EU EDF – SOPAC Project Report 69g
Reducing Vulnerability of Pacific ACP States

SAMOA TECHNICAL REPORT –
ECONOMIC ANALYSIS OF FLOOD RISK REDUCTION MEASURES FOR THE LOWER VAISIGANO CATCHMENT AREA

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ACRONYMS

ADB	Asian Development Bank
AAD	Average annual damage
BCA	Benefit-cost analysis
CSIRO	Australian Commonwealth Scientific and Research Organisation
EDF	European Development Fund
EPC	Electric Power Corporation
EU	European Union
FMAP	Flood Management Action Plan
GIS	Geographic Information Systems
HYCOS	Hydrological Cycle Observing System
IRR	Internal rate of return
LVCA	Lower Vaisigano Catchment Area
MNRE	Ministry of Natural Resources and Environment
NDMO	National Disaster Management Office
NDMP	National Disaster Management Plan
NUS	National University of Samoa
NOAA	National Oceanic and Atmospheric Administration
NPV	Net present value
PIC	Pacific Island Country
PUMA	Planning and Urban Management Agency
SNDMP	Samoa's National Disaster Management Plan
SOPAC	Pacific Islands Applied Geoscience Commission
SWA	Samoa Water Authority
USACE	United States Army Corps of Engineers
WaSSP	Water Sector Support Programme
WST$	Western Samoa Tala[1]

[1] In July 2007, WST$1 was equivalent to approximately AU$0.44 or €0.28

EXECUTIVE SUMMARY

Flooding imposes significant costs on households and businesses located in the lower Vaisigano catchment area. SOPAC, under the European Development Fund (EDF) project *Reducing Vulnerability of Pacific ACP States*, has worked with the Government of Samoa to develop the Samoa Flood Management and Action Plan, which identifies actions for government agencies, the private sector, NGOs and communities responsible for flood and floodplain management that can assist in reducing flood risks in Samoa, particularly in the lower Vaisigano catchment area located in Apia, which is subject to frequent flooding.

The aim of this study is to assess the structural and non-structural flood management options for the lower Vaisigano catchment area proposed under the Action Plan that were identified as priority measures during a stakeholder consultation meeting in March 2007. These options include: floodwalls, a diversion channel, an improved flood forecasting system and development control, through the construction of homes with elevated floor heights.

Economic analysis of flood management measures is useful since it can be used to guide policy decisions regarding the choice of flood measures by comparing the costs and benefits of each option, by identifying the measure which offers the greatest net benefits. This allows scarce resources allocated to disaster management to be used as efficiently as possible. Economic analysis can also be used as an advocacy tool for securing resources since it can demonstrate the long-term cost savings which can result from being proactive and investing in flood risk reduction measures in the short term.

The study finds that flooding in the lower Vaisigano catchment area imposes large costs on all sectors, including households, businesses, schools, churches and infrastructure. Using information on the estimated damages associated with 1 in 5, 1 in 20, 1 in 50 and 1 in 100 flood events and their associated probability of occurrence, annual average damages from flooding for all sectors are estimated to be WST$618,529. The estimated damage costs associated with flooding in the area were calculated using data collected from business and household surveys conducted in the four districts located in the study area, from previous flood studies, and flood maps produced by SOPAC, which provided information on estimated floodwater depths for selected flood events.

Non-structural measures, including an improved flood forecasting system, which would require the purchase of additional rainfall gauges and flood modeling software; and development control, which would require new homes constructed in the floodplain to be constructed with elevated floor heights, were found to be the most economically viable flood management options. A project is deemed to be acceptable from an economic perspective when the ratio of benefits to costs is greater than one. In the case of an improved forecasting system, the ratio of benefits to costs was estimated to range from 1.92 to 1.72, depending on the choice of discount rate used to carry out the analysis. In other words, for the first estimate, for every WST$1 invested in the improved forecasting system, at least WST$1.92 would be realized in avoided future damages from flooding. The most significant economic pay-off from investing in flood management options is found to be from constructing homes with raised floors. For new homes, the benefit cost ratio is found to range from 4 to 44 for wooden homes, and from 2 to 28 for cement block homes.

Structural measures, on the other hand, were found not to be economically viable. In the case of floodwalls, the benefit-cost ratios ranged from 0.11 to 0.64 depending on the choice of floodwall design and discount rate used in the analysis. For the construction of a diversion channel, the benefit-cost ratios ranged from 0.01 to 0.09. Although, it is likely that many of the indirect or non-monetary benefits not captured in the analysis such as avoided health costs or trauma suffered by residents during flooding, or reduced flood damages to households and businesses in nearby districts, would raise the benefit-cost ratios, it is unlikely that they would be significant enough to raise benefit-cost ratios above one.

It is therefore recommended that the Government consider investing in an improved forecasting system in conjunction with public awareness campaigns which educate the local population on the risks associated with flooding, and with the development of an effective flood advisory system. In addition, policies should be put into place in order to encourage residents living in the floodplain to construct new homes with elevated floor heights. This can be achieved either through development of zoning regulations which require that new homes constructed in floodplains have floor heights which exceed 1-in-100-year flood levels or the use of grants, tax rebates or low-interest loans to make flood-proofing of new homes more affordable to residents.

1. INTRODUCTION

1.1 European Development Fund Project *Reducing Vulnerability in Pacific ACP States*

SOPAC currently executes the European Development Fund (EDF) Project *Reducing Vulnerability of Pacific ACP States*. The Project is intended to reduce Pacific ACP states vulnerability to natural disasters through the development of an integrated planning and management system, which targets:

- hazard mitigation and risk assessment;
- aggregates for construction; and
- water resources and sanitation.

These 'geoscience outputs' are to be used to underpin the development of planning and management tools in the context of 'island systems management' to reduce vulnerability to natural risks. Additionally, the Project is intended to promote access to the maps and databases by all stakeholders via communications networks drawing on Map Servers provided by the project.

Intended benefits of the EDF Project

Through this work, the project is intended to:

- enhance sustainable development of coastal zones through the identification of alternative sources of aggregate;
- improve planning practices for safe and adequate water supplies and sanitation systems;
- implement comprehensive hazard and risk management tools within the framework of an integrated holistic approach for sustainable development;
- establish infrastructure in participating countries and support its use; and
- strengthen the capacity of Pacific ACP states.

This economic analysis of selected flood mitigation measures proposed under the Flood Management Action Plan (FMAP) was carried out in response to the Government of Samoa's request for flood management assistance. The need for flood management was first identified in Samoa's work plan for the EDF 8 Project in WS 3.4 and 3.5 pertaining to hazard assessment and risk reduction. The Plan was developed as part of the regional EDF Project *Reducing Vulnerability of the Pacific ACP States*, executed by the Pacific Islands Applied Geoscience Commission (SOPAC).

The EDF Project task began in Samoa in April 2006. Under the Project, SOPAC and the Government of Samoa aimed to build national capacity in flood management by strengthening the ability of technical agencies to forecast and develop flood maps. Although the work carried out under the EDF Project was focused on the modeling and management of risks presented by the lower-Vaisigano catchment area, it would have implications for flood risk assessment and management nationally. Specific activities carried out under the EDF Project included:

- **Capacity Building:** Under the EDF Project, Government of Samoa personnel were trained (Figure 1) in the areas of flood hydrology, conducting river modeling, floodplain mapping and flood mitigation in order to:
    - enable local government staff to collect, interpret, model scientific data in order to make forecasts which reduce flood risk;
    - allow early detection of flood risk to minimise damage; and
    - ensure flood risk monitoring is ongoing.
- **Flood Modeling:** Free of cost flood modeling software packages have been introduced which will allow better prediction of flooding patterns and hazards.
- **Hazard Mapping:** Produced hazard maps, assessed risks and enabled Government of Samoa personnel to make flood predictions at different intervals.
- **Improved Management Practices**: Drafted management guidelines and plan of action. Improved strategies for addressing disaster risk will hopefully reduce the damages caused by flooding in the lower Vaisigano catchment area.

The Samoa Flood Management Action Plan identifies actions for Government agencies, the private sector, NGOs and communities responsible for flood and floodplain management that can assist in reducing flood risks to the Samoan people and their property, as well as improving public safety and enhancing the environment. Although, the scope of the Plan is nationwide, there is a particular focus on the lower Vaisigano catchment area. It identifies a wide range of possible measures for the management of flood risks in the lower Vaisigano catchment area. These include structural measures, which generally involve some type of construction (for example, flood defence embankments and walls) and non-structural measures such as flood warning, land-use planning, development control and building control. A list of these options is presented in Table 1.

Table 1. Structural and non-structural flood management measures proposed under the Samoa Flood Management Action Plan.

Structural Flood Management Options	Non-Structural Mitigation Measure Options
▪ Flood embankments and walls ▪ Flood storage ▪ By-pass or diversion channel ▪ Increasing channel conveyance ▪ Pumping ▪ River Maintenance ▪ Flood proofing of buildings	▪ Development control ▪ Flood forecasting ▪ Flood warnings ▪ Increasing flood preparedness ▪ Land use change

1.2 Objective of study

Figure 1. Participants taking part in the workshop conducted by SOPAC in March 2007.

The aim of this study was to carry out an economic analysis of the flood mitigation measures listed in Table 1 above. Economic analysis can be used to guide policy decisions regarding the choice of flood measures by comparing the costs and benefits of each option, and identifying the measure which offers the greatest net benefits (benefits less costs). This will allow the Government to use scarce resources allocated to the disaster management sector in the most efficient way possible. The economic analysis can also be used as an advocacy tool for securing resources, e.g. from the Ministry of Finance or donor agencies, for the disaster management sector, since it can highlight the long-term cost savings which result from being proactive and investing in flood risk reduction measures in the short term.

A detailed discussion of the methodology used in this study is presented in Section 2. The analysis has been restricted to a benefit-cost analysis of flood management options which were identified as priority measures by the Government of Samoa during a workshop conducted by SOPAC in March 2007.

These include:

1. construction of flood embankments;
2. construction of by-pass/diversion channel;
3. development control i.e. raising floor heights; and
4. improved flood forecasting, warning and public awareness.

1.3 Background Samoa

Samoa is located between 130° 25' and 140° 05' south of the equator and between 171° 23' and 172° 48' west longitudes. The islands stretch over a distance of approximately 200 km with a total land area of approximately 2,800 km^2 which consists of the two main islands, Upolu and Savai'i, and a number of small, uninhabited islands (Taule'alo 2002).

Figure 2. Location of Samoa.

Apia, the economic and political capital of Samoa, is located at the foothills of the Upolu Central Range and occupies an area of approximately 60 km^2. The total population of the Apia Urban Area is estimated to be 37,237 which accounts for approximately 20% of the national population (Statistics Department 2007). Economic activity in Apia is significant as it accounts for 70% of national income (Jones 2002). The capital is built on the low-lying floodplains of five rivers: the Fagalii to the east, and the Fulouasou, the Gasegase, the Mulivai, and the Vaisigano, to the west (Taule'alo 2002). The Vaisigano River, which flows north through Apia, and drains an area of around 34 km^2, is the largest river on Upolu (Terry and Kostaschuk 2004). The river is one of the main sources of water in Apia, and also feeds two hydroelectric stations, which supply the bulk of the city's electricity.

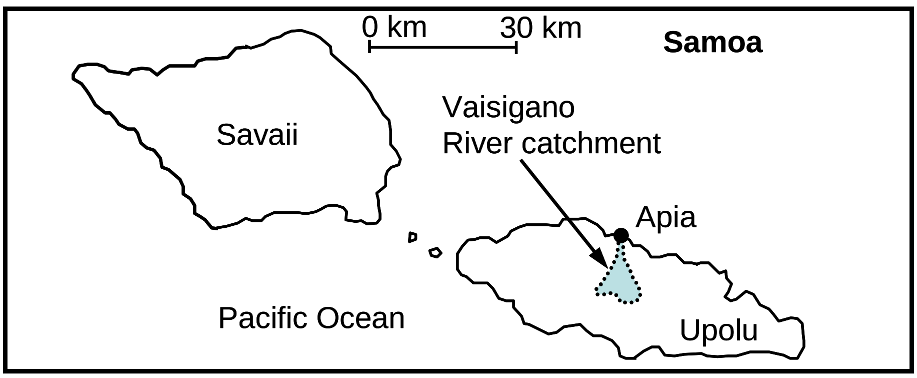
1.4 Flooding in Apia

River floods, especially severe flash floods caused by heavy rainfall, are a frequent occurrence in Apia during the rainy season due to its geography and high rainfall. Severe floods have occurred in Apia in 1939, 1974, 1990 and 2001. The most recent flood event was in February 2006. Less severe floods occur more frequently, and moderately severe flooding was reported in 1982, 1991, and 2000 (Yeo 2001). However, detailed historical records on the frequency and extent of flooding are limited.

There is a lack of urban planning in Apia with many commercial and residential properties located on the floodplain, which makes them vulnerable to flooding. For example, the city's central business district is located on a floodplain. Settlement of areas vulnerable to flooding and reclamation of swamps have been induced by a scarcity of land fuelled by migration to Apia for work and education (Taule'alo 2002). One of the greatest urban planning challenges is the lack of an effective sewerage system in the densely-populated areas of Apia. Existing drains are poorly maintained and are often blocked by rubbish. Often, heavy rains cause drains to overflow, flooding homes, businesses and schools (Gill 2003). During flooding, raw sewage is often discharged directly to groundwater or surface drains, which can pose a significant public health risk. Smaller channels have been constructed to address this problem; however, they are undersized and vulnerable to back-flooding when they fill up too quickly (Gill 2003).

1.5 The Study Area: Lower Vaisigano Catchment Area

The focus of this study is the lower Vaisigano catchment area of Apia (shown in Figure 3), located around the lower basin of the Vaisigano, to the east of the Central Business District.



Source: Terry and Kostaschuck 2004

Figure 3. Map of Samoa and location of lower Vaisigano catchment.

The catchment area consists of four districts including Leone, Vaisigano, Matautu Uta, and Vaiaila Uta, located between the Leone Bridge and Beach Road in Apia. An aerial photo of the catchment area is shown in Figure 4. According to the most recent census, conducted in 2006, there are approximately 1,863 people living in the study area (Statistics Department 2007). Section 3 discusses the population, assets and infrastructure at risk from flooding in the lower Vaisigano catchment area in greater detail.

Unlike many of the other areas in Apia that suffer from heavy flooding, which have been settled in recent years by rural migrant squatters, the majority of households interviewed as part of this study, have been living on their land for a least 20 years (see Table 2). In addition, almost all residents living in the area own their land, which includes mainly customary and freehold tenure arrangements (see
Table *3*).

Table 2. Land ownership by district.

District	Freehold	Customary	Other
Leone	72%	24%	4%
Vaisigano	7%	93%	0%
Matautu Uta	89%	4%	7%
Vaiala Uta	70%	20%	10%

Table 3. Household years of residence by district.

Number of years of residence in district	Leone	Vaisigano	Matautu Uta	Vaiala Uta
Less than 1	4%	0%	2%	0%
1 – 10	0%	0%	11%	13%
10 – 20	12%	7%	9%	13%
More than 20	83%	93%	78%	75%

Figure 4. Aerial image of lower Vaisigano catchment area.

1.6 Other Flood Management Projects in Apia

The Government of Samoa has sought to integrate numerous programmes in order to address Apia's flood problems and reduce future risks. In addition to the activities carried out under the EDF Project described earlier in this section, other projects include the Asian Development Bank Sanitation and Drainage project, which is focused on addressing flooding in the central business district; the ADB Institutional Strengthening for Drainage and Water Management Project, the EU-funded Samoan Water Sector Support Programme, and the Pacific HYCOS Project funded by the EU-ACP Water Facility. Details of these projects are presented in Appendix 2.

2. METHODOLOGY: ECONOMIC ANALYSIS

2.1 Purpose of an Economic Analysis

Under the Samoa Flood Management Action Plan, a number of options are proposed for reducing the flood risk in the lower Vaisigano catchment area. These include both structural measures (e.g. flood walls, upstream flood storage) and non-structural measures (e.g. flood warning, land-use planning, development control).

The purpose of this study was to conduct a benefit-cost analysis (BCA) of selected mitigation measures proposed under the Plan, which were identified as priority actions by stakeholders, in order to determine which measure produce the greatest net benefits (benefits less costs) in terms of avoided flood damage costs.

2.2 Benefit-cost analysis procedure

The procedure involved in carrying out a benefit-cost analysis, illustrated in Figure 5 is presented below. Step 1 is necessary only if the measures to be assessed have not yet already been defined.

1) Options identified by stakeholders

a. Flood embankments
b. Diversion channel
c. Improved flood forecasting, warning and public awareness of flood risks

d. Development control i.e. specification of minimum floor heights in zoning laws

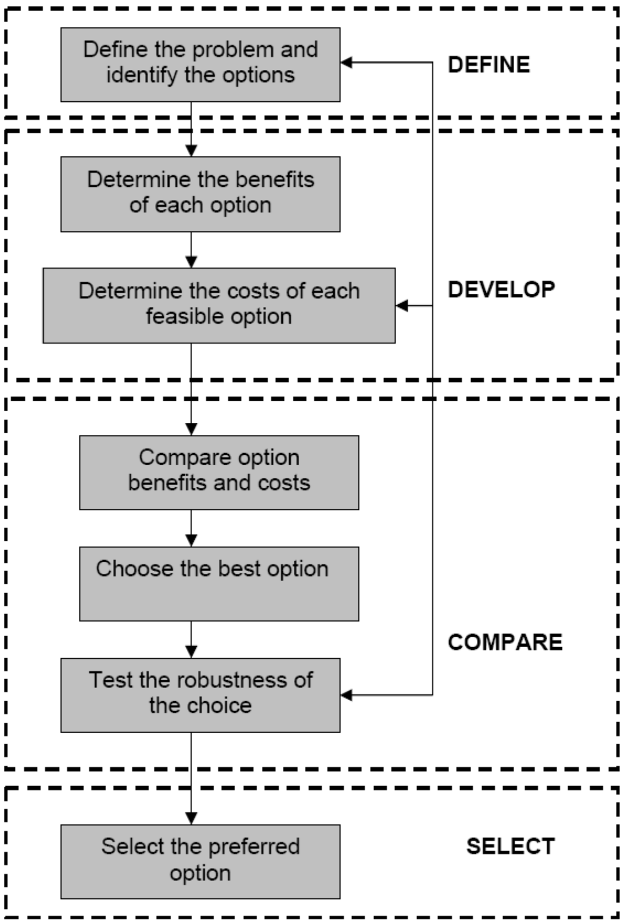


Figure 5. Steps involved in conducting a benefit-cost analysis (Source: Ridell and Green 1999).

2) The benefits of each option are considered:

- Benefits in this economic analysis are measured as 'damages avoided' from investing in flood management measures. In other words, benefits are the difference between damages from flooding without measures in place and damages from flooding with measures in place.

> Benefits from flood measure:
> = Avoided flood damage
> = Flood damage without mitigation – Flood damage with mitigation

- Damages from flooding take different forms including tangible and intangible damages.

  Tangible:

  - **Direct damages**: these are damages caused during flooding e.g. physical damages to buildings and their contents, damage to roads, and evacuation costs.
  - **Indirect damages**: these are damages that occur following the flood event e.g. lost income as a result of business interruption, increased transportation costs due to damages to roads.

  Intangible:

  - **Direct damages:** These include damages during flooding that have no market value e.g. damage to historical records and cultural artifacts, biodiversity loss.
  - **Indirect damages:** These damages that occur following flooding e.g. trauma suffered as a result of being displaced during flooding loss of business confidence.

Whereas tangible damages can be estimated directly by calculating repair or replacement values, economic valuation techniques must be used to indirectly estimate the value of intangible damages since they have no prices related to them.

3) The costs of each option are considered

- **Direct costs:** include initial investments in implementing flood measures (e.g. construction of floodwalls, purchase of rainfall gauges) as well as ongoing operation and maintenance costs over the entire life-time of a flood project. These costs can be estimated directly using their market values.

- **Externality costs:** costs include not only monetary construction and repair costs but also externality costs e.g. impact on biodiversity, visual impacts of structural flood measures on residents, social impact of population resettlement. Externality costs cannot be measured directly since they have no market values associated with them. As a result, economic valuation techniques must be used to estimate their values through indirect means. These values are identified and discussed along with the economic analysis, even if they are not quantified in monetary terms.

4) Comparison of costs and benefits

- **Choice of discount rate**: The benefits and costs of a project occur over time, usually with costs occurring first with investments made in flood management measures e.g. floodwalls, while benefits are not realised until later when flooding occurs. This makes it difficult to compare the costs of the flood measure with avoided damages, since a *tala* spent today does not have the same value as a *tala* saved in the future. This is due to people's time preference for money, which puts greater value on money received today than in the future. In order to make current costs and future benefits comparable, all future money values are converted into present value terms by using a 'discount rate', which weighs current monetary values of costs and benefits more heavily than future values.

  Given the existing debate on the discount rate that should be used to assess the value of projects in Pacific Island Countries (PICs) discussed in Holland (in prep.), the economic analysis conducted as part of this study will use discount rates of 3%, 7% and 10%.

- Once benefits and costs are identified, converted into monetary terms, and discounted to present-day values, comparison may take several forms:

  Benefit-cost ratio: compares the total discounted benefits with the total discounted costs and provides an indication of the scale of return on investment. This is done by examining the ratio of the present value of benefits to the present value of costs. If the ratio of benefits to costs is greater that one, the project can be viewed as viable from an economic perspective.

