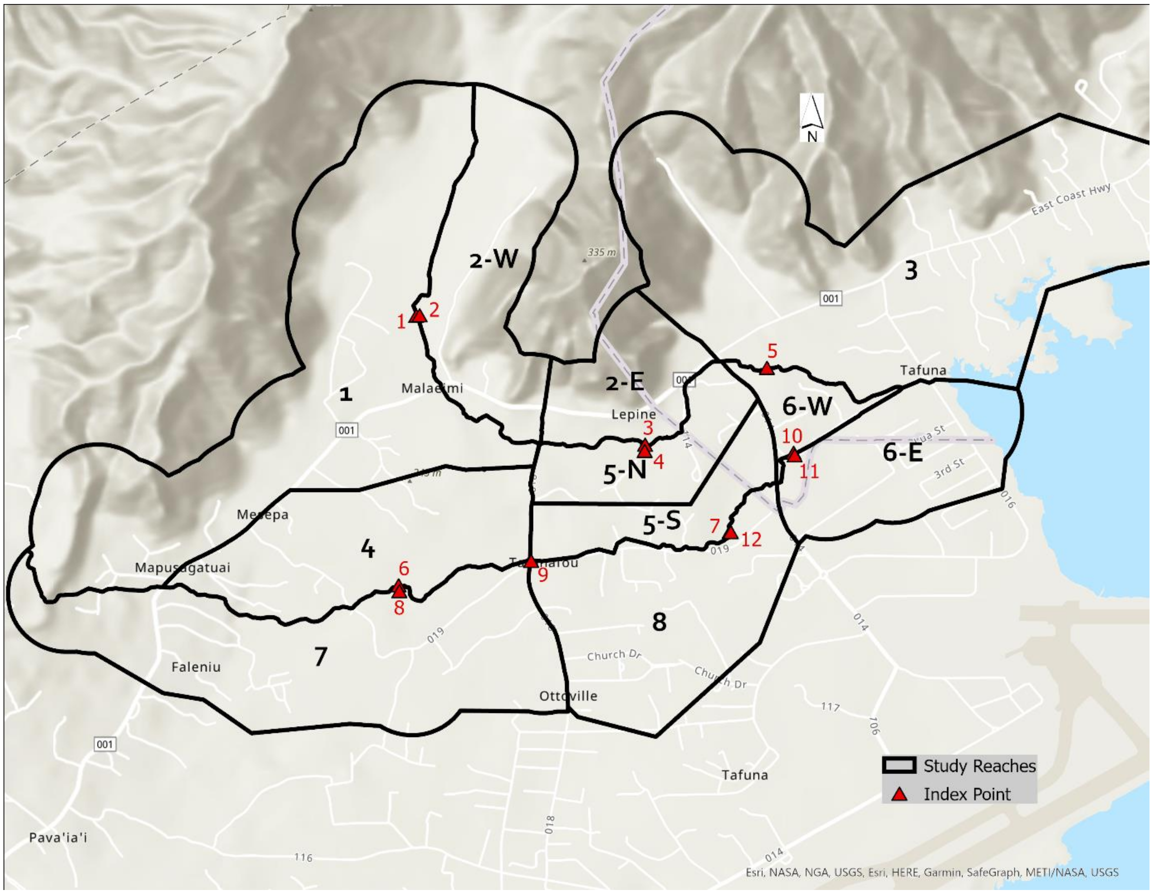


Figure 12. Study Reach Areas and Engineering Index Points

4.6 The HEC-FDA Program

The basic assumption underlying use of a risk analysis program is that data in flood-risk studies are based on imperfect knowledge and unpredictable future developments, so that key variables for which median or most likely values are specified could take on a range of values above and below the specified values. The Hydrologic Engineering Center - Flood Damage Analysis - (HEC-FDA) software, version 1.4.2 was used to estimate flood related damages and engineering performance.

In HEC-FDA, there are two main types of data required, 1) economic inventory data, which includes: structure values, first-floor elevations, structure stationing, occupancy type (one-story homes, retail businesses, government offices, etc.), content to structure values ratios, depth-damage relationships, and uncertainty factors for all economic variables, and 2) engineering related data, which includes: depths of flooding for each structure (floodplains), exceedance probability-discharge relationships, stage-discharge relationships, geotechnical related data, and related uncertainty data. All engineering and economic data are entered into the program in terms of mean values and are accompanied by appropriate uncertainty parameters specifying the range of possible values for each variable.

The first step of the modeling analysis produces an economic aggregated stage-damage function. The program performs numerous iterations, each combining various possible values for each economic input (depths of flooding, economic value, and depth-damage) by sampling the uncertainty distributions provided for those variables. Estimated flood damages for each foot of flooding are computed based on the level of investment subject to flooding, the beginning damage elevation, and the estimated damage to that structure associated with various depths of flooding. The HEC-FDA program references each structure's first floor elevation or beginning damage elevation to the corresponding flood event elevation at the representative index point. Stage-damage relationships for each structure within each damage category are then aggregated to the reach index location to derive the aggregated stage-damage functions.

The second step of the modeling analysis integrates the economic aggregate stage-damage function with the engineering data. The HEC-FDA program utilizes a Monte Carlo process to randomly sample multiple probability distribution functions to produce tens of thousands of possible flood events instead of a few discrete scenarios. For each event, the program samples the range of possible values for each variable and determines (a) whether the flood event results in damage, and (b) how much damage occurs. The result is to effectively extend the period of record synthetically to thousands of flood events in a manner that reflects uncertainty in assumptions and the dynamic interaction of variables over long periods of time.

The calculation of expected annual damages is a weighted average where damages corresponding to each AEP event are computed and multiplied by the incremental probability of that event and then all these products are summed. This total, referred to as expected annual damages (EAD), represents an estimate of the average damages that would be expected in any given year over the long term. The outcome of the Monte Carlo simulations is a single expected value for EAD that represents an average of the thousands of synthetic events. Even though it is a single value, the EAD value integrates many variables, including their uncertainty distributions. EAD computations are made for the without-project and with-project conditions.

4.7 Without-Project Economic Inputs for HEC-FDA

The structure inventory for the study area discussed above, including structure values, depth-damage functions, uncertainty factors, and structure flood depths for each AEP event were entered into HEC-FDA to estimate base year and future year damages. Damages in this analysis consist of physical inundation damages to automobiles, commercial, industrial, public, and residential structures, and contents. Raster files produced from the HEC-RAS model output provide distinct flood depths at each structure throughout the study area.

4.8 Without-Project Engineering Inputs for HEC-FDA

Hydrology: Standard hydrologic engineering inputs were used in the HEC-FDA analysis. These inputs include graphical exceedance probability-discharge curves containing eight data points (50, 20, 10, 4, 2, 1, 0.5, and 0.2 percent AEP events) for each index point and an equivalent record length (ERL) associated with the Tafuna Study Area. An ERL of 20 years was used in HEC-FDA to estimate discharge uncertainty. For this assessment, all eleven index points were used to estimate expected annual damages (EAD).

Hydraulic Engineering: Standard hydraulic engineering HEC-FDA inputs were used in the HEC-FDA analysis. These inputs include stage-discharge rating curves for each representative index point. The rating curve contains eight data points corresponding to the eight AEP events used to develop the hydrology listed above. A suite of eight floodplains corresponding the same AEP events were used to assess the without project conditions. The floodplains were provided in raster format containing depths of flooding. ArcPro was used to extract the depths of flooding at each structure and for each AEP event. The depths of flooding data were then exported and formatted as tab-delimited text files for input into HEC-FDA as water surface profiles. An additional 11 rows of data, each row representing the 11-index point location's stage data at the HEC-FDA representative index location, were included in the water surface profile; the index location stage data of the water surface profile serves as the connection between the exterior (in-channel) hydraulics and the interior (floodplain) depths of flooding data and allows for the correct scaling and computation of the stage-damage curves in HEC-FDA. Table 15 shows the exceedance-probability discharge and stage data for each eight AEP events and all representative index points.

Table 15: 2030 Alternative A (Without Project) Exceedance-Probability, Discharge and Stream Stage Relationships by Index Point

Representative Index Point(s) Station(s)	Exceedance Probability	Discharge in CFS	Stage (Feet)
Index Points 1 and 2 at Station 8898	0.5	54.9	133.0
	0.2	183.7	133.30
	0.1	225.9	133.49
	0.04	277.0	133.7
	0.02	329.3	134.0
	0.01	369.8	134.2
	0.005	412.8	134.5
	0.002	473.4	134.8
Index Points 3 and 4 at Station 4550	0.5	40.1	75.4
	0.2	118.1	76.0
	0.1	254.5	76.45
	0.04	428.2	76.90
	0.02	584.4	77.3
	0.01	735.7	77.6
	0.005	902.6	77.9
	0.002	1301.5	78.6
Index Point 5 at Station 2114	0.5	488.5	40.5
	0.2	917.0	41.3
	0.1	1292.3	41.79
	0.04	1731.0	42.18
	0.02	2020.7	42.4
	0.01	2343.9	42.7
	0.005	2676.8	43.0
	0.002	3423.0	43.5
Index Points 6 and 8 at Station 8412	0.5	161.2	104.8
	0.2	161.3	104.8
	0.1	300.8	105.36
	0.04	479.5	105.93
	0.02	659.9	106.4
	0.01	795.8	106.6
	0.005	930.5	106.9
	0.002	1124.2	107.2
Index Points 7 and 12 at Station 3444	0.5	419.9	39.7
	0.2	775.0	40.5
	0.1	1056.2	41.07
	0.04	1418.8	41.88
	0.02	1824.7	42.6
	0.01	2165.2	43.1
	0.005	2535.1	43.6
	0.002	3060.1	44.3
Index Points 10 and 11 at Station 1671	0.5	505.5	33.3
	0.2	1042.9	34.6
	0.1	1467.5	35.32
	0.04	1990.6	35.90
	0.02	2496.4	36.4
	0.01	2901.5	36.8
	0.005	3304.5	37.1
	0.002	3886.2	37.6

Table 16: 2079 Alternative A (Without Project) Exceedance-Probability, Discharge and Stream Stage Relationships by Index Point

Representative Index Point(s) Station(s)	Exceedance Probability	Discharge in CFS	Stage (Feet)
Index Points 1 and 2 at Station 8898	0.5	104.1	132.9
	0.2	183.7	133.3
	0.1	225.9	133.5
	0.04	285.1	133.8
	0.02	329.2	134.0
	0.01	369.8	134.2
	0.005	412.8	134.5
	0.002	473.3	134.8
Index Points 3 and 4 at Station 4550	0.5	56.4	75.2
	0.2	118.0	76.0
	0.1	254.5	76.5
	0.04	440.3	76.9
	0.02	584.4	77.3
	0.01	735.8	77.6
	0.005	902.6	77.9
	0.002	1301.6	78.6
Index Point 5 at Station 2114	0.5	422.1	40.4
	0.2	917.0	41.3
	0.1	1292.3	41.8
	0.04	1756.5	42.2
	0.02	2020.7	42.4
	0.01	2343.9	42.7
	0.005	2676.7	43.0
	0.002	3423.0	43.5
Index Points 6 and 8 at Station 8412	0.5	161.0	104.8
	0.2	161.1	104.8
	0.1	300.8	105.4
	0.04	506.3	106.0
	0.02	659.9	106.4
	0.01	795.7	106.6
	0.005	930.5	106.9
	0.002	1124.2	107.2
Index Points 7 and 12 at Station 3444	0.5	419.9	40.4
	0.2	774.9	40.5
	0.1	1056.2	41.1
	0.04	1473.1	42.0
	0.02	1824.8	42.6
	0.01	2165.2	43.1
	0.005	2535.2	43.6
	0.002	3060.6	44.3
Index Points 10 and 11 at Station 1671	0.5	548.3	33.5
	0.2	1042.9	34.6
	0.1	1467.4	35.3
	0.04	2051.9	36.0
	0.02	2496.6	36.4
	0.01	2901.6	36.8
	0.005	3304.7	37.1
	0.002	3886.2	37.6

Geotechnical Engineering: Since there are no existing levees in the Tafuna Study Area, geotechnical engineering inputs (i.e., levee fragility curves) that are often used in HEC-FDA were not required for the without project Tafuna study modeling. Top of bank elevation data were entered into HEC-FDA models; top of bank elevations are used by HEC-FDA in its calculation of engineering performance and expected annual damages. Table 17 display the top of bank elevation for all representative index points used in the without-project condition HEC-FDA analysis.

Table 17. Top of Bank Elevations for all Index Points, Without Project

Index Point	Top of Bank Elevation (Feet)
IP 1 – Taumata/Left Bank	131.32
IP 2 – Taumata/Right Bank	131.37
IP 3 – Taumata/Left Bank	70.69
IP 4 – Taumata/Right Bank	70.29
IP 5 – Taumata/Left Bank	37.48
IP 6 – Leaveave/Left Bank	103.46
IP 7 – Leaveave/Right Bank	32.76
IP 8 – Leaveave/Left Bank	103.92
IP 10 – Leaveave/Left Bank	26.39
IP 11 – Leaveave/Right Bank	26.87
IP 12 – Leaveave/Right Bank	32.29

It is important to note that based on the exceedance probability-discharge-stage relationships along with the top of bank elevation information, overtopping occurs prior to the 50 percent AEP event at most of the index locations in the Tafuna Study Area. This information is pertinent because it indicates that, based on the hydrologic and hydraulic curves and top of bank elevations, the study area experiences frequent flooding from each of the study area streams. This is reflected in the HEC-FDA engineering performance results shown below.

4.8.0 Without Project Expected Annual Damages (EAD) by Year

Expected annual damages represents an estimate of the average damages that would be expected in any given year over the long term. It is the primary economic statistic used to describe the flooding problem in the study area; it is also used as the baseline to measure potential benefits from proposed flood risk management projects. Without project condition expected annual damages for the base year, 2030, and most likely future year (MLFY), 2079, by year and study area reach for commercial, industrial, public, residential structures and contents are shown in Table 18; total base year EAD is estimated as $8.96 million and total MLFY EAD is estimated to be $9.5 million. EAD is slightly higher in the MLFY due to the minimal impacts of sea level change on flood depths.

Table 18. Without-Project Expected Annual Damages by Study Reach (in $1,000's, October 2021 prices)

Year	Study Area	COM	IND	PUB	RES	Total
2030	1	11	19	13	349	392
	2-W	12	0	11	580	603
	2-E	7	26	0	275	308
	3	379	17	12	1,181	1,589
	4	5	0	0	554	559
	5-N	16	0	110	934	1,060
	5-S	0	78	0	403	481
	6-W	148	0	10	884	1,042
	6-E	0	21	20	29	70
	7	10	23	10	835	878
	8	196	247	22	1,512	1,978
	Total	**785**	**431**	**210**	**7,536**	**8,961**
2079	1	10	18	14	338	380
	2-W	12	0	11	566	589
	2-E	7	25	0	247	279
	3	359	15	11	1,153	1,539
	4	5	0	0	571	577
	5-N	15	0	105	881	1,001
	5-S	0	84	0	511	596
	6-W	151	0	10	872	1,034
	6-E	0	22	20	30	72
	7	10	24	11	958	1,003
	8	257	275	28	1,867	2,426
	Total	**825**	**463**	**211**	**7,995**	**9,494**

4.8.1 Without-Project Equivalent Annual Damages (EqAD)

Equivalent annual damages reflect the effects of engineering and economic changes over the life of the project, that is the period between the base year and MLFY. However, as stated above, for the Tafuna study area, only engineering related inputs are assumed to change between the base year and MLFY and there no assumed changes in economic related inputs. Equivalent annual damages are calculated by annualizing the sum of the present value of linearly interpolated EAD values between the base year and MLFY. The annualization and interpolated present values are calculated using the federal discount rate while the annualization calculation also uses the 50-year period of analysis. An important difference between EAD and EqAD is discounting; discounting has the effect of lowering expected values of future flood damages. Table 19 shows that without-project EqAD are approximately $9.2 million.

Table 19. Without-Project Equivalent Annual Damages by Study Reach (in $1,000's, October 2021 prices)

Study Area Reach	COM	IND	PUB	RES	Total
1	10	19	13	345	387
2-W	12	0	11	574	597
2-E	7	25	0	264	296
3	371	16	12	1,170	1,569
4	5	0	0	561	566
5-N	16	0	108	912	1,036
5-S	0	81	0	447	528
6-W	149	0	10	879	1,038
6-E	0	22	20	30	71
7	10	23	11	885	929
8	221	258	25	1,657	2,161
Total	801	444	210	7,723	9,178

4.8.2 Without-Project Engineering Performance

Engineering performance, shown in Table 20, is computed by HEC-FDA and is a function of the hydrologic, hydraulic (in-channel), and top of bank. The results indicate that flooding in the study area is frequent, having an AEP of 100% for all study reaches. The engineering performance results are consistent with the index point-specific exceedance probability-discharge functions, stage-discharge functions, and the top of bank elevation data provided for input into the HEC-FDA models.

Table 20. Engineering Project Performance by Year and Study Reach, ALTERNATIVE A

Year	Study Area Reach	ENGINEERING PROJECT PERFORMANCE									
		AEP	Long-Term Risk			Assurance					
			10yr	30yr	50yr	10%	4%	2%	1%	0.50%	0.20%
2030	1	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	2-W	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	2-E	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	3	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	4	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	5-N	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	5-S	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	6-W	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	6-E	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	7	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	8	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
2079	1	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	2-W	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	2-E	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	3	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	4	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	5-N	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	5-S	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	6-W	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	6-E	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	7	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	8	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%

5. ALTERNATIVES EVALUATION

5.0 Initial Array of Alternatives

Alternative plans are a set of one or more management measures functioning together to address one or more planning objectives. A final array of alternative plans was formulated through combinations of screened management measures. Early iterations of the alternatives included detention basins along both the Taumata and Leaveave Stream. Detention Basins showed limited benefit in the hydraulic modeling and knowing the likely real estate challenges associated with securing sufficient lands for the Tafuna study area, the project team screened out detention basins as a potential flood reduction measure.

The final array of alternatives is as follows:

5.0.0 Alternative A – No Action

The No-Action Alternative is synonymous with no Federal action. This alternative is analyzed as the Future Without Project (FWOP) condition for comparison with the action alternatives.

5.0.1 Alternative B – Channel Conveyance

This alternative includes approximately 6,340 feet of channel conveyance on the Taumata Stream and 13,120 feet of channel conveyance on the Leaveave Stream. This alternative includes vegetation removal and conveyance improvements such as excavation of material to create a uniform channel with a varying bottom width of 5 to 20 feet and 2:1 side slope. Alternative B has the potential to reduce flood risk in all study reaches except Reach 1.

5.0.2 Alternative B1 – Flood Barrier and Channel Conveyance

This alternative includes the conveyance improvements described in Alternative B above. In addition, it includes construction of flood barriers on the Leaveave and Taumata . There is approximately 2,400 linear feet of barrier with an average height of 7 feet (from ground elevation) on the Taumata Stream and approximately 3,400 linear feet of barrier with an average height of 5 feet (from ground elevation) on the Leaveave Stream. The potential flood barrier on the Leaveave Stream is expected to provide flood risk protection for structures primarily in Reach 8 while the flood barrier on the Taumata Stream will provide flood risk protection primarily for structures in Reach 5N.

5.0.3 Alternative C – Flood Barrier and Nonstructural

This alternative includes the 2,400 foot Taumata Stream flood barrier that was included in Alternative B1 and nonstructural measures. As in Alternative B1, this flood barrier will provide flood risk protection primarily for Reach 5-N while the nonstructural component of this alternative will provide nonstructural measures structures in all other reaches, which is to dry floodproof 38 nonresidential buildings and elevate 242 residential structures.

5.0.4 Alternative D – Nonstructural

Alternative D includes only nonstructural measures. Preliminary benefit-cost analysis, see below, show that nonstructural measures affecting 312 structures can provide flood risk management benefits comparable to a structural improvement plan. At this stage of the study, dry floodproofing 40 nonresidential structures and elevating 272 residential structures is assumed to be the most effective nonstructural solution given the frequency and depth of flooding. The number and type of nonstructural improvements for this alternative will be refined as the analysis continues. The aggregation methodology and participation rate sensitivity analysis for Alternative D is described below in Section 5.1.

5.1 Nonstructural Analysis, Aggregation and Participation Rate

The nonstructural flood risk reduction measures considered for this study are: 1*) dry floodproofing* non-residential structures and 2) *elevation* for residential structures. Dry floodproofing consists of waterproofing the structure to prevent flood waters from entering. Although, dry floodproofing can be done to residential homes as well as commercial and industrial structures as it does achieve flood risk damage reduction, dry floodproofing residential structures was not considered for this study as these structures are NOT recognized by the National Flood Insurance Program (NFIP) for any flood insurance premium rate reductions, whereas a commercial structure may achieve insurance premium reduction if dry flood proofed in compliance with NFIP. Elevation is a measure that raises a structure’s first floor elevation to an elevation which is at least equal or greater than a design water surface elevation. The PDT ruled out other nonstructural measures (e.g., acquisitions, relocations) as the potential local cultural, environmental, geographic, and other issues associated with these measures in the Tafuna study area did make them viable measures.

Based on discussions with the Nonstructural Working Group (NSWG) and FRM-PCX, the nonstructural aggregation methodology was determined by grouping structures based on their potential flood risk and then select the grouping that reasonably maximizes net-benefits. This analysis consisted of grouping the Tafuna Study Area structure inventory into four groups based on flood risk associated with the 10.0%, 4.0%, 2.0% and 1% AEP event floodplains; to be contained in a specific AEP event floodplain a structure had to have a first-floor elevation (FFE) less than the stage associated with that floodplain. For example, the structures contained in the 10% AEP floodplain group all had FFE less than or equal to the flood stages associated with the 10% AEP event. A benefit-cost analysis was performed on each of the four AEP event floodplains listed above and the 10% AEP floodplain grouping maximized net-benefits, thus the 10% AEP floodplain grouping was carried forward for all nonstructural alternatives (Alternatives C and D). Table 21 shows the results of this aggregation analysis.

Table 21. Nonstructural Aggregation Analysis Results (100% Participation Rate), Oct 2020 Price Level, in $1000's, 2.5% discount rate, 50 year POA

	10% AEP	4% AEP	2% AEP	1% AEP
First Cost	131,346	163,925	180,059	191,874
Equivalent Annual Benefits	6,643	7,023	7,194	7,266
Average Annual Cost	4,631	5,780	6,349	6,765s
Net Benefits	2,012	1,244	846	501
BCR	1.4	1.2	1.1	1.1
Total Number of Structures	312	388	429	465
-Residential	272	335	367	396
-Non-Residential	40	53	62	69

5.2 Nonstructural Participation Rate and Sensitivity Analysis

To determine how benefit-cost metrics will be affected by changes in participation rates, a sensitivity analysis, like the risk-based approach outlined in the Nonstructural Best Practices Guide 2020-03, Sensitivity Analysis for Participation Rates in Nonstructural Alternatives, was performed. This analysis used Palisade @Risk to randomly select from all structures included in the 10% AEP floodplain based three different participation rate (25%, 50%, and 75%) assumptions. 50,000 combinations of the 312 structures were run in the Palisade @Risk model for each of the assumed participation rates. Table 22 shows the benefit-cost metrics for the five summary statistics of the Palisade @Risk model output; these five summary statistics were selected as they are recommended in Planning Manual Part II: Risk-Informed Planning (July 2017). These results demonstrate that for all three of the assumed participation rates, nonstructural measures have positive net benefits for most summary statistics; the exception is the minimum estimated net benefit value for the 25 percent participation rate, all other summary statistics for net-benefit estimates are positive for all participation rates. The amber and green highlighted cells indicate the highest value of each summary statistic for BCRs and net-benefits, respectively.

Table 22. Results of the Nonstructural Participation Rate Sensitivity Analysis on 10% AEP Floodplain, Oct 2020 Price Level in $1000's

Participation Rate	Metric	Minimum	25% Percentile	Median	75% Percentile	Maximum
25%	BCR	0.71	1.26	1.37	1.49	2.16
	Net Benefits	-247	$291	$426	$566	$1,365
50%	BCR	1.01	1.31	1.38	1.45	1.74
	Net Benefits	18	$706	$865	$1,025	$1,761
75%	BCR	1.13	1.34	1.38	1.42	1.62
	Net Benefits	$428	$1,164	$1,305	$1,437	$2,020

To determine which participation rate assumption will be used the PDT coordinated with the Office of Water Project Review (OWPR) where it was determined that the: 1) Tafuna NED benefit-cost analysis and 2) basis for the project cost and cost sharing will be based on a 100% participation rate. The rationale being that if the participation rate is less than 100%, it is uncertain how to identify non-participating structures that would be left out of the analysis. Given the issues associated with basing the analysis on a lower participation rate, using the 100% rate is preferable, particularly for the Tafuna FRM study, where the sensitivity analysis shows the project is justified and NED Plan determination is not significantly impacted under the lower participation rates. All nonstructural results presented in the following tables assume that 100% percent of the structures contained in the 10% AEP floodplain will receive dry floodproofing protection or will be elevated. This assumption will be refined as the study moves to the Agency Decision Milestone (ADM).

5.3 National Economic Development (NED) Analysis

The NED analysis reflects FRM benefits associated with reduced flood damages to structures, their contents and vehicles. The HEC-FDA software was used to model both the without-project condition and a full array of alternatives. This section describes the with-project engineering inputs used in the HEC-FDA analysis, reports the results of the HEC-FDA analysis, and compares the results across each alternative.

With-Project HEC-FDA Inputs

The with-project analysis used all representative index points to link floodplain damages to the Tafuna Study Area for Alternatives B, B1, C, and D.

Economics Economic HEC-FDA inputs (e.g., structure inventory, depth damage curves, etc.,) are the same for the with-project as they are for the without project condition.

Hydrology – Standard hydrologic engineering inputs were used for the with-project HEC-FDA analysis. These inputs include graphical exceedance probability-discharge curves containing eight data points (50%, 20%, 10%, 4%, 2%, 1%, 0.5%, and 0.2% AEP events) for each index point and an equivalent record length (ERL) associated in the Tafuna Study Area. An ERL of 20 years was used in HEC-FDA to estimate discharge uncertainty for the with-project analysis.

Hydraulic Engineering: Standard hydraulic engineering HEC-FDA inputs were used in the with-project HEC-FDA analysis. These inputs include stage-discharge rating curves for each representative index point. The rating curve contains eight data points corresponding to the eight AEP events used to develop the hydrology listed above. A suite of eight floodplains corresponding the same AEP events were used to assess the without project conditions. The with-project floodplains were provided in raster format containing depths of flooding and the same methodology to develop the without-project water surface profiles was used for each with-project alternative.

Tables 23 through 28 display graphical exceedance-probability curves along with the stage-discharge (rating) curves for all index points under both the Base Year (2030) and Most Likely Future Year (2079) conditions and for Alternatives B, B1, and C.

Table 23. 2030 Alternative B

Representative Index Point(s) Station(s)	Exceedance Probability	Discharge in CFS	Stage (Feet)
Index Points 1 and 2 at Station 8898	0.5	160.0	133.2
	0.2	253.2	133.6
	0.1	314.2	133.8
	0.04	399.8	134.0
	0.02	476.4	134.3
	0.01	543.6	134.5
	0.005	610.9	134.7
	0.002	696.7	135.0
Index Points 3 and 4 at Station 4550	0.5	92.2	74.7
	0.2	159.1	76.0
	0.1	216.4	76.4
	0.04	291.3	76.9
	0.02	453.1	77.7
	0.01	523.2	78.1
	0.005	787.5	79.0
	0.002	878.0	79.0
Index Point 5 at Station 2114	0.5	598.2	40.2
	0.2	1206.6	41.1
	0.1	1613.3	41.6
	0.04	2237.1	42.2
	0.02	2635.0	42.5
	0.01	3112.8	42.8
	0.005	3469.9	43.1
	0.002	3977.9	43.4
Index Points 6 and 8 at Station 8412	0.5	226.4	104.2
	0.2	292.1	104.4
	0.1	326.2	104.49
	0.04	383.2	104.50
	0.02	440.1	104.7
	0.01	589.7	105.0
	0.005	742.7	105.3
	0.002	956.9	105.6
Index Points 7 and 12 at Station 3444	0.5	452.2	39.5
	0.2	852.1	40.1
	0.1	1130.0	40.6
	0.04	1515.6	41.3
	0.02	1862.8	41.9
	0.01	2221.0	42.4
	0.005	2590.1	42.9
	0.002	3091.3	43.5
Index Points 10 and 11 at Station 1671	0.5	534.2	30.9
	0.2	1078.5	32.0
	0.1	1463.1	32.8
	0.04	2043.2	33.5
	0.02	2556.4	34.0
	0.01	3147.7	34.6
	0.005	3717.4	35.0
	0.002	4434.2	35.5

Table 24 2079 Alternative B

Representative Index Point(s) Station(s)	Exceedance Probability	Discharge in CFS	Stage (Feet)
Index Points 1 and 2 at Station 8898	0.5	160.0	133.2
	0.2	253.2	133.6
	0.1	314.2	133.8
	0.04	399.8	134.0
	0.02	476.4	134.3
	0.01	543.6	134.5
	0.005	610.9	134.7
	0.002	696.7	135.0
Index Points 3 and 4 at Station 4550	0.5	92.2	74.7
	0.2	159.1	76.0
	0.1	216.4	76.4
	0.04	291.3	76.9
	0.02	453.1	77.7
	0.01	523.2	78.1
	0.005	787.5	79.0
	0.002	878.0	79.0
Index Point 5 at Station 2114	0.5	598.1	40.2
	0.2	1206.6	41.1
	0.1	1621.3	41.6
	0.04	2236.8	42.2
	0.02	2634.9	42.5
	0.01	3113.0	42.8
	0.005	3469.4	43.1
	0.002	3977.7	43.4
Index Points 6 and 8 at Station 8412	0.5	226.4	104.2
	0.2	332.6	104.5
	0.1	370.8	104.6
	0.04	408.9	104.6
	0.02	550.4	104.9
	0.01	700.6	105.2
	0.005	742.7	105.3
	0.002	956.8	105.6
Index Points 7 and 12 at Station 3444	0.5	452.3	39.5
	0.2	839.2	40.1
	0.1	1130.2	40.6
	0.04	1492.7	41.3
	0.02	1822.6	41.8
	0.01	2169.4	42.3
	0.005	2589.5	42.9
	0.002	3091.2	43.5
Index Points 10 and 11 at Station 1671	0.5	534.2	30.9
	0.2	1059.3	32.0
	0.1	1465.8	32.8
	0.04	1998.7	33.5
	0.02	2492.0	34.0
	0.01	3060.8	34.6
	0.005	3717.5	35.0
	0.002	4434.0	35.5

Table 25 2030 Alternative B1

Index Point(s) + Station(s)	Exceedance Probability	Discharge in CFS	Stage (Feet)
Index Points 1 and 2 at Station 8898	0.5	160.0	133.2
	0.2	252.7	133.6
	0.1	313.5	133.8
	0.04	399.8	134.0
	0.02	476.3	134.3
	0.01	543.8	134.5
	0.005	611.1	134.7
	0.002	697.3	135.0
Index Points 3 and 4 at Station 4550	0.5	92.2	74.7
	0.2	159.1	76.0
	0.1	216.4	76.4
	0.04	291.3	76.9
	0.02	453.1	77.7
	0.01	523.2	78.1
	0.005	787.5	79.0
	0.002	878.0	79.0
Index Point 5 at Station 2114	0.5	681.6	40.3
	0.2	1247.4	41.2
	0.1	1628.6	41.6
	0.04	2169.7	42.1
	0.02	2417.1	42.3
	0.01	2642.4	42.4
	0.005	2867.7	42.6
	0.002	3234.6	42.9
Index Points 6 and 8 at Station 8412	0.5	226.6	104.2
	0.2	293.5	104.4
	0.1	327.1	104.5
	0.04	328.0	104.5
	0.02	440.1	104.7
	0.01	589.7	105.0
	0.005	743.2	105.3
	0.002	957.3	105.6
Index Point 7 at Station 3444	0.5	461.4	39.5
	0.2	850.6	40.1
	0.1	1115.4	40.6
	0.04	1471.7	41.2
	0.02	1768.4	41.7
	0.01	2221.0	42.4
	0.005	2316.7	42.5
	0.002	2606.3	43.0
Index Points 10 and 11 at Station 1671	0.5	479.7	30.7
	0.2	888.2	31.7
	0.1	1160.0	32.2
	0.04	1529.0	32.9
	0.02	1842.9	33.3
	0.01	2354.7	34.0
	0.005	2866.6	34.3
	0.002	3561.6	34.9
Index Point 9 at Station 6425	0.5	327.9	75.1
	0.2	520.6	75.5
	0.1	651.4	75.7
	0.04	819.2	75.9
	0.02	838.9	76.1
	0.01	858.7	76.1
	0.005	1201.6	76.4
	0.002	1352.0	76.5

Table 26 2079 Alternative B1

Index Point(s) + Station(s)	Exceedance Probability	Discharge in CFS	Stage (Feet)
Index Points 1 and 2 at Station 8898	0.5	160.0	133.2
	0.2	252.7	133.6
	0.1	313.5	133.8
	0.04	399.8	134.0
	0.02	476.3	134.3
	0.01	543.8	134.5
	0.005	611.1	134.7
	0.002	697.3	135.0
Index Points 3 and 4 at Station 4550	0.5	92.2	74.7
	0.2	159.1	76.0
	0.1	216.4	76.4
	0.04	291.3	76.9
	0.02	453.1	77.7
	0.01	523.2	78.1
	0.005	787.5	79.0
	0.002	878.0	79.0
Index Point 5 at Station 2114	0.5	681.6	40.3
	0.2	1247.4	41.2
	0.1	1628.6	41.6
	0.04	2169.7	42.1
	0.02	2417.1	42.3
	0.01	2642.4	42.4
	0.005	2867.7	42.6
	0.002	3234.6	42.9
Index Points 6 and 8 at Station 8412	0.5	226.6	104.2
	0.2	293.5	104.4
	0.1	327.1	104.5
	0.04	328.0	104.5
	0.02	440.1	104.7
	0.01	589.7	105.0
	0.005	743.2	105.3
	0.002	957.3	105.6
Index Point 7 at Station 3444	0.5	461.4	39.5
	0.2	850.6	40.1
	0.1	1115.4	40.6
	0.04	1471.7	41.2
	0.02	1768.4	41.7
	0.01	2221.0	42.4
	0.005	2316.7	42.5
	0.002	2606.3	43.0
Index Points 10 and 11 at Station 1671	0.5	479.7	30.7
	0.2	888.2	31.7
	0.1	1160.0	32.2
	0.04	1529.0	32.9
	0.02	1842.9	33.3
	0.01	2354.7	34.0
	0.005	2866.6	34.3
	0.002	3561.6	34.9
Index Point 9 at Station 6425	0.5	327.9	75.1
	0.2	520.6	75.5
	0.1	651.4	75.7
	0.04	819.2	75.9
	0.02	838.9	76.1
	0.01	858.7	76.1
	0.005	1201.6	76.4
	0.002	1352.0	76.5

Table 27 2030 Alternative C

Index Point(s) + Station(s)	Exceedance Probability	Discharge in CFS	Stage (Feet)
Index Points 1 and 2 at Station 8898	0.5	54.9	133.0
	0.2	183.7	133.30
	0.1	225.9	133.49
	0.04	277.0	133.7
	0.02	329.3	134.0
	0.01	369.8	134.2
	0.005	412.8	134.5
	0.002	473.4	134.8
Index Point 3 at Station 4550	0.5	40.1	75.4
	0.2	118.1	76.0
	0.1	254.5	76.45
	0.04	428.2	76.90
	0.02	584.4	77.3
	0.01	735.7	77.6
	0.005	902.6	77.9
	0.002	1301.5	78.6
Index Point 4 at Station 4550	0.5	92.2	74.7
	0.2	159.1	76.0
	0.1	216.4	76.4
	0.04	291.3	76.9
	0.02	453.1	77.7
	0.01	523.2	78.1
	0.005	787.5	79.0
	0.002	878.0	79.0
Index Point 5 at Station 2114	0.5	488.5	40.5
	0.2	917.0	41.3
	0.1	1292.3	41.79
	0.04	1731.0	42.18
	0.02	2020.7	42.4
	0.01	2343.9	42.7
	0.005	2676.8	43.0
	0.002	3423.0	43.5
Index Points 6 and 8 at Station 8412	0.5	161.2	104.8
	0.2	161.3	104.8
	0.1	300.8	105.36
	0.04	479.5	105.93
	0.02	659.9	106.4
	0.01	795.8	106.6
	0.005	930.5	106.9
	0.002	1124.2	107.2
Index Points 7 and 12 at Station 3444	0.5	419.9	39.7
	0.2	775.0	40.5
	0.1	1056.2	41.07
	0.04	1418.8	41.88
	0.02	1824.7	42.6
	0.01	2165.2	43.1
	0.005	2535.1	43.6
	0.002	3060.1	44.3
Index Points 10 and 11 at Station 1671	0.5	505.5	33.3
	0.2	1042.9	34.6
	0.1	1467.5	35.32
	0.04	1990.6	35.90
	0.02	2496.4	36.4
	0.01	2901.5	36.8
	0.005	3304.5	37.1
	0.002	3886.2	37.6