  Net present value (NPV): compares the present value of project cost streams with the associated present value of benefit streams. Rather than taking the ratio of benefits to costs, total discounted costs are subtracted from total discounted benefits. If the resulting NPV is greater than zero, a project is deemed to be economically viable.

5) Choosing the best option

Once all costs and benefits associated with each flood risk-reduction measure have been identified, quantified in monetary terms, and expressed in present value terms, the best option for reducing flood risk in the lower Vaisigano catchment area can be selected. The option which yields the greatest potential net benefits (benefits relative to costs) is the most desirable option from an economic perspective.

6) Testing the robustness

Estimation of the costs and benefits of each of the proposed flood mitigation measures involves making assumptions about the values of parameters that are not known with certainty e.g. rate of compliance with flood warnings or costs of raising floor heights. In order to test the robustness of the results, a sensitivity analysis is required around each of the uncertain variables.

7) Further Issues

- Realisation of benefits: Calculating the benefits of selected flood management options through a benefit-cost analysis involves predicting the future impacts of each of the measures under consideration. It is important to note that estimated benefits are potential and are not yet realised. In the assessment of each flood management option, factors which affect the realisation of benefits are discussed. Examples include:

- o The likelihood that residents will understand the meaning of flood warnings and act accordingly to reduce their vulnerability to flooding (e.g. if flood warnings are not effectively conveyed to the public, benefits from improved forecasting system will not materialise);
- o The likelihood that residents will make additional financial outlays in order to raise floor heights during the construction of new homes;
- o The likelihood that the Government will be able to acquire land and resettle households bordering the Vaisigano River at a reasonable cost.

2.3 Time span of the economic analysis

The time span for conducting an economic analysis is generally the engineering life of the longest lasting component used in a project (Ridell & Green 1999). For structural measures including floodwalls and diversion channels, a project life of 50 years is assumed. For non-structural measures, based on the life of a rainfall gauge, a project life of 30 years is assumed, and for raising floor heights, a life of 30 years is also assumed.

2.4 Scope of Analysis

Although flooding and the proposed measures while most likely be felt more widely, the analysis is restricted to the impacts of flooding and avoided damages from proposed measures to households and businesses located in the four districts located in the lower Vaisigano catchment area between the Leone and Vaisigano bridges.

3. IMPACT OF FLOODING IN THE LOWER VAISIGANO CATCHMENT AREA

As discussed in the Section 1, the lower Vaisigano catchment area is subject to frequent flooding. However, determining the economic impact of flooding in the area is difficult due to the lack of historical flood records such as damage assessments.

3.1 Vulnerability: population and infrastructure at risk from flooding

Population at risk

The urban districts located in the lower Vaisigano catchment area of Apia are densely populated. The districts are mainly residential, with commercial businesses located on the coastal roads, and the main road that separates Leone district from Matautu Uta. According to the 2006 census the number of people living in the area was 1,863.

The number of households living in the area is estimated to be 242.[2] The population and number of households in each district are presented in Table 4.

[2] The number of households was extrapolated using data on the number of households in the 2001 census and population growth between 2001 and 2006, since the number of households was not included in the preliminary 2006 population census findings.

Table 4. Population and number of households according to district.

District	Population 2006	Number of households (est. 2006)
Leone	583	67
Vaisigano	313	44
Matautu Uta	788	102
Vaiala Uta	179	29
TOTAL	1863	242

Source: Statistics Department 2007

Infrastructure at risk

Figure 6 taken from the Pacific Cites Database, shows the number and location of different buildings including residential houses, commercial businesses, community facilities, public buildings, churches and schools located in the lower Vaisigano catchment area.

Typically each household has a number of buildings located on their property including at least one enclosed western-style home, a fale and an outdoor kitchen building. Two main bridges, which cross the Vaisigano River, the Vaisigano and Leone, are located at the upper and lower bounds of the study area. In addition, Apia's main tourist hotel, Aggie Grey's is also located in the flood zone. During the floods of 2001, the hotel sustained over WST$1 million in damages when the entire ground floor was flooded and stocks were completely destroyed (Tanya Gray, Manager, Aggie Grey Hotel, personal communication, 2007). Table below presents infrastructure data from the Pacific Cities Database.[3]

Table 5. Buildings located in the lower Vaisigano catchment area.

Building Type	Number of Buildings	Percent of total
House	157	68.56
Fale	28	12.23
Commercial property	20	8.73
Accommodation	9	3.93
Education	4	1.75
Public Services	3	1.31
Church	6	2.62
Community facilities	2	0.87
Total	229	100

[3] Note data from the Pacific Cities Database was compiled in 2001, so it does not cover recently constructed buildings in the area.

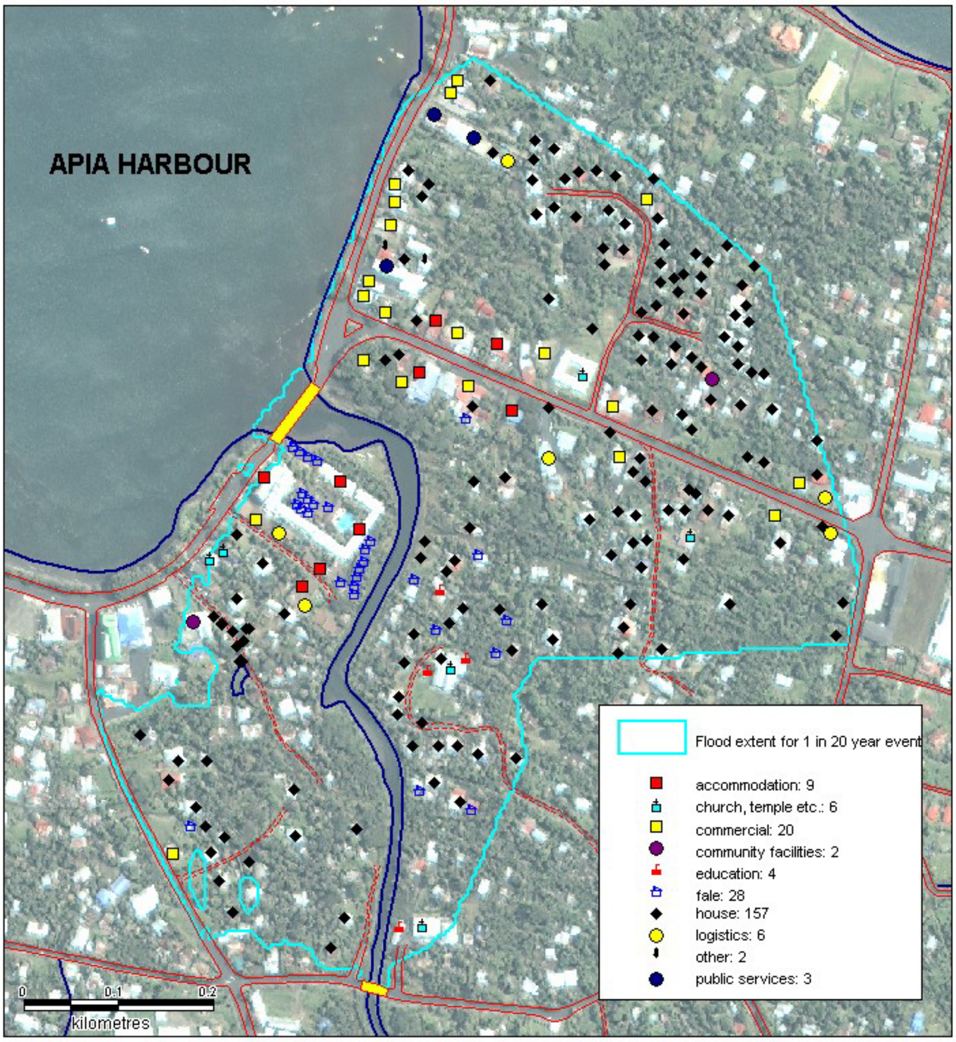


Figure 6. Infrastructure at risk from flooding in the lower Vaisigano catchment area (Source: SOPAC Pacific Cities Database 2001).

3.2. Flood Hazard Maps

As part of the SOPAC EDF work in Samoa, flood maps were produced for 1-in-5, 1-in-20, 1-in-50 and 1-in-100 flood events. Flood maps allow the depth of floodwaters during each flood event for each district to be calculated, which allows the extent of vulnerability of people and infrastructure to flooding to be determined. This information can be used to assess the economic impact of flooding (see Appendix 3 for flood maps).

3.3 Impact of Past Flood Events

As discussed at the beginning of this section, there is a lack of data on the impacts of past flood events in Samoa. The most comprehensive summary of flood damages, including those that occurred in the lower Vaisigano catchment area was compiled by Yeo (2001) (Table 6).

Table 6. The consequences of floods in Samoa as detailed in various newspapers.

Date of flood	Consequences
March 1923	It was reported that there was considerable damage to roadways and two or more bridges were washed away by the floodwaters.
January 1939	Widespread flooding took place in the Apia area. Water supplies were disrupted and many houses were washed away. The Vaisigano Bridge was destroyed. It was estimated that it cost US$100,000 at 1939 prices to repair the damage to the roads and bridges alone. At least two people died as a result of the flooding.
November 1974	Nine people were killed at Falaveo. Five bridges were washed away and numerous buildings and houses were destroyed. The road in the vicinity of the village of Solosolo was washed away. The MP for the Solosolo area requested US$100,000 for a rehabilitation fund for the village. Aggie Greys Hotel was flooded twice by water from the Vaisigano River.
January 1975	Several banana plantations were destroyed and the bridge at Leone in Apia was washed away.
February 1982	Schools closed for more than a week. Many properties were without water. Several bridges were destroyed and airports were closed. The damage was estimated to be at least US$300,000.
January 1989	Livestock was lost as a result of flooding from Afega River.
February 1990	At least ten people died and extensive damage on Upolu and Savai'i as a result of flooding from cyclone Ofa. Many kilometres of roads were washed away. The damage from the cyclone and flooding cost around US$170 million.
December 1991	A state of emergency was declared after Cyclone Val. Twelve people died and 19 people were seriously injured. Thousands of people were left homeless. The National Disaster Council estimated the damage of coastal and river flooding caused by Cyclone Val as: • US$3.2 million to repair damaged bridges. • US$11.6 million to restore water supply infrastructure. • US$4.7 million for coastal protection works. The total cost of the damage caused by Cyclone Val was estimated at US$331 million.
January 2000	Floodwater covered the streets of Fugalei as a result of poor drainage.
April 2001	Approximately 5,000 residents of Apia were directly affected by flooding with up to 28,000 people experiencing disruptions to their water supply. The total damage to infrastructure after the 2001 flood was estimated to be US$3.3 million. This includes an estimated loss of US$1.1 million as a result of damage to roads; a loss of US$2.0 million to Samoa Water Authority with almost half the damage sustained at Alaoa Treatment Plant and a loss of US$0.2 million to Electric Power Corporation, which manages hydro stations. The damage to commercial and residential properties was estimated to be some US$8 million. In total, 1,300 buildings are estimated to have suffered from flooding (Yeo 2001). Flood waters are reported to have entered sewage tanks, leading to the discharge of raw sewage and water into the environment, causing an increase in the reported number of water-borne diseases (AMS 2001).
February 2006	Flooding closed down businesses, schools and caused traffic congestion in Apia. The Fugalei area was hardest hit with some families having to be evacuated and Fugalei market having to be closed (P. Nelson, pers. comm. 2007).

3.4 Household and Business Survey

In order to assess the vulnerability of businesses and residents to flood events in the lower Vaisigano catchment area, as part of this study, it was necessary to collect data on the structure of buildings (construction material, floor height and floor area) and the contents of homes and businesses, as well as clean-up costs and lost income as a result of flooding. Approximately 97 households and 15 businesses were interviewed in four districts using one-stage cluster sampling techniques, where clusters in each district were randomly selected and all households located in each of the identified clusters were targeted (see Table 7).[4]

[4] Household and business survey questionnaires are included in Appendix 4 and Appendix 5, respectively.

Figure 7. Member of survey team measuring the floor height at a home in Matautu Uta (left); member of survey team conducting interview with household in Leone (right).

Table 7. Households included in survey of lower Vaisigano catchment area.

District	Number of households interviewed	Est. 2006 Number of households	Percent of Households interviewed
Leone	25	67	37.12
Vaisigano	15	44	34.09
Matautu Uta	47	102	46.29
Vaiala Uta	10	25	39.85

3.5 Estimated economic impact of flooding

Floodwaters carry debris, mud, silt and sewage. Floodwaters and floating debris can cause structural damage to businesses, homes and other infrastructure including roads and bridges. The higher the floodwaters, the greater the pressure on walls and floors, and the greater the damage and repair costs. Also, if flooding is severe enough, homes and structures such as fales, may be completely destroyed if swept away by floodwaters.

Significant costs may be incurred replacing or cleaning items affected by flooding. Contents of businesses and homes such as food items may be contaminated by floodwaters. Items such as upholstery, carpeting and mattresses when waterlogged are generally not salvageable, and must be replaced. Cleaning up homes and businesses when floodwaters recede will also be costly in terms of hours of labour and cleaning supplies.

Residents may incur health costs associated with treating sickness and injury such as water-borne illnesses like diarrhoea and dysentery as a result of flood events. If water supplies are contaminated, residents must spend money on fuel or electricity in order to boil water or purchase water purification tablets to avoid sickness. If electricity services are interrupted during and after flood events, residents must use batteries, candles and kerosene lamps to provide lighting and to power small appliances. Also, flooding events may cause psychological stress to residents such as fatigue while cleaning up after floods and anxiety over lost income or damaged possessions. In addition to interruption in basic services such as water and electricity, floodwaters may block roads and lead to traffic congestion and long delays or detours, thereby increasing travel costs.

Flooding may also have significant negative impacts on commercial activity. Businesses may be forced to close until floodwater recedes, water and electricity services restored, and the building cleaned, which leads to lost revenue and wages. Higher operating costs can also result from flooding. For example, businesses may use generators to supply electricity during power cuts, or incur higher transport costs if roads are flooded and longer routes must be used to deliver goods. Finally, businesses may incur significant costs in replacing damaged stock, furniture, equipment and machinery. A summary of possible flood damages is provided in Table .

In this study, due to the limited availability of data, not all costs associated with a flood event listed in Table will be measured and quantified in monetary terms. Since direct and indirect monetary losses to business, households and infrastructure damage, account for the largest components of flood damages, only these values will be considered. Other values such as health costs associated with flood events were found to be insignificant in the lower Vaisigano catchment area, and were therefore not included in the economic impact assessment.

Table 8. Summary of potential damages caused by flooding in lower Vaisigano.

Sector	Direct Monetary	Indirect Monetary	Direct and Indirect Non-Monetary
Household	Damage to Homes Damage to contents of home (furniture, appliances)	Clean-up costs Lost income Lost days of school Temporary evacuation costs	Loss of family records and heirlooms
Commercial	Damage to commercial buildings Damage to contents (stock, furniture, equipment)	Clean-up costs Lost revenue Higher operating costs	Loss of business confidence (deterioration in investment climate)
Infrastructure	Damage to bridges and roads Damage to water and sewerage systems Damage to power and telephone lines	Costs of service disruption to water, electricity, telephone Increased operating costs Costs of demolition and debris removal Loss of income from tariffs	Reduced confidence in provision of public services (e.g. if water supply is contaminated or there are lengthy power cuts)
Health [5]	Emergency health service costs (ambulance etc.) Health treatment costs incurred by population during flooding	Health treatment costs incurred by population after flooding (e.g. physical illness, counseling)	Stress and trauma Loss of life
Education	Damage to classrooms and buildings Damage to contents (books, desks, equipment)	Clean-up costs Temporary relocation costs Loss of income from student fees Additional education service operation costs	Lost of learning opportunities

Adapted from McKenzie and others (2005)

[5] Note that no major healthcare facilities are located in the study area.

3.5.1 Household Losses

The extent of damages suffered by households will depend on the level of floodwaters, the value of the building structure, the value of its contents and the susceptibility of each to flooding[6].

3.5.1.1 Structural Damage to Homes

According to the flood maps produced for the lower Vaisigano, except certain areas during 1-in-5 year flood events, all homes in the four districts under consideration are expected to suffer from flooding, although to different degrees. Some households have constructed their homes with raised floor heights, which will reduce or eliminate damage to their homes caused by flooding.

Using data collected as part of the survey on the floor heights of homes, and predicted flood depths provided by the flood maps it was possible to estimate the extent to which each home would be flooded given the existing floor height of the house. Table provides a summary of the characteristics of homes located in the study area.

Table 9. Characteristics of homes in lower Vaisigano catchment area.

Structural characteristics of homes	Leone	Vaisigano	Matautu Uta	Vaiala Uta
Percent with floor heights:				
Less than 0.5 m	50%	33%	68%	70%
0.5 – 1 m	33%	40%	31%	20%
1 – 2 m	12.5%	26%	0	10%
More than 2 m	4%	0	0	0
Floor Area				
Average	105	218	122	125
Median	100	218	100	98
Main house				
Closed Western-style	72%	93%	96%	90%
Samoan Fale	28%	7%	4%	10%
Percent of homes constructed from wood	67%	13%	28%	50%
Percent of homes constructed from concrete block	33%	87%	72%	50%

As the table above shows, the majority of households interviewed live in enclosed western-style homes constructed of wood or concrete block, with a floor height of less than 50 cm[7]. According to the survey, the average floor area of homes in the lower Vaisigano catchment is 100 m^2. The cost of constructing an average-sized 100 m^2 home is estimated to be WST$25,000 (WST$250/m^2) for a wood home and WST$40,000 (WST$400/m^2) a concrete block home (OSM Consulting, pers. comm. 2007)

Once the flood level above floor height and building material (wood or concrete block) for each home was determined, it was then possible to estimate the structural damage to homes in monetary terms using stage-damage curves for single-story homes developed by the US Corps of Army Engineers (USACE 1995; see Figure 8). These curves are used to determine the relationship between flood height and percent damage to the structure of a home.[8]

6 In the survey, households were asked to value the losses that they suffered during the 2001 flood event, however in most cases memory lags meant that most households had difficulty recalling the exact value of these losses. As a result indirect measures were used to assess the level of damages to household buildings and their contents.

7 Due to outliers, it is likely that average floor area and floor height is overestimated in Vaisigano, since typical homes in this district are similar to the homes in the other districts included in the survey.

8 The Australian Department of Natural Resources and Mines, in their manual on assessing flood damages strongly recommends the use of locally developed stage-damage curves that represent local conditions. However, when the required information is unavailable, the use of stage-damage curves from other flood studies is recommended (Queensland Government 2002).

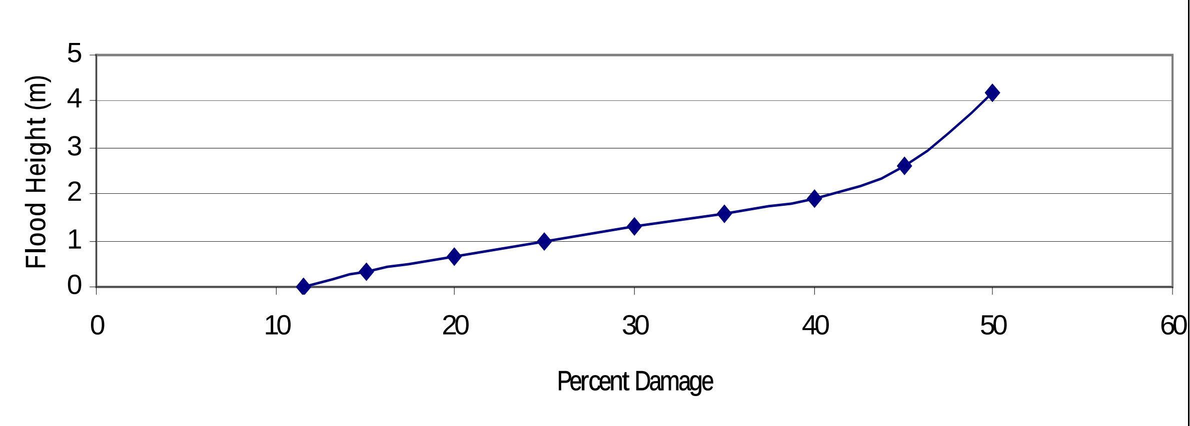


Figure 8. Stage-damage curve for a one-story home (USACE 1995).

Using this information it was possible to estimate the potential structural flood damages to homes included in the sample for 1-in-5, 1-in-20, 1-in-50 and 1-in-100 flood events. Since it was assumed that homes included in the survey were representative of the population of each district as a whole, structural damages to all homes located in the study could be estimated.[9] Table 10 through Table 13 provide a summary of the estimated structural damages to homes located in the lower Vaisigano catchment area for each of the selected flood events.

Table 10. Estimated structural damage to homes for a 1-in-5 flood event.

	Average above floor flood depth (m)	Total estimated damages for sample ($WST)	Total estimated damages for population ($WST)	Estimated damage per household ($WST)
Leone	0.1	26,350	70,618	1,054
Vaisigano	0	0	0	0
Matautu Uta	0.65	394,000.00	855,064	8,383
Vaiala Uta	0.40	9,690	28,101	969
Total	0.29	430,040	953,783	3,941

Table 11. Estimated structural damage to homes for a 1-in-20 flood event.

	Average above floor flood depth (m)	Total estimated damages for sample ($WST)	Total estimated damages for population ($WST)	Estimated flood damage per household ($WST)
Leone	0.12	38,700	103,716	1,548
Vaisigano	0.15	15,000	44,000	1,000
Matautu Uta	1.09	394,000	855,064	8,382
Vaiala Uta	0.4	35,250	102,225	3,525
Total	0.4	482,950	1,105,005	4,566

[9] Note that only damage to main homes (enclosed western-style and samoan fales) were assessed since additional buildings on household properties, usually fales used for social events or kitchen buildings, tend to be easily repaired after cyclones and flooding, and even when such buildings are washed away. They are easily replaced since scrap wood and other materials (Beca, 2006; John Tagiilima, Assistant Engineer, OSM Consulting, personal communication, 2007).