Table 28 2079 Alternative C

Index Point(s) + Station(s)	Exceedance Probability	Discharge in CFS	Stage (Feet)
Index Points 1 and 2 at Station 8898	0.5	104.1	132.9
	0.2	183.7	133.3
	0.1	225.9	133.5
	0.04	285.1	133.8
	0.02	329.2	134.0
	0.01	369.8	134.2
	0.005	412.8	134.5
	0.002	473.3	134.8
Index Point 3 at Station 4550	0.5	56.4	75.2
	0.2	118.0	76.0
	0.1	254.5	76.5
	0.04	440.3	76.9
	0.02	584.4	77.3
	0.01	735.8	77.6
	0.005	902.6	77.9
	0.002	1301.6	78.6
Index Point 4 at Station 4550	0.5	92.2	74.7
	0.2	159.1	76.0
	0.1	216.4	76.4
	0.04	291.3	76.9
	0.02	453.1	77.7
	0.01	523.2	78.1
	0.005	787.5	79.0
	0.002	878.0	79.0
Index Point 5 at Station 2114	0.5	422.1	40.4
	0.2	917.0	41.3
	0.1	1292.3	41.8
	0.04	1756.5	42.2
	0.02	2020.7	42.4
	0.01	2343.9	42.7
	0.005	2676.7	43.0
	0.002	3423.0	43.5
Index Points 6 and 8 at Station 8412	0.5	161.0	104.8
	0.2	161.1	104.8
	0.1	300.8	105.4
	0.04	506.3	106.0
	0.02	659.9	106.4
	0.01	795.7	106.6
	0.005	930.5	106.9
	0.002	1124.2	107.2
Index Points 7 and 12 at Station 3444	0.5	419.9	40.4
	0.2	774.9	40.5
	0.1	1056.2	41.1
	0.04	1473.1	42.0
	0.02	1824.8	42.6
	0.01	2165.2	43.1
	0.005	2535.2	43.6
	0.002	3060.6	44.3
Index Points 10 and 11 at Station 1671	0.5	548.3	33.5
	0.2	1042.9	34.6
	0.1	1467.4	35.3
	0.04	2051.9	36.0
	0.02	2496.6	36.4
	0.01	2901.6	36.8
	0.005	3304.7	37.1
	0.002	3886.2	37.6

Top of Bank Elevations: Alternatives B is a channel improvement alternative with no structural measures as such its top of bank elevations are the same as Alternative A (without project). The nonstructural alternatives will also have the same top of bank elevations as Alternative A as no structural measures are being proposed, with the exception of Reach 5N in Alternative C, where the Taumata Flood Barrier is being proposed. Alternative B1 includes proposed flood barriers on the Taumata and Leaveave Streams, so the top of bank elevations are adjusted in Reaches 5N and 8 (Index Points 4 and 9) to reflect the elevation of the barriers. Alternative C includes the Taumata Flood Barrier, so only the top of bank elevation for Reach 5N (IP 4) is adjusted. Tables 29 through 31 display the top of bank elevation for all representative index points used for all alternatives in the HEC-FDA analysis; the top of bank elevations for each reach are the same in the base year and MLFY.

Table 29. Top of Bank Elevations for all Index Points, Alternatives A, B, D

Index Point	Top of Bank Elevation (Feet)
IP 1 – Taumata/Left Bank	131.32
IP 2 – Taumata/Right Bank	131.37
IP 3 – Taumata/Left Bank	70.69
IP 4 – Taumata/Right Bank	70.29
IP 5 – Taumata/Left Bank	37.48
IP 6 – Leaveave/Left Bank	103.46
IP 7 – Leaveave/Right Bank	32.76
IP 8 – Leaveave/Left Bank	103.92
IP 10 – Leaveave/Left Bank	26.39
IP 11 – Leaveave/Right Bank	26.87
IP 12 – Leaveave/Right Bank	32.29

Table 30. Top of Bank Elevations for all Index Points, Alternative B1

Index Point	Top of Bank Elevation (Feet)
IP 1 – Taumata/Left Bank	131.32
IP 2 – Taumata/Right Bank	131.37
IP 3 – Taumata/Left Bank	70.69
IP 4 – Taumata/Right Bank	79.4
IP 5 – Taumata/Left Bank	37.48
IP 6 – Leaveave/Left Bank	103.46
IP 7 – Leaveave/Right Bank	32.76
IP 8 – Leaveave/Left Bank	103.92
IP 9 – Leaveave/Right Bank	75.8
IP 10 – Leaveave/Left Bank	26.39
IP 11 – Leaveave/Right Bank	26.87

Table 31. Top of Bank Elevations for all Index Points, Alternative C

Index Point	Top of Bank Elevation (Feet)
IP 1 – Taumata/Left Bank	131.32
IP 2 – Taumata/Right Bank	131.37
IP 3 – Taumata/Left Bank	70.69
IP 4 – Taumata/Right Bank	79.4
IP 5 – Taumata/Left Bank	37.48
IP 6 – Leaveave/Left Bank	103.46
IP 7 – Leaveave/Right Bank	32.76
IP 8 – Leaveave/Left Bank	103.92
IP 10 – Leaveave/Left Bank	26.39
IP 11 – Leaveave/Right Bank	26.87
IP 12 – Leaveave/Right Bank	32.29

5.4 With-Project Economic Results

Separate inventory modules were set-up in HEC-FDA for the nonstructural alternatives, Alternative C (combination) and Alternative D. The structures that were determined to be potential candidates for dry floodproofing had their occupancy types adjusted so they could be linked to the appropriate adjusted nonstructural depth-percent damage curves. The “dry floodproofed” occupancy types use the same depth-percent damage curves used for the other alternatives but were adjusted to reflect zero percent damages below three feet of flooding to account for dry floodproofing. The structures identified as potential candidates for elevation had their FFE set to three feet which serves to raise these structures above the water surface elevations for most AEP events in the study area.

It should be noted that this is a preliminary identification of structures based only on the economics. It does not account for other factors (engineering, environmental, cultural) that may determine whether a structure might be a good candidate for nonstructural measures. A more in-depth assessment of structures will be undertaken if Alternative C or D is carried forward as the tentatively selected plan.

Probability Damages by AEP – Probability damages are estimated damages to structures and contents that are attributable to specific AEP events. Probability damages are calculated within HEC-FDA incorporating risk and uncertainty using data on structure inventory, hydrologic conditions, hydraulic conditions, and geotechnical information. Table 32 and Table 33 display total damages by annual exceedance probability (AEP) and reach for each project alternative in the base year (2030) and MLFY (2079), respectively.

Table 32. 2030 Probability Damages by Reach and Alternative (Oct 2021 prices, $1,000):

Reach	Alternative	Damages by AEP							
		0.5	**0.2**	**0.1**	**0.04**	**0.02**	**0.01**	**0.005**	**0.002**
1	Alt A	114	686	1,099	1,891	2,580	2,924	3,096	3,199
	Alt B	94	562	1,154	2,206	2,903	3,251	3,425	3,529
	Alt B1	94	562	1,155	2,208	2,904	3,252	3,426	3,530
	Alt C	12	510	899	1,683	2,368	2,710	2,881	2,983
	Alt D	12	510	899	1,683	2,368	2,710	2,881	2,983
2-W	Alt A	311	966	1,269	2,142	2,991	3,415	3,628	3,755
	Alt B	344	730	1,137	2,035	2,702	3,035	3,202	3,302
	Alt B1	344	730	1,137	2,035	2,702	3,035	3,202	3,302
	Alt C	14	244	481	1,365	2,234	2,668	2,886	3,016
	Alt D	14	244	481	1,365	2,234	2,668	2,886	3,016
2-E	Alt A	137	509	690	911	1,092	1,597	2,116	2,427
	Alt B	114	299	573	863	1,026	1,588	2,028	2,291
	Alt B1	249	649	970	1,197	1,334	2,058	2,478	2,729
	Alt C	33	90	178	323	453	872	1,402	1,720
	Alt D	33	90	178	323	453	872	1,402	1,720
3	Alt A	683	2,276	3,837	5,322	6,984	12,461	15,200	16,844
	Alt B	1,049	3,182	4,666	6,274	7,967	14,193	17,306	19,174
	Alt B1	1,187	3,275	4,946	6,941	12,706	15,917	17,522	18,485
	Alt C	19	147	1,196	2,236	3,470	7,966	10,213	11,562
	Alt D	19	147	1,196	2,236	3,470	7,966	10,213	11,562
4	Alt A	367	760	981	1,262	2,154	3,127	3,613	3,905
	Alt B	251	831	1,235	2,770	3,281	3,537	3,665	3,741
	Alt B1	258	841	1,252	2,786	3,297	3,553	3,680	3,757
	Alt C	35	144	307	491	1,144	2,038	2,486	2,754
	Alt D	35	144	307	491	1,144	2,038	2,486	2,754
5-N	Alt A	763	1,326	1,819	2,370	2,830	4,047	5,361	6,150
	Alt B	760	1,286	1,736	2,332	2,651	4,193	5,259	5,898
	Alt B1	0	0	0	0	0	0	0	2,676
	Alt C	0	0	0	0	0	0	0	2,418
	Alt D	101	257	623	1,064	1,408	2,459	3,750	4,524
5-S	Alt A	384	595	718	885	1,047	1,282	2,327	3,435
	Alt B	489	648	754	885	989	1,111	2,251	2,959
	Alt B1	486	639	729	871	1,000	1,420	1,861	2,125
	Alt C	32	102	162	263	389	589	1,652	2,812
	Alt D	32	102	162	263	389	589	1,652	2,812
6-W	Alt A	734	1,322	1,714	2,227	2,756	4,467	6,963	8,461
	Alt B	632	1,092	1,458	1,912	2,265	3,605	6,380	8,045
	Alt B1	353	657	878	1,224	1,622	2,109	4,138	5,429
	Alt C	174	261	370	574	917	2,546	5,437	7,172
	Alt D	181	266	375	576	919	2,543	5,436	7,171
6-E	Alt A	8	39	115	522	804	2,213	3,224	3,831
	Alt B	0	19	101	239	424	727	2,590	3,876
	Alt B1	0	2	57	184	286	423	1,081	1,548
	Alt C	0	1	72	471	748	2,173	3,179	3,782
	Alt D	0	1	72	471	748	2,173	3,179	3,782
7	Alt A	648	1,202	1,479	1,945	3,213	4,489	5,127	5,510
	Alt B	295	1,238	1,824	3,828	4,496	4,830	4,997	5,098
	Alt B1	209	1,226	1,827	3,691	4,313	4,624	4,779	4,872
	Alt C	34	168	335	661	1,621	2,807	3,400	3,755
	Alt D	34	168	335	661	1,621	2,807	3,400	3,755
8	Alt A	1,610	2,419	2,857	3,415	3,937	4,704	10,398	16,138
	Alt B	1,742	2,654	3,162	3,795	4,318	4,999	12,313	17,183
	Alt B1	0	3,071	5,886	10,304	11,777	12,513	12,881	13,102
	Alt C	87	188	293	559	930	1,435	7,118	13,310
	Alt D	87	188	293	559	930	1,435	7,118	13,310

Table 33. 2079 Probability Damages by Reach and Alternative (Oct 2021 prices, $1,000):

Reach	Alternative	Damages by AEP							
		0.5	0.2	0.1	0.04	0.02	0.01	0.005	0.002
1	Alt A	110	658	1,069	1,820	2,544	2,906	3,087	3,196
	Alt B	94	562	1,154	2,206	2,903	3,251	3,425	3,529
	Alt B1	94	562	1,155	2,208	2,904	3,252	3,426	3,530
	Alt C	10	484	871	1,612	2,332	2,692	2,872	2,980
	Alt D	10	484	871	1,612	2,332	2,692	2,872	2,980
2-W	Alt A	304	943	1,249	2,046	2,943	3,391	3,616	3,750
	Alt B	345	730	1,137	2,035	2,701	3,035	3,202	3,302
	Alt B1	344	730	1,137	2,035	2,702	3,035	3,202	3,302
	Alt C	12	229	464	1,273	2,188	2,645	2,874	3,011
	Alt D	12	229	464	1,273	2,188	2,645	2,874	3,011
2-E	Alt A	107	483	671	900	1,087	1,583	2,108	2,424
	Alt B	112	270	538	852	1,020	1,572	2,019	2,288
	Alt B1	244	595	946	1,207	1,337	2,074	2,485	2,732
	Alt C	12	82	165	316	450	858	1,395	1,717
	Alt D	12	82	165	316	450	858	1,395	1,717
3	Alt A	667	2,145	3,741	5,293	6,866	12,454	15,249	16,925
	Alt B	1,079	3,227	4,700	6,291	8,041	14,283	17,404	19,277
	Alt B1	1,219	3,307	4,929	6,902	12,687	15,958	17,594	18,575
	Alt C	52	136	1,149	2,228	3,379	7,972	10,269	11,646
	Alt D	52	136	1,149	2,228	3,379	7,972	10,269	11,646
4	Alt A	388	751	978	1,269	2,197	3,148	3,624	3,910
	Alt B	248	708	1,350	2,815	3,304	3,548	3,670	3,744
	Alt B1	254	719	1,360	2,829	3,319	3,563	3,686	3,759
	Alt C	48	135	304	495	1,185	2,059	2,496	2,758
	Alt D	48	135	304	495	1,185	2,059	2,496	2,758
5-N	Alt A	688	1,258	1,764	2,344	2,815	4,012	5,344	6,143
	Alt B	750	1,223	1,675	2,309	2,642	4,152	5,238	5,890
	Alt B1	0	0	0	0	0	0	0	2,206
	Alt C	0	0	0	0	0	0	0	2,206
	Alt D	91	223	581	1,045	1,399	2,439	3,739	4,520
5-S	Alt A	516	680	789	931	1,075	1,298	2,473	3,613
	Alt B	489	650	762	903	1,009	1,128	2,285	3,048
	Alt B1	487	641	737	878	1,006	1,372	1,780	2,024
	Alt C	73	142	199	292	416	614	1,823	3,006
	Alt D	73	142	199	292	416	614	1,823	3,006
6-W	Alt A	715	1,355	1,739	2,247	2,795	4,610	7,035	8,489
	Alt B	664	1,173	1,510	1,949	2,278	3,522	6,339	8,029
	Alt B1	353	656	874	1,277	1,774	2,317	4,248	5,406
	Alt C	172	267	376	580	937	2,695	5,512	7,202
	Alt D	172	267	376	580	937	2,695	5,512	7,202
6-E	Alt A	8	41	122	531	812	2,262	3,248	3,841
	Alt B	0	19	100	245	432	714	2,540	3,856
	Alt B1	0	1	53	159	235	371	975	1,505
	Alt C	0	2	79	479	756	2,219	3,202	3,791
	Alt D	0	2	79	479	756	2,219	3,202	3,791
7	Alt A	771	1,192	1,477	1,958	3,283	4,524	5,144	5,517
	Alt B	290	1,080	1,996	3,901	4,535	4,853	5,011	5,107
	Alt B1	193	1,042	1,917	3,712	4,310	4,609	4,758	4,848
	Alt C	51	157	332	667	1,666	2,830	3,411	3,760
	Alt D	51	157	332	667	1,666	2,830	3,411	3,760
8	Alt A	2,146	2,723	3,094	3,576	4,036	4,761	11,186	16,973
	Alt B	1,728	2,640	3,152	3,813	4,355	4,994	12,183	17,130
	Alt B1	0	1,733	4,025	8,330	9,765	10,483	10,842	11,057
	Alt C	142	258	390	646	991	1,475	7,795	14,033
	Alt D	142	258	390	646	991	1,475	7,795	14,033

Several key takeaways can be gleaned by comparing the AEP damages for the above tables:

- Damages are very similar in all reaches for both the Base Year (2030) and MLFY (2079) which indicates there are not significant differences in the hydrologic and hydraulic inputs between the Base Year and MLFY.
- Probability damages for high-frequency events (50% AEP) are prevalent in most reaches in the Base Year (2030) and MLFY (2079) for Alternative A (without project). This is consistent with the without project engineering results presented above.
- Alternative B is not effective at reducing damages in any reach and induces damages in certain reaches when compared to Alternative A (without project).
- Alternatives B1, C, and D are all effective in reducing damages in both years and across most study reaches when compared to Alternative A (without project).
- The Taumata Stream flood barrier in Alternatives B1 and C is very effective at reducing damages in Reach 5-N where damages only occur at the 0.2% AEP event.
- As expected, damages in Alternatives C and D are identical for most study reaches, with the exception being Reach 5-N where the Taumata Stream flood barrier is proposed.
- The nonstructural alternatives (Alternative C and D) are the most effective alternatives in terms of preventing damages in most reaches.

With-Project Expected Annual Damages (EAD) – With-project EAD by damage category, year, and reach for Alternatives B1, C and D are presented in Tables 35 through 37. EAD represents an estimate of the average damages that would be expected in any given year over the long term. The results for Alternative B are NOT presented in the following four tables as it provides minimal benefits and significantly negative net benefits. The Alternative A (without project) are also presented again in Table 34 for ease of comparison to the with-project alternatives.