Table 12. Estimated structural damage to homes for a 1-in-50 flood event.

	Average above floor flood depth (m)	Total estimated damages for sample ($WST)	Total estimated damages for population ($WST)	Estimated damage per household ($WST)
Leone	0.39	82,050	219,894	3,282
Vaisigano	0.52	64,450	172,726	3,926
Matautu Uta	1.09	394,000.00	855,064	8,383
Vaiala Uta	0.85	59,750	173,275	5,975
Total	0.71	600,250	1,420,959	5,872

Table 13. Estimated structural damage to homes for a 1-in-100 flood event.

	Average above floor flood depth (m)	Total estimated damages for sample ($WST)	Total estimated damages for population ($WST)	Estimated damage per household ($WST)
Leone	1.06	120,350	322,538	4,814
Vaisigano	0.40	55,000	161,333	3,667
Matautu Uta	1.09	394,000	855,063	8,383
Vaiala Uta	1.07	63,000	182,700	6,300
Total	0.9	603,700	1,442,522.50	5,961

3.5.1.2 Damage to Household Contents

According to the flood maps, most households located in the lower Vaisigano catchment area are vulnerable to flooding. Unless floor heights are raised high enough, flood waters will enter homes and cause damage to contents.

The value of household contents was estimated by using information on the type of possessions that each household surveyed kept in their homes. Table 14 below presents of summary of household contents according to district.

Table 14. Percent household ownership of typical contents of homes by district.

Household Item	Household Ownership (%)			
	Leone	Vaisigano	Matautu Uta	Vaiala Uta
Television	96	100	89	100
Radio	84	100	91	100
Landline Telephone	68	87	45	20
Mobile Telephone	80	80	83	100
Computer	16	27	83	20
DVD Player	64	80	60	50
Washing Machine	32	47	21	40
Refrigerator	64	80	72	90
Stove/oven	56	93	75	70
Cabinets	32	80	70	90
Sofa	60	100	83	90
Chairs	96	100	94	90
Table	88	100	94	90
Mats	96	100	92	90
Beds and mattresses	92	93	85	90
Chest	76	93	75	70
Vehicles	56	53	51	50
Food crops	72	53	36	70

Livestock	40	33	13	50
Machinery and equipment	12	7	4	0
Other	8	13	0	0

A stage-damage curve developed by the USACE (1995) for household contents, which estimates the relationship between floodwater depths and the percentage of damage to household contents, was used to value damages to household contents in the study area during 1-in-5, 1-in-20, 1-in-50 and 1-in-100 flood events. The value of typical household contents was determined by conducting a survey of appliance, furniture and electronics prices in shops located in the central business district of Apia.[10] Damage to mobile phones, vehicles and machinery and equipment were not included in the damage assessment, either because it is assumed that households would evacuate with these items and/or because items could not be accurately priced due to the large price range of such items.

Again, using the predicted flood heights from flood maps, information on the floor heights of each home included in the survey and the stage-damage curve presented in Figure 9, the total damage to household contents caused by selected flood events was calculated.

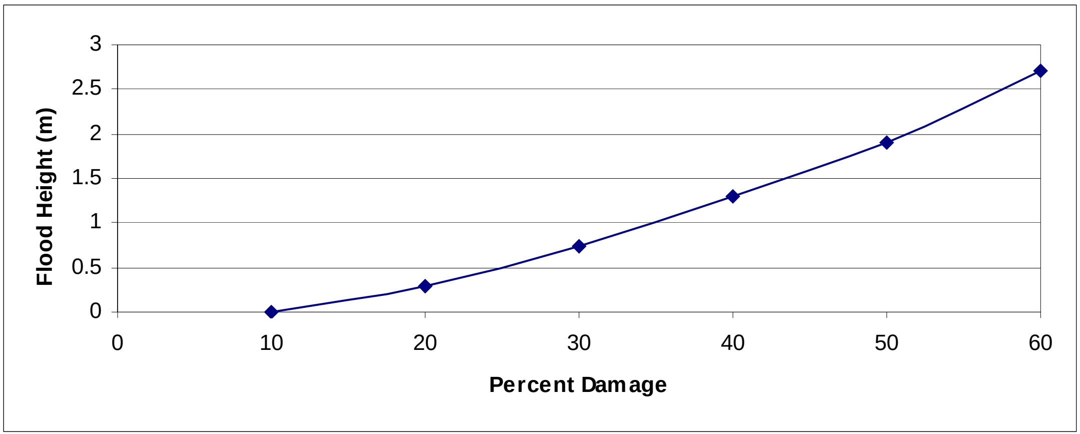


Figure 9. Stage-damage curve for household contents (USACE, 1995).

The Tables 15 to 18 provide a summary of the estimated damage to content of homes located in the lower Vaisigano catchment area for 1-in-5, 1-in-20, 1-in-50 and 1-in-100 flood events.

Table 11. Estimated damage to household contents during a 1-in-5 year flood event.

	Average above floor flood depth (m)	Total damages for Sample (WST$)	Total estimated damages for population (WST$)	Estimated contents damage per household ($WST)
Leone	0.1	26,350	22,382	334
Vaisigano	0	0	0	0
Matautu Uta	0.65	394,000	259,499	2,544
Vaiala Uta	0.40	9,690	14,168	489
Total	0.29	430,040	296,049	1,223

10 Replacement value, based on the cost of new furniture and appliances is used as a proxy for valuing household contents. This will likely overestimate the true value of household contents since depreciation over time will reduce their value.

Table 16. Estimated damage to household contents during a 1-in-20 year flood event.

	Average above floor flood depth (m)	Total estimated damages for sample ($WST)	Total estimated damages for population ($WST)	Estimated contents damage per household ($WST)
Leone	0.12	13,0801	35,056	523
Vaisigano	0.15	6,953	20,394	464
Matautu Uta	1.09	119,573	259,499	2,544
Vaiala Uta	0.4	29,786	86,378	2,979
Total	0.4	169,392	401,327	1,658

Table 17. Estimated damage to household contents during a 1-in-50 year flood event.

	Average above floor flood depth (m)	Total estimated damages for sample ($WST)	Total estimated damages for population ($WST)	Estimated contents damage per household ($WST)
Leone	0.39	26,348	70,613	1,054
Vaisigano	0.52	25,400	74,507	1,693
Matautu Uta	1.09	119,573	259,499	2,544
Vaiala Uta	0.85	26,454	7,672	265
Total	0.71	197,775	412,290	1,704

Table 18. Estimated damage to household contents during a 1-in-100 year flood event.

	Average above floor flood depth (m)	Total damages for Sample (WST$)	Total estimated damages for population (WST$)	Estimated contents damage per household ($WST)
Leone	1.06	36,536	97,916	1,461
Vaisigano	0.40	21,726	63,730	1,448
Matautu Uta	1.09	119,573	259,499	2,544
Vaiala Uta	1.07	29,786	86,378	2,979
Total	0.9	207,621	507,522	2,097

3.5.1.3 Household clean-up costs

According to the survey results, households spent an average of ten days cleaning up their homes following the major flood event in 2001, which has been estimated to be a 1-in-100 flood event (Michael Bonte-Grapentin, pers. comm. 2007). Using the methodology adopted by Gill (2003), clean-up costs per household were estimated by multiplying the number of days the households included in the survey reported cleaning up following flooding by the minimum wage in Samoa (WST$30)[11]. Total estimated clean-up costs incurred by households as a result of a 1-in-100 flood events are presented in Table 19.

Table 19. Estimated clean-up costs incurred by households during a 1-in-100 year flood event.

District	Average number of days	Total cleanup cost per household ($WST)	Total cleanup cost for district ($WST)
Leone	14.4	432	28,944
Vaisigano	10.8	324	14,256
Matutu Uta	6.7	201	20,502
Vaiala Uta	6.3	189	5,481
Total	10	287	69,183

[11] In their analysis, Gill (2003) assumes a minimum wage of WST$30/day.

Since data on clean-up costs for other flood events was unavailable, costs are estimated based on damage cost differentials for damages to household contents and structures. For example, since damages incurred during a 1-in-20 flood event are 27% lower compared with a 1-in-100 year event, clean-up costs are assumed to be lower by the same proportion.

Table 20. Estimated clean-up costs incurred by households during selected flood events.

District	Total clean-up cost for district during 1-in-5 year flood ($WST)	Total clean-up cost for district during 1-in-20 year flood ($WST)	Total clean-up cost for district during 1-in-50 year flood ($WST)
Leone	17,945	21,129	26,050
Vaisigano	0	10,407	12,830
Matutu Uta	12,711	14,966	18,452
Vaiala Uta	3,398	4,001	4,933
Total	34,055	50,504	62,265

3.5.1.4 Lost household income

The results from the household survey revealed that the average household had two family members miss four days of work as a result of the flooding in 2001. Although it is likely to significantly underestimate the true extent of lost household income, each day of work missed by each family member is valued at the minimum daily wage rate of WST$30 (Gill 2003).

Table 21. Estimated lost household income resulting from a 1-in-100-year flood.

District	Average number of working household members	Average number of days missed	Average lost household income ($WST)	Estimated total lost household income by district ($WST)
Leone	2.3	6.8	469.2	31,436
Vaisigano	1.3	5.1	198.9	8,751
Matutu Uta	2.1	3.0	189.0	19,278
Vaiala Uta	2.0	1.5	90.0	2,610
Total				62,076

Since data on lost income as a result of flooding for other flood events was unavailable, costs are estimated based on damage cost differentials for damages to household content and structures. For example, since damages incurred during a 1-in-5 flood event are 38% lower compared with a 1-in-100 year event, clean-up costs are assumed to be lower by the same proportion.

Table 22. Estimated lost household income during selected flood events.

District	Estimated total lost household income due to 1-in-5 year flood event ($WST)	Estimated total lost household income due to 1-in-20 year flood event ($WST)	Estimated total lost household income due to 1-in-50 year flood event ($WST)
Leone	19,491	22,949	28,293
Vaisigano	0	6,389	7,876
Matutu Uta	11,952	14,073	17,350
Vaiala Uta	1618.2	1,905	2,349
Total	33,061.13	45,315	55,868

3.5.2 Commercial Losses

Figure 10. Small shop in Vaisigano.

According to the Pacific Cities database, in 2001, approximately 17 businesses were located in the lower Vaisigano catchment area, mostly along the main road, which separates Leone from Matautu Uta. Average annual GDP growth in Samoa between 2001 and 2006 was approximately 4% (ADB 2005). It is therefore assumed that the business sector in the study area has grown by the same amount, meaning that approximately 21 businesses are now located in the area. However, it is important to note that businesses operating from homes would not be included in the database records (Figure 10) and therefore the analysis may underestimate total damages suffered by businesses during flood events.

In order to collect data on business assets that are vulnerable to flooding and losses suffered during past flood events, a business survey, which included 15 businesses (71% of estimated total) was conducted as part of this study. The types of businesses in the area are diverse, and include hotels, retail stores, restaurants, a bakery and a laundromat. In addition to the business survey, a separate interview was conducted with the manager of Aggie Grey's Hotel, since the large hotel complex was to known to have suffered enormous losses during previous flood events. Tables 23 to 29 provide a summary of the characteristics and impact of the 2001 floods on businesses in the lower Vaisigano catchment area.[12]

Table 23. Characteristics of businesses located in the lower Vaisigano catchment area.

Average floor area	221 m^3
Average floor height	Less than 0.5 m
Average number of employees	14
Median number of employees	7
Average value of contents	WST$519,874
Median value of contents	WST$359,516

3.5.2.1. Estimated damage to structure and contents of businesses

Estimated losses are based on figures provided by businesses in the survey for the 2001 flood event.[13] Since appropriate stage-damage curves for businesses in the study area could not be identified, the same technique used for valuing household structural and contents damages could not be used for businesses.

Table 24 provides a summary of losses suffered by businesses in 2001 (a 1-in-100 year flood event). Total structural and contents damages for a 1-in-100 year flood event are presented in Table 25.

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12 Flood damages to Aggie Grey's Hotel were not included in the analysis, since the hotel has made significant investments in order to reduce their vulnerability to flooding – including the construction of floodwalls. Installation of a pumping system, storing stock and placing the generator at above-flood water levels (Tanya Grey, Manager, Aggie Greys Hotel, personal communication, 2007).

13 Given that the 2001 flood occurred more than five years before the survey was conducted, it is likely that estimates provided are less than actual losses suffered due to memory-lags.

Table 24. Summary of estimated losses suffered by businesses during the 2001 (1-in-100) flood event.

Average daily revenue lost due to flooding	WST$5,387
Average number of days that business was interrupted	4 days
Average number of days to cleanup after flooding	3.5 days
Average value of structural damage	WST$32,419
Average value of damage to contents	WST$50,873

Table 25. Summary of estimated losses suffered by businesses during a 1-in-100 flood event.

Total estimated structural damage for all businesses ($WST)	680,794
Total estimated damage to contents for all businesses ($WST)	1,068,323
Total estimated direct business losses for a 1 in 100 flood event ($WST)	1,749,116.25

Unfortunately information on business losses for other flood events was unavailable, therefore contents and structural losses were calculated using damage cost differentials for damages to household content and infrastructure between 1-in-100 and selected flood events as in the previous section (Table 26).

Table 26. Summary of estimated losses suffered by businesses during other flood events ($WST).

	1-in-5 flood event	1-in-20 flood event	1-in-50 flood event
Structural damage to businesses ($WST)	0	510,595	633,138
Damage to contents for all businesses ($WST)	0	801,242	867,860
Total estimated direct business losses ($WST)	0	1,311,837	1,500,998

3.5.2.2. Business clean-up costs

In the survey, businesses reported that cleaning up their premises following the major flood in 2001 took an average of 3.5 days. Again, using the methodology adopted by Gill (2003), clean-up costs are obtained by multiplying the number of days spent cleaning up by the daily minimum wage of WST$30, in order to estimate clean-up costs of approximately WST$105 per business. Again, since data was unavailable for other flood events, losses were calculated using the methodology discussed above (Table 27).

Table 27. Estimated clean-up costs incurred by businesses.

Flood Event	Business Clean-up Costs ($WST)
1-in-5	0
1-in-20	2,143
1 in 50	2,620
1 in 100	2,933

3.5.2.3. Lost business revenue

Total lost revenues resulting from closure of businesses during and after a 1-in-100 flood event was based on average losses reported by businesses in the survey. On average businesses were closed for four days because of flooding, and lost an average of WST$4,050 per day. Since data was unavailable for other flood events, losses were calculated using the methodology discussed previously. Table 28 provides a summary of estimated lost revenue suffered by businesses due to flooding in the study area.

Table 28. Estimated lost revenue incurred by businesses for various flood events.

Flood Event	Lost business revenues ($WST)
1-in-5	0
1-in-20	255,150
1-in-50	303,845
1-in-100	340,200

3.5.3 Infrastructure Losses

Estimated damage to infrastructure including road (Figure 11), water and power infrastructure are based on reported inflation-adjusted damage values for the 2001 flood provided in Yeo (2001). Since infrastructure losses are reported for Apia as a whole, and not at district level, it is assumed that 25% of reported losses were felt in the lower Vaisigano catchment area, since although, it accounts for less than 25% of the total area of Apia, it is one of the areas most heavily affected by flooding. Table 29 provides a summary of estimated infrastructure losses for the lower Vaisigano catchment area.

Figure 11. Vaisigano Bridge.

Table 29. Estimated infrastructure damage for a 1-in-100 flood event.

Infrastructure Authority	Estimated Loss from Floods from 2001 flood (2006 WST$)
Public works	$365,975
Samoa Water Authority	$665,409
Electric Power Company	$66,541
Total Losses	1,097,925

Unfortunately information on infrastructure losses for other flood events was unavailable, therefore infrastructure losses were calculated using damage cost differentials for damages to household content and structures between 1-in-100 and selected flood events as in the previous section.

Table 30. Estimated infrastructure damages for selected flood events.

Infrastructure Authority	Estimated total infrastructure damages (WST$ terms)
1-in-5 year flood	0
1-in-20 year flood	802,264.21
1-in-50 year flood	980,595.94

3.5.4 Social Sector Losses: Damage to Schools and Churches

Figure 12. Secondary school that was badly affected by major flooding in 2001.

According to the 2001 Pacific Cities Database, there are four schools (Figure 12) located in the lower Vaisigano catchment area. During the 2001 flood, Yeo (2001) reported that schools incurred an average loss of WST$5,000 mainly caused by damage to books and walls. Therefore it is assumed that during a 1-in-100 flood event, total inflation-adjusted damage to the four schools would be approximately WST$26,616. Damages to schools estimated again to be 25% lower during 1-in-20 flood events, which are estimated to result in WST$19,962 in damages.

There are six churches and temples located in the lower Vaisigano catchment area. Since no damage assessments for these structures were available, it is assumed that during a 1-in-100 flood event, they would sustain the same amount of damage as schools. Therefore, based on the values provided by Yeo (2001) total inflation-adjusted damages to the six buildings are estimated to be WST$46,579 for a 1-in 100 flood event. Since data for other flood events was unavailable, social sector losses for 1-in-5, 1-in-20 and 1-in-50 year events were estimated using the methodology described above.

Table 31. Estimated flood damages to schools and churches.

Social Sector	Damages for 1-in-5 (WST$)	Damages 1-in-20 (WST$)	Damages 1-in-50 (WST$)	Damages 1-in-100 ($WST)
Education	0	19,449	23,772	26,616
Religious	0	34,035	41,601	46,579
Total	0	53,484	65,373	73,195

3.5.5 Total estimated flood losses for all sectors

Total estimated damages for all sectors for both 1-in-20 and 1-in-100 year events are presented in Table 32.

Table 32. Summary of total estimated flood losses.

Sector	1-in-5 Flood Damages	1-in-20 Flood Damages	1-in-50 Flood Damages	1-in-100 Flood Damages
Household	1,249,832	1,578,544	1,951,382	2,160,417
Business	0	1,493,797	1,807,463	2,092,250
Infrastructure	0	802,264	980,596	1097925
Social	0	53,484	65,373	73195
Total	1,249,832	3,928,090	4,804,814	5,423,787

3.5.5.1 Annual average flood damages

The annual average damage (AAD) from flooding is a common indicator used to measure the extent of potential flood damages. It expresses the costs of flood damage as a uniform annual amount based on potential damages caused by various flood events (Queensland Government 2002). The AAD is calculated as the area under the line which plots the damages for each flood event and its associated annual probability of occurrence shown in Table 33 below. Figure 13 illustrates the plot of potential damages versus annual exceedance probability.

Table 33. Annual probability and estimated damages from selected flood events.

Flood Event	Annual Probability	Estimated Damages
1-in-5	0.2	1,249,832
1-in-20	0.05	3,928,090
1-in-50	0.02	4,804,814
1-in-100	0.01	5,423,787

The annual average damage, calculated as the area under the curve, is estimated to be approximately WST$618,529. Given that extreme floods such as 1-in-200 year events, were not considered in the analysis, it is likely that the AAD calculated provides a minimum estimate of the actual figure.

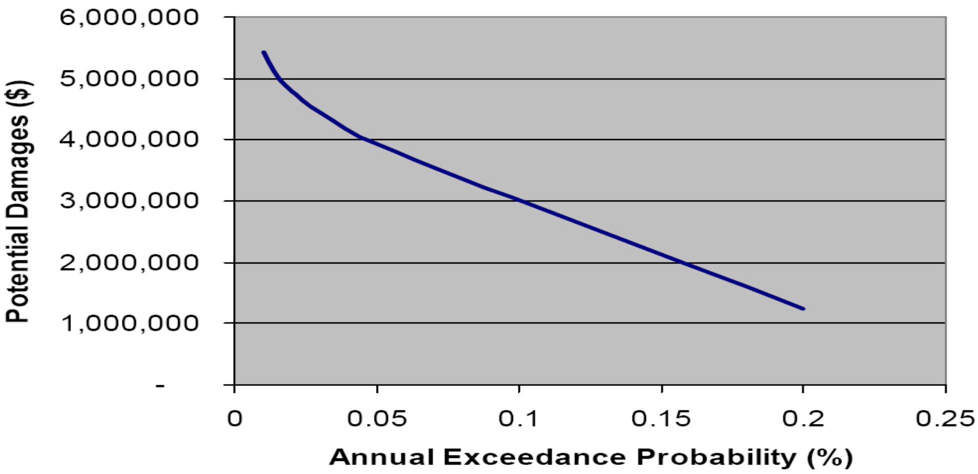


Figure 13. Plot of potential damages versus annual exceedance probability.

4. ECONOMIC ANALYSIS OF SELECTED STRUCTURAL FLOOD MANAGEMENT OPTIONS

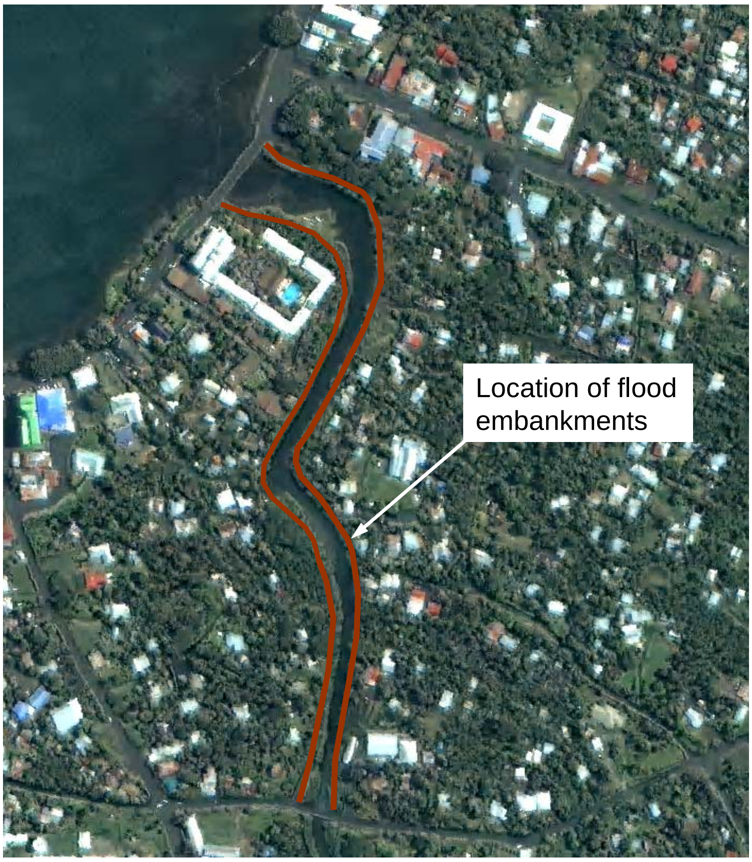
Two of the structural measures identified in the Samoa Flood Management Action Plan for reducing vulnerability to flooding in the lower Vaisigano catchment area, were proposed by stakeholders to be included in the economic analysis. These are flood walls/embankments and a flood diversion/bypass channel. This section seeks to identify and, where feasible, estimate the associated benefits, in terms of reduced flood damage, and the costs associated with each of the two structural options.

4.1 Flood Embankments/walls

One option for addressing flood risk in the lower Vaisigano catchment area is to construct flood embankments along the river. Flood embankments will act as a barrier on each side of the Vaisigano River, so that when river levels rise, areas surrounding the river will be protected from flooding. However, there is a risk that the embankments may fail if not adequately maintained or if overtopped during flood events that exceed their design standards.

4.1.1 Location and design of flood embankments

It has been proposed that embankments/walls be constructed over the entire 900 m length on each side of the river, between Vaisigano and Leone bridges, as shown in Figure 14.



Source: Pelesikoti and others 2007

Figure 14. Proposed location of flood embankments along Vaisigano River.

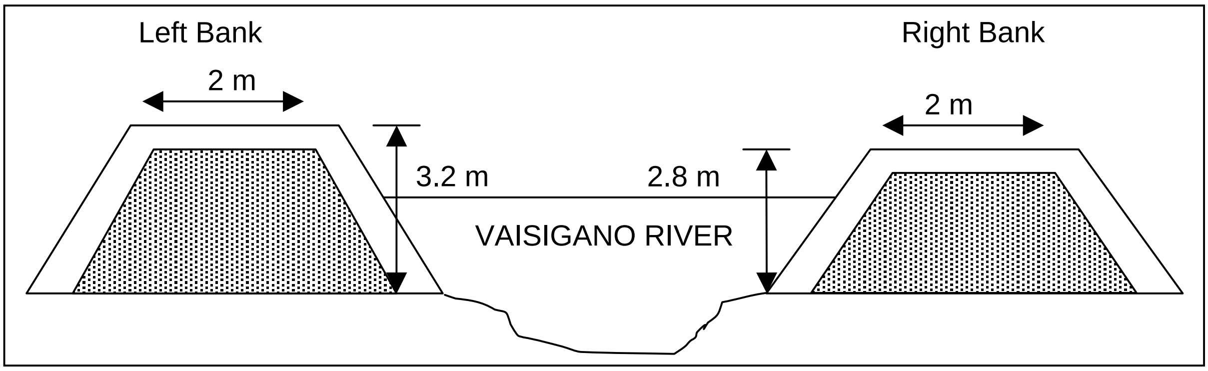
Table 34 presents the design specifications for floodwalls for different return periods.

Table 34. Summary of embankment/wall heights.

Return period (years)	Average height of the embankment (m)		Maximum height of embankment (m)	
	Left bank	Right bank	Left bank	Right bank
1-in-2	0.96	0.61	1.72	1.37
1-in-5	1.72	1.35	2.60	2.18
1-in-20	2.54	2.13	3.51	2.97
1-in-50	2.83	2.40	3.82	3.23
1-in-100	3.24	2.81	4.29	3.62

Note: There is no allowance for freeboard in these estimates
Source: Pelesikoti and others, 2007

A cross-section of the proposed floodwalls designed for a 1-in-100-year flood event included in the Samoa Flood Management Action Plan is presented in Figure 15.



Source: Pelesikoti and others, 2007

Figure 15. Cross-section of proposed floodwall for 1-in-100 year event.

4.1.2 Costs flood walls/embankments

The cost of building embankments including machinery, material and labour is estimated to be approximately WST\$500/m^3 based on the costs of constructing the Apia seawall and marina (Gary Martin, Manager, Fletcher Construction, pers. comm. 2007). In addition, annual maintenance costs are assumed to be 5% of initial embankment construction costs. The costs of floodwalls designed to protect people and property for selected flood events is presented in Table 35 below.

Table 35. Estimated costs of constructing floodwalls.

Floodwall design	Cross-section Left Bank (m^2)	Cross-section Right Bank (m^2)	Total area (length 90 m) m^3	Total Cost of Floodwall ($WST)	Annual maintenance costs (5%, $WST)
1-in-5	6.88	5.40	11,052	5,526,000	276,300
1-in-20	10.6	8.52	16,812	8,406,000	420,300
1-in-50	11.32	9.60	18,828	9,414,000	470,700
1-in-100	12.96	11.24	21,780	10,890,000	544,400

4.1.3 Benefits of Flood Walls/Embankments

Construction of flood embankments along each side of the river in the Vaisigano catchment area between Vaisigano and Leone bridges would hopefully prevent floodwaters from bursting their banks, thereby preventing damage to homes, commercial properties, schools, churches and other community facilities as well as infrastructure such as roads, power and sewerage lines.

Benefits from flood walls are measured as damages avoided from flooding, which is measured as the difference between estimated damages from flooding under current flood management regime and estimated damages from flooding if flood walls were in place.

The benefits associated with the construction of floodwalls for various flood events are estimated as the area between the line that plots damages without floodwalls and the line that plots the damages with floodwalls, for a particular floodwall design, as illustrated by Figure 16 below.

Table 36 presents the estimated benefits for each floodwall design.

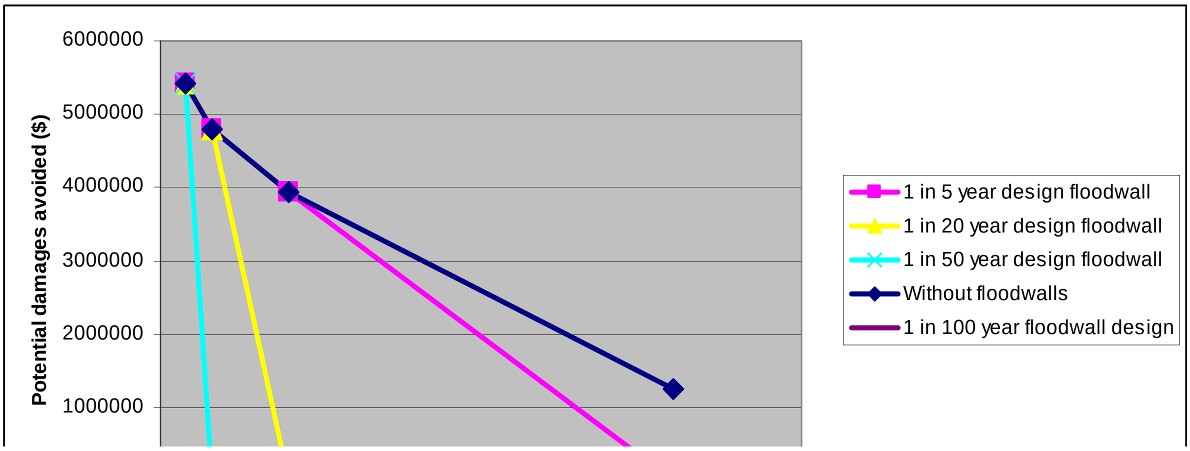


Figure 16. Plot of avoided damages from the construction of floodwalls.

Table 36. Annual average damage avoided by constructing floodwalls.

Floodwall Design	Benefits (damages avoided)
1-in-5 floodwall	93,737
1-in-20 floodwall	447,265
1-in-50 floodwall	474,384
1-in-100 floodwall	618,529

It is important to note that estimated annual benefits from floodwalls do not consider the risk of failure of floodwalls, which can occur due to a variety of reasons including inadequate maintenance. Also, when flooding exceeds the design capacity of the floodwall, flood waters can be trapped behind the walls and cause even more severe damages, than would normally occur in the absence of floodwalls.

4.1.4 Economic pay-off from investing in floodwall embankments

Benefit-cost analysis was conducted in order to assess the associated costs and benefits associated with each floodwall design option. It was assumed that while floodwalls are being constructed in the first year, benefits from flood walls are zero. The lifetime of the project is assumed to be 50 years.

The economic pay-off from investing in a 1-in-100 year design floodwalls over a 50-year period is presented in Table 37 below.

Table 37. Economic pay-off from investing in floodwalls.

Floodwall design	Discount rate	Present value of Benefits	Present value of costs	Net present value	Benefit-cost ratio
1-in-5	3%	2,411,841	12,635,134	– 10,223,304	0.19
	7%	1,293,641	9,339,146	– 8,045,506	0.14
	10%	929,385	8,265,463	– 7,336,078	0.11
1-in-20	3%	11,508,023	19,220,220	– 7,712,197	0.60
	7%	6,172,591	14,206,454	– 8,033,863	0.43
	10%	4,434,550	12,573,197	– 8,138,647	0.35
1-in-50	3%	12,205,788	21,525,000	– 9,319,212	0.57
	7%	6,546,853	15,910,011	– 9,363,158	0.41
	10%	4,703,429	14,080,903	– 9,377,474	0.33
1-in-100	3%	15,914,605	24,899,857	– 8,985,251	0.64
	7%	8,536,162	18,404,506	– 9,868,345	0.46
	10%	6,132,600	16,288,616	–10,156,016	0.38

The results from the economic analysis indicate that regardless of the discount rate used, the ratio of benefits to costs is less than one for all of the four floodwall designs.[14] However, it is important to note that in reality, the potential benefits to building both types of floodwalls could be much higher since many avoided damages such as health costs, stress and trauma, and temporary evacuation costs were not included in the analysis. It is also likely that households and businesses in nearby districts, not included in the survey, would also benefit from reduced flood damages, although to a lesser extent than those households and businesses located in the vicinity of the lower Vaisigano catchment.

4.1.5 Constraints to building floodwalls/embankments

In addition to the high cost of building, additional factors which might pose an obstacle to the construction of flood walls is the need to acquire private land along the banks of the Vaisigano for the construction of embankments. Furthermore, access roads will have to be constructed through private properties in order to transport material and equipment to the construction sites (Garry Martin, pers. comm. 2007). Therefore, landowner consent and adequate compensation for loss of land and construction of access roads must be negotiated before flood embankments could be constructed.

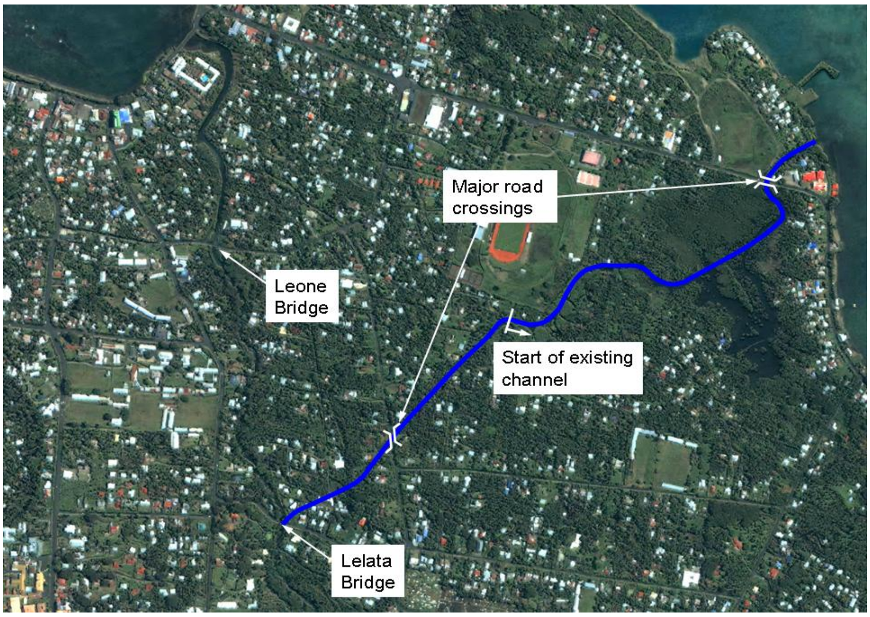
[14] Note that risk of walls failing e.g. due to poor maintenance, which would reduce the benefits, is not considered in the analysis.

4.2 Construction of by-pass/diversion channel

Another flood management measure proposed in the FMAP is the construction of a bypass or diversion channel, which would redirect a portion of flood flow away from areas at risk, and reduce flood levels along the channel downstream of the diversion off take.

4.2.1 Proposed design for by-pass/diversion channel

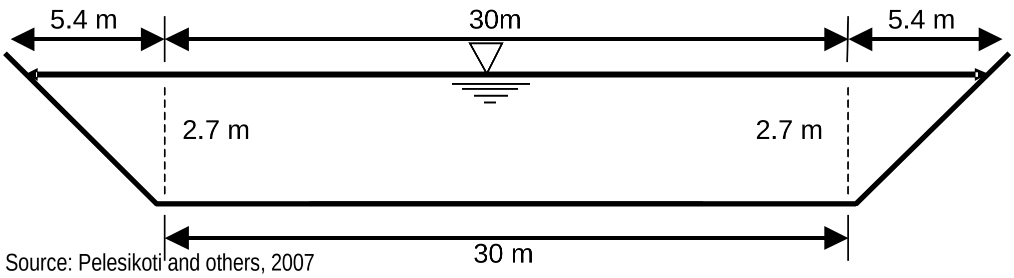
The feasibility of this option is determined by the topography of the area, ecological considerations and availability of land. A route proposed for a flood diversion channel is presented in Figure 17. The off take for the diversion channel would be located in the vicinity of Lelata Bridge. The channel would run in a north-easterly direction before joining an existing river channel to the south of the Apia Park sports stadium. The length of the channel would be between 1.5 km and 2 km depending on the route that was taken. The construction of such a channel would entail the construction of one new road crossing and the increase in capacity of another crossing on the main road to the east of the Apia Park sports stadium.



Source: Pelesikoti and others 2007

Figure 17. Proposed route for by-pass/diversion channel.

Using HEC-RAS hydrological modelling software developed by the US Army Corps of Engineers, a preliminary estimate of the size of the channel was produced as part of SOPAC's work under the EDF 8 Project. It was assumed that the channel would be trapezoidal in shape with a bed width of 30 m. A cross-section for the proposed by-pass channel for a 1-in-100 flood event is shown in Figure 18.



Source: Pelesikoti and others, 2007

Figure 18. Cross-section of the proposed by-pass channel for a 1-in-100 flood event.

Table 38 provides details of the channel's dimensions for a number of design period flood flows.

Table 38. Preliminary dimensions of a flood diversion channel for the lower Vaisigano.[15]

Return period (years)	Capacity of the channel (m^3/s)	Depth of channel (m)	Top width of channel (m)
1-in-2	74	0.9	33.6
1-in-5	183	2.0	38.0
1-in-20	318	2.1	38.4
1-in-50	370	2.4	39.6
1-in-100	450	2.7	40.8

It should be noted that in the low-lying area to the west of Apia Park stadium, flood embankments may need to be constructed along the sides of the channel to avoid the water spilling out of the channel and exacerbating flooding in this area.

4.2.2 Costs of constructing diversion channel

Constructing a diversion channel would involve digging an artificial channel through 1.5 to 2 km of land to connect the Vaisigano with an existing channel, which begins near Apia Park stadium. The cost of excavating soft sediment is estimated to be approximately WST$500/$m^3$ of soil. The cost of digging through bedrock, which is likely to be encountered under the route proposed, are significantly higher at WST$2,000/$m^3$ of excavated sediment (Gary Martin, Manager, Fletcher Construction, pers. comm. 2007).

In addition, a road crossing (bridge) would have to be constructed over the diversion channel. Based on the current costs of recent bridge constructions in Apia, the estimated cost is approximately WST$2.67 million (John Tagilima, Assistant Engineer, OSM Consulting, pers. comm. 2007). The cost of building embankment walls along the banks of the channel was not considered. In addition, based on estimates provided by Fletcher Construction Samoa, it is estimated that annual maintenance costs would be approximately 5% of initial capital costs (Garry Martin, personal communication, 2007). The life of the diversion channel is estimated to be 50 years.

Table 39 presents the minimum cost (assuming only soft sediment must be excavated) of building diversion channels designed for selected flood events.

[15] Note that the channel is assumed to be trapezoidal with 1 in 2 side slopes and a bottom width of 30 m. No allowance for freeboard has been made when estimating the depth of the channel.

Table 39. Estimated costs of constructing a by-pass channel.

By-pass Channel design	Cross-section (m^2)	Total volume (length 1500 m) m^3	Excavation costs ($WST)	Total costs (including bridge construction costs)	Annual maintenance costs (5%, $WST)
1-in-5	68.0	102,000	51,000,000	53,670,000	2,683,500
1-in-20	71.82	107,730	53,865,500	56,535,500	2,826,775
1-in-50	83.52	125,280	62,640,000	65,310,000	3,265,500
1-in-100	95.58	143,370	71,685,000	74,355,000	3,717,750

4.2.3 Benefits of constructing a by-pass/diversion channel

Benefits of constructing a 1-in-100 year design diversion channel

The construction of a diversion channel would significantly reduce flood levels by diverting floodwaters into the existing channel. This would reduce the impact of flooding on infrastructure (roads, water and sewerage systems), households and commercial businesses. It is estimated that damages associated with flood events with a 1-in-100-year return period or less could be completely avoided with the construction of a diversion channel.

Benefits are calculated as damages avoided, which is the average annual flood damages in absence of a diversion channel less average annual damages associated with flooding that occur with diversion channels designed for selected flood events in place. They are calculated by estimating the area between the line that plots damages without floodwalls and the line that plots the damages with floodwalls, for a particular diversion channel, as illustrated by Figure 19 below. Estimated benefits are presented in Table 40 below.

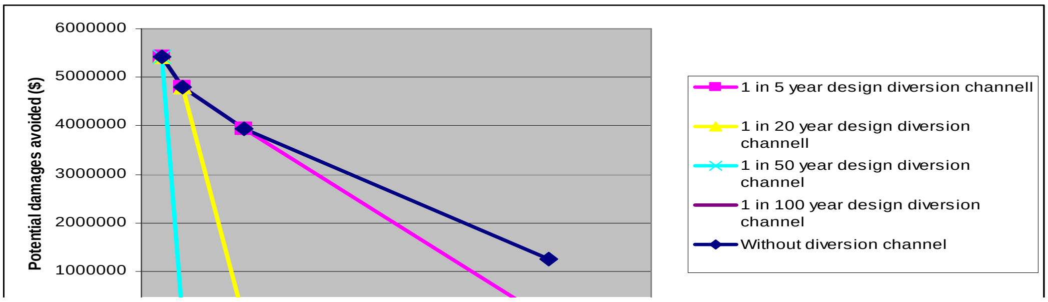


Figure 19. Plot of avoided damages from the construction of a diversion channel.

Table 40. Annual average damage avoided by constructing diversion channels.

By-pass Channel Design	Benefits (damages avoided)
1-in-5 floodwall	93,737
1-in-20 floodwall	447,265
1-in-50 floodwall	474,384
1-in-100 floodwall	618,529

4.2.4 Economic pay-off from investing in flood by-pass/diversion channel

Benefit-cost was conducted in order to evaluate the costs and benefits associated with each by-pass channel design option. A benefit-cost ratio of at least one is considered the minimum for a project to be economically viable. This is because each *tala* invested in the by-pass channel project should yield at least 1 *tala* in benefits, in terms of avoided damages from flooding. The benefit-cost analysis was done using three different discount rates in order to ensure that results were not sensitive to the choice of discount rates.

Table 41 below presents a summary of the results of the analysis for each by-pass channel design.

Table 41. Economic pay-off from investing in various design diversion channels.