Table 34. Without-Project EAD by Damage Category, Year, and Reach; October 2021 Price Level, In $1,000s, 50-Year Period of Analysis; ALTERNATIVE A

Year	Study Area Reach	Damage Category				
		COM	IND	PUB	RES	Total
2030	1	11	19	13	349	392
	2-W	12	0	11	580	603
	2-E	7	26	0	275	308
	3	379	17	12	1,181	1,589
	4	5	0	0	554	559
	5-N	16	0	110	934	1,060
	5-S	0	78	0	403	481
	6-W	148	0	10	884	1,042
	6-E	0	21	20	29	70
	7	10	23	10	835	878
	8	196	247	22	1,512	1,978
	Total	**785**	**431**	**210**	**7,536**	**8,961**
2079	1	10	18	14	338	380
	2-W	12	0	11	566	589
	2-E	7	25	0	247	279
	3	359	15	11	1,153	1,539
	4	5	0	0	571	577
	5-N	15	0	105	881	1,001
	5-S	0	84	0	511	596
	6-W	151	0	10	872	1,034
	6-E	0	22	20	30	72
	7	10	24	11	958	1,003
	8	257	275	28	1,867	2,426
	Total	**825**	**463**	**211**	**7,995**	**9,494**

Table 35. EAD by Damage Category, Year, and REACH; October 2021 Price Level, In $1,000s, 50-Year Period of Analysis; ALTERNATIVE B1

Year	Study Area Reach	Damage Category				
		COM	IND	PUB	RES	Total
2030	1	46	21	9	290	366
	2-W	4	0	13	537	554
	2-E	38	85	0	307	430
	3	752	33	14	1,510	2,309
	4	15	0	4	521	540
	5-N	1	0	1	13	14
	5-S	0	84	0	479	564
	6-W	26	0	0	494	520
	6-E	0	0	19	5	24
	7	11	16	6	660	694
	8	122	151	24	920	1,217
	Total	**1,016**	**392**	**90**	**5,736**	**7,233**
2079	1	46	21	9	290	366
	2-W	4	0	13	537	554
	2-E	39	86	0	297	421
	3	751	33	13	1,538	2,335
	4	14	0	3	494	511
	5-N	0	0	1	13	14
	5-S	0	84	0	480	565
	6-W	30	0	0	493	524
	6-E	0	0	19	3	22
	7	10	16	6	610	641
	8	89	117	16	686	908
	Total	**983**	**358**	**80**	**5,440**	**6,861**

Table 36. EAD by Damage Category, Year, and Reach; October 2021 Price Level, In $1,000s, 50-Year Period of Analysis; ALTERNATIVE C

Year	Study Area Reach	Damage Category				
		COM	IND	PUB	RES	Total
2030	1	11	19	13	221	264
	2-W	13	0	11	139	163
	2-E	0	0	0	79	79
	3	98	0	12	233	343
	4	1	0	0	115	116
	5-N	1	0	1	13	14
	5-S	0	1	0	75	76
	6-W	2	0	10	243	256
	6-E	0	21	19	12	53
	7	2	3	3	130	138
	8	11	0	1	163	175
	Total	**137**	**45**	**72**	**1,422**	**1,677**
2079	1	10	18	14	212	254
	2-W	12	0	11	133	155
	2-E	0	0	0	64	65
	3	93	0	11	254	358
	4	1	0	0	123	124
	5-N	0	0	1	13	14
	5-S	0	1	0	111	112
	6-W	2	0	11	244	256
	6-E	0	22	20	12	54
	7	2	3	3	141	149
	8	16	0	1	216	234
	Total	**136**	**45**	**72**	**1,523**	**1,777**

Table 37. EAD by Damage Category, Year, and Reach; October 2021 Price Level, In $1,000s, 50-Year Period of Analysis; ALTERNATIVE D

Year	Study Area Reach	Damage Category				
		COM	IND	PUB	RES	Total
2030	1	11	19	13	221	264
	2-W	13	0	11	139	163
	2-E	0	0	0	79	79
	3	98	0	12	233	343
	4	1	0	0	115	116
	5-N	7	0	2	244	253
	5-S	0	1	0	75	76
	6-W	2	0	10	249	262
	6-E	0	21	19	12	53
	7	2	3	3	130	138
	8	11	0	1	163	175
	Total	**143**	**45**	**74**	**1,660**	**1,922**
2079	1	10	18	14	212	254
	2-W	12	0	11	133	155
	2-E	0	0	0	64	65
	3	93	0	11	254	358
	4	1	0	0	123	124
	5-N	6	0	2	230	239
	5-S	0	1	0	111	112
	6-W	2	0	11	244	256
	6-E	0	22	20	12	54
	7	2	3	3	141	149
	8	16	0	1	216	234
	Total	**142**	**45**	**73**	**1,741**	**2,001**

Equivalent Annual Damages – Equivalent annual damages by damage category and reach for Alternatives B1, C and D are presented in Tables 39 through 41. Equivalent annual damages for Alternative A (without-project condition) are also presented again in Table 38 for ease of comparison to the with-project alternatives.

Table 38. ALTERNATIVE A: Equivalent Annual Damages (EqAD) by Damage Category and Reach; October 2021 Price Level, 50-Year Period of Analysis, 2.25% Discount Rate, In $1,000s

Study Area Reach	Damage Categories				
	COM	IND	PUB	RES	Total
1	10	19	13	345	387
2-W	12	0	11	574	597
2-E	7	25	0	264	296
3	371	16	12	1,170	1,569
4	5	0	0	561	566
5-N	16	0	108	912	1,036
5-S	0	81	0	447	528
6-W	149	0	10	879	1,038
6-E	0	22	20	30	71
7	10	23	11	885	929
8	221	258	25	1,657	2,161
Total	**801**	**444**	**210**	**7,723**	**9,178**

Table 39. ALTERNATIVE B1: Equivalent Annual Damages (EqAD) by Damage Category and Reach; October 2021 Price Level, 50-Year Period of Analysis, 2.25% Discount Rate, In $1,000s

Study Area Reach	Damage Categories				
	COM	IND	PUB	RES	Total
1	46	21	9	290	366
2-W	4	0	13	537	554
2-E	38	85	0	302	426
3	751	33	14	1,521	2,320
4	15	0	4	510	529
5-N	1	0	1	13	14
5-S	0	84	0	479	564
6-W	28	0	0	494	521
6-E	0	0	19	4	23
7	11	16	6	640	673
8	109	137	21	825	1,092
Total	**1,002**	**378**	**86**	**5,615**	**7,081**

Table 40. ALTERNATIVE C: Equivalent Annual Damages (EqAD) by Damage Category and Reach; October 2021 Price Level, 50-Year Period of Analysis, 2.25% Discount Rate, In $1,000s

Study Area Reach	Damage Categories				
	COM	IND	PUB	RES	Total
1	10	19	13	217	260
2-W	12	0	11	136	160
2-E	0	0	0	73	73
3	96	0	12	241	349
4	1	0	0	118	119
5-N	1	0	1	13	14
5-S	0	1	0	90	91
6-W	2	0	10	243	256
6-E	0	21	20	12	53
7	2	3	3	134	143
8	13	0	1	185	199
Total	**137**	**45**	**72**	**1,463**	**1,718**

Table 41. ALTERNATIVE D: Equivalent Annual Damages (EqAD) by Damage Category and Reach; October 2021 Price Level, 50-Year Period of Analysis, 2.25% Discount Rate, In $1,000s

Study Area Reach	Damage Categories				
	COM	IND	PUB	RES	Total
1	10	19	13	217	260
2-W	12	0	11	136	160
2-E	0	0	0	73	73
3	96	0	12	241	349
4	1	0	0	118	119
5-N	7	0	2	239	247
5-S	0	1	0	90	91
6-W	2	0	10	247	259
6-E	0	21	20	12	53
7	2	3	3	134	143
8	13	0	1	185	199
Total	**143**	**45**	**74**	**1,693**	**1,954**

Equivalent Annual Benefits – Table 42 summarizes the equivalent annual benefits for each alternative. An alternative’s equivalent annual benefits are calculated by subtracting “with-project” EqAD from “without-project” EqAD. Alternative C has the highest EqAD, $7.461M among all alternatives.

Table 42. Equivalent Annual Benefits by Alternative; October 2021 Price Level, 50-Year Period of Analysis, 2.25% Discount Rate, In $1,000s

Item	Alternative			
	A	B1	C	D
Equivalent Annual Damages (EqAD)	9,178	7,081	1,718	1,954
Equivalent Average Annual Benefits	-	2,097	7,461	7,224

Project Cost Estimates – Preliminary estimates of structural project costs were developed by Cost Engineering (SPN) for Alternatives B, B1, and C; see Appendix G Cost Engineering for more information. Project costs for the nonstructural components of Alternative C and Alternative D were based on costs developed by the New Orleans District.

The New Orleans District dry floodproofing costs were based on implementing a veneer wall and dry floodproofing to three feet above the ground, including panels for doors and windows. The dry floodproofing costs were estimated to be approximately $116,000 per structure for all structures less than 20,000 square feet; it was assumed for the Tafuna Study that all dry floodproofed structures are less than 20,000 square feet. The base residential structure elevation costs were also developed by New Orleans District. Elevation costs for the Tafuna Study are based on averages of the New Orleans costs and were calculated by taking the average of the dollar per square foot cost to raise on one- and two-story slab foundations for each foot raised up to five feet and then averaging these for each foot raised over one to five feet. The dollar cost to raise a structure is estimated to be $97 per structure square foot.

The dry floodproofing and elevation costs were both escalated by 97% to reflect the American Samoa Area Cost Factor (ASACF) and an additional 30% cost contingency was applied; the following two bullets show these cost adjustments:

- Tafuna Dry Floodproofing per structure:

  (New Orleans Costs) x (ASACF) x (Contingency Factor)

  ($115,922) x (1.97) x (1.30) = $296,875 per structure

- Tafuna Elevation Costs per square foot:

  (Averaged New Orleans Costs) x (ASACF) x (Contingency Factor)

  ($97) x (1.97) x (1.30) = $249 per square foot.

Interest During Construction (IDC) – IDC was calculated for each alternative assuming mid-month payments based on the following construction periods:

- Alternative B- Estimated 6-month construction schedule
- Alternative B1- Estimated 15-month construction schedule
- Alternative C- Estimated 12-month construction schedule for flood barrier and 3-month construction for nonstructural measures.
- Alternative D- Estimated 3-month construction schedule.

The three-month construction schedule for nonstructural IDC calculations is consistent with the Planning Bulletin 2019-03, Further Clarification of Existing Policy for USACE Participation in Nonstructural Fool Risk Management and Coastal Storm Management Measures (PB2019-03). It is assumed to complete nonstructural construction measures for the entire project could take up to a year or more, however the time to implement a nonstructural measure on a single structure is approximately three-months. As such, PB2019-03 recommends that time period when calculating IDC for nonstructural measures IDC should be three-months.

5.5 Results of Final Array of Alternatives:

Table 43 shows a summary of results for Alternatives B, B1, C, and D. Alternative C reasonably maximizes net-benefits at $2.724 million, highlighted in blue.

Table 43. Summary Results of Final Array of Alternatives (Oct 2021 Price Level, $1,000):

Item	ALTERNATIVE				
	A	B	B1	C	D
Expected Annual Damages (EAD) 2030 Base Year	8,961	9,178	7,233	1,677	1,922
Expected Annual Damages (EAD) 2079 Future Year	9,494	9,154	6,861	1,777	2,001
Equivalent Annual Damages (EqAD), 50-Year Period of Analysis, 2.25% Discount Rate	9,178	9,168	7,081	1,718	1,954
Equivalent Average Annual Benefits (AAB), 50-Year Period of Analysis, 2.25% Discount Rate	0	10	2,097	7,461	7,224
Project First Costs	0	29,126	49,087	138,386	143,072
Interest During Construction	0	163	689	1,551	399
Total Economic Costs	0	29,289	49,776	139,937	143,470
Average Annual Costs (AAC) @ 50-year period of analysis and 2.25%	0	982	1,668	4,690	4,809
Annual OMRR&R	0	146	244	46	TBD
Total AAC	0	1,128	1,912	4,736	4,809
Net Benefits	--	-1,118	185	2,724	2,415
Benefit-to-Cost Ratio (BCR)	--	0.01	1.1	1.6	1.5

5.6 Alternative C (Tentatively Selected Plan) Incremental Analysis

It was recommended at the Tentatively Selected Plan (TSP) Milestone meeting on November 5, 2021, that the PDT perform an incremental analysis to ensure the structural (Taumata Flood Barrier) and nonstructural portions of Alternative C both incrementally provide positive net-benefits. The results of this analysis show that both components of Alternative C have positive net benefits and are shown in Table 44. This incremental analysis was done before recent cost updates, economic modeling revisions, and updates to reflect October 2021 price levels and FY22 discount rates were implemented, as such the values in this table will not match the other Alternative C values presented in this appendix, however these revisions do not change the conclusions of the analysis.

Table 44. Alternative C Separable Analysis (Oct 2020 Prices, $1,000)

Item	Alternative C “Flood Barrier”	Alternative C “Nonstructural”	Alternative C “Total”
Annual Equivalent Benefits (Oct 2020 prices, 2.5%, 50 yr. POA)	934	5,915	6,849
Average Annual Costs (Oct 2020 prices, 2.5%, 50 yr. POA)	224	4,169	4,394
Net-Benefits	709	1,746	2,456
BCR	4.2	1.4	1.6

5.7 With-Project Engineering Performance

Engineering Performance – Engineering performance as measured by annual exceedance probability (AEP), long-term risk, and assurance are presented by study reach and year for Alternatives A, B1, and C in Tables 45 through 47. In base years and MLFY, Alternative B1 reduces flood risk in study reaches 5-N and 8; the chance of flooding in any given year, as measured by AEP, is reduced from about 100% to 1% for Reach 5-N and from 100% to 30% for Reach 8. Alternative C, under base year and MLFY conditions, reduces flood risk in Reach 5N from 100% to 0%. Further, the ability to contain a specific exceedance probability flow event (i.e., assurance) is improved with Alternative B1; for example, under Base Year and MLFY conditions for study reach 5N, Alternative B1 has an assurance of 99% for the 10% AEP and an 98% assurance for the 4% AEP, whereas under Base Year and MLFY without-project conditions (Alternative A), assurance for the 10% and 4% AEP is 0%.

Table 45. Engineering Project Performance by Year and Study Reach, ALTERNATIVE A

Year	Study Area Reach	Engineering Project Performance									
		AEP	Long-Term Risk			Assurance					
			10yr	30yr	50yr	10%	4%	2%	1%	0.50%	0.20%
2030	1	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	2-W	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	2-E	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	3	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	4	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	5-N	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	5-S	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	6-W	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	6-E	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	7	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	8	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
2079	1	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	2-W	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	2-E	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	3	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	4	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	5-N	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	5-S	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	6-W	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	6-E	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	7	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	8	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%

Table 46. Engineering Project Performance by Year and Study Reach, ALTERNATIVE B1

Year	Study Area Reach	Engineering Project Performance									
		AEP	Long-Term Risk			Assurance					
			10yr	30yr	50yr	10%	4%	2%	1%	0.50%	0.20%
2030	1	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	2-W	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	2-E	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	3	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	4	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	5-N	1%	3%	10%	16%	99%	98%	95%	93%	89%	86%
	5-S	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	6-W	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	6-E	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	7	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	8	30%	97%	100%	100%	54%	43%	40%	38%	27%	26%
2079	1	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	2-W	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	2-E	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	3	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	4	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	5-N	1%	3%	10%	16%	99%	98%	95%	93%	89%	86%
	5-S	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	6-W	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	6-E	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	7	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	8	30%	97%	100%	100%	55%	45%	39%	35%	32%	29%

Table 47. Engineering Project Performance by Year and Study Reach, ALTERNATIVE C

Year	Study Area Reach	Engineering Project Performance									
		AEP	Long-Term Risk			Assurance					
			10yr	30yr	50yr	10%	4%	2%	1%	0.50%	0.20%
2030	1	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	2-W	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	2-E	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	3	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	4	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	5-N	1%	3%	10%	16%	99%	98%	95%	93%	89%	86%
	5-S	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	6-W	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	6-E	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	7	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	8	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
2079	1	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	2-W	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	2-E	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	3	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	4	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	5-N	1%	3%	10%	16%	99%	98%	95%	93%	89%	86%
	5-S	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	6-W	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	6-E	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	7	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%
	8	100%	100%	100%	100%	0%	0%	0%	0%	0%	0%

5.8 Probabilistic Benefits and Costs

The computed values of EqAD are uncertain, and their probability distributions, resulting from the risk and uncertainty assessment described in this appendix, are represented in various ways. The values of EAD and EqAD reported in the previous tables are the mean of the probability distribution of the without and with-project alternatives.

Probabilistic Benefits

Table 48 reports equivalent annual damage reduced (benefits) probabilistic values; these values are an output of HEC-FDA. The damage reduced is reported with more information about its probability distribution, in addition to the mean and the quartiles of the distribution are included. The quartiles are the values of the probability distribution with cumulative probabilities of 25, 50 and 75 percent, meaning there is the specified likelihood that the value will be greater than the quartile, so these values describe both the width and the asymmetry of the probability distribution. There is a 50 percent chance that the actual value of damages reduced is between the 0.25 and 0.75 quartiles. The 0.5 quartile is the median estimate, meaning there is a 50 percent chance the actual value is greater and 50 percent chance it is less. The median differs from the mean when the probability distribution is asymmetrical.

Table 48. Expected Value and Probabilistic Values of EqAD Reduced (Benefits) 1000's, October 2021 price levels)

Alternative	Mean Damages Reduced	75% Probability Benefits Exceed	50% Probability Benefits Exceed	25% Probability Benefits Exceed
Alternative A	-	-	-	-
Alternative B	10	-723	137	749
Alternative B1	2,097	826	2,614	3,787
Alternative C	7,461	5,087	6,410	9,406
Alternative D	7,224	4,989	6,265	9,126

Probabilistic Costs

Table 49 provides the cost probability distribution information for each alternative; these values were taken from the Tafuna FRM Abbreviated Risk Assessment (ARA), see Appendix G Cost Engineering for more information.

Table 49. Abbreviated Risk Assessment Total Costs (1,000's, October 2021 price levels)

Alternative	Before Contingency Cost	Most Likely Cost	With Contingency Cost
Alternative A	-	-	-
Alternative B	18,711	19,451	34,289
Alternative B1	13,998	14,737	34,268
Alternative C	96,947	97,209	142,756
Alternative D	102,628	102,628	144,114

5.9 Probabilistic Net Benefits

The estimate of net NED benefits and benefit/cost (B/C) ratio will be reported both as an expected (mean) value and on a probabilistic basis for each alternative. The probability that net benefits are positive and that the B/C ratio is at or above one (1.0) will be presented for each alternative. ER 1105-2-101.

Using the information in Table 50 and Table 49 on benefit and cost probabilities for each alternative, the Palisade @Risk program was used to develop @Risk Pert probability distributions for both benefits and costs. These distributions were then used to develop net-benefit probability distributions; from these net-benefits distributions, determining the probability of maintaining positive net-benefits for each alternative was of interest. The Palisade @Risk produced net-benefit probability distributions, based on 10,000 iterations, for each alternative are presented in Figures 13 through 16. The following summarizes the results from these figures:

- Alternative B: the probability net-benefits are greater than zero is 25.7 percent
- Alternative B1: the probability net-benefits are greater than zero is 69.4 percent
- Alternative C: the probability net-benefits are greater than zero is 88.3 percent
- Alternative D: the probability net-benefits are greater than zero is 87.3 percent

Based on these figures, the probability of Alternative C yielding positive net-benefits is approximately 88.3 percent, which has the highest percentage of any alternative, although only slightly higher than Alternative D (87.3 percent). In Figures 13 through 16, the y-axis values represent the relative frequencies the corresponding x-values appeared in the Palisade @Risk simulations and the x-axis values represent outcomes of net benefits.