Bypass Channel design	Discount rate	Present value of Benefits	Present value of costs	Net present value	Benefit-cost ratio
1-in-5	3%	2,411,831	122,715,822	-120,303,991	0.02
	7%	1,293,641	90,704,303	-89,410,662	0.01
	10%	929,385	80,276,405	-79,347,020	0.01
1-in-20	3%	11,508,023	129,267,754	-117,759,731	0.09
	7%	6,172,591	95,547,105	-89,374,514	0.06
	10%	4,434,550	84,562,450	-80,127,900	0.05
1-in-50	3%	12,205,917	149,330,544	-137,124,627	0.08
	7%	6,546,922	110,376,337	-103,829,415	0.06
	10%	4,703,479	97,686,827	-92,983,348	0.05
1-in-100	3%	15,914,600	170,011,830	-154,097,230	0.09
	7%	8,536,159	125,662,725	-117,126,565	0.07
	10%	6,132,598	111,000,000	-105,083,203	0.06

Regardless of the discount rate used, the benefit-cost ratio is less than zero for all diversion channel design options. As in the case of floodwalls, it is important to note that many benefits, in terms of avoided damages, have not been included in the analysis, such as health care costs and reduced damages for households in nearby districts. If such values were included in the analysis, the benefit-cost ratio would be higher, however it is unlikely that these benefits excluded from the analysis would be significant enough to raise benefit-cost ratios above zero.[16]

4.2.5 Constraints to building a diversion channel

Building a diversion channel would require compensation and resettlement of households located in the path of the proposed diversion channel in the lower Vaisigano catchment area. Generally, the market value of land is offered to households who own freehold land, and since customary land by definition has no market value, a complex formula is used to determine its value (Jude Kolhase (PUMA CEO) pers. comm. 2007). The negotiation partnership process between the Government and landowners can be time-consuming and costly, since often negotiations involve multiple, even absent, landowners.

[16] In particular, surrounding districts not included in the household and business surveys would benefit significantly from the construction of a diversion channel in terms of reduced flood damages. However, given the small benefit-cost ratios, it is unlikely that including avoided flood damages in these districts would raise benefits sufficiently to make the construction of a by-pass channel economically viable.

5. ECONOMIC ANALYSIS OF SELECTED NON-STRUCTURAL FLOOD MANAGEMENT OPTIONS

5.1 Improved Forecasting System

Flood forecasting, flood advisories and public awareness campaigns which raise flood awareness and preparedness must all be part of an improved and integrated system, in order for each individual measure to be successful. For example, an accurate flood forecast will not reduce flood damage unless it is accompanied by effective communication of the flood advisory to the target population and members of the public know, and are able and willing to react to the advisory.

5.1.1 Monitoring and Forecasting

Monitoring involves the early detection of weather patterns using rain gauges to monitor the magnitude and effects of storms. Forecasts, on the other hand, predict the location, magnitude and timing of flood events. These are produced once information from the rain gauges is entered into a flood forecast model. Without the ability to forecast the amount and the location of precipitation before it hits the ground, the forecast lead-time (the time between the amount and location of the precipitation is forecasted and when it actually hits the ground) is limited. In order to improve the ability to monitor and forecast floods, SOPAC, under the EDF 8 Project, conducted a capacity building workshop which provided training in the use of hydrological software HEC-HMS and hydraulic modelling software HEC-RAS, the proper application of which can be expected to reduce vulnerability to flooding in the lower Vaisigano catchment area.

However, the lead time, regardless of the model used, depends crucially on the size and topography of the basin, and the source and magnitude of flooding. Flood forecasting water levels several hours in advance is difficult in Samoa, due to steep and relatively small catchments and intense rainfall events (Pelesikoti and others 2007). As a result, floodplains can flood in a matter of hours. In the lower Vaisigano, flood events can be described as 'flash flooding', which is sudden and unexpected caused by heavy rainfall. Flash floods are difficult to forecast accurately.

It may be possible to issue flash flood warnings based on flash flood guidance estimates. These are indices of the volume of rainfall of a given duration over the Vaisigano catchment that is just enough to cause minor flooding at the downstream end of the river. These estimates can be used with the estimated or forecast precipitation to arrive at flash flood threat indices which form the basis for issuing flood warnings (Pelesikoti and others, 2007).

5.1.2 The existing flood monitoring and forecasting system in Apia

There are a number of rainfall stations in, or adjacent to the Vaisingano. However, only 2 of the 5 rainfall stations record rainfall intensity (list of gauges in Table 42), and none of the stations are telemetered. Real-time rainfall intensity is needed in order to accurately forecast floods.

Table 42. Rainfall gauges in the Vaisigano catchment.

Station	Elevation (m above mean sea level)	Period of record
Afiamulu	720	1903-07, 1947-
Alaoa Pond	260	1958-
Apia	2	1890-
Moamoa	100	1906-1908, 1913-1914, 1962-
Nafanua	150	1965-

Source: Lumbroso and others 2007

The Alaoa East gauging station is the only functioning gauging station in the Vaisigano catchment. At this station, water levels are recorded continuously using a chart and pen recorder linked to a stilling well upstream of the abandoned water supply intake which comprises a broad-crested weir which is silted up. It has been estimated that a catchment area of approximately 17.3 km^2 drains to this gauge. Flow gauging is undertaken at this station. At high flows, this station is unlikely to be by-passed. However, the stage versus discharge curve is questionable especially for estimating flood flows (Lumbroso and others 2007).

Under the current forecasting system used by the meteorological office, rainfall predictions can be produced up to 24 hours in advance, which provides sufficient time to issue flood advisories. However, higher-resolution models would assist in increasing the accuracy of these predictions (Sala Sagata Tuiafiso, Principal Scientific Officer, Meteorology Division, pers. comm. 2007).

5.1.3 Improved flood monitoring and forecasting system

In order to improve the accuracy of flood forecasts, the following measures have been proposed in the Samoa Flood Management Action Plan:

1. Installation of 3 additional telemetered automatic rainfall gauges in order to validate the flood-forecasting model and to understand the uncertainty in the forecast rainfall.
    - The cost of installing each gauge is estimated to be WST$15,000 (Michael Bonte-Grapentin, pers. comm. 2007)
    - In order to provide accurate readings, rainfall gauges require regular maintenance including: site inspection, testing of sensor performance, availability of sufficient spare parts, and trained technical personnel to carry out maintenance work. In addition, a supply of spare parts must be kept in stock, and communication costs must be covered. Annual operation and maintenance costs are therefore assumed to be 5% of initial capital costs (WST$2,250 per year).

2. Obtaining a forecast model that will more accurately forecast hourly rainfall up to six hours for the lower Vaisigano catchment area. Currently, the meteorological office is seeking funds to purchase software from the Australian Commonwealth Scientific and Research Organisation (CSIRO) at a licensing cost of US$10,000 (WST$26,300) per year (Sala Sagata Tuiafiso, Principal Scientific Officer, Meteorology Division, pers. comm. 2007). The new software would result in better resolution models, which would improve the accuracy of flood forecasts for different locations in Samoa.

3. Collection of hydrological data over a 3-year period in order to validate the existing hydrological model to determine what rainfall intensity patterns trigger flooding in the lower Vaisigano floodplain.

4. Overall improved system of data collection and storage.

5.1.4. Cost of Improved Forecasting System

Cost of purchasing and installing 3 rainfall gauges	= $45,000 ($15,000 each)
Annual rainfall gauge maintenance costs (5%)	= $2,500
Annual licensing fee CSIRO forecasting software	= WST$26,300

5.2 Flood Advisory System

Flood advisories are communicated to residents by providing information and resources necessary for floodplain occupants to take actions to reduce their vulnerability to flooding.

Timely flood advisories will give residents time to prepare for floods by lifting and removing the contents of their homes and businesses, putting up temporary flood barriers (e.g. sandbags, sealing entrances) to reduce structural damage and clean-up costs, and to evacuate, if necessary. It also gives time for emergency services to prepare for the flood event by putting into place evacuation and disaster relief (shelter, food, medicine) plans.

Also the effectiveness of flood advisories depends crucially on the quality of forecasts, since inaccurate forecasts may lead to false alarms, thereby reducing the credibility of future advisories, which residents may then decide to ignore.

Benefits of advisory systems, in terms of damages avoided, depend on the following (USACE 2001):

1) Accuracy and timeliness of forecasts.
2) Timeliness, coverage, informativeness and credibility of the advisory.
3) Reliability of forecast system to consistently give accurate, site-specific and timely flood predictions.
4) The degree and effectiveness of the response from individuals.

5.2.1 Existing Flood Advisory System

Currently flood advisories are broadcast on local TV and radio stations, and emergency services are contacted (Sala Sagato Tuiafiso, Principal Scientific Officer, Meteorology, and Filomena Nelson, Principal Disaster Management Officer, DMO, pers. comm. 2007). As a result, if flood advisory is issued at night, the likelihood of the messages reaching those at risk is very low.

During the 2001 flood that occurred on the evening of Easter Sunday, many residents interviewed as part of the household survey conducted for this study, claimed that they received no formal warning prior to flood events. This is despite the fact that TV and radio ownership exceeds 89 and 84 percent in all districts in the lower Vaisigano catchment area, respectively (see Table 43). In many cases, only when residents saw heavy rain and river levels rise, did they realise that flooding was imminent, which did not leave much time for lifting and/or removing household possessions and evacuating the area. It is evident from the statistics presented in Table 43 that media broadcasts alone are not sufficient to effectively communicate and disseminate warnings, especially at night time when TV and radios are switched off.

Table 43. Percent of households that received warning of 2001 flood and ownership of TV and radios.

	Households that received no warning (%)	Households with mobile telephones (%)	Households with televisions (%)	Households with radios (%)
Leone	60	80	96	84
Vaisigano	67	80	100	100
Mata Uta	64	83	89	92
Vaiala	50	100	100	100

5.2.2. Improved Advisory System

Additional channels of communication for disseminating flood advisories must be put into place in order to fill the gaps and ensure that the majority of the population can be reached both during the day or night.

A system can be as low-tech as ringing church bells, or as high-tech as the use of flood sirens or mobile phones, to raise the alarm. For example, the Netherlands is working with mobile phone service providers to employ mobile phone broadcasts to communicate emergency warnings via text message (Swartz 2005). Such systems have the advantage that they are inexpensive to run since they use existing network infrastructure, and they are effective, since they can reach all mobile phones in a specific geographical area regardless of the permanent address of the subscriber and without having to know the subscribers' telephone numbers. In addition, warning broadcasts are not subject to clogging during emergencies, as with regular frequencies used by mobile phone users on a day-to-day basis, since messages are sent over a different channel (Wood 2006). However, this technology is new and largely untested and as a result, the exact costs of implementing such a system are uncertain.

Given the high rate of mobile phone ownership among residents of the lower Vaisigano catchment area (see Table 43); this system offers a potentially effective way of targeting the population 24 hours a day. However, there would be a need to ensure that only designated authorities would be able to broadcast to users to avoid hoaxes, and mobile phone owners would have to be educated about this system for warnings to be credible and effective, and to ensure that their mobile phones were kept switched on at all times.

Since no alternative systems for improving the flood warning system have been proposed under the Flood Management Action Plan; for the purpose of the economic analysis, it will be assumed that the advisory system already in place is effective. In reality, however, authorities will have to work towards improving the advisory system if the benefits associated with the improved forecasting system and public awareness campaigns are to be realised.

5.3 Public Awareness and Preparedness

Even if there is sufficient lead time to disseminate advisories that reach the majority of residents, if residents do not know how to interpret advisories and/or what actions to take to protect themselves in the event of a flood, an improved forecasting system will not result in reduced flood damages.

5.3.1 Current public awareness disaster initiatives

Currently, both the National Disaster Management Office (NDMO) and the Samoa Red Cross Society hold disaster 'road shows' to educate people on how to effectively prepare and respond to disasters. NDMO has been conducting 2-3 day village-level workshops around the country at a cost of approximately WST$6,000 per village (Filomena Nelson, pers. comm. 2007). Red Cross has produced disaster posters and flood brochures at a cost of WST$15,000 and WST$10,000, respectively (Peni Mulitalo, Red Cross Society, pers. comm. 2007).

5.3.2 Need for an effective public awareness campaign on flood risks and preparedness

In order to reduce the impact of flooding, residents must be made aware of the benefits of permanent measures such as lifting floor heights or using flood-proof materials for construction and temporary measures such as lifting property and sealing entrances to buildings when a flood advisory has been issued. The household survey indicated that the households that took preventative measures against flooding were more likely to be those that had been affected by previous flood events. If residents and businesses can be informed and induced to take preventative action before a flood hits, this will result in savings through avoided damages.

Residents and business owners should be educated on flood risks and preparedness. In addition, continual reminders of flood risks will have to be issued to the public. Measures that might improve people's understanding and awareness of flood events include:

- District-level workshops which educate community members on flood risks, how to interpret warnings and actions to take in the event of flooding (evacuation procedures, protecting buildings and contents), and even to establish informal networks to ensure that all residents in a district receive flood warnings.[17]
- Television and radio advertisements at least twice a year (once right before rainy season, and once during the dry season in order to continually remind residents that flooding poses a hazard). In Samoa, the cost of running radio and TV advertisement campaigns for one month is WST$5,500 (Filomena Nelson, pers. comm. 2007).
- Brochures and posters will remind businesses and households of flood risks and actions that can be taken to reduce flood risks.
- Involvement of church organisations in raising awareness on flood risks

5.3.3 Total Cost of Public Awareness Campaign for lower Vaisigano catchment area:

Workshops in 4 districts in lower Vaisigano	= $24,000
TV and radio bulletins (2 months per year – every 6 months)	= $11,000
Posters and brochures[18]	= $5,000

It is assumed that workshops and poster/brochure campaigns are conducted during the initial implementation of the improved forecasting and advisory system, and then once every five years. In order to maintain awareness of flood risks and the importance of preparedness, television and radio bulletins would be run regularly for one month, twice a year.

5.4 Total Cost of Monitoring, Forecasting, Warning system

Residents and businesses located in the four districts in the lower Vaisigano catchment area must be educated frequently on the hazards associated with flooding. It is assumed that by broadcasting TV and radio ads twice for one month annually, and by conducting flood preparedness workshops and poster/brochure campaigns every 5 years, the public will be sufficiently educated and prepared for flood events. The breakdown of costs associated with an improved forecasting system and an effective public awareness campaign is as follows:

Initial costs of implementing flood forecasting and advisory system:

Rainfall gauge purchase and installation	= $45,000
CSIRO software licensing	= $26,300
Public awareness workshops	= $24,000
Posters and brochures	= $2,500
TV and radio bulletins	= $11,000
TOTAL	**= WST$108,800**

17 This could also include educational activities such as community theatre productions

18 This figure is based on the assumption that 10% of the volume of posters and brochures produced during the Red Cross National campaign will be produced for the four districts located in the lower Vaisigano. Although residents account for significantly less than 1/10 of the population of Samoa, it will be assumed that a higher proportion of residents and businesses will be targeted by the campaign.

Annual costs of flood forecasting and advisory system:

Rainfall gauge maintenance	= $2,250
CSIRO software licensing	= $26,300
TV and radio bulletins	= $11,000
TOTAL	**= WST$39,550**

Additional public awareness costs incurred every 5 years:

Public awareness workshops	= $24,000
Posters and brochures	= $2,500
TOTAL	**= WST$26,500**

5.5 Benefits (Damages Avoided) associated with Improved System

It is assumed that the greatest benefits associated with early communication of flood warnings and public awareness are protection of human life and property. Other benefits include the collection historic rainfall and streamflow data, use of the data in hydrology models, and increased understanding of the hydrology of the area, all of which aids in decision-making and planning.

However, as mentioned previously, benefits will not be realized if any one of the components of the system is not functioning adequately. Also, there is a great deal of uncertainty over how well any one component will operate e.g. a person may not be willing to take action even if this person receives an early flood warning and knows what action to take in order to reduce their vulnerability.

According to the USACE, a basic tool that can be used to assess the benefits of a forecasting and warning system is the lead time-damages prevented function, developed by Harold Day in 1970 shown in Figure 20 (USACE, 2001). It can be used to determine the physical amount of damage that can be avoided and prevented within a given amount of time. For example, according to the Day Curve, if forecasts are available six hours in advance, damages can be reduced by approximately 13%. For example, damages can be avoided since the contents of homes and businesses can be shifted or removed, temporary structures can be erected to protect homes and buildings, and residents can be evacuated.[19]

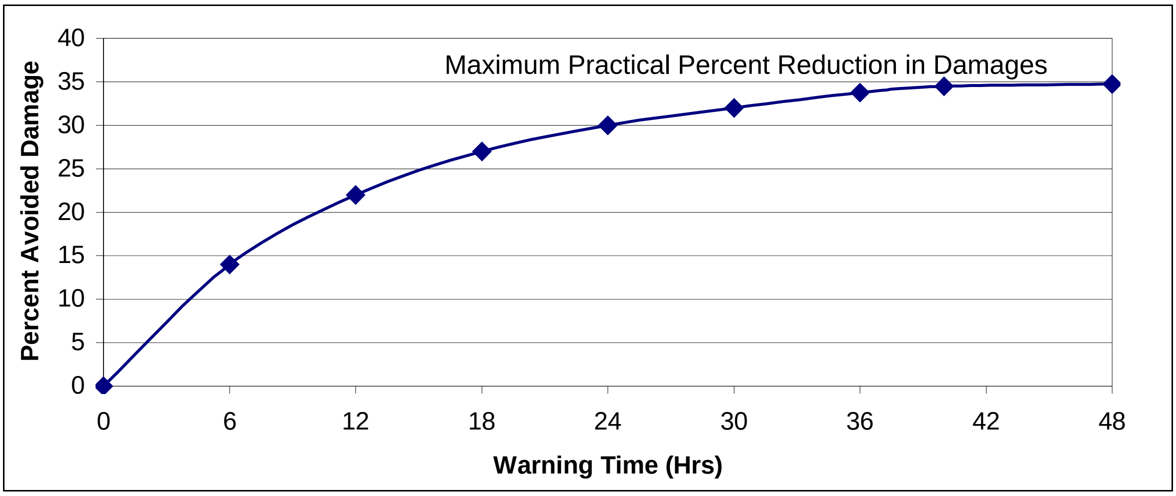


Figure 20. Day Lead time – Damages Prevented Curve (Day 1970).

[19] However, there are limits to Day's model. First, it does not take water depths into account. It can be argued the higher the depth, the greater the effectiveness of flood warning. Also it assumes 100% awareness and compliance with flood warnings, which is generally not the case.

Other studies, such as Chatterton and Farrell (1977) discussed in Carsell and others (2004) have produced a table of household contents that can be protected with different lead times presented in Table 44 below.

Table 44. Chatterton and Farrell (1977) estimated damage avoided with various flood warning times.

½ Hour Warning	2 Hours Warning	4 Hours Warning	> 4 Hours Warning
Colour television (console) Colour television (portable) Stereo equipment Small electric appliances Vacuum cleaner Personal effects	Large appliances such as microwaves, toaster ovens, items in cupboards Expensive clothing Curtains and drapery Vehicles Additional personal effects	Largest appliances such as refrigerator Tables, chairs and other furniture Food Some carpet Additional clothing and personal effects	Appliances such as oven, freezer, washer, kitchen utensils Air conditioners Piano Dressers Beds Linoleum/times

5.5.1 Damages without improved forecasting and flood advisory system

If an improved forecasting and warning system is not implemented and the current system remains, the expected average annual damages from flooding, as outlined in Chapter 3, are estimated to be approximately WST$618,529.

5.5.2 Damages with improved forecasting and flood advisory system

For the lower Vaisigano catchment area, based on information contained in the Samoa Flood Management Action Plan, an improved forecast system could result in accurate flood forecasts six hours before actual flooding occurs. Assuming that it would take approximately two hours to analyse and disseminate advisories, this would leave four hours for households and businesses to respond. Table 45 below lists the ways in which damages can be avoided with increased flood lead times.

Table 45. Damages avoided with increased flood lead time.

Direct	Indirect	Direct/indirect intangible
▪ Reduced damage to contents of homes, businesses, schools and churches ▪ Reduced structural damages e.g. use of sandbags to protect buildings ▪ Lower emergency response costs e.g. lower evacuation costs ▪ Reduced incidence of sickness/injury during flooding e.g. taking more care to avoid strain when lifting/removing items	▪ Reduced clean-up costs ▪ Reduced days of business closure ▪ Fewer days lost of work/school ▪ Reduced incidence of sickness/injury after flooding (e.g. time to store clean drinking water)	▪ Lower trauma and stress ▪ Lower loss of business confidence

With at least four hours of warning, the Day curve predicts that 10% of all physical damages (to structures and contents) could be avoided as shown in Figure 20, while Chatterton and Farrell (1977) assume most household contents could be saved from flood damage as shown in Table 44. For the purposes of the economic analysis, it is assumed that no structural damage can be prevented, while 50% of damages to business and household contents can be avoided with four hours of warning. Since residents and business owners have four hours to prepare and lift and remove the contents of their homes and businesses, it is assumed that clean-up costs and lost income will be 50% lower.[20]

***Table 46**. Estimated damage avoided from flooding.*

Flood Event	Annual Probability	Damages without improved systems	Damages with improved systems	Estimated Damages Avoided
1-in-5	0.2	1,249,832	1,135,365	114,467
1-in-20	0.05	3,928,090	3,315,646	612,444
1-in-50	0.02	4,804,814	3,952,440	852,374
1-in-100	0.01	5,423,787	4,280,583	1,143,205

The benefits from investing in the improved forecasting system can be estimated as the difference in the area under the annual average damage without improvements to the system curve and the annual average damage with improvements to the system curve. These curves are plotted in Figure 21.