In addition to the net-benefit probabilities, ER 1105-2-101 does specify the probability of the benefit-cost ratios being greater than one also be presented. This effort was completed for this study; however, the results are not presented as they are nearly identical to the net-benefit results.

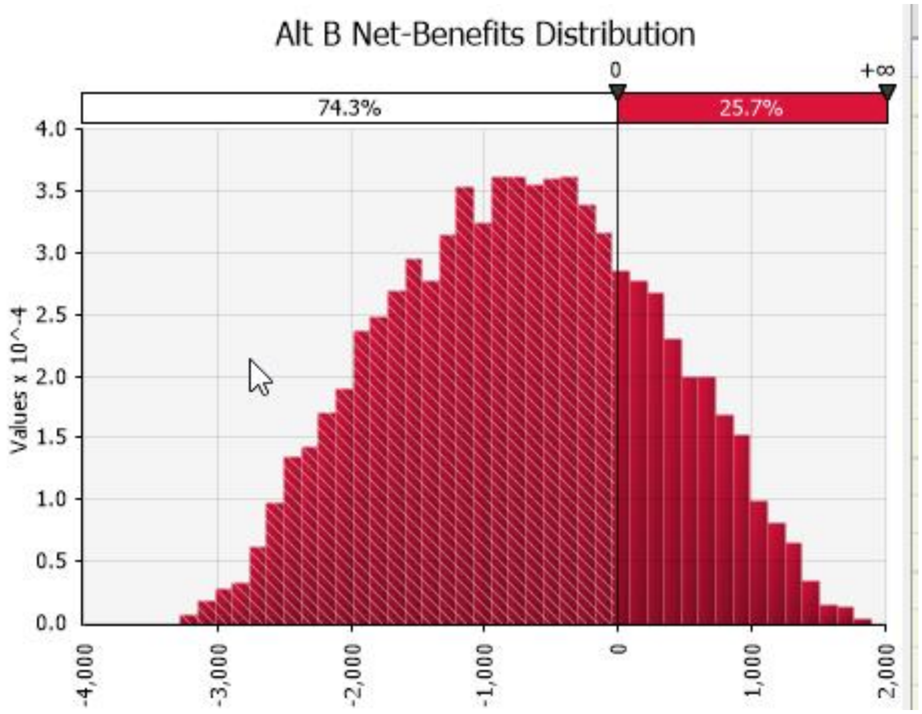


Figure 13. Alternative B Net-Benefits Probability Distribution

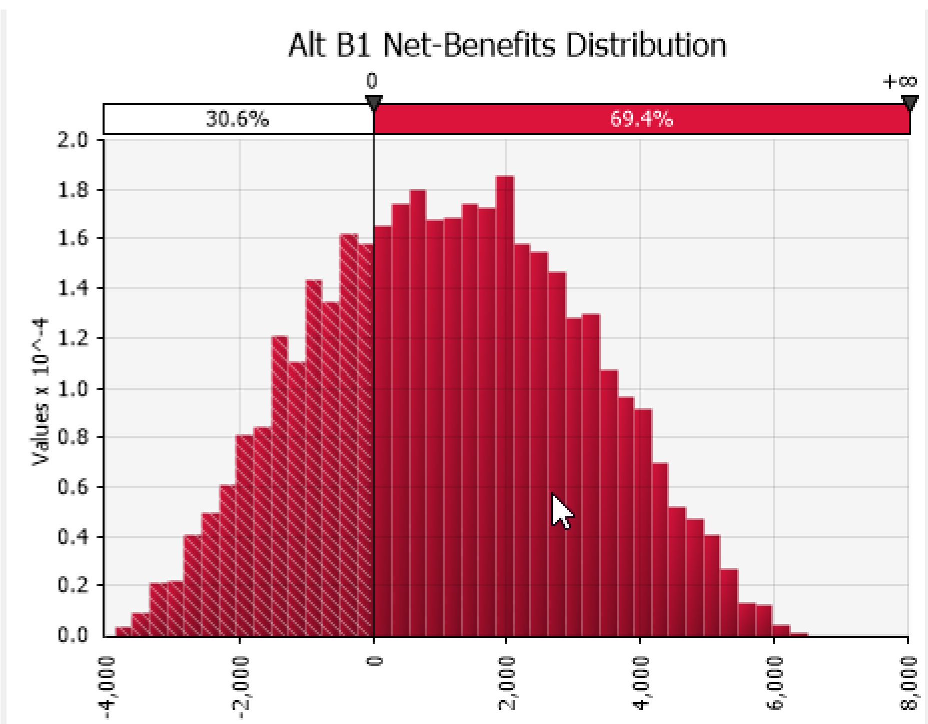


Figure 14. Alternative B1 Net Benefits Probability Distribution

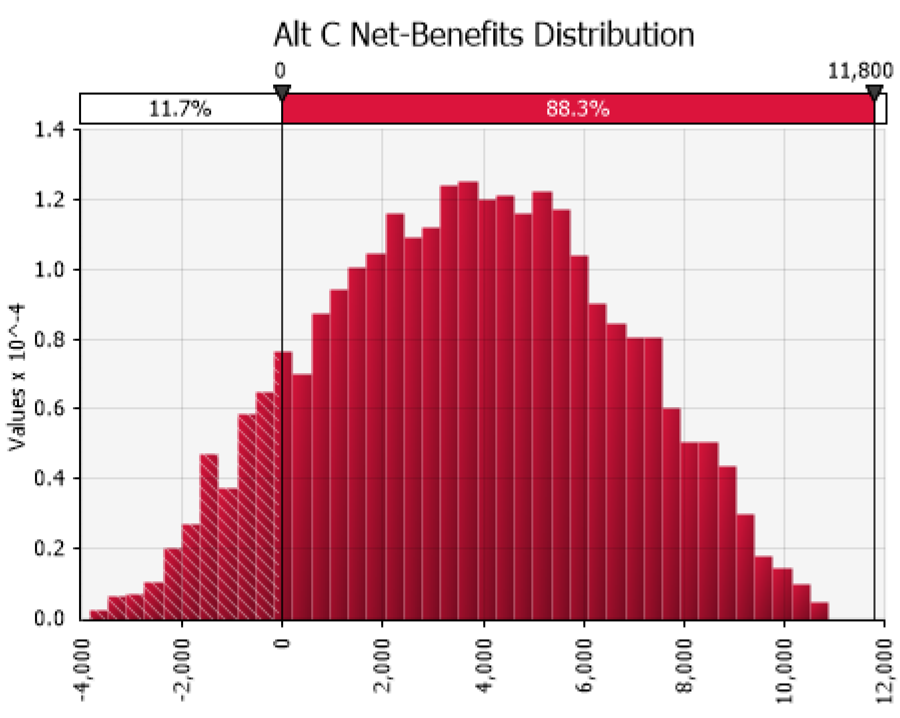


Figure 15. Alternative C Net-Benefits Probability Distribution

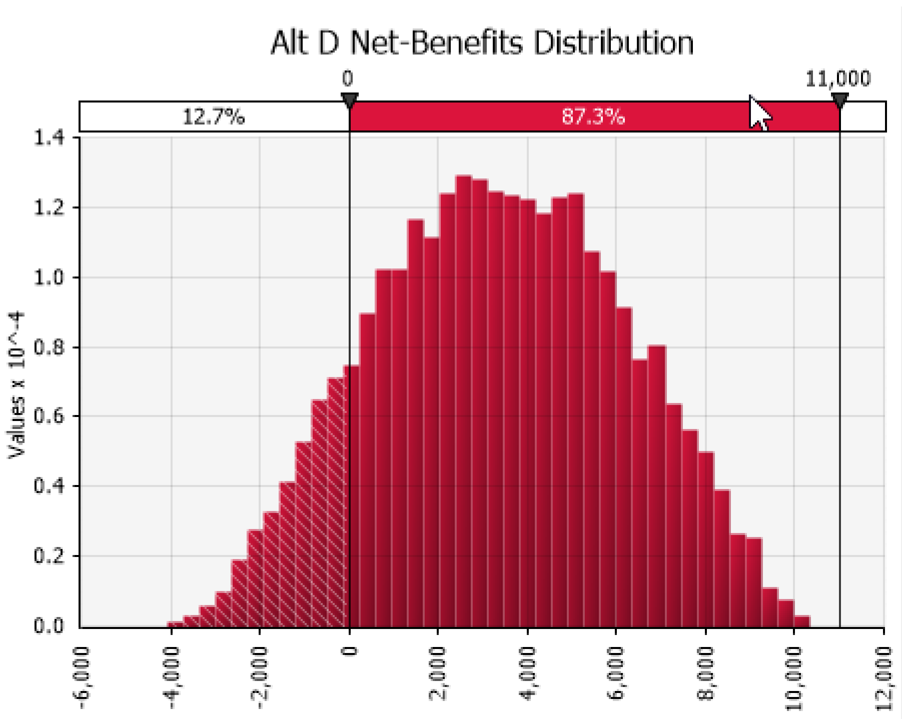


Figure 16. Alternative D Net-Benefits Probability Distribution

6. LIFE SAFETY ASSESSMENT

A life safety assessment using the USACE-certified software Hydrologic Engineering Center (HEC)-LifeSim (v 2.0) was used to estimate life loss under the without-project condition (Alternative A) and the potential life loss from implementing Alternative B1. A HEC LifeSim model for the structural portions of Alternative C has not yet been developed, however it is expected that life loss risk will be similar to Alternative B1, especially for Reach 5-N. A HEC LifeSim model that focuses on the Taumata Flood Barrier in Alternative C is expected to be developed for the Agency Decision Milestone (ADM). Alternative D, the full nonstructural alternative, was not modeled in LifeSim since the results would be the same as Alternative A (without-project condition).

The default HEC-LifeSim parameters for the hazard identification, warning issuance, and protective action initiation curves were used for the Tafuna FRM assessment. These curves estimate how much time it will take for emergency managers (hazard identification, warning issuance) and the general population (protective action) to decide upon and execute these actions, respectively. The three potential modes of failure for life safety estimates: 1) overtopping - no breach 2) overtopping with breach and 3) breach prior to overtopping, have NOT yet been modeled, however these potential failure modes for the structural alternatives are expected to be modeled for the Agency Decision Milestone.

The economic structure inventory is based on data collected for the HEC-FDA analysis and is presented in Section. More details about the population distribution are presented in Section 2.

6.0 Past Life Loss

The Tafuna study area has not experienced any life loss in the past due to flooding.

6.1 Incremental Risk

Flooding in a levee system can occur from four generalized mechanisms, as shown in Figure 17

1. Breach prior to overtopping
2. Overtopping with breach
3. Component malfunction or improper operation
4. Overtopping without breach

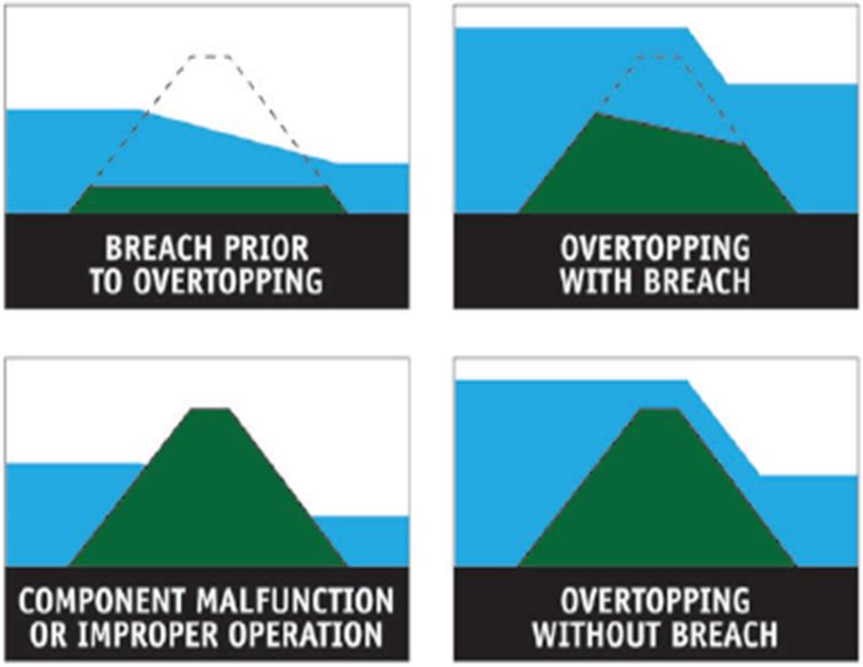


Figure 17. Flooding Mechanisms

Incremental risk for an existing levee system is defined in ECB 2019-15 as the risk of inundation posed by a levee system for the following three inundation scenarios: prior to overtopping, overtopping with breach, and component malfunction/mis-operation. In other words, the incremental risk is the risk associated with non-performance of the levee or floodwall. It is the risk to the floodplain occupants that can be attributed to the presence of the levee/floodwall. Total flood risk includes both incremental risk (scenarios 1-3) and the non-breach risk (scenario 4: overtopping without breach). The Tafuna Study Area does not have any existing levees or floodwalls. ECB 2019-15 and Planning Bulletin 2019-04 state that incremental risk is to be used when evaluating the Tolerable Risk Guidelines, which are described below.

6.2 Tolerable Risk Guidelines

One goal of planning studies is to achieve all four Tolerable Risk Guidelines (TRG) (USACE 2019a). Where TRGs are not currently met, measures and alternatives can be formulated to reduce risk and achieve all four TRGs. USACE considers risk to life safety related to the TRGs from two perspectives, societal life risk and individual life risk.

- Societal life risk is the risk of widespread or large-scale catastrophes from the inundation of a leveed area that would result in a negative societal response. In general, society is more averse to risk if multiple fatalities were to occur from a single event. In contrast, society tends to be less averse to risks that result from many events resulting in only one or two fatalities, even if the total losses from the small events is larger than that from the single large event.
- Individual life risk is represented by the probability of life loss for the identifiable person or group by location that is most at risk of loss of life due to a levee breach. Individual life risk is influenced by location, exposure, and vulnerability within a leveed area.

The four TRGs include:

- TRG 1 – Understanding the Risk. The first tolerable risk guideline involves considering whether society is willing to live with the risk associated with the levee system to secure the benefits of living and working in the leveed area. In other words, it answers a basic question: are the risks commensurate with the benefits? The life risk matrix is used to evaluate compliance with TRG 1. Risks that plot above the societal life risk line are considered unacceptable except in exceptional circumstances.
- TRG 2 – Building Risk Awareness. The second tolerable risk guideline involves determining that there is a continuation of recognition and communication of the levee risk, because the risk associated with levee systems are not broadly acceptable and cannot be ignored. The rationale for meeting TRG 2 will be determined qualitatively and may be met through USACE levee safety program activities and/or levees sponsor activities, which includes risk communication.
- TRG 3 – Fulfilling Daily Responsibilities. The third tolerable risk guideline involves determining that the risks associated with the levee system are being properly monitored and managed by those responsible for managing the risk. The rationale for meeting TRG 3 will be determined qualitatively and may be met through USACE levee safety program activities and/or levees sponsor activities. TRG 3 can be met through demonstrated monitoring and risk management activities. This would include an active operation and maintenance program, visual monitoring (documented regular inspections), updated and tested emergency plan, instrumentation program, and interim risk reduction measures plan.
- TRG 4 – Actions to Reduce Risk. The fourth guideline involves determining if there are cost effective, socially acceptable, or environmentally acceptable ways to reduce risks from an individual or societal risk perspective. If it is determined that there are no cost effective or acceptable ways to further reduce risks, USACE may consider this an exceptional circumstance and therefore might consider the levee risk to be tolerable even if the life safety risk exceeds the associated tolerability guideline under TRG 1.

6.3 Model Set-Up

A HEC-LifeSim 2.0 model was developed to assess life loss consequences. HEC-LifeSim is designed to simulate the entire warning and evacuation process for estimating potential life loss resulting from catastrophic floods.

HEC-LifeSim life loss estimate computations rely on a timeline of emergency response personnel and population at risk actions that are expected to occur. This timeline begins with the identification of an imminent hazard through avenues such as a river forecast predicting water surface elevations to rise above emergency action thresholds leading to a levee overtopping situation. An example of identification of an imminent hazard is a levee safety patrol noticing a wet area below the levee crest that may indicate underseepage or boils leading to a failure prior to overtopping situation. The timeline ends when a person exposed to the hazard decides to take protective action either by remaining in the structure and moving vertically upward onto the roof or exiting the structure to seek higher ground. This timeline is illustrated in Figure 18.

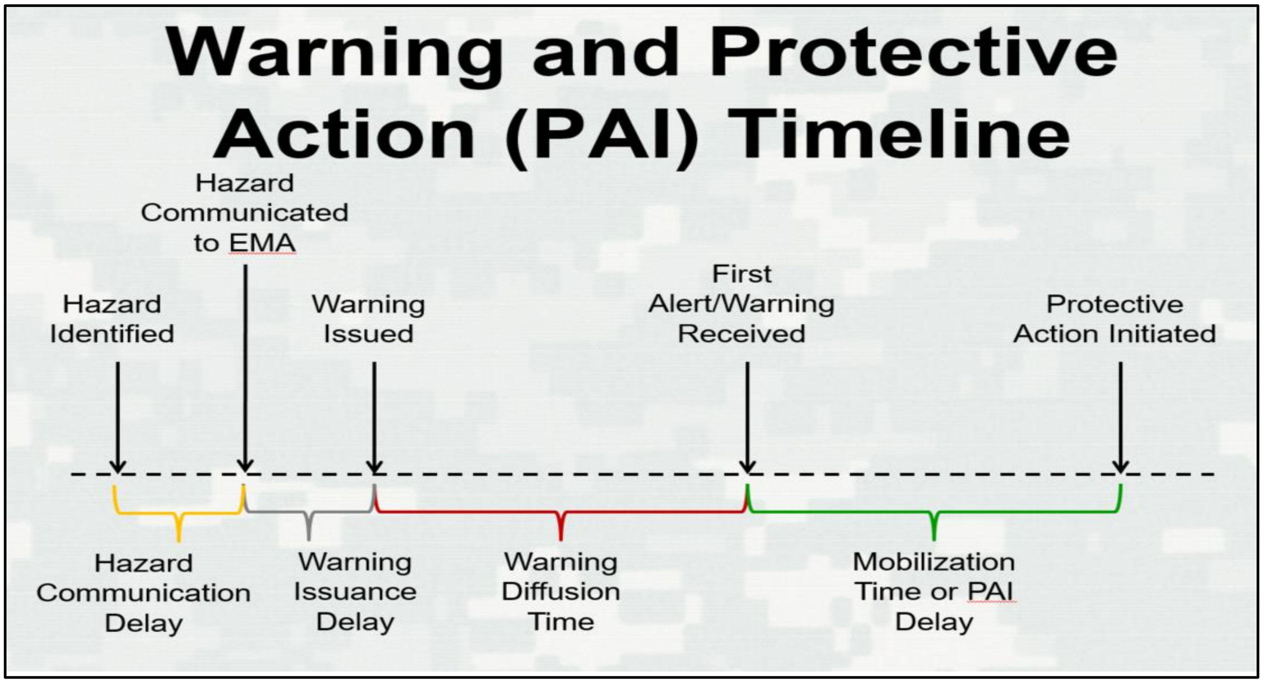


Figure 18. HEC-LifeSim Warning and Protective Action Timeline

Population: Chapters 2 and 3 present a detailed description of the number of structures and the population in the consequence area. The consequence area is composed of approximately 2,500 structures, of which 581 are affected by flooding. The population data used for purposes of the HEC-LifeSim modeling are summarized in Table 51.