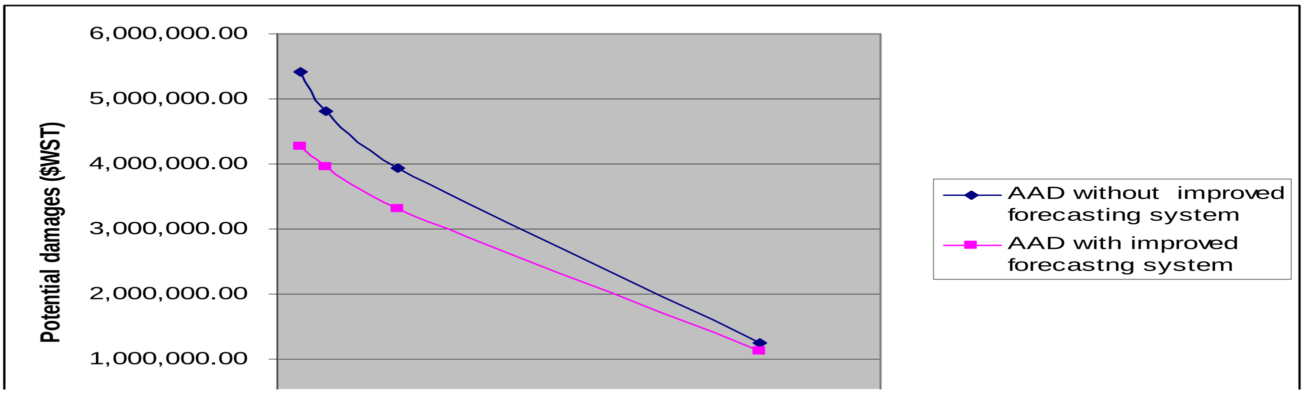


Figure 21. Plot of avoided damages from improved flood forecasting system.

Total benefits are estimated to be WST$94,992 per year in terms of avoided damages suffered by businesses and households in the lower Vaisigano catchment area.

20 For example, if damages to business stocks and furniture are avoided, trading will begin again sooner and employees will be able to go back to work earlier. Similarly, if residents lift or move carpets and furniture to safety, they will have to spend less time cleaning these items after flooding, and as a result can return to work sooner.

5.6. Economic Pay-off Associated with Improved Forecasting System

Benefit-cost analysis was conducted in order to assess the costs and benefits of improving the flood forecasting and warning system currently in place. It is assumed that no benefits will be realized until the second year, when all components of the system are in place (i.e. rainfall gauges, software, public awareness campaigns have been conducted).The timeframe of the analysis is 30 years, which is the expected life of a typical rain gauge (Michael Bonte-Grapentin, personal communication, 2007). The results are presented in Table 47 below.

Table 47. Benefit-cost analysis indicators.

Indicator	Discount Rate		
	3%	7%	10%
Present value of benefits	1,861,888	1,178,762	895,483
Present value of costs	970,913	653,279	521,035
Net present value	890,975	525,483	374,448
Benefit-cost ratio	1.92	1.80	1.72

The results from the analysis indicate that, regardless of the discount rate used, the benefits of the improved forecasting and warning system outweigh the costs. In the worst-case scenario (using discount rate of 10%), for each *tala* invested in the system, WST$1.72 is avoided in future flood damages. Since additional benefits such as avoided health-care costs, stress and trauma have not been included in the analysis, it is likely that the benefits from the improved forecasting and warning system have been underestimated, which will result in a lower benefit-cost ratios.

In reality, a substantial part of the benefits from the improved system will not be captured by residents and businesses in the lower Vaisigano catchment area since benefits will spill over (produce positive externalities) into other communities, and are therefore not captured in the economic analysis. For example, TV and radio bulletins could also be expected to reduce flood vulnerability in other communities by raising awareness about flooding and improving flood preparedness. In addition, the new software package can be used to improve forecasting for rainfall events in different locations across the country. Also, the installation of rainfall gauges could be expected to assist in improving data available on rainfall, which, for example, can assist EPC in planning decisions regarding its hydro-power stations.

Therefore, it is important for the national Government to step in and invest in such the system, since there would be no incentive to do so, on the part of local government or community members, since they cannot capture all of the benefits from the improved system.

5.6.1 Sensitivity Analysis

Not all households receive flood warnings

The above analysis assumes that all households and businesses in the lower Vaisigano catchment area will receive and act upon flood advisories by taking appropriate actions to lift or remove the contents of their homes. In reality, no matter how good the system, there may always be a small portion of the population who choose not to, or cannot, take action. For example, households may be out of town or may not know how to interpret floods, or disabled/elderly residents may not be physically capable of taking action.[21] In order to take such factors into account, the economic analysis was conducted again, and it was assumed that only 80% total estimated avoided damages are realised, since certain households and businesses will not receive flood advisories or act accordingly. The results are presented in Table 48.

[21] In Samoa, this portion of the population is assumed to be relatively small, since households tend to be large – as a result elderly and disabled residents are more likely to live with other family members, and there is a greater chance that at least one family member is likely to be home to react to flood warnings.

Table 48. Benefit-cost analysis indicators assuming 80% compliance with flood warnings.

Indicator	Discount Rate		
	3%	7%	10%
Present value of benefits	1,489,511	943,009.35	716,386
Present value of costs	970,913	653,279	521,035
Net present value	518,597	289,731	195,352
Benefit-cost ratio	1.53	1.44	1.37

The results from the benefit-cost analysis indicate that in all cases, regardless of the discount rate used, the benefits of an improved forecasting system are greater than the associated costs, even if a small proportion of households and businesses do not receive flood advisories. However, as mentioned above, many of the benefits from the improved system either have not been captured in the analysis (e.g. avoided trauma and health-care costs) or will spill into other communities and therefore, are likely to be much higher than the level calculated in the analysis for the lower Vaisigano catchment area only.

Economic pay-off from improved forecasting system and public awareness campaigns if current flood advisory system is not improved

Since flood warnings are currently disseminated via radio and television and emergency services such as the police, it is likely that a large segment of the population of the lower Vaisigano catchment area will not receive adequate warning in the event of a flood, especially if the warnings are issued during the night.

In order to estimate the economic pay-off from investing in an improved forecasting system and public awareness campaigns in the absence of an improved flood advisory system, a benefit-cost analysis was conducted assuming that total estimated benefits, in terms of avoided damages from flooding, are reduced by 50%, since many households and business are expected not to evacuate or lift/remove the contents of their businesses and homes.

Table 49. Benefit-cost analysis indicators assuming the current warning system is not improved.

Indicator	Discount Rate		
	3%	7%	10%
Present value of benefits	930944	589,381	447,742
Present value of costs	970,913	653,279	521,035
Net present value	– 39,969	– 3,898	– 73,293
Benefit-cost ratio	0.96	0.90	0.86

The results from the analysis indicate that in the absence of an improved flood advisory system, the costs of investing in an improved forecasting system and public awareness campaigns outweigh the benefits. However, it is important to note that many of the non-monetary benefits are not captured in the analysis, and are therefore likely to be underestimated. Therefore, the analysis demonstrates that the benefits from an improved forecasting system and public awareness campaigns can be significantly increased if an effective warning system is put into place.

5.7 Flood Proofing Buildings (Raising Floor Height)

One of the most effective means of reducing damages associated with flooding is to raise the floor height of buildings (raised concrete slab, stilts), (see Figure 22 and 24). The area below is left open to allow floodwaters to flow under the building, which ensures that there is little structural damage to the building or its contents.

Already, a small number of homes located in the lower Vaisigano catchment area have been constructed with raised floor heights in order to reduce the damage associated with flooding (see Table 50).

Figure 22. A raised threshold prevents damage from minor flooding.

Figure 23. Living space of home is elevated well above ground level.

5.7.1 Benefits of Elevated Floor Heights

Flood proofing homes and buildings by raising the floor height above expected floodwater depths reduces the impact of flooding by reducing structural damage to a building and its contents. However, when floodwaters exceed 1 m, evacuation will still be necessary to protect lives (Pelesikoti and others 2007). This also results in less business interruption and lower clean-up costs. Therefore, for the purposes of the economic analysis, it is assumed that raised floor height reduces potential household losses from flooding to zero. The benefit for a particular household are estimated as the difference in the area between the plot of annual average damages without a raised floor and the plot of the annual average damages with a raised floor, as illustrated by Figure 24. Benefits, as measured by the area between the two curves, are estimated to be WST$1,132 per household per year.

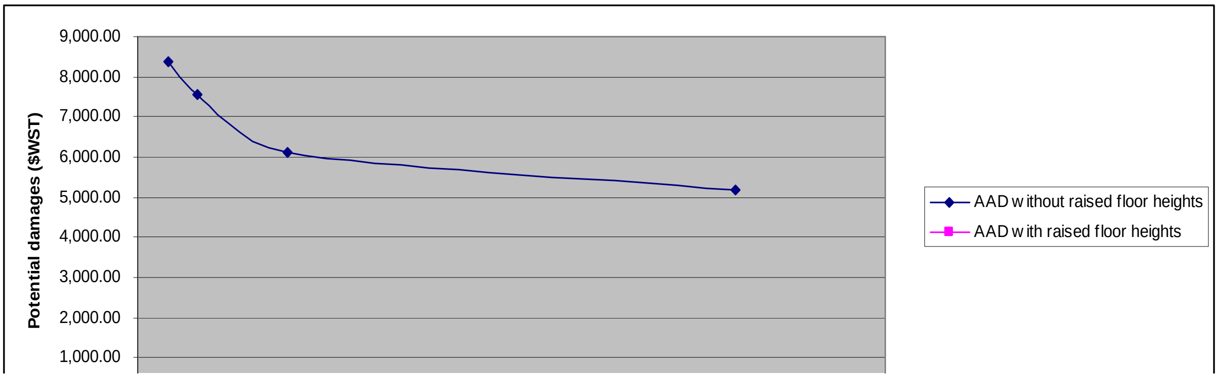


Figure 24. Plot of avoided damages from raising the floor height of a home.

5.7.2 Costs of Elevated Floor Heights

The cost of flood proofing varies with the type of structure and the height to which it is raised (USACE, 1995; Williams, 1978). Generally the costs of flood proofing are less expensive for new versus existing buildings since requirements can be introduced during the planning and design stages. The process of raising the floor height of an existing building involves jacking it up, and setting it on cribbing, while a new foundation is built underneath. Foundation walls are raised to the required protection level, and the house is lowered on to the new foundation (USACE, 2001).

General cost guidelines for elevated floor heights for various types of buildings are provided by Williams (1978) and are presented in Table 50 below. [22]

Table 50. Cost of raising floor heights for various structures.

Type of Structure	Area (m^2)	Cost of Raising Flood Height (% of Total Construction Cost)	
		New	Existing
Single Family	<150	2-12	11-50
Commercial/retail	<2080	6-16	Variable
Multi-story	<5750	2-4	2-4
Industrial	<8400	3-7	3-<7

Lighter wood-frame buildings are generally less expensive to raise than masonry structures. Also, the larger the building and the higher it is raised, the higher the costs. Further, the higher the floor height, the greater the cost. For example, once homes are raised over two meters, construction

[22] It is assumed that these cost estimates are still valid, since although building costs will have increased since 1978, it is assumed that percentage of costs attributed to elevating the floor heights of various structures will remain approximately the same.

cranes must be used to lift homes, which raises costs (Vijay Goundar (Engineer, JS Hill Construction) pers. comm. 2007).

In addition, it is important to note that raising homes on stilts is the preferred option compared with raised concrete foundations. This is because raised floor levels can reduce the amount of available flood plain storage as water which would otherwise flood buildings is now unable to do so. This problem can be avoided by building homes on stilts.

5.8 Economic pay-off from raising floor heights of residential homes

Given the large cost range associated with elevating the heights of new and existing homes, the economic pay-off for investing in these measures is calculated for the minimum, maximum and middle-cost ranges. These costs are presented in Table 51 below.

Table 51. Cost range of elevating the floor heights of new and existing homes.

Type of Structure	Value	Cost of raising floor height of new home (WST$)			Cost of raising floor height of existing home ($WST)		
		Minimum	Middle	Maximum	Minimum	Middle	Maxium
		2%	7%	12%	11%	31%	50%
Wooden House	25,000	500	1,750	3,000	2,750	7,625	12,500
Cement Block House	40,000	800	2,800	4,800	4,400	12,200	20,000

A benefit-cost analysis of raising floor heights of homes in the lower Vaisigano catchment area was then conducted for using minimum, maximum and middle-cost estimates, using varying discount rates. The timeframe for the analysis is 30 years, the assumed life of a typical home in the lower Vaisigano catchment area. The results are presented in Table 52 below.

Table 52. Economic pay-off from investing in elevated floor heights in residential homes.

Type of Structure	Discount rate	Elevated Floor Height for New Home			Elevated Floor Height for Existing Home		
		Benefit-Cost Ratio			Benefit-Cost Ratio		
		2%	7%	12%	11%	31%	50%
Wooden House	3%	44.38	12.68	7.34	8.07	2.91	1.78
	7%	28.10	8.03	4.68	5.11	1.84	1.12
	10%	21.34	6.10	3.56	3.88	1.39	0.85
Cement Block House	3%	27.74	7.93	4.62	5.04	1.82	1.11
	7%	17.56	5.01	2.92	3.19	1.15	0.70
	10%	13.34	3.81	2.22	2.43	0.87	0.53

The benefit-cost ratios for raising the floor height of new homes are greater than one for all discount rates and for the entire range of building costs. The pay-off from investing in elevated floor heights is largest for wooden homes, given that building costs are lower, since materials can be supplied locally. On the other hand, all cement is imported into Samoa, so building costs are higher (John Tagiilima, Assistant Engineer, OSM Consulting, pers. comm. 2007).

For existing wood homes, the benefit-cost ratios are also estimated to be greater than one in all cases, except the highest-cost scenario, when the cost of raising floor heights accounts for 50% of the total home construction costs. For existing cement homes, the economic pay-off is less clear cut, with positive benefit-cost ratios estimated in just over half of all estimates, when a low discount rate is used and/or low-end buildings costs are assumed.

Therefore, the results from the economic analysis indicate that measures which encourage households to construct new homes with elevated floor heights, particularly with wooden homes, in the lower Vaisigano catchment area would be desirable from an economic perspective since it would yield large savings in terms of damages avoided from future flood events.

5.8.1 Realising benefits

According to the "Draft Guidelines for the Development of Land Adjoining Rivers, Streams and on Flood Prone Land and Priority Actions for Mitigating Drainage Impacts in the Catchments of Urban Apia" produced by PUMA and MNRE in 2006 – for applications for the construction of new buildings in floodplains to be approved – habitable floor rooms in any development are to have floor levels 300 millimeters above the estimated flood level resulting from a 1-in-100-year flood (Pelesikoti and others 2007). Currently, new developments are approved by PUMA on a case-by-case basis, however, compliance and enforcement of building standards is weak (Jude Kohlhase (PUMA CEO) pers. comm. 2007). Therefore additional measures to ensure that residents construct new homes with elevated floor heights are required, these could include:

Command-and-control measures

- Zoning regulations which specify minimum flood proofing requirements for new homes could be developed in order to ensure that homes located in the floodplain are built with raised floor heights. However, such measures would have to be strictly enforced i.e. employment of sufficient number of compliance officers, combined with greater penalties for failure to comply with regulations.

Voluntary measures

- Awareness campaigns which educate the public on why flood proofing measures are cost-effective in the long run, even if it involves higher up-front costs. Greater awareness could result in more willingness to construct new homes with elevated floor heights

Market mechanisms

- Subsidies (grants, low-interest loans) or tax rebates could assist in inducing capital-constrained residents to design higher-cost homes with elevated floor heights, which will result in long-term savings, despite higher up-front costs. Often low-income households have a high discount rate, i.e. they discount the value of future savings very heavily, since income today tends to be scarce – so even if residents are aware of benefits of flood proofing, they may not invest in such measures due to limited income available for home construction. Also, if raised floor heights reduce the likelihood that residents will have to be evacuated and temporarily housed during flood events, providing subsidies will also result in long-term Government savings.

Private sector participation

- Insurance companies could require that homes have a specific minimum floor height in order to receive compensation following floods. Already, many of the insurance companies in Apia require that businesses located in the central business district store and display goods at least 30 cm off the ground (Daryl Williamson, pers. comm. 2007). However, the effectiveness of such a measure would be limited by the fact that few households in the lower Vaisigano catchment area have flood insurance (according to the household survey results).

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

It is clear that frequent flood events have a significant direct and indirect economic impact on residents and business owners in the lower Vaisigano catchment area. The Samoa Flood Management Action Plan developed under the EDF Project has proposed a series of measures to address flooding and reduce associated flood damages, including the construction of floodwalls and a diversion channel, as well as improvement of the flood forecasting system and flood proofing of buildings.

The economic analysis conducted as part of the study assessed the economic feasibility of each of the options listed above for addressing flood risk in the lower Vaisigano catchment area. The analysis revealed that structural flood measures including floodwalls and a diversion channel were not economically viable options for the study area. This is because the costs of building and maintaining such structures are significantly higher than the benefits yielded in terms of damages avoided from flooding. Also, time-consuming and costly negotiations with landowners would reduce the viability of this option.

On the other hand, non-structural measures included an improved forecasting system (combined with an improved flood advisory system and public awareness campaigns) and flood proofing of new residential homes were found to be economically feasible options, since every *tala* invested in these measures were found to yield more than one *tala* in avoided future flood damages. Flood proofing of new homes yielded the most significant benefits since in the best-case scenario, every dollar invested in raising floor heights would result in WST$44 *tala* in avoided flood damages, and in the worse-case scenario, WST$2 in damages would be avoided. However, for benefits from an improved forecasting system to be realised, it is important to ensure that the flood advisory system is functioning well, so that flood alerts can be effectively communicated to residents in the lower Vaisigano catchment area. Also, for flood proofing measures to be effective, residents must be aware of the benefits or have incentives to design new homes with elevated floor heights above 1-in-100-year floodwater levels. Ideally, since flood proofing will only reduce the vulnerability of households that build new homes with elevated floor heights, an improved flood forecasting system can simultaneously reduce the vulnerability (although to a lesser extent) of the remaining households in the area.

6.2 Recommendations

Therefore, it is recommended that the following measures be considered in order to address the flood risk in the lower Vaisigano catchment area:

1) Implement the proposed improved forecasting system combined with an effective flood advisory system and public awareness campaigns.

2) Provide incentives for residents to design new homes with elevated floor heights through appropriate measures, which might include one or a combination of the following measures:
    - Education campaigns to educate the public on the long-term benefits of flood proofing measures.
    - Stricter enforcement of zoning regulations.
    - Grants, tax rebates, or low-interest loans.

REFERENCES

Asia Development Bank (ADB) 2003. Report of the President to the Board of Directors on a Proposed Loan and Technical Assistance Grant to the Independent State of Samoa for the Sanitation and Drainage Project, November 2003.

ADB. 2005. Economic Outlook. Asian Development Bank, Manila. http://www.adb.org/documents/books/ADO/2005/default.asp

Apia Management Services (AMS) Ltd. 2001. Flood Study of the Occurrence of 15-16 April 2001 Flooding Areas of the Apia Township. Report prepared for the Department of Public Works, Government of Samoa.

BECA International Consultants Ltd. 2006. Disaster Insurance for Samoa. Report prepared for the Ministry of Natural Resources, Environment and Meteorology, Samoa.

Carsell, K.M., Pingel, N.D., and Ford, D.T. 2004. “Quantifying the Benefit of a Flood Warning System”. *Natural Hazards Review.* Volume 5, Number 3. pp. 131-140.

Chatterton, J.B. and Farrell, S.J. 1977. “Nottingham Flood Warning Scheme: Benefit Assessment” Report prepared for Severn-Trent Water Authority, Middlesex, U.K.

Day, H.J. 1970. “Flood Warning Benefit Evaluation – Susquehana River Basin (urban residences)” ESSA Technical Memorandum WBTM Hydro-10, National Weather Service, Silver Spring, Maryland.

Holland, P. (in prep). An Economic Analysis of Flood Warning in Navua, Fiji. SOPAC Technical Report xx. Suva, SOPAC Secretariat.

Gill, Ian 2003. ‘Capital Clean-up’ ADB Review, Sept.-Oct. 2003, pp16-17.

Jones, P. 2002. Growing Pacific Towns and Cities: Urban Management as a Tool to Improve Urban Services – the Recent Experience of Samoa. Pacific Economic Cooperation Council, Report prepared for Sustainable Cities Taskforce Seminar 4th and 5th November 2002, Noumea.

Lumbroso, D., Titimaea, A., Penia, A., Bonte-Grapetin, M. 2007. 13th July – 3rd August, 2006 WS 3.5.4 Capacity Building in Flood Risk Management. EU-EDF8 SOPAC Project Report 69 – in press.

McKenzie, E., Prasad, B., M. and Kaloumaira, A. 2005, Economic Impact of Natural Disasters on Development in the Pacific – Volume 1: Research Report, SOPAC/USP/AusAID.

Pelesikoti, N., Lumbroso, D, Bonte-Grapentin, M and, Biukoto, L. 2007. Samoa Flood Management Action Plan 2007-20012 with Specific Reference to the Vaisigano River. EU-EDF 8 SOPAC Project Report 69 – in press.

Queensland Government. 2002. Guidance of the Assessment of the Tangible Flood Damages. Natural Resources and Mines. Bulletin. Natural Resources and Mines.

Riddell, K. and Green, C. 1999. Flood and Coastal Defense Project Appraisal Guide: Economic Appraisal. Report prepared for the Ministry of Agriculture, Fisheries and Food, UK.

SOPAC 2001. “Pacific Cities Database” Pacific Cities Project. Suva, SOPAC Secretariat.

Statistics Department. 2007. "Tuisigaigoa O Tagata Ma Fale 2006". (Population Census 2006) Government of Samoa.

Swartz, J. 2005. "Text Messaging – a tool for disaster warning?" International Herald Tribune website, 05 January. http://www.iht.com/articles/2005/01/04/business/text.php

Terry, J.P. and Kostaschuk, R.A. 2004. Extreme river behaviour in the Pacific Islands – case studies from Samoa and Fiji. Proceedings of the Asia Pacific Association of Hydrology and Water Resources, 2nd Annual Conference, 5-8 July 2004, Singapore.

Taule'alo, T. 2002. Planning for Sustainable Drainage and Sewerage Services in Apia. Pacific Economic Cooperation Council, Report prepared for Sustainable Cities Taskforce Seminar 4th and 5th November 2002, Noumea

USACE 1995. Flood Proofing, How to Evaluate your Options? National Flood Proofing Committee Report. http://www.usace.army.mil/cw/cecw-p/NFPC/fphow/ace8toc.htm

USACE. 2001. Non-Structural Flood Damage Reduction within the Corps of Engineers: What Districts are Doing. National Flood Proofing Committee report. http://www.usace.army.mil/cw/cecw-p/NFPC/Nsfdr/NSFDR_Report.pdf

Williams, G.P. 1978. "Flood Proofing: A Component of Flood Damage Reduction" Report Prepared by J. F. MacLaren Ltd., for Department of Fisheries and Environment, Gatineau, Canada.

Wood, M. 2006. Cellalert Technical Overview. 23 February. Document posted on the Cellular Emergency Alert Service Association website. http://www.ceasa-int.org

Yeo. 2001. A Review of Flooding in Apia, April 2001. SOPAC Technical Report 338. Suva.

APPENDIX 1

List of People Who Provided Information for Study

Mulipola Ausetalia, CEO, Meteorological Division

Tanya Grey, Aggie Grey Hotel

Sulumalo Amataga Penaia, ACEO, WRD/MNREM

Ludo Prins, WaSSP, Ministry of Finance

Vijay Goundar, J S Hill Construction (Fiji)

Jude Kohlhase, CEO, PUMA

Latu Kuper, Managing Director, KEW Consulting

Siosina Lui, Country Intern, EDF8/MNREM

Gary Martin, Manager Samoa, Fletcher Construction Samoa

Peni Mulitalo, Samoa Red Cross

Nadia Meredith, WaSSP, Ministry of Finance

Filomena Nelson, Principal Disaster Management Officer, DMO/MNREM

John Tagiilima, Assistant Engineer, OSM Consulting

Sala Sagato Tuiafiso, Principal Scientific officer, MET/MNREM

Darryl Williamson, Managing Director, National Pacific Insurance

APPENDIX 2

Flood Projects in Apia

ADB Sanitation and Drainage Project

In addition, to the project activities being carried out under the EDF by SOPAC, the ADB Apia Sanitation and Drainage Project commenced in February 2006 and is expected to end by December 2008. A key objective is to reduce the frequency of flooding in specific low lying areas of West Apia, by carrying out activities in the following areas:

Drainage:	Outputs of this component of the project will include: • the improvement of floodways; • rehabilitation of existing drains; and • the installation of water gauges for flood monitoring.
Wastewater management and sanitation:	Outputs of this component of the project: • The establishment of a piped sewerage scheme to service the highly built up central business of Apia. • Improvements to on-site sanitation.
Capacity building:	Within Government agencies to manage drainage and sanitation.

The focus of the drainage component of the ADB Project is Apia's central business district (CBD). The expected outcomes of the project include reduced risk of flooding in the CBD due to improved drainage. Beneficiaries will include business owners and employees in addition to residents and visitors to the CBD. This includes more than 150 businesses and 2,000 working people and 50,000 visitors per year.

The wastewater component of the project will benefit an estimated 8,200 households in Apia through a regular pump-out system for septic tanks and latrines in identified priority low-lying areas (patients and employees of the National Hospital, students and staff at the Malifa school compound, and stallholders and visitors at the Fugalei market.

ADB Institutional Strengthening for Drainage and waste Water Management Project

The ADB Institutional Strengthening for Drainage and Waste Water Management Project aims to provide technical assistance to Government of Samoa agencies in:

- identifying priority flood areas on the Apia floodplain;
- examining options and alternatives to alleviate localised flooding and wastewater impacts, including costing;
- liaising with local villages on flooding and wastewater problems and access to land for drainage rehabilitation;
- assessing existing problems of constructing septic tanks and pit latrines and setting up affordable and pragmatic building standards; and
- working with local stakeholders to develop new procedures and processes to operationalise the new Planning and Urban Management Bill.

EU Samoan Water Sector Support Program (WaSSP)

The purpose of this project is to accelerate achievement of water sector policy goals and objectives. The component of the project most relevant to the EDF work is aimed at:

- establishing an effective and skilled Water Resources Division;
- promoting environmentally-sensitive development in the water sector;

- improving the conservation and protection of water catchments areas and sources;
- identifying, delimiting and digitising catchments boundaries; and
- improving the assessment and monitoring of waster resources.

Pacific HYCOS Project

The Pacific HYCOS Project, funded by the ACP-EU Water Facility through the 9th European Development Fund (EDF) for water and sanitation and implemented by SOPAC, was launched in April 2007. It is a regional water resources management initiative to improve management and protection of Pacific Small Island States freshwater resources, through the provision of appropriate water resources management systems to demonstrate sustainable catchment and aquifer management.

The Pacific HYCOS Project is expected to strengthen the human and technical capacity of National Hydrological Services (NHSs) for water resources management and provide reliable information to decision-makers on integrated catchment and aquifer management and planning in 14 Pacific Island Countries.

The project will ensure that the data collected is of improved quality and easily accessible to all users, primarily via the Internet. To achieve this the project is expected to reinforce the hydrological observing networks by using various remote-sensing technologies; facilitating development of national and regional databases; promoting regional cooperation; and organising training programmes.

The project focuses on the following 6 technical components:

1. Flood forecasting capability.
2. Water resources assessment in major rivers.
3. Water resources databases.
4. Drought forecasting.
5. Groundwater monitoring and assessment.
6. Water quality monitoring and assessment.

APPENDIX 3

Flood Maps

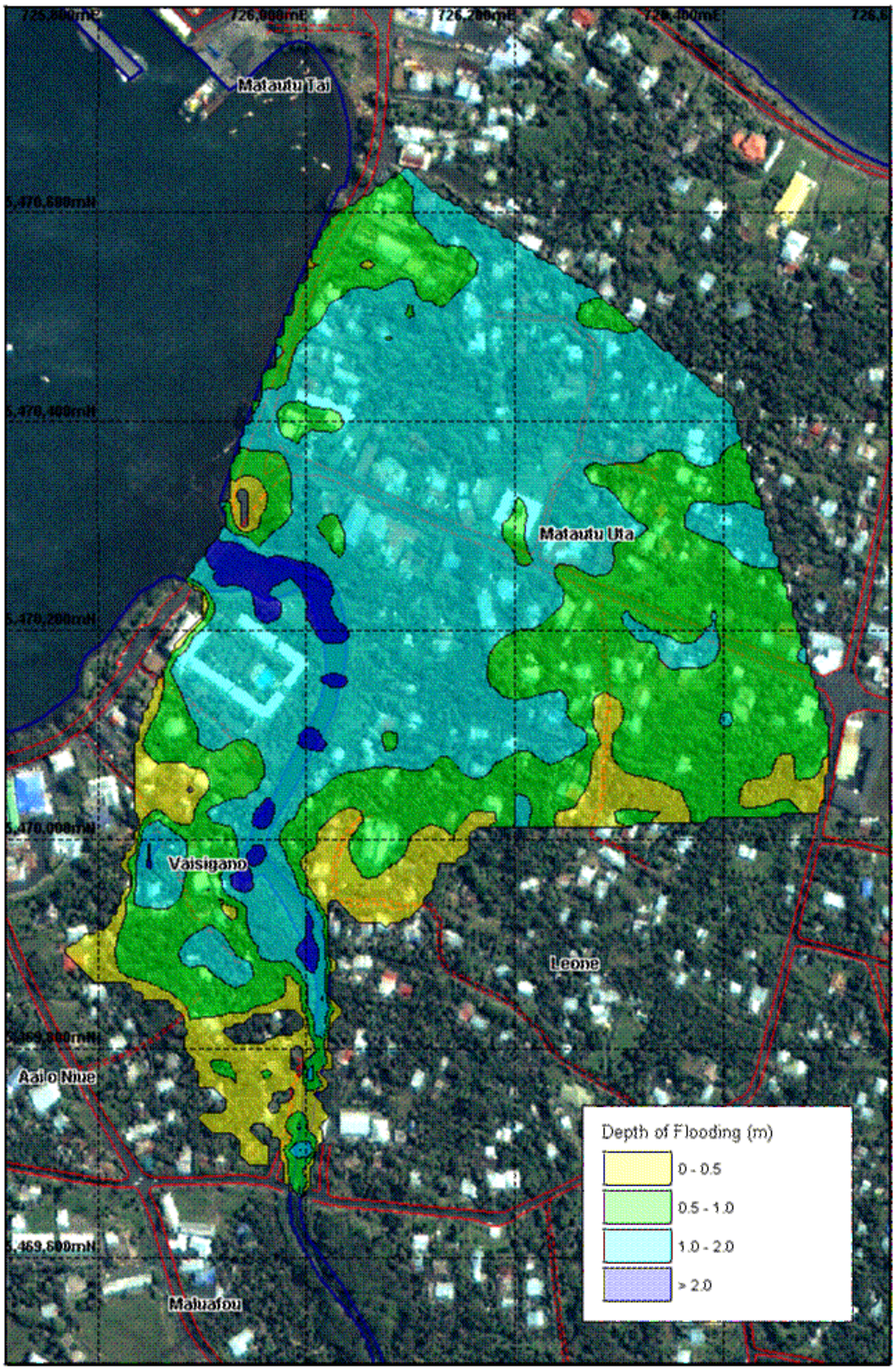


Figure A1 Flood depth map for the 1-in-5-year flood for the lower Vaisigano.

(Source: Pelesikoti and others, 2007)

Figure A2. Flood depth map for the 1-in-20-year flood for the lower Vaisigano.

(Source: Pelesikoti and others, 2007)

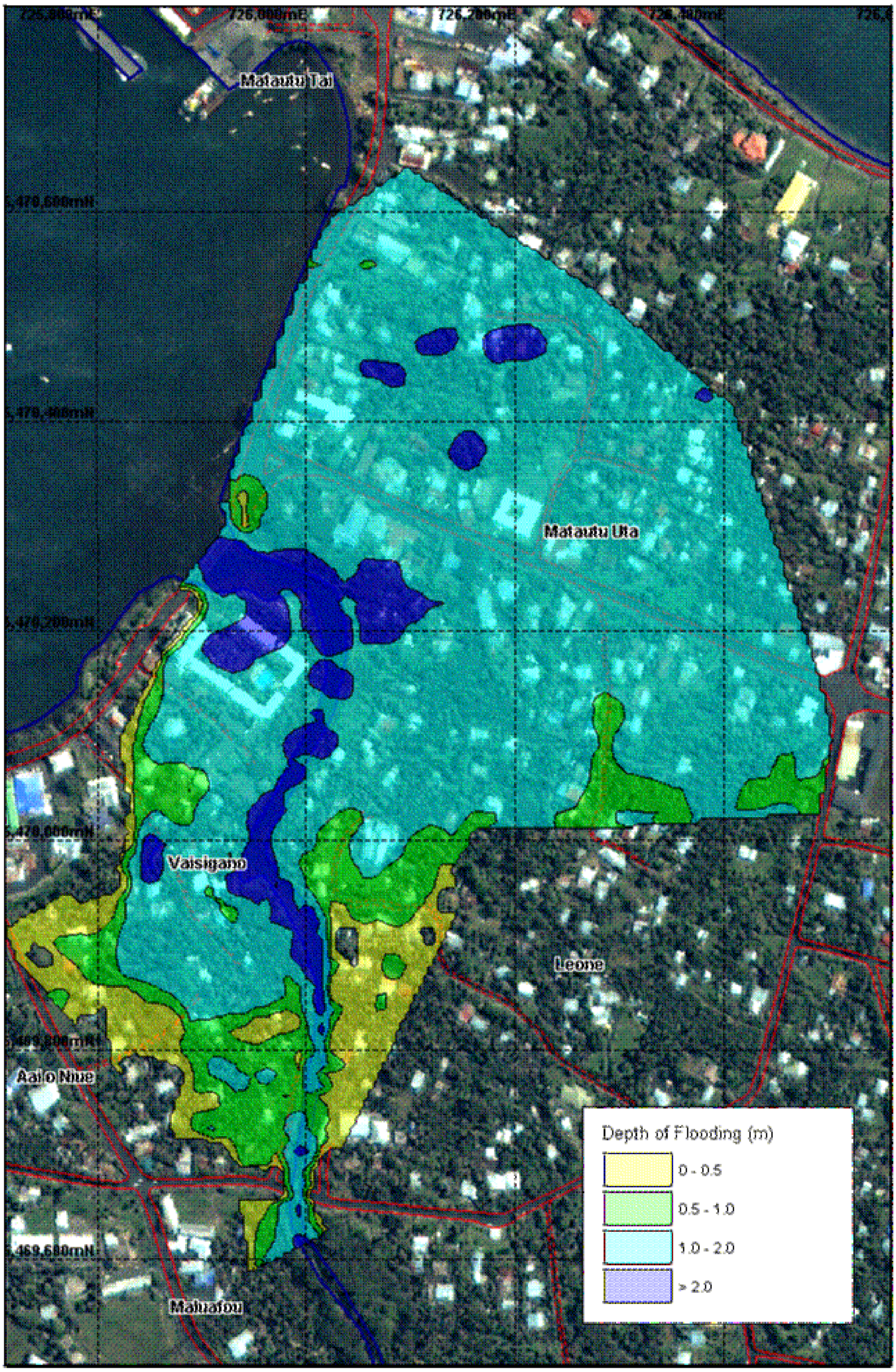


Figure A3. Flood depth map for the 1-in-50-year flood for the lower Vaisigano.

(Source: Pelesikoti and others, 2007)

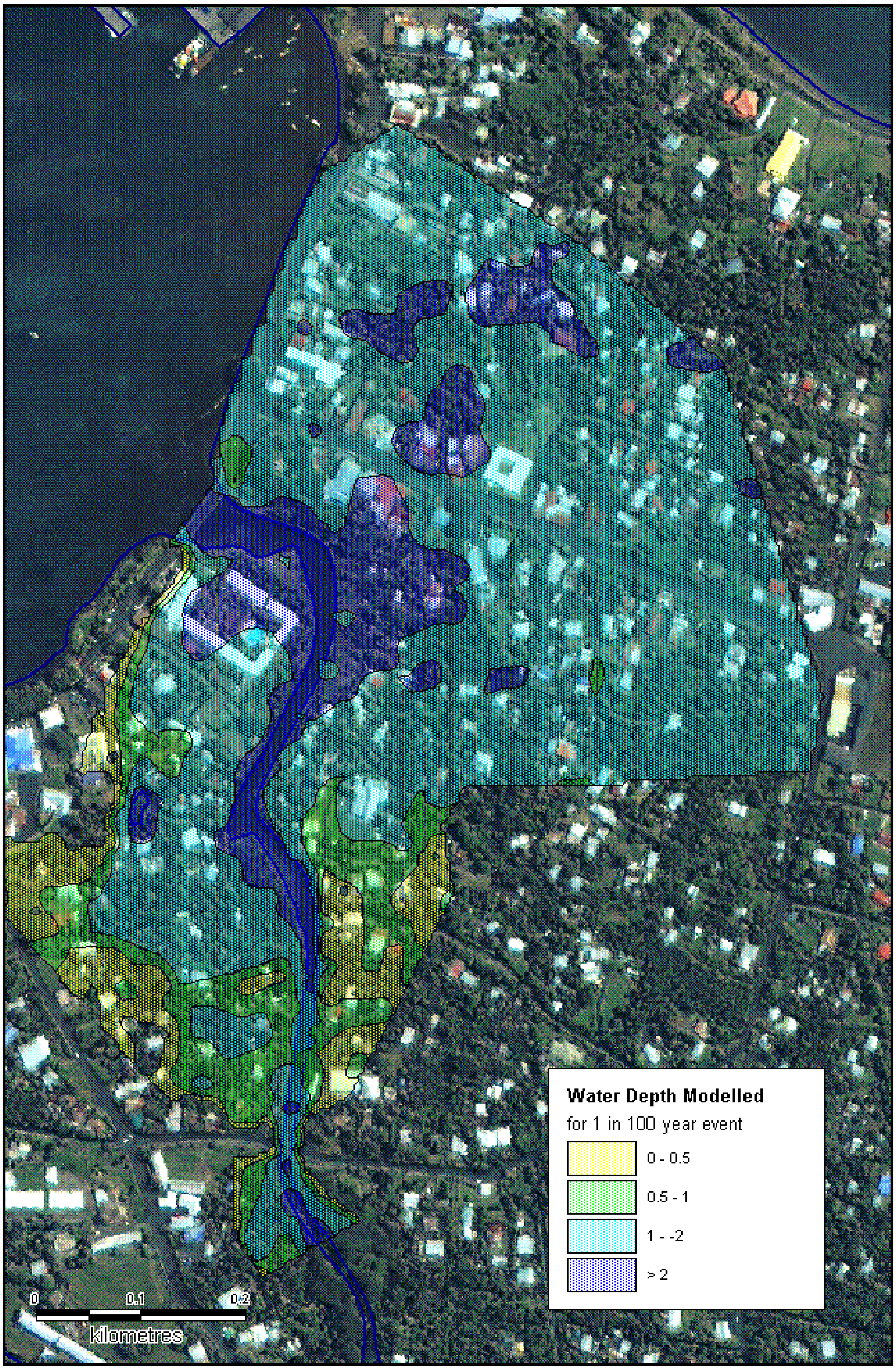


Figure A4. Flood depth map for the 1-in-100-year flood for the lower Vaisigano.

(Source: Pelesikoti and others, 2007)

APPENDIX 4

Household Survey

Survey Number:

QUESTIONNAIRE 1: HOUSEHOLD SURVEY

Residential property location: ______________________________

☐ Vaisigano
☐ Leone
☐ Matautu Uta

SECTION A: BACKGROUND INFORMATION

1. What is the style of your home?

☐ Open Samoan Fale
☐ Closed Samoan Fale
☐ Open European house
☐ Closed European house
☐ European house 2 or more floors
☐ Samoan house 2 or more floors
☐ Other________

2. What type of material are the outer walls of your home constructed from?

☐ Open wall
☐ Brick
☐ Wood
☐ Rock
☐ Metal sheet
☐ Other_________

3. What type of material are the floors of your home constructed from

☐ Concrete
☐ Wood
☐ Sand
☐ Stone
☐ Other______

4. What is the approximate height of main floor level of your home? (above ground height)

☐ Less than 0.5 m
☐ 0.5-1 m
☐ 1-2 m
☐ Greater than 2 m

5. What is the approximate floor area of your home? ________square meters

6A. Are there any other buildings or structures located on your property that you own?

☐ Yes Number of buildings (excluding main house)_______
☐ No

6B. If yes, please give a description of each structure (e.g. size, building type, construction material, purpose) ____

____

____

7. Do you own or lease the property?

☐Own ☐ Rent☐ Other_________

8. Land tenure

☐ Customary
☐ Freehold
☐ Government
☐ Other________________

9. Number of people living in household?

9A. Number of Adults (18 years and older) _______

9B. Number of Children (under 18 years old)_______

10. How many years have you been at this address? _____Years

11. What possessions do you keep in your home?

Put a check mark next to items owned by household

Television	
Radio	
Telephone (landline)	
Mobile Telephone	
Computer	
DVD Player	
Washing machine	
Refrigerator	
Stove/Oven	
Cabinets	
Sofas	
Chairs	
Tables	
Mats	
Beds and mattresses	
Chest	
Car/truck	
Crops	
Livestock	
Machinery and equipment	
Other valuable possessions: ________________ ________________	

12A. Do you have flood insurance? ☐ Yes ☐No

12B. If yes, what does it cover? (tick all boxes that apply)

☐ Full coverage household possessions
☐ Partial coverage household possessions
☐ Full coverage damage to buildings on property
☐ Partial coverage damage to buildings on property
☐ Other__________________________________

SECTION B: FLOOD VULNERABILITY AND IMPACT

13A. Have you experienced past floods?

☐ Yes
☐ No, *GO TO SECTION D*

13B. If yes, which years did your property flood? ___________________

14. Did you experience flooding in 2001?
☐ Yes
☐ No, *GO TO SECTION D*

16A. Did the flood waters rise above the main floor height?
☐ Yes
☐ No

16B. If yes, how many meters above floor height? _____meters

17A. Did flooding cause any physical damage to buildings on your property?

☐ Yes
☐ No

17B. If yes, what type of structural damage? (tick all boxes that apply)

☐ Damage to floors, Cost of repair_____
☐ Damage to walls, Cost of repair_____
☐ Damage to foundation, Cost of repair _____
☐ Totally destroyed, Cost of repair _____

18. Were any of your household possessions damaged?

☐ Yes (record DETAILS and COST of damage in Table 18 below)
☐ No (skip to question 19)

Table 18

	Details of Damage	**Cost of Damage**	**Lifted or removed items? (Question 27B)**
Television			
Radio			
Telephone (landline)			
Mobile Telephone			
Computer			
DVD Player			
Washing machine			
Refrigerator			
Stove/Oven			
Cabinets			
Sofas			
Chairs			
Tables			
Mats			
Beds and mattresses			
Clothes			
Car/truck			
Crops (Food./cash crop,			

specify)			
Livestock			
Machinery and equipment			
Other___________			
Other___________			
Other___________			

19A. Did anyone in your household suffer from sickness or injury as a result of the flooding?

☐ Yes
☐ No

19B. If yes, did sickness or injury occur

☐ During flooding ☐ After flooding ☐ Both

19C. If yes, please provide details of sickness or injury

☐ Dengue fever
☐ Diarrhea
☐ Physical injury (e.g. broken bones, cuts, scratches)
☐ Other__________________________

19D. If yes, what were the costs of treating the sickness or injury?