Table 51. Population in the Consequence Area

Night Total	Day Total	Night - U62	Night - O62	Day - U62	Day - O62
10,121	14,641	9,820	301	13,387	754

The population for each structure in the consequence area is based on information from the U.S. Census Bureau (average household size and percent of population under and over the age of 62), Google Earth Pro (square footage of structures and occupancy types), and the Certified Commercial Property Inspectors Association (maximum occupancy information per building code based on square footage/occupant and occupancy type).

The maximum occupancy for each structure was estimated using square footage, numbers of occupants/SF information, and occupancy type information. The night and day population for each structure was then estimated by making assumptions based on the occupancy type and the maximum occupancy. For example, a public library with a maximum occupancy of 200 would have a typical day population of 50 (i.e., assumption of 25% capacity during day – 2 p.m.) and a night population of 0 (i.e., no one in the library at 2 a.m.).

The percentage of the population in Tafuna Study Area under and over the age of 62 are approximately 94.4 and 5.6 percent, respectively. These percentages were then used to estimate the night and day populations that are under and over the age of 62 for each structure.

Emergency Action and Public Response Input Curves: The HEC-LifeSim software comes preloaded with three default time series curves:

1. Warning issuance delay: how long it takes for emergency managers to issue a warning after being made aware of a problem
2. Warning diffusion: how fast warning is received by the population at risk
3. Protective action initiation: how long it takes for a person to decide to take protective action

These three curves are used in Monte Carlo simulations that model the probability of different outcomes in processes that are difficult to accurately predict when random variables are present. In the context of predicting loss of life during a flood hazard, the random variables include natural variability in how people will react to warnings and the actions they will take, if any, upon receiving the warning. Examples of these time series curves are shown in Figure 19 below.

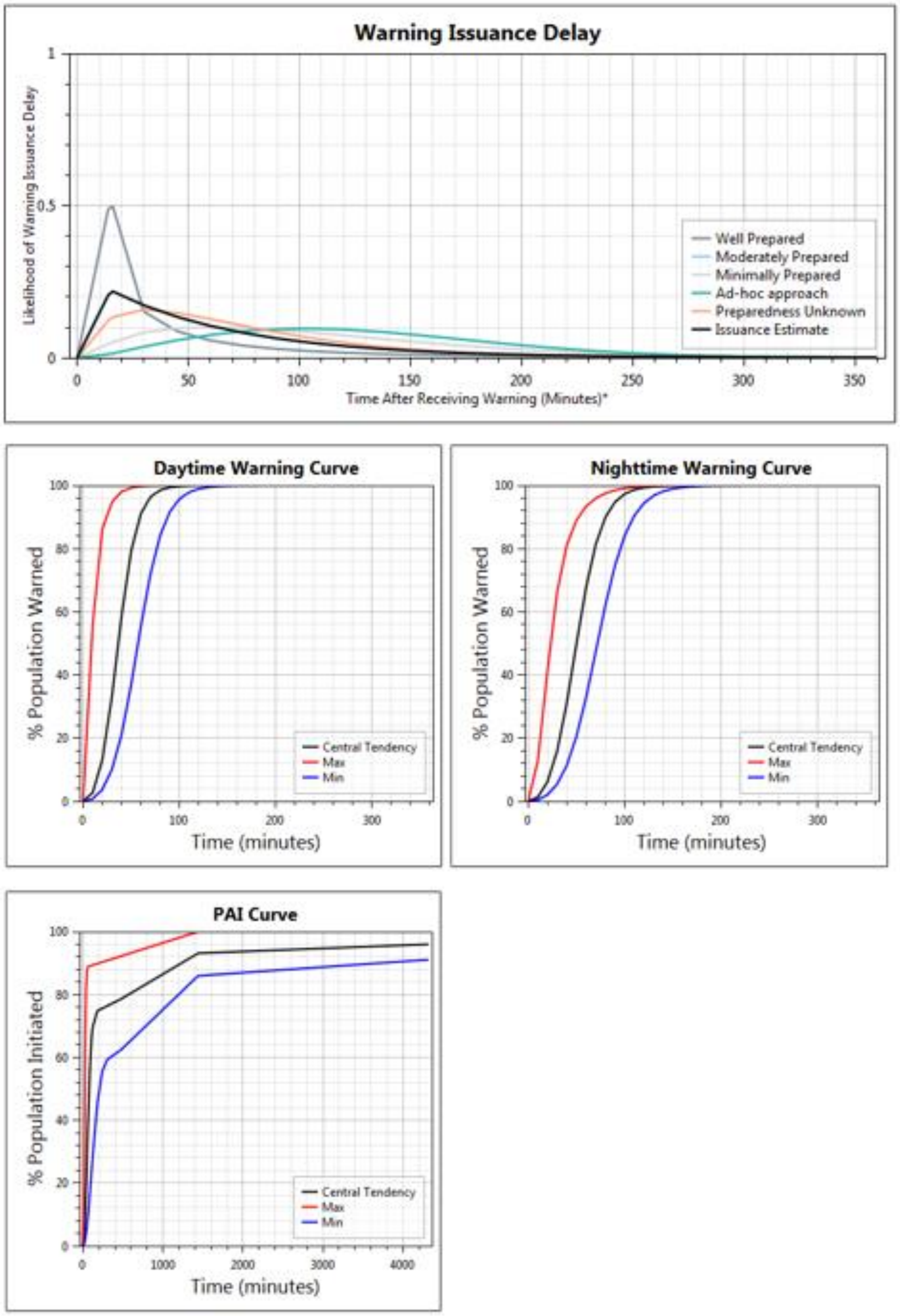


Figure 19. Examples of HEC-LifeSim Warning and Protective Action Curves

Historically, there has been no life loss due to flooding in the Tafuna study area. Since flooding-related life risk is low, there was no formal elicitation process to estimate the current state of effectiveness of the Tafuna's flood warning issuance and protective action initiation. As the degree of flood risk preparedness is unknown for this study area, the preparedness unknown warning issuance delay was assumed in the LifeSim model and shown in Figure 20.

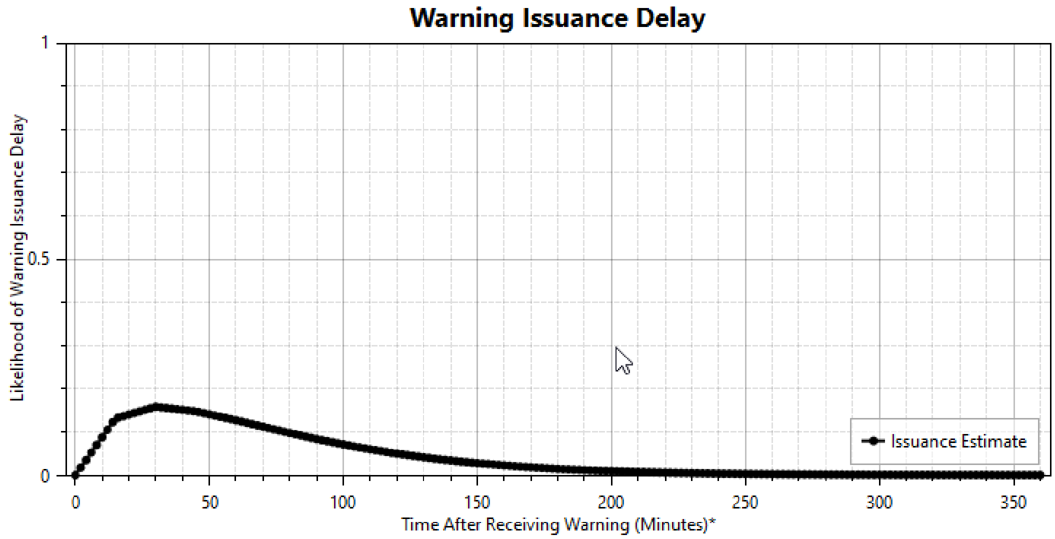
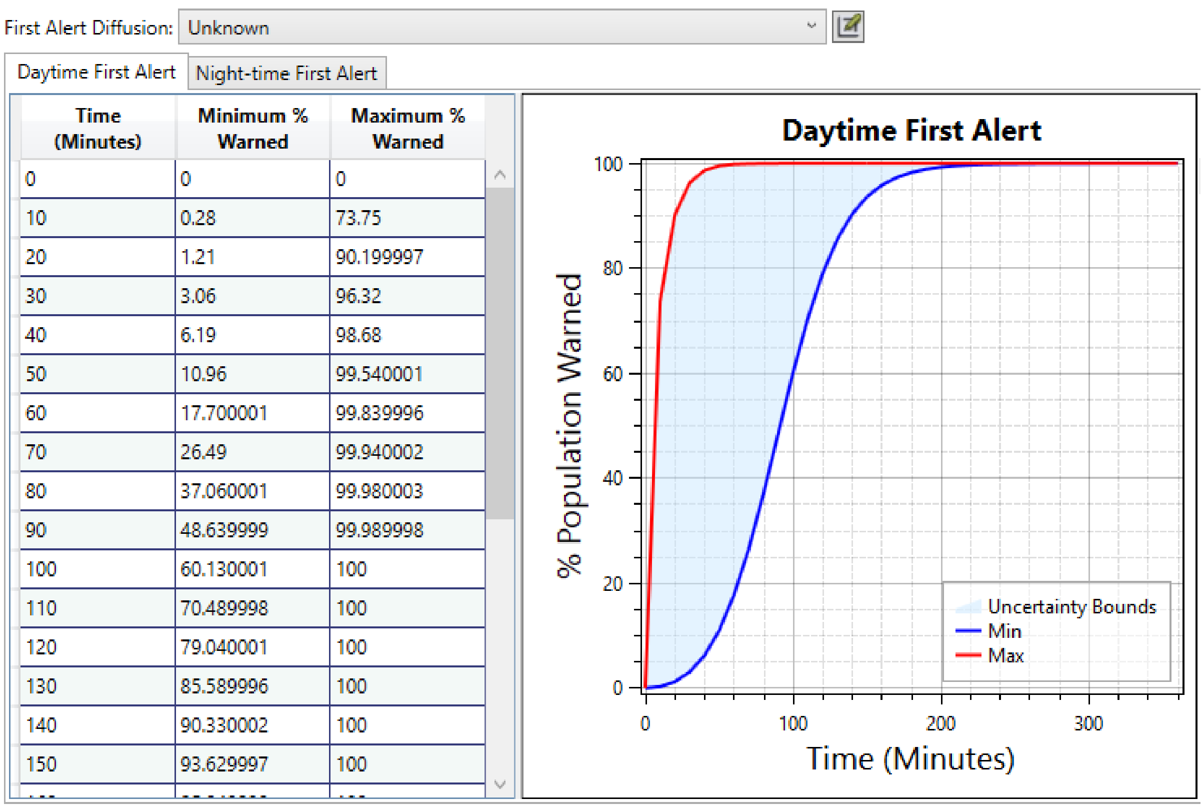


Figure 20. Warning Issuance Delay: Preparedness Unknown

Similarly, for first alert diffusion for day and nighttime, the unknown alert parameters were assumed. These relationships are shown in Figure 21 and Figure 22.



Time (Minutes)	Minimum % Warned	Maximum % Warned
0	0	0
10	0.28	73.75
20	1.21	90.199997
30	3.06	96.32
40	6.19	98.68
50	10.96	99.540001
60	17.700001	99.839996
70	26.49	99.940002
80	37.060001	99.980003
90	48.639999	99.989998
100	60.130001	100
110	70.489998	100
120	79.040001	100
130	85.589996	100
140	90.330002	100
150	93.629997	100

Figure 21. Daytime First Alert: Unknown

First Alert Diffusion: Unknown

Daytime First Alert | Night-time First Alert

Time (Minutes)	Minimum % Warned	Maximum % Warned
0	0	0
10	0.18	39.889999
20	0.73	72.139999
30	1.73	83.360001
40	3.24	89.400002
50	5.33	93.3[illegible]001
60	8.07	95.910004
70	11.51	97.510002
80	15.67	98.489998
90	20.52	99.089996
100	26.030001	99.449997
110	32.07	99.669998
120	38.490002	99.800003
130	45.119999	99.879997
140	51.740002	99.93
150	58.16	99.959999

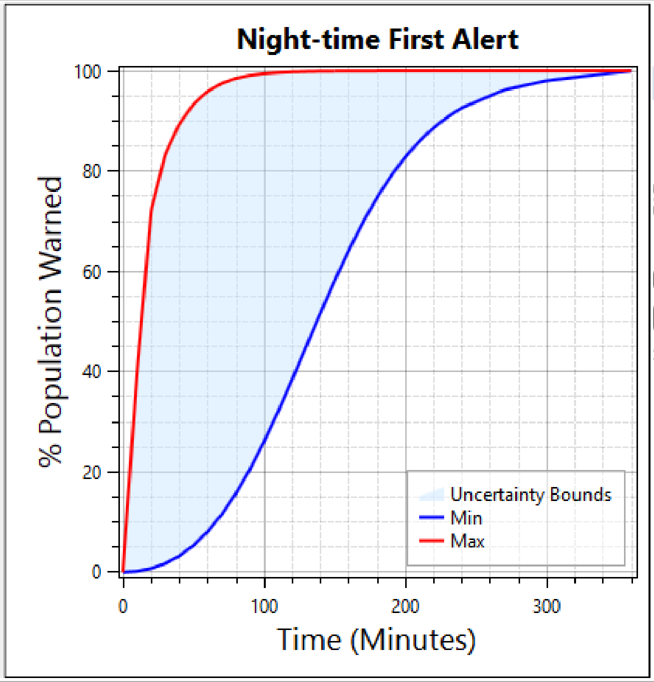


Figure 22. Night-Time First Alert: Unknown

For protective action initiation, the “Preparedness: Unknown / Perception Unknown” was assumed and shown in Figure 23.

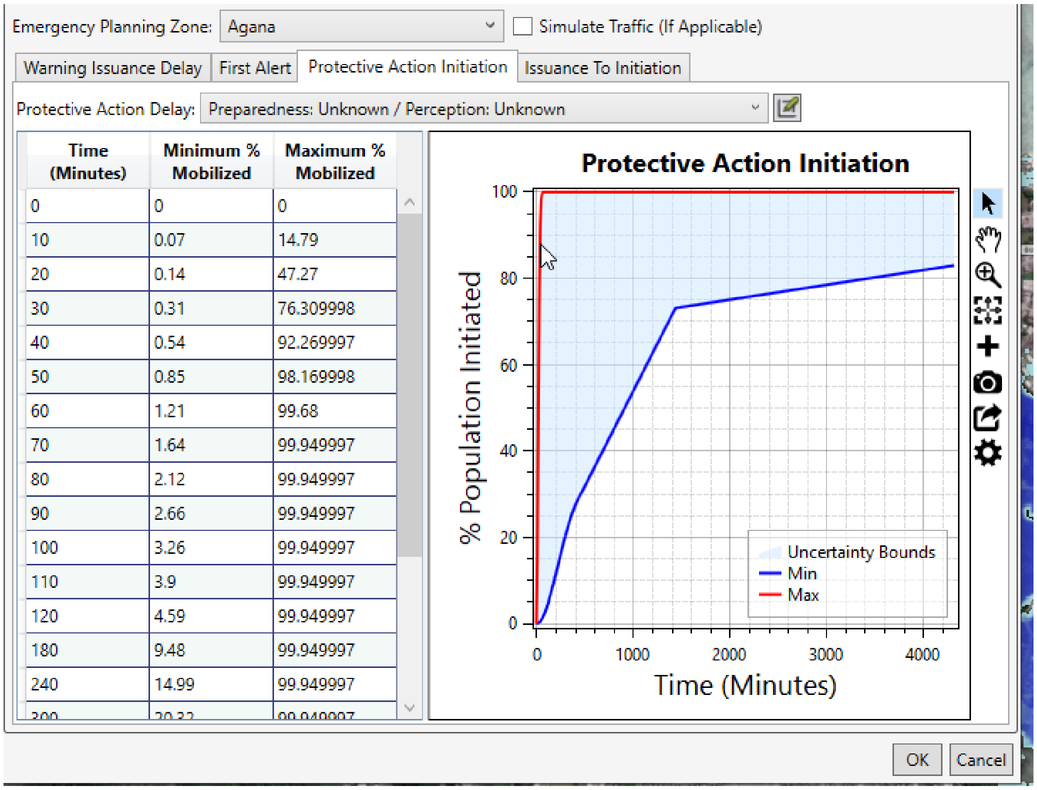


Figure 23. Protective Action Initiation: Preparedness Unknown and Perception Unknown

<u>Hydraulic Inputs</u>: A 2-D HEC-RAS model was used to produce inputs to HEC-LifeSim. Table 52 shows the annual exceedance probability (AEP) events that were run in HEC-LifeSim for Alternatives A and B1. Since Alternative D and the nonstructural portions of Alternative C do not include structural features, the HEC LifeSim results will be identical to the without project condition (Alternative A). At this point, there have been no breach prior to overtopping or overtopping scenarios developed for Tafuna that would measure incremental risk, as such the results shown in the following tables will not provide any information regarding the incremental risk of Alternatives B1 or C. However, the following results may help inform decisions regarding life risk based on the performance of these events for Alternatives A and B1.

Table 52. HEC-LifeSim Model Runs, Base Year 2030

Alternatives A and B1	
AEP Event	Modeled in LifeSim
50%	Yes
20%	Yes
10%	Yes
4%	Yes
2%	Yes
1%	Yes
0.5%	Yes
0.2%	Yes

6.4 Life Loss Consequence Results

Population at risk (PAR) describes the number of people that would experience any level of flooding if no protective action were taken. Table 53 and Table 54 show the HEC LifeSim PAR and mean life loss estimates associated with each AEP event for Alternative A (without-project) and Alternative B1, respectively. The mean life loss estimates are only reported for the daytime (2:00 PM) scenario as these are slightly higher than the nighttime (2:00 AM) estimates. The life loss estimates are the mean values generated from one thousand LifeSim Monte-Carlo simulations.

Table 53. Mean Life Loss Estimates by AEP Event, Base Year 2030

ALT A BASE YEAR WITHOUT-PROJECT		
AEP Event	**Population at Risk (PAR)**	**Mean Life Loss**
50%	684	0.00
20%	1,299	0.03
10%	1,749	0.10
4%	1,987	0.22
2%	1,332	0.02
1%	2,489	0.32
0.5%	2,710	0.39
0.2%	2,995	0.46

Table 54. Mean Life Loss Estimates by AEP Event, Alternative B1, Base Year 2030

ALT B1-FLOOD BARRIERS		
AEP Event	**Population at Risk (PAR)**	**Mean Life Loss**
50%	807	0.00
20%	1,536	0.03
10%	1,919	0.09
4% 1	2,196	0.16
2% 2	2,359	0.28
1% 2	2,561	0.35
0.5% 2	2,698	0.36
0.2% 2	3,405	0.51
4%[1]	ADM	ADM
2%[2]	ADM	ADM
1%[2]	ADM	ADM
0.5%[2]	ADM	ADM
0.2%[2]	ADM	ADM

[1]Breach prior to overtopping- results expected for ADM
[2]Overtopping with breach- results expected for ADM

6.5 Annualization of Life Loss and the Life Risk Matrix

To evaluate system performance related to Tolerable Risk Guideline (TRG) 1, a life safety risk matrix composed of both societal and individual risk criteria would generally be used (Figure 24). These plots are used to help determine whether a study area meets the TRGs under current conditions and to identify incremental risk associated with each with-project alternative. However, if, for the with-project breach scenario (Alternative B1), the probability of failure stems from the probability of hydrologic loading, then the expected annual life loss estimates for the Tafuna Study under the without- and with-project conditions are too low to plot on the Life Risk Matrix.

Table 55 and Table 56 display the annualized life loss estimates for Alternative A and Alternative B1 respectively. The calculations were completed in an MS Excel spreadsheet. Life loss estimates in both cases are estimated to be lower than 0.1, which is the lowest point on the Risk Matrix and therefore does not plot on the Risk Matrix.

Table 55. Annualized Life Loss Estimate, Alternative A (Future Without-Project Condition), Base Year 2030

ALTERNATIVE A					
1/AEP Event	**Frequency**	**Interval**	**Mean Life Loss**	**Average Life Loss**	**Sum Life Loss**
2	50.0%		0		
		30.00%		0.02	0.01
5	20.0%		0.04		
		10.00%		0.08	0.01
10	10.0%		0.12		
		6.00%		0.19	0.01
25	4.0%		0.255		
		2.00%		0.14	0.00
50	2.0%		0.0230		
		1.00%		0.2480	0.0025
100	1.0%		0.4730		
		0.50%		0.4575	0.0023
200	0.5%		0.4420		
		0.30%		0.5000	0.0015
500	0.2%		0.5580		
Average Annual Life Loss					**0.0343**

Table 56. Annualized Life Loss Estimate, Alternative B1 – Levee Breach, Base Year 2030

ALTERNATIVE B1					
1/AEP Event	**Frequency**	**Interval**	**Mean Life Loss**	**Average Life Loss**	**Sum Life Loss**
2	50.0%		0.003		
		30.00%		0.02	0.01
5	20.0%		0.034		
		10.00%		0.06	0.01
10	10.0%		0.085		
		6.00%		0.18	0.01
25	4.0%		0.272		
		2.00%		0.31	0.01
50	2.0%		0.3430		
		1.00%		0.3635	0.0036
100	1.0%		0.3840		
		0.50%		0.4235	0.0021
200	0.5%		0.4630		
		0.30%		0.5415	0.0016
500	0.2%		0.6200		
Average Annual Life Loss					**0.0357**

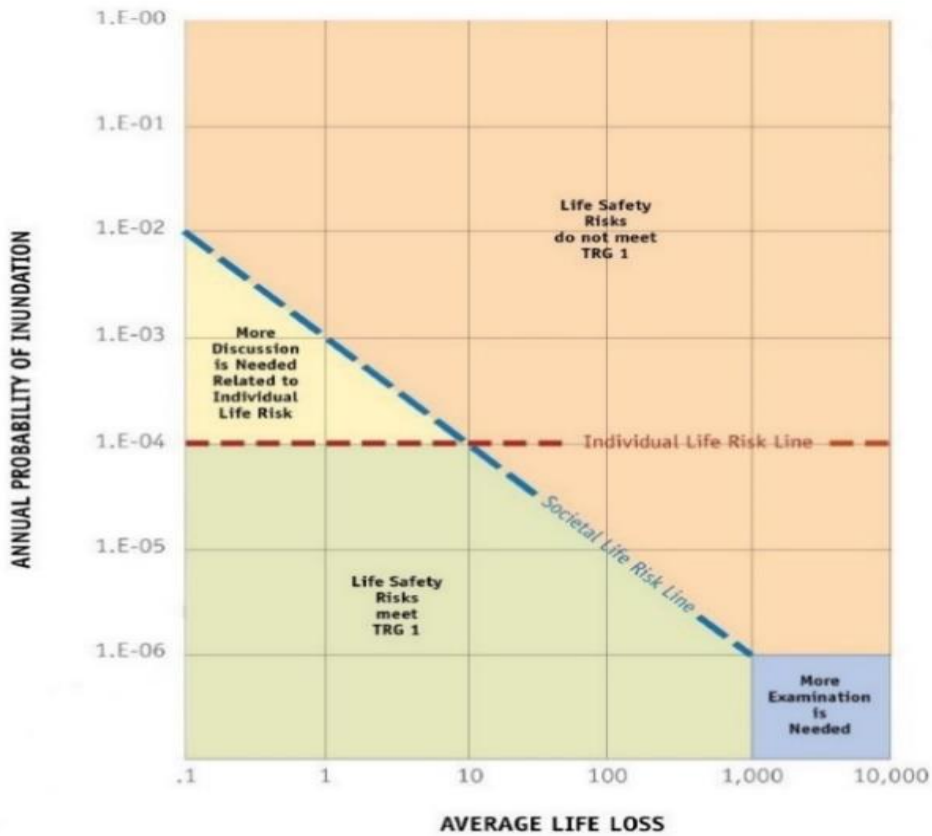


Figure 24. Life Safety Risk Matrix

Incremental Risk: As stated previously, it is anticipated that HEC LifeSim models to measure the incremental risk of Alternatives B1 and C will be developed for the ADM. Table 57 shows the anticipated scenarios for Alternatives B1 and C that will be developed for the ADM milestone.

Table 57. Proposed HEC LifeSim Scenarios for Alternatives B1 and C

AEP Event	Breach Prior to Overtopping-Levee	Overtopping with Breach - Levee	Breach Prior to Overtopping-Floodwall	Overtopping with Breach - Floodwall
4%	Yes	--	Yes	--
2%	--	Yes	--	Yes
1%	--	Yes	--	Yes
0.5%	--	Yes	--	Yes
0.2%	--	Yes	--	Yes

7. REGIONAL ECONOMIC DEVELOPMENT (RED)

7.0 Purpose and Methodology

The U.S. Army Corps of Engineers (USACE) Planning Guidance Notebook (ER 1105-2-100) states that while the National Economic Development (NED) and Environmental Quality (EQ) accounts are required, display of the Regional Economic Development (RED) effects are discretionary. The Corps' NED procedures manual affirms that RED benefits are real and legitimate; however, the concern (from a Federal perspective) is that they are often offset by RED costs in other regions. Nevertheless, for the local community these benefits are important and can help them in making their preferred planning decisions.

Although the RED account is often examined in less detail than NED, it remains useful. For example, Hurricane Katrina caused a significant economic hardship to not just the immediate Gulf Coast but for entire counties, watersheds, and the state of Louisiana. Besides the devastating damage to homes (which are often captured by the NED account), hundreds of thousands of people lost their jobs, property values fell, and tourism and tax revenues declined significantly and were transferred to other parts of the U.S. In this example, the RED account can provide a better depiction of the overall impact to the region.

The distinction between NED and RED is a matter of perspective, not economics. A non-federal partner may consider the impacts at the state, regional, and local levels to be a true measure of a project's impact or benefit, whereas from the Corps' perspective, this may not constitute a national benefit. Gains in RED to one region may be partially or wholly offset by losses elsewhere in the nation. For example, if a Federal project enables a firm to leave one state to relocate to a newly protected floodplain of another state, the increase in regional income for the project area may come at the expense of the former area's loss. In this case, there is no net increase in the value of the nation's output of goods and services and should be excluded from NED computations.

7.1 Key RED Concepts

Econometric analysis allows for the evaluation of a full range of economic impacts related to specific economic activities by calculating effects of the activities in a specific geographic area. These effects are:

- Direct effects, which consist of economic activity contained exclusively within the designated sector. This includes all expenditures made by the companies or organizations in the industry and all employees who work directly for them

- Indirect effects, which define the creation of additional economic activity that results from linked business, suppliers of goods and services, and provisions of operating inputs

- Induce effects, which measure the consumption expenditures of direct and indirect sector employees

Input-output (I/O) models are characterized by their ability to evaluate the effects of industries on each other. Unlike most typical measures of economic activity that examine only the total output of an industry or the final consumption demand provided by a given output, I/O models provide a much more comprehensive view of the interrelated economic impacts. I/O analysis is based on the notion that there is a fundamental relationship between the volume of output of an industry and the volume of the various inputs used to produce that output. Industries are often grouped into production, distribution, transportation, and consumption categories. Additionally, the I/O model can be used to quantify the multiplier effect, which refers to the idea that an increase in spending can lead to an even greater increase in income and consumption, as monies circulate (or multiply) throughout the economy.

7.2 Flood Risk Management RED Considerations

There are project-related effects for each type of improvement related to the RED account. The estimation of RED flood-related effects can be very complex. At a minimum, the RED analysis should include a qualitative description of the types of businesses at risk from flooding, particularly those that could have a significant adverse impact (output, employment, etc.) upon the community or regional economies if their operations should be disrupted by flooding and how this would be affected by the recommended project. The potential RED effects to flood risk management projects are summarized in . Table 57 below.

Table 58. Potential RED Effects to Flood Risk Management

RED Factor	Potential RED Effects
Construction	Additional construction-related activity and resulting spillovers to suppliers
Revenues	Increased local business revenues due to reduced flooding, particularly from catastrophic floods
Tax Revenues	Increased income and sales taxes from the direct project and spillover industries
Employment	Short-term increase in construction employment; with catastrophic floods, significant losses in local employment (apart from the debris and repair businesses, which may show temporary gains)
Population Distribution	Disadvantage groups may benefit from the creation of a flood-free zone
Increased Wealth	Potential increase in wealth for floodplain residents as less is spent on damaged property, repairs, etc.; potential increase in property values.

7.3 RECONS Software

A variety of software programs are available to measure the RED impacts of a project. The Corps of Engineers' Institute for Water Resources (IWR) along with the Louis Berger Group has developed a regional economic impact modeling tool called Regional Economic System (RECONS) that estimates regional and national job creation, retention, and other economic measures. The expenditures made by the USACE for various services and products generate economic activity that can be measured in jobs, income, sales, and gross regional product. The software automates calculations and generates estimates of economic measures associated with USACE's annual civil works program spending. RECONS was built by extracting multipliers and other economic measures from more than 1,500 regional economic models that were built specifically for USACE's project locations by the Minnesota IMPLAN Group. These multipliers were then imported into a database. The software ties various spending profiles to the matching industry sectors by location to produce economic impact estimates. The RECONS program is used to document the performance of direct investment spending by the USACE and allows users to evaluate project and program expenditures associated with annual expenditures.

7.4 RECONS Proxy Area Used for American Samoa

The RECONS software does not include American Samoa in its database. As a work-around, the Island of Kauai (Kauai County), which has a population size and an island economy comparable (but admittedly not completely the same) to that of American Samoa's, was chosen as a proxy geographic area to perform the RED assessment in RECONS.

7.5 RECONS Results

The economic impacts presented below show economic impacts resulting from an injection of flood risk management construction funds. For this assessment, the island of Kauai (Kauai County) was used as the proxy geographic designation in RECONS to assess the overall impacts to the American Samoa economy from constructing either Alternative B, B1, C or D; Kauai County was used as the proxy geographic area because its population size is comparable to that of American Samoa's. Using this proxy area places a frame around the economic impacts where the activity is internalized; leakages, which are payments made to imports or value-added sectors that do not in turn re-spend the dollars within the area, are not included in the total impacts. The default input parameters in RECONS associated with the Kauai County proxy area were not adjusted to reflect potential differences in input parameters that might be associated with American Samoa.

<u>Input Costs</u>: The total project costs of each alternative are $27,641,000 for Alternative B, $47,345,000 for Alternative B1, $136,628,000 for Alternative C, and $141,272,000 for Alternative D. The RED analysis requires the adjustment of costs for two items: (1) interest during construction (IDC) and (2) purchase of land. Interest during construction is used in the NED analysis to estimate the opportunity cost of using money for one economic endeavor (e.g., building a FRM project) instead of another (e.g., building a bullet train); IDC is not actually expended within the region and therefore is excluded from the RED analysis. Similarly, the purchase of land, not including administrative costs, is considered a transfer payment from one party to another and therefore is also excluded from the RED analysis.

The RECONS software uses the input costs in conjunction with its region-based locality factors to generate estimates of economic impacts to the region. Tables 2 through 5 display the results of the RECONS assessment for Alternatives B, B1, C and D, respectively.

<u>Alternative B</u> – The RECONS results indicate that a total of approximately 190 full-time (temporary) jobs may be created from constructing Alternative B. The direct impact to the American Samoa economy associated with construction spending for Alternative B is approximately $18.3 million. Direct impacts consist of economic activity contained exclusively within the designated sector. This includes all expenditures made by the companies or organizations in the industry and all employees who work directly for them. The secondary impact associated with construction spending for Alternative B is approximately $12.5 million. Secondary impacts include both indirect effects, which define the creation of additional

economic activity that results from linked business, suppliers of goods and services, and provisions of operating inputs, and induced effects, which measure the consumption expenditures of direct and indirect sector employees. The total impact to American Samoa's economy of constructing Alternative B is approximately $30.8 million.

Table 59. RECONS Economic Impacts to American Samoa Economy, ALTERNATIVE B

Local Impacts					
IMPLAN Sectors	**Industries**	**Output**	**Jobs***	**Labor Income**	**Value Added**
	Direct Impacts				
29	Sand and gravel mining	$0	0.0	$0	$0
54	Construction of new highways and streets	$276,410	1.1	$88,510	$158,916
55	Construction of new commercial structures, including farm structures	$276,410	1.8	$136,006	$164,528
56	Construction of other new nonresidential structures	$6,910,248	65.9	$5,001,220	$3,608,483
57	Construction of new single-family residential structures	$276,410	1.6	$122,499	$173,138
203	Cement manufacturing	$0	0.0	$0	$0
215	Iron and steel mills and ferroalloy manufacturing	$0	0.0	$0	$0
269	All other industrial machinery manufacturing	$0	0.0	$0	$0
331	Switchgear and switchboard apparatus manufacturing	$0	0.0	$0	$0
395	Wholesale - Machinery, equipment, and supplies	$6,009	0.0	$1,500	$2,588
400	Wholesale - Other nondurable goods merchant wholesalers	$346,922	1.4	$76,086	$148,185
401	Wholesale - Wholesale electronic markets and agents and brokers	$8,104	0.3	$15,783	$5,849
414	Air transportation	$3,625	0.0	$701	$2,359
415	Rail transportation	$0	0.0	$0	$0
416	Water transportation	$3,773	0.0	$648	$1,112
417	Truck transportation	$154,145	0.8	$52,949	$76,175
444	Insurance carriers, except direct life	$117,967	0.2	$14,707	$40,599
453	Commercial and industrial machinery and equipment rental and leasing	$840,407	2.1	$169,733	$576,882
457	Architectural, engineering, and related services	$1,179,058	8.0	$397,280	$459,823
463	Environmental and other technical consulting services	$86,646	1.3	$40,343	$38,812
470	Office administrative services	$87,288	1.4	$47,102	$27,675
544	* Employment and payroll of federal govt, non-military	$3,040,509	19.2	$2,487,741	$3,040,509
5001	Private Labor	$4,698,968	85.2	$4,698,968	$4,698,968
	Direct Impact	**$18,312,898**	**190.3**	**$13,351,778**	**$13,224,600**
	Secondary Impact	**$12,491,507**	**75.1**	**$3,744,660**	**$7,301,831**
	Total Impact	**$30,804,405**	**265.3**	**$17,096,438**	**$20,526,431**
	* Jobs are presented in full-time equivalence (FTE)				

Alternative B1 – The RECONS results indicate that a total of approximately 325 full-time (temporary) jobs may be created from constructing Alternative B1. The direct impact to the American Samoa economy associated with construction spending for Alternative B1 is approximately $31.4 million. Direct impacts consist of economic activity contained exclusively within the designated sector. This includes all expenditures made by the companies or organizations in the industry and all employees who work directly for them. The secondary impact associated with construction spending for Alternative B1 is approximately $21.4 million. Secondary impacts include both indirect effects, which define the creation of additional economic activity that results from linked business, suppliers of goods and services, and provisions of operating inputs, and induced effects, which measure the consumption expenditures of direct and indirect sector employees. The total impact to American Samoa's economy of constructing Alternative B1 is approximately $52.8 million.