	Cost
Doctors visits	
Medicine (painkillers, creams, antibiotics etc.) dressings (purchase of bandages etc.)	
Days in hospital	
Other	

20A. Did any household members lose any days of work because of flooding?

☐ Yes
☐ No

20B. If yes, number of family members who missed work? ______

20C. If yes, how many days of work? ______ days

20D. If yes, what was the DAILY wage rate/income of each household member who missed work because of flooding?

Wage of household member 1________________Tala/day
Wage of household member 2________________Tala/day
Wage of household member 3________________Tala/day

21A. Did any children in the household miss school because of flooding (or associated sickness/injury)?

☐ Yes
☐ No

21B. If yes, how many days of school? ______days

22. How many days did it take to clean up property after flooding? ______days

23. Did you experience disruption in services?

Transport (e.g bus service) Number of days______

Water supply Number of days______
Electricity Number of days______
Telephone Number of days______

24A. Were the roads around your home flooded?

☐ Yes,
☐ No

24B. If yes, how long were they flooded for? _____hours

SECTION C: FLOOD WARNING AND RESPONSE

25. Was there any time between the time you became aware of that flooding might reach your home and the time when flood waters actually reached your property?

☐ None
☐ Less than 1 hour
☐ 2 - 3 hours
☐ 4 - 6 hours
☐ 7 –12 hours
☐ 1 day or more

26. How did you become aware of the flood event?

☐ Radio
☐ Television
☐ Newspaper
☐ Contacted by family/friends/neighbours
☐ Saw heavy rain
☐ Saw river rise
☐ Other______________

27A. When you became aware of the floods, did you lift or remove any property to protect it from flooding?
☐ Yes
☐ No

27B. If yes, which items did you lift or remove?
Please mark items lifted in Table 18 (page 4 Question 18)

28A. Did you evacuate the house during the flooding event?
☐ Yes
☐ No

28B. If yes, how long did it take to evacuate your home? _______hours

28C. If yes, for how long did you leave your home?

☐ 6 hours or less
☐ One day or less
☐ 2- 3 days
☐ 4-6 days
☐ 1 week or more

28D. If yes, how did you evacuate?

☐ Household vehicle
☐ Friends/relatives vehicle
☐ On foot
☐ Other_________

28E. Did you incur any costs associated with the evacuation?

☐ Yes, How much?_______
☐ No

SECTION D: FLOOD RISK REDUCTION

29A. *For homeowners only:* Have you ever taken any preventative measures to protect the buildings on your property from flooding?

☐ Yes (go to Question 29B)
☐ No (go to Question 29C)

29B. If yes, what measures have you taken?

☐ Built floodwall
☐ Raised floor height of home
☐ Improved drainage around property
☐ Changed construction material of home
☐ Other____

29C. Why have you never taken any preventative measures to protect the buildings on your property from flooding?

☐ Too expensive
☐ Uncertain of benefits
☐ Property has never been affected by flooding
☐ Other_____________________________________

END OF SURVEY

APPENDIX 5

Business Survey

Survey Number:

QUESTIONNAIRE 2 – BUSINESS SURVEY

SECTION A: BACKGROUND INFORMATION

Function of person being interviewed (e.g. owner, manager)_____________

1. **Business address and location**:___________________

- ☐ Vaisigano
- ☐ Leone
- ☐ Matautu Uta
- ☐ Matautu Tai

2. **Type of business?**

- ☐ Retail (e.g. shop)
- ☐ Restaurant
- ☐ Service (e.g. banking, insurance company)
- ☐ Hotel
- ☐ Factory
- ☐ Other_______________

3. **Type of Building**

- ☐ Commercial building 1 floor
- ☐ Commercial building 2 or more floors Number of floors______
- ☐ Other (e.g. hotel) _______________ Number of floors______

4. Building material of outer walls:

- ☐ Open wall
- ☐ Brick
- ☐ Wood
- ☐ Rock
- ☐ Metal sheet
- ☐ Other_________

5. **Material of Floor**

- ☐ Concrete
- ☐ Wood
- ☐ Sand
- ☐ Stone
- ☐ Other_____

6. Approximate height of main floor level above ground

☐ Less than 0.5 m
☐ 0.5-1 m
☐ 1-2 m
☐ Greater than 2 m

7. Approximate floor area of business? ________square meters

8. Do you own or lease the property?
☐Own ☐ Rent☐ Other

9. Number of employees? ______Workers

10. How long have you been operating at this address? _____years

11. What stock, equipment/machinery do you keep in your building? What is the estimated value of these items?

Items	**Yes**	**Estimate Value**
Business stock		
Telephone (landline)		
Mobile telephone		
Radio		
Display counters		
Machinery and equipment		
Desks		
Chairs		
Filing Cabinets		
Computers		
Photocopy machine		
Car/truck		
Other___________		
Other___________		
Other___________		

12A. Do you have flood insurance? ☐ Yes ☐No

12B. If yes, what does it cover?
☐ Full coverage of stock, furniture and equipment
☐ Partial coverage stock, furniture and equipment
☐ Full coverage damage to building
☐ Partial coverage damage to building
☐ Other_______________________________________

12C. What is the total value of insurance coverage? __________

SECTION B: FLOOD VULNERABILITY AND IMPACT

13A. Have you experienced past floods?

☐ Yes
☐ No*, GO TO SECTION D*

13B. If yes, which years did your business flood? (e.g. 1975, 2001) _______

15. Did you experience flooding in 2001?

- ☐ Yes
- ☐ No, *GO TO SECTION D*

16A. Did the flood water levels rise above the main floor height?

- ☐ Yes
- ☐ No

16B. If yes, how many metres above floor height? _____metres

17A. Did your building suffer structural damage from flooding?

- ☐ Yes,
- ☐ No

17B. If yes, what type of structural damage?

- ☐ Damage to floors, Cost of repair_____
- ☐ Damage to walls, Cost of repair_____
- ☐ Damage to foundation, Cost of repair _____
- ☐ Totally destroyed, Cost of repair _____

18. Was any stock, equipment, machinery or furniture damaged?

- ☐ Yes (record DETAILS and COST of damage in Table 18 below)
- ☐ No (go to Question 19A)

Table 18

	Details	**Cost of Damage**	**Items lifted or removed (Question 27B)**
Business stock			
Telephone (landline)			
Mobile telephone			
Radio			
Display counters			
Machinery and equipment			
Desks			
Chairs			
Filing Cabinets			
Computers			
Photocopy machine			
Car/truck			
Other__________			
Other__________			
Other__________			

19A. Did your business close during the flooding event?

☐ Yes
☐ No

19B. If yes, for how long did your business close? ______ days

20. What are your typical DAILY revenues? ____________ Tala/day

21A. How many days did it take to clean up after the flood? ______days

21B. How much did it cost to clean up? (e.g. wages to employees, cleaning materials) _______Tala

22A. Did your business set up temporary quarters at another location because of the flood?

☐ Yes
☐ No

22B.If yes, for how long? _____days

23. Did you experience disruption in services?

Transport Number of days______
Water supply Number of days______
Electricity Number of days______
Telephone Number of days______

24A. Were the roads around your business flooded?

☐ Yes,
☐ No

24B. If yes, how long were they flooded for? _____hours

SECTION C: FLOOD WARNING AND RESPONSE

25. Was there any time between the time you became aware of that flooding might reach your business and the time when flood waters actually reached your property?

☐ Yes How much warning? ____________ hours
☐ No

26. How did you become aware of the flood event?

☐ Radio
☐ Television
☐ Contacted by family/friends
☐ Saw heavy rain
☐ Saw river rise
☐ Other______________

27A. Did you lift or remove any stock, equipment or machinery to protect it from flooding?

☐ Yes
☐ No

27B. If yes, which items did you lift or remove?

Please mark items lifted in Table 18 (page 3 Question 18)

27C. If yes, how did you move these items?

- ☐ Business vehicle
- ☐ Borrowed vehicle
- ☐ Other________

27D. If yes, how long did it take to move/lift stock, equipment of machinery from your building?
_________hours

28. How much additional money did the flood cost your business in increased operational expenses, such as temporary quarters, additional transportation, communication or storage expenses? _________Tala

SECTION D: FLOOD RISK REDUCTION

29A. *For building owners only?* Have you ever taken any preventative measures to protect your business from flooding?

- ☐ Yes (go to Question 29B)
- ☐ No (go to Question 29C)

29B. If yes, what measures have you taken?

- ☐ Built floodwall
- ☐ Raised floor height of building
- ☐ Improved drainage around property
- ☐ Changed construction material of building
- ☐ Other____

29C. Why have you never taken any preventative measures to protect your building from flooding?

- ☐ Too expensive
- ☐ Uncertain of benefits
- ☐ Business has never been affected by flooding
- ☐ Other_________________________________

END OF SURVEY

APPENDIX 6

Glossary

AVERAGE ANNUAL DAMAGE (AAD)
The average annual damage is the average damage in *Tala* per year that would occur in a designated area from flooding over a very long period of time. In many years there may be no flood damage, in some years there will be minor damage (caused by small, relatively frequent floods) and, in a few years, there will be major flood damage (caused by large, rare flood events). Estimation of the average annual damage provides a basis for comparing the effectiveness of different floodplain management measures (i.e. the reduction in the annual average damage).

ANNUAL PROBABILITY
The estimated annual probability of a flood of given magnitude occurring or being exceeded in any year. Expressed as, for example, 1-in-100 (1 %) chance per year.

BANK
The lateral boundaries of a stream confining all flow levels that do not rise above them and flow out onto the floodplain. The bank on the left side of a channel looking downstream is the left bank.

BENEFIT-COST RATIO
The value of total discounted benefits is compared with the value of total discounted costs. If the ratio of benefits to costs is greater than one, a project is economically viable.

BYPASS CHANNEL
A flood protection facility through which a portion of a stream's flow is diverted from one point and reintroduced into the stream at the downstream end of the bypass channel. Bypass channels can be used during the construction or maintenance process. Permanent bypass channels can also be designed to accommodate flood flows.

CATCHMENT
The land draining through the main stream, as well as tributary streams.

CONVEYANCE
The ability of a watercourse or other flow path to carry (or convey) water.

DEPTH-DAMAGE CURVE
See stage-damage curve

DESIGN EVENT
An historic or a flood event of a given annual flood probability, against which the suitability of a proposed development is assessed and mitigation measures, if any, are designed.

DESIGN FLOOD LEVEL
The maximum estimated water level during the design event.

DEVELOPMENT
The carrying out of building, engineering, mining or other operations in, on, over or under land or the making of any material change in the use of any buildings or other land.

DISCHARGE
The rate of flow of water, as measured in terms of volume per unit time, for example cubic metres per second (m^3/s or cumecs).

DISASTER
A serious disruption of the functioning of a community or a society causing widespread human, material, economic or environmental losses which exceed the ability of the affected community or society to cope using its own resources. A disaster is a function of the risk process. It results from the combination of hazards, conditions of vulnerability and insufficient capacity or measures to reduce the potential negative consequences of risk.

DISASTER MANAGEMENT
The organisation and management of resources and responsibilities for dealing with all aspects of emergencies/disasters, in particular preparedness, response and (relief/rehabilitation).

DISASTER RISK MANAGEMENT
The systematic management of administrative decisions, organisation, operational skills and abilities to implement policies, strategies and coping capacities of the society and communities to lessen the impacts of natural hazards and related environmental and technological disasters. This comprises all forms of activities, including structural and non-structural measures to avoid (prevention) or to limit (mitigation and preparedness) adverse effects of hazards.

DISASTER RISK REDUCTION
The conceptual framework of elements considered with the possibilities to minimise vulnerabilities and disaster risks throughout a society, to avoid (prevention) or to limit (mitigation and preparedness) the adverse impacts of hazards, within the broad context of sustainable development.

DISCOUNT RATE
A discount rate is commonly applied in economic and financial analysis because it provides a means for converting future costs and benefits into present value *tala* amounts (i.e., their worth today). The principle behind discounting is the “time value of money”, i.e., a *tala* paid today is worth more than a *tala* paid a year into the future because the person holding the *tala* can invest it and earn a return.

DISCHARGE
In the simplest form, discharge means outflow of water. The use of this term is not restricted as to course or location and it can be used to describe the flow of water from a pipe or from a drainage basin. Other words related to it are *runoff*, *streamflow*, and yield.

EARLY WARNING
The provision of timely and effective information, through identified institutions, that allow individuals exposed to a hazard, to take action to avoid or reduce their risk and prepare for effective response. Early warning systems consists of three primary elements (i) forecasting of impending events; (ii) processing and dissemination of warnings to political authorities and population; and (iii) undertaking appropriate and timely actions.

EFFECTIVE WARNING TIME
The time available for the evacuation of people and their goods and possessions before the onset of flooding.

EMERGENCY
A situation generated by the real or imminent occurrence of an event that requires immediate attention. A significant or unusual event, requiring the coordinated response of more than one agency.

EXTERNALITY
An externality is a side effect borne by parties not directly involved in (i.e., external to) an activity or market exchange. For example, a raised concrete floor to reduce the vulnerability of a factory located in a floodplain to flooding may impose flood damage externalities to the surrounding population by raising floodwater levels.

FALE
Traditional Samoan building with a raised floor and no walls.

FLASH FLOOD
Sudden and unexpected flood which follows within a few (usually less than six) hours of heavy or excessive rainfall, which by its very nature is difficult to forecast.

> **Flash Flood Warning** – A warning issued by the meteorological services to warn of flash flooding that is imminent or occurring.

FLOOD AWARENESS
The appreciation of the likely effects of flooding and knowledge of the relevant flood warning and response procedures.

FLOOD DAMAGE
The economic loss (including tangible and intangible damages) caused by floods, including damage by inundation, erosion, and/or sediment deposition. Damages also include emergency costs and business or financial losses. Evaluation may be based on the cost of replacing, repairing, or rehabilitating; or the comparative change in market or sales value; or on the change in the income or production caused by flooding.

FLOOD DEFENSE
Flood defense infrastructure, such as flood walls and embankments, intended to protect an area against flooding, to a specified standard of protection.

FLOOD DEFENSE LEVEL
The level to which flood defenses are constructed, that is the level of the top of flood walls and embankments, expressed relative to the national datum (e.g. mean sea level).

FLOOD EMERGENCY
A condition or situation caused by flooding that requires urgent action or assistance.

FLOOD EVENT
A flooding incident characterised by its peak level or flow, or by its level or flow hydrograph.

FLOOD FORECASTING
Prediction of stage, *discharge*, time of occurrence and duration of a flood, especially of peak discharge at a specified point on a stream, resulting from precipitation

FLOOD HAZARD
A flood hazard may be defined as a situation with the potential to result in harm. A flood hazard does not necessarily lead to harm, but identification of a hazard does mean that there is a possibility of harm occurring.

FLOOD MANAGEMENT
Flood management includes physically “managing” flood water, for example by providing storage areas, and other measures to reduce the impacts of flood, like flood warning schemes or development control.

FLOOD PROOFING
Any combination of structural and non-structural additions, changes, or adjustments to structures which reduce or eliminate flood damage.

FLOOD RECOVERY
Flood recovery refers to clean-up, welfare, restoration of services and other forms of assistance provided by the relevant authorities and voluntary organisations after a flood.

FLOOD RISK
Flood risk is defined as:

(Probability of flooding) x (Consequence of flooding)

Flood risk is normally measured in terms of economic damages for a particular probability of flooding, or Annual Average Damages based on the full range of floods that could occur.

FLOOD STAGE
The stage at which overflow of the natural banks of a stream begins to cause damage in the reach in which the elevation is measured.

FLOOD WALLS
Walls constructed of water-resistant material around the perimeter of a facility and extending above the design-flood elevation to keep floodwaters away from the facility.

FLOOD WARNING
A warning issued by the national weather services to warn of river flooding which is imminent or occurring. A flood warning is issued when a river first exceeds its flood stage, and it may be reissued if a new river forecast for a forecast point or reach is significantly higher than a previous forecast.

FLOODING
Flooding can result from a wide range of events and processes. Flooding occurs naturally, when specific environmental factors or combinations of factors occur. These factors can be diverse and site specific, and can include heavy rain, tidal surges and raised groundwater levels, among others. Flooding can also result from human interference with natural processes, such as changes to river channels, increases in runoff from land or blocked drainage systems. Flooding becomes a problem only when it has an adverse impact on people, property, infrastructure or the environment.

FLOODPLAINS
Floodplains are the areas adjacent to rivers and coasts which flood during periods of heavy rain and high river flows, or severe sea conditions. The exact definition of the floodplain is usually based on the magnitude of particular flood events (the “defined flood events”). In many countries a flood with a 1-in-100 chance of occurring in any year is used for rivers in non-tidal areas, and a flood with a 1-in-200 chance of occurring in any year in tidal areas including the coast. However, larger floods than these can occur, and in some countries the floodplain for the estimated flood with a 1-in-1000 chance of occurring in any year, or the probable maximum flood is shown on flood maps.

FLOODPLAIN MANAGEMENT MEASURES
The full range of measures available to prevent or reduce flood hazard and disruption.

FLOODPLAIN MANAGEMENT OPTION
A set of possible measures for the management of a particular area of the floodplain.

FLOODWAY
Zones of a floodplain where there are significant flows during flood events.

FLOW
See discharge.

FLUVIAL
Relating to rivers.

FREEBOARD

The height above a defined flood level typically used to provide a factor of safety in, for example, the setting of floor levels and embankment crest levels.

HYDROLOGY
The science dealing with the origin, distribution and circulation of waters of the earth such as rainfall, streamflow, infiltration, evaporation, and groundwater storage.

INTERNAL RATE OF RETURN (IRR)
Indicator used in economic and financial analysis that reveals the discount rate for which the discounted benefits are equal to discounted costs. In other words, the IRR reveals the economic ‘break even’ point of an investment where the values of costs is just covered by benefits. If the resulting IRR is greater than the chosen discount rate, a project is economically viable.

MITIGATION
The process of implementing measures that reduce the intensity and severity of the impact of potential hazards.

MITIGATION MEASURE
A generic term used to refer to structural and non-structural measures undertaken to limit the adverse impacts of flooding.

MONITOR

To check, supervise, observe critically, or record the progress of an activity, action or system on a regular basis in order to identify change.

NON-STRUCTURAL MEASURES

A term originally devised to distinguish techniques that modify susceptibility to flooding (such as regulation, floodplain acquisition and floodproofing techniques) from the more traditional structural methods (such as dams, levees, and channels) used to control flooding.

PEAK DISCHARGE

The maximum discharge occurring during a flood event past a given point on a river system.

PREPAREDNESS

Activities and measures taken in advance to ensure effective response to the impact of flooding, including the issuance of timely and effective early warnings and the temporary removal of people and property from a threatened location.

PRESENT VALUE

In relation to flood damage, is the sum of all future flood damages that can be expected over a fixed period expressed as a cost in today's value.

PROBABILITY

The probability of flooding is the chance of a flood occurring, and may be expressed as the chance of a particular flood occurring in any one year (for example, the flood with a 1-in-200 chance of occurring in any year) or as annual probability (for example a 1-in-100 flood has a 1% probability of occurrence in any one year).

PROBABLE MAXIMUM FLOOD

The largest flood that could conceivably occur at a particular location.

PREVENTION

Activities to provide outright avoidance of the adverse impact of hazards and means to minimise related environmental, technological and biological disasters. Depending on social and technical feasibility and cost/benefit considerations, investing in preventative measures is justified in areas frequently affected by disasters. In the context of public awareness and education, related to disaster risk reduction changing attitudes and behaviour contribute to promoting a "culture of prevention".

RECOVERY

Programming measures that are designed to support affected communities in the reconstruction of the physical infrastructure and restoration of emotional, economic and physical well being.

REHABILITATION

Restoring peoples lives to normal, as well as essential services, including the beginning of the repair of physical, social and economic damages.

RESPONSE

Programming measures that develop the action to be taken in anticipation of, during and/or immediately after, a hazard impact to ensure its effects are minimised.

RESIDUAL FLOOD RISK

The remaining level of flood risk that a community is exposed to after floodplain management measures to reduce risk have been implemented.

RETURN PERIOD

The average time interval between occurrences of a hydrological event of a given or greater magnitude, usually expressed in years.

RISK
The probability of harmful consequences, or expected losses (deaths, injuries, property, livelihoods, economic activity disrupted or environment damaged) resulting from interactions between natural or human-induced hazards and vulnerable conditions.

RISK REDUCTION
A selective application of appropriate techniques and management principles to reduce either likelihood of harm, or the consequences of harm, or a combination of the two.

RUNOFF
The amount of precipitation appearing in surface *streams*, *rivers*, and *lakes*; defined as the depth to which a drainage area would be covered if all of the runoff for a given period of time were uniformly distributed over it.

STAGE–DAMAGE CURVE
A relationship between different water depths and the predicted flood damage at that depth.

STREAMFLOW
The *discharge* that occurs in a natural channel. Although the term "discharge" can be applied to the flow of a canal, the word "streamflow" uniquely describes the discharge in a surface stream. The term "streamflow" is more general than the term "*runoff*," as streamflow may be applied to discharge whether or not it is affected by *diversion* or regulation.

STRUCTURAL MEASURES
Measures such as dams, reservoirs, dikes, levees, floodwalls, channel alterations, high-flow diversions and spillways, and land treatment measures designed to modify floods.

20-YEAR FLOOD
A flood having 5% or greater annual probability of occurring.

100-YEAR FLOOD
A flood having 1% or greater annual probability of occurring.

200-YEAR FLOOD
A flood having 0.5% or greater annual probability of occurring.