Table 60. RECONS Economic Impacts to American Samoa Economy, Alternative B1

IMPLAN Sectors	Industries	Output	Jobs*	Labor Income	Value Added
	Direct Impacts				
29	**Sand and gravel mining**	0	0	0	0
54	Construction of new highways and streets	$473,452	1.9	$151,605	$272,200
55	Construction of new commercial structures, including farm structures	$473,452	3.1	$232,960	$281,814
56	Construction of other new nonresidential structures	$11,836,290	113.0	$8,566,392	$6,180,827
57	Construction of new single-family residential structures	$473,452	2.7	$209,824	$296,560
203	Cement manufacturing	$0	0.0	$0	$0
215	Iron and steel mills and ferroalloy manufacturing	$0	0.0	$0	$0
269	All other industrial machinery manufacturing	$0	0.0	$0	$0
331	Switchgear and switchboard apparatus manufacturing	$0	0.0	$0	$0
395	Wholesale - Machinery, equipment, and supplies	$10,292	0.1	$2,570	$4,433
400	Wholesale - Other nondurable goods merchant wholesalers	$594,228	2.3	$130,325	$253,820
401	Wholesale - Wholesale electronic markets and agents and brokers	$13,881	0.4	$27,034	$10,018
414	Air transportation	$6,209	0.0	$1,200	$4,041
415	Rail transportation	$0	0.0	$0	$0
416	Water transportation	$6,463	0.0	$1,110	$1,905
417	Truck transportation	$264,029	1.4	$90,694	$130,477
444	Insurance carriers, except direct life	$202,061	0.3	$25,191	$69,540
453	Commercial and industrial machinery and equipment rental and leasing	$1,439,500	3.5	$290,730	$988,118
457	Architectural, engineering, and related services	$2,019,562	13.7	$680,485	$787,613
463	Environmental and other technical consulting services	$148,412	2.3	$69,102	$66,480
470	Office administrative services	$149,511	2.4	$80,680	$47,403
544	* Employment and payroll of federal govt, non-military	$5,207,967	32.9	$4,261,154	$5,207,967
5001	Private Labor	$8,048,677	145.9	$8,048,677	$8,048,677
	Direct Impact	$31,367,438	325.9	$22,869,731	$22,651,893
	Secondary Impact	**$21,396,207**	**128.6**	**$6,414,080**	**$12,507,017**
	Total Impact	**$52,763,645**	**454.4**	**$29,283,811**	**$35,158,910**
	*** Jobs are presented in full-time equivalence (FTE)**				

Alternative C – The RECONS results indicate that a total of approximately 941 full-time (temporary) jobs may be created from constructing Alternative C. The direct impact to the American Samoa economy associated with construction spending for Alternative C is approximately $90.5 million. Direct impacts consist of economic activity contained exclusively within the designated sector. This includes all expenditures made by the companies or organizations in the industry and all employees who work directly for them. The secondary impact associated with construction spending for Alternative C is approximately $61.7 million. Secondary impacts include both indirect effects, which define the creation of additional economic activity that results from linked business, suppliers of goods and services, and provisions of operating inputs, and induced effects, which measure the consumption expenditures of direct and indirect sector employees. The total impact to American Samoa's economy of constructing Alternative C is approximately $152.2 million.

Table 61. RECONS Economic Impacts to American Samoa Economy, Alternative C

IMPLAN Sectors	Industries	Output	Jobs*	Labor Income	Value Added
	Direct Impacts				
29	Sand and gravel mining	$0	0.0	$0	$0
54	Construction of new highways and streets	$1,366,277	5.5	$437,498	$785,510
55	Construction of new commercial structures, including farm structures	$1,366,277	9.0	$672,270	$813,252
56	Construction of other new nonresidential structures	$34,156,913	325.9	$24,720,713	$17,836,499
57	Construction of new single-family residential structures	$1,366,277	7.9	$605,506	$855,808
203	Cement manufacturing	$0	0.0	$0	$0
215	Iron and steel mills and ferroalloy manufacturing	$0	0.0	$0	$0
269	All other industrial machinery manufacturing	$0	0.0	$0	$0
331	Switchgear and switchboard apparatus manufacturing	$0	0.0	$0	$0
395	Wholesale - Machinery, equipment, and supplies	$29,700	0.1	$7,416	$12,792
400	Wholesale - Other nondurable goods merchant wholesalers	$1,714,811	6.8	$376,088	$732,469
401	Wholesale - Wholesale electronic markets and agents and brokers	$40,057	1.3	$78,014	$28,911
414	Air transportation	$17,917	0.0	$3,463	$11,660
415	Rail transportation	$0	0.0	$0	$0
416	Water transportation	$18,652	0.0	$3,203	$5,496
417	Truck transportation	$761,929	3.9	$261,723	$376,529
444	Insurance carriers, except direct life	$583,105	1.0	$72,697	$200,677
453	Commercial and industrial machinery and equipment rental and leasing	$4,154,079	10.2	$838,982	$2,851,491

457	Architectural, engineering, and related services	$5,828,009	39.6	$1,963,729	$2,272,876
463	Environmental and other technical consulting services	$428,285	6.5	$199,412	$191,845
470	Office administrative services	$431,457	6.8	$232,823	$136,794
544	* Employment and payroll of federal govt, non-military	$15,029,042	94.9	$12,296,747	$15,029,042
5001	Private Labor	$23,226,701	421.0	$23,226,701	$23,226,701
	Direct Impact	**$90,519,485**	**940.5**	**$65,996,984**	**$65,368,353**
	Secondary Impact	**$61,744,721**	**371.0**	**$18,509,615**	**$36,092,483**
	Total Impact	**$152,264,207**	**1311.4**	**$84,506,599**	**$101,460,836**
	* Jobs are presented in full-time equivalence (FTE)				

<u>Alternative D</u> – The RECONS results indicate that a total of approximately 972 full-time (temporary) jobs may be created from constructing Alternative D. The direct impact to the American Samoa economy associated with construction spending for Alternative D is approximately $93.6 million. The secondary impact associated with construction spending for Alternative D is approximately $63.8 million. The total impact to American Samoa's economy of constructing Alternative D is approximately $157.4 million.

Table 62. RECONS Economic Impacts to American Samoa Economy, Alternative D

IMPLAN Sectors	Industries	Output	Jobs*	Labor Income	Value Added
	Direct Impacts				
29	Sand and gravel mining	$0	0.0	$0	$0
54	Construction of new highways and streets	$1,412,718	5.7	$452,369	$812,211
55	Construction of new commercial structures, including farm structures	$1,412,718	9.3	$695,121	$840,896
56	Construction of other new nonresidential structures	$35,317,956	337.0	$25,561,006	$18,442,787
57	Construction of new single-family residential structures	$1,412,718	8.1	$626,088	$884,898
203	Cement manufacturing	$0	0.0	$0	$0
215	Iron and steel mills and ferroalloy manufacturing	$0	0.0	$0	$0
269	All other industrial machinery manufacturing	$0	0.0	$0	$0
331	Switchgear and switchboard apparatus manufacturing	$0	0.0	$0	$0
395	Wholesale - Machinery, equipment, and supplies	$30,710	0.2	$7,668	$13,226
400	Wholesale - Other nondurable goods merchant wholesalers	$1,773,100	7.0	$388,872	$757,367
401	Wholesale - Wholesale electronic markets and agents and brokers	$41,418	1.3	$80,666	$29,893
414	Air transportation	$18,527	0.0	$3,581	$12,056
415	Rail transportation	$0	0.0	$0	$0
416	Water transportation	$19,286	0.0	$3,312	$5,683

417	Truck transportation	$787,828	4.1	$270,620	$389,328
444	Insurance carriers, except direct life	$602,925	1.0	$75,168	$207,499
453	Commercial and industrial machinery and equipment rental and leasing	$4,295,282	10.5	$867,500	$2,948,417
457	Architectural, engineering, and related services	$6,026,111	41.0	$2,030,479	$2,350,135
463	Environmental and other technical consulting services	$442,843	6.8	$206,191	$198,367
470	Office administrative services	$446,123	7.1	$240,737	$141,444
544	* Employment and payroll of federal govt, non-military	$15,539,900	98.1	$12,714,731	$15,539,901
5001	Private Labor	$24,016,210	435.3	$24,016,210	$24,016,210
	Direct Impact	**$93,596,373**	**972.4**	**$68,240,316**	**$67,590,317**
	Secondary Impact	**$63,843,513**	**383.6**	**$19,138,783**	**$37,319,318**
	Total Impact	**$157,439,886**	**1356.0**	**$87,379,100**	**$104,909,635**
	* Jobs are presented in full-time equivalence (FTE)				

7.6 Summary

While absolute estimates of impacts in terms of dollars and jobs can be informative, especially for the non-federal partner, more meaningful information may be the relative comparison between the various alternatives. A comparison can show which of the alternatives has the potential to provide the most economic impact to the local economy. For the Tafuna FRM, the RECONS assessment indicates that construction spending associated with Alternatives C or D would be more impactful than the other alternatives in terms of jobs and spending activity.

8. OTHER SOCIAL EFFECTS (OSE)

8.0 Introduction

As mentioned above, the Other Social Effects (OSE) analysis is one of the four accounts evaluated in USACE water resource planning. The OSE account displays the effects of a proposed intervention, such as a flood risk management project, on social aspects such as well-being that are integral to personal and community definitions of satisfaction and happiness (Dunning/Master Day LLC & Durden/USACE,2009). The OSE account evaluates the beneficial and adverse effects water resource plans have on social well-being (USACE, Appendix D, 2004). This section begins with a discussion of aspects that highlight the social profiles within the study area followed by a consideration of social effects of a project and a matrix which compares the social effects across the alternatives.

8.1 Social Landscape of Study Area

The study area consists of a mix of traditional villages and non-traditional settlements, presenting some nuances for considering social effects of a flood risk management project. The Tafuna Plain commonly refers to the flat region nestled in the mountains and stretches towards the coast in south-western Tutuila Island. Tafuna was initially a village established on the coast with most of the land acreage left untouched. Traditional knowledge holds that it was at the Tafuna coast where the *Sa'o* (high chief) *Fonoti* arrived in his *va'a* (canoe) and founded the village (Personal Comm. , 2021). The village was relocated inland during World War II (WWII) to accommodate the construction of the airport on the coast. The airport construction was accompanied by the cutting of roads and clearing of acres of bush for material storage at the airport site (Stover, 1999).

The events of WWII and the designated location of the airport not only altered the physical landscape but also the social landscape of Tafuna village and the greater Tafuna Plain. Widespread interest for developing the area for homes, gardens and churches soon followed. Tafuna also attracted commercial interests to set up businesses. Some local government services either relocated from the capital of Pago Pago or set up a branch in Tafuna. The land rush in the years following WWII coincided with the application of adverse possession land rights first introduced in 1901 by US Naval Administration (Kruse, 2019). Tracts of communal land were transferred from the *fa'amatai* (chiefly institution) to individually owned land. This in part led to the emergence of settlements in areas that were previously under the jurisdiction of traditional Tafuna village, an anomaly to American Samoa. More information on the land tenure system is discussed in the next section. For the purposes of this report, "settlements" refer to neighborhoods that are without a village governing structure. Settlements include Ottoville where Trade Winds Hotel (one of the two main hotels in the territory) is located. In 2002, the Pele US Army Reserve Center broke ground just outside the airport (Overson, 2019). Today, the village of Tafuna still exists within the sub-urban settlements of greater Tafuna area. Characteristics of traditional villages and settlements affect the evaluation of social effects in the study area. An assessment of these characteristics is consistent with the policy directive on the comprehensive documentation of benefits which directs PDT to consider urban, rural and community impacts (SACW, 2021).

For the purposes of this analysis, traditional villages have four foundational characteristics: a village council *(Fono a Matai/Fono)*, an appointed mayor (*Pulenu'u)*, a central field that serves similar functions to a town-hall (*Malae*). The fourth characteristic of a traditional village is a set of salutations of the chiefly titles, historic traditions or "charter" summarized in *Fa'alupega* (Meleisea, 1987 p. 6). Settlements are areas of individually owned land without the four characteristics of a traditional village.

The study area consists of following villages along Route 1 road from west to east: Pavai'a'i, Faleniu, Mesepa, Malaeimi to a part of Nu'uuli. Along Route 19 from the west to east are settlement of Koko Land, Tafuna village and settlement of Ottoville along the south-bound Route 18.

8.2 Land Tenure

The preceding sub-section mentioned two categories of land ownership: Communal Lands (CL) and Individually Owned Lands (IOL). Historically, all lands in the territory were native (communal) lands (Crocombe, 1987; Kruse, 2019). Kruse further describes communal lands as specific tracts of large, medium and small lands collectively owned by an extended family (*'aiga*) within a village (*nu'u)* that were demarcated by settlement, cultivation and virgin bush lands where natural features of rivers and hills were understood as boundary markers (p.75). Family clans, descendants of family lines and successors to the chief (*matai*) title have direct interest in the communal lands as they would be considered as part-owners.

Individually owned lands evolved out of the adverse land possession land rights instituted by the Naval Administration. IOL was subsequently established as a land tenure classification by the court. These IOL are not subject to authority nor the stewardship of the *matai* and family clans. Moreover, the IOL registrants are not bound to any cultural obligation to communal sharing, distribution and as mentioned above, village governance. Freehold land are those lands that may be sold or transferred. This land tenure classification at present, remains a small portion of registered lands because freehold land was granted by the International Claims Commission in Apia (capital of present day independent Samoa) prior to the US taking possession of eastern Samoa.

There are five land ownership categories currently recognized by the Office of the Territorial Registrar. These are: Communal Land, Individually Owned Land, Government-Owned Land, Church Owned Land and Freehold Land. About 8,000 acres of land in the Territory are registered of which 27 percent is Communal Land, 25.7 percent is Individually Owned Land, 21 percent is Government Owned followed by Church Owned and Freehold lands representing 13 percent each (American Samoa DOC, 2019, p. 86).

The majority of IOL are in the Tafuna Plain. Compared to the rest of Tutuila Island, the Tafuna Plain is flat and favorable for residential and commercial development. In the absence of FRM measures, the potential for future development and growth is limited. Residents would be subjected to future floods and damages.

8.3 Life Safety

The PDT assessed and identified potential risks to life safety in the initial stages of the study in accordance with USACE guidance for incorporation of life safety into flood and coastal storm risk management studies (PB 2019-04). A qualitative review of historical reports and discussions with the local sponsor determined that historical and existing flooding do not significantly impact life safety. Results of the existing conditions run on LifeSim 2.0 showed no significant life loss. LifeSim modeling for the alternatives to evaluate breaching and overtopping scenarios will be conducted prior to the Agency Decision Milestone, see Chapter 6.

8.4 Social Factors

a. Health and Safety

An important basic human need is for personal and group safety (Maslow 1943). While flooding events in the existing conditions have reported a low significant impact on life loss, flooding still negatively impact health and safety. Flooding damages that result in unsafe or unhealthy conditions, can cause stress and dissatisfaction among those affected.

Flooding events pose threats to the physical health and safety of residents. Road closures due to flooding cut access to essential services and places of employment. In some cases, people would decide to walk the flooded roads to avoid missing work or to get to an area less flooded and still accessible by public transportation. These conditions negatively impact mental and physical health. Alternatives B1 and C are expected to reduce the duration and depth of flooding can reduce these negative impacts on health and safety.

b. Social Connectedness

Social connectedness refers to the intricate social networks within which individuals interact; these networks provide meaning and structure to life (Dunning and Durden, 2009). These social networks comprise of families and community members cultivating an array of diverse voluntary associations the World Bank call "civic infrastructures." These civic infrastructures can provide individuals with greater opportunities for connectedness, communication, and reciprocity, as well as support for times of need. These civic infrastructures are simply known as villages in American Samoa. For the non-traditional settlements, these civic infrastructures take form within the church congregations. Alternatives that reduce flooding at key places for these community gatherings such as the *malae* and churches can support social connectedness.

When social connectedness is strengthened, community members are more active in aiding those vulnerable individuals or groups, thereby increasing community resilience. Social connectedness is typically on display during post-disaster recovery efforts when churches assist their congregation members and when village council selects a group of men as labor to rebuild homes of those affected.

c. Cultural Identity

A flood risk management project that reduces disruptions to daily life and cultural activities in villages support retaining or enhancing cultural identity in the study area. It should also be noted that family clans build graves for their relatives on their lands. This is true for both communal and individually owned lands. Senior *matai* are laid to rest in communal land and their graves serve as a cultural monument in the village. While non-structural alternatives would not alleviate damages to these graves, the structural alternatives are expected to reduce damages and contribute to preserving grave sites.

8.5 Planning Matrix and Scoring System.

This analysis adapts a practical framework developed by Weiss, Prakash and Amarakoon for OSE evaluation. The framework consists of a scoring system and planning matrix to aid in the evaluation of OSE impacts of the formulated alternatives on the communities in the study area. The social factors considered are reflective of issues that are important to communities in the study area and the impacts of the alternatives. From each of these social factors, metrics are developed. Social factors are not easily quantified, therefore a scoring system with a scale of -3 to +3 is developed. Where -3 indicates significant negative effects on a particular metric, and +3 indicates a significant effect. Figure 24 below presents the scores and associated description in relation to the Without Project Alternative (FWOP or No Action). The score is an assessment of the relative impact an alternative would have on a particular metric in relation to the No Action Alternative.

Score	In Relation to the Without Project Alternative, the With Project Alternative Has …
-3	Significant negative effects (showstopper)
-2	Moderate negative effects
-1	Minor negative effects
0	Negligible effects (no impact)
1	Minor beneficial effects
2	Moderate beneficial effects
3	Significant beneficial effects

Figure 25. Key to Scoring Metrics Source: Weiss et al. 2013

Weiss et al propose that it may be appropriate for FRM studies to modify the evaluation of metrics to assess OSE impacts to a community both during a flood event and in daily (non-event) life. While acknowledging the rationale for this delineation, this analysis currently evaluates the OSE impacts during flood events only. Modifications to the evaluation will be revisited following the public review period and site visit. For the purposes of this matrix, the

Future Without Project Condition is considered a neutral point and is therefore omitted from the scoring evaluation. To be clear, the OSE impacts in the FWOP condition are discussed qualitatively in preceding sub-sections. The OSE matrix is presented below in Table 57 with preliminary scoring based upon PDT judgement and subject to modification following stakeholder meetings scheduled for early 2022.

Table 63. OSE Alternatives Matrix

Social Factor and Metrics	**Alt B: Channel Conveyance**	**Alt B1: Flood Barrier and Channel Conveyance**	**Alt C: Combined Structural and Non-Structural**	**Alt D: Non-Structural**
Health and Safety				
Mental Health	1	1	1	1
Physical Health	2	2	1	1
Physical Safety	1	3	2	1
Social Connectedness				
Community Cohesion	1	1	0	0
Community Facilities	1	2	1	0
Identity				
Cultural Identity	1	2	1	0
Community Identity	1	2	1	0
Social Vulnerability and Resiliency				
Residents of Study Area	1	1	1	1
Socially Vulnerable Groups	0	1	-1	-1
Total Score	8	15	7	3

8.6 OSE Results Summary

From an OSE perspective, Alternative B1 has the highest score of 15 followed by Alternatives B and C with total scores of 8 and 7 respectively. Alternative D scored the lowest with a score of 3. Alternative B1 which combines channel conveyance and flood barrier along Taumata and Leaveave streams is expected to reduce flooding on the roads and potentially improve physical safety in the residential communities along both streams. Alternative B1 is also expected to moderately strengthen cultural identity because the flood barriers are expected to reduce flooding to grave sites which have cultural value to residents. Moreover, the reduced flooding to roads and areas like *malae* would reduce disruption to cultural events and therefore support cultural identity.