



SAMOA

Waterfall upper Vaisigano River

1. COUNTRY INTRODUCTION

Description:

Description: Samoa comprises of two main islands, Upolu and Savaii, several smaller islands, plus some uninhabited islets. It is located in the South Pacific between 171° & 172° W and 14° & 13° S. The islands generally have a narrow coastal plain with steep volcanic rugged and forested mountains within the interior. In 1962, Samoa became the first country in the Pacific to gain independence.

Economy:

Approximately two-thirds of the labour force is engaged in agriculture, which provides 90% of the exports (coconut cream, coconut oil and copra). Limited manufacturing concentrates on refining some of the agricultural products. Fish stocks in the area are considered to be in decline raising concern on reliance of this traditional revenue source. Tourism is growing and now represents 25% of the GDP. The economy of Samoa has traditionally been dependent on development aid and family remittances from overseas but there are positive signs that this balance is changing.

Water Availability:

Water supply in northern, eastern and southern Upolu and eastern Savaii is from surface water intakes. For western Upolu and the rest of Savaii it is generally from groundwater. Water shortages occur during the dry season, especially during extended dry periods associated with the ENSO. This is more evident in the Apia area on Upolu (served by surface water intakes) where demand is high, and in the Falealupo Peninsula on Savaii where groundwater is often brackish, and the population subsequently relies upon rainwater harvesting for much of their potable water needs. Water consumption in Apia has recently been better controlled through the introduction of household metering.

Island Vulnerability:

Flooding associated with cyclones and storm surge is exacerbated by small catchments and very steep slopes that respond rapidly to storm events. El Niño related dry periods can cause urban water supply problems in Apia, even where rainfall is reduced for a relatively short period impacts can be felt due to limited catchment and reservoir storage. Population growth,

increasing urbanisation, and an increase in major developments, including tourism, is exerting pressure on water resources with increased land degradation, waste generation and waste water pollution.

Power Generation:

There are five micro-hydropower stations, all in Upolu, which provide about 40 - 60% of the national requirement depending on the time of the year, dry or wet season. Catchment erosion is compromising hydropower generation and has resulted in the abandonment of the Fulausou hydropower plant. There is potential for more effective use of water to better optimise production.

Health:

Improved access to drinking water is high in urban areas (90%, 2004, UN) as well as rural areas (87%, 2004, UN). However, only around a third of the population of Samoa receives treated water and, even when treated, only 85% of samples taken pass the relevant WHO standards.

Environment and Tourism:

Tourism in Samoa is growing with all resorts located on the coast. Tourism contributes to heavy water demand and high wastewater production, placing pressure on the watershed as well as the near-shore environment. Increased coastal development impinges on beaches, reefs, mangroves and other habitats, which contribute to the protection of the terrestrial environment from storm waves, tsunamis and coastal erosion. The impact of integrated coastal and catchment management on the terrestrial and marine environments as well as the economy is recognised.

2. GEOGRAPHIC

Some basic geographic information is presented in the following maps identifying the extent of the main islands group as well as a general soil and land classification map for Upolu.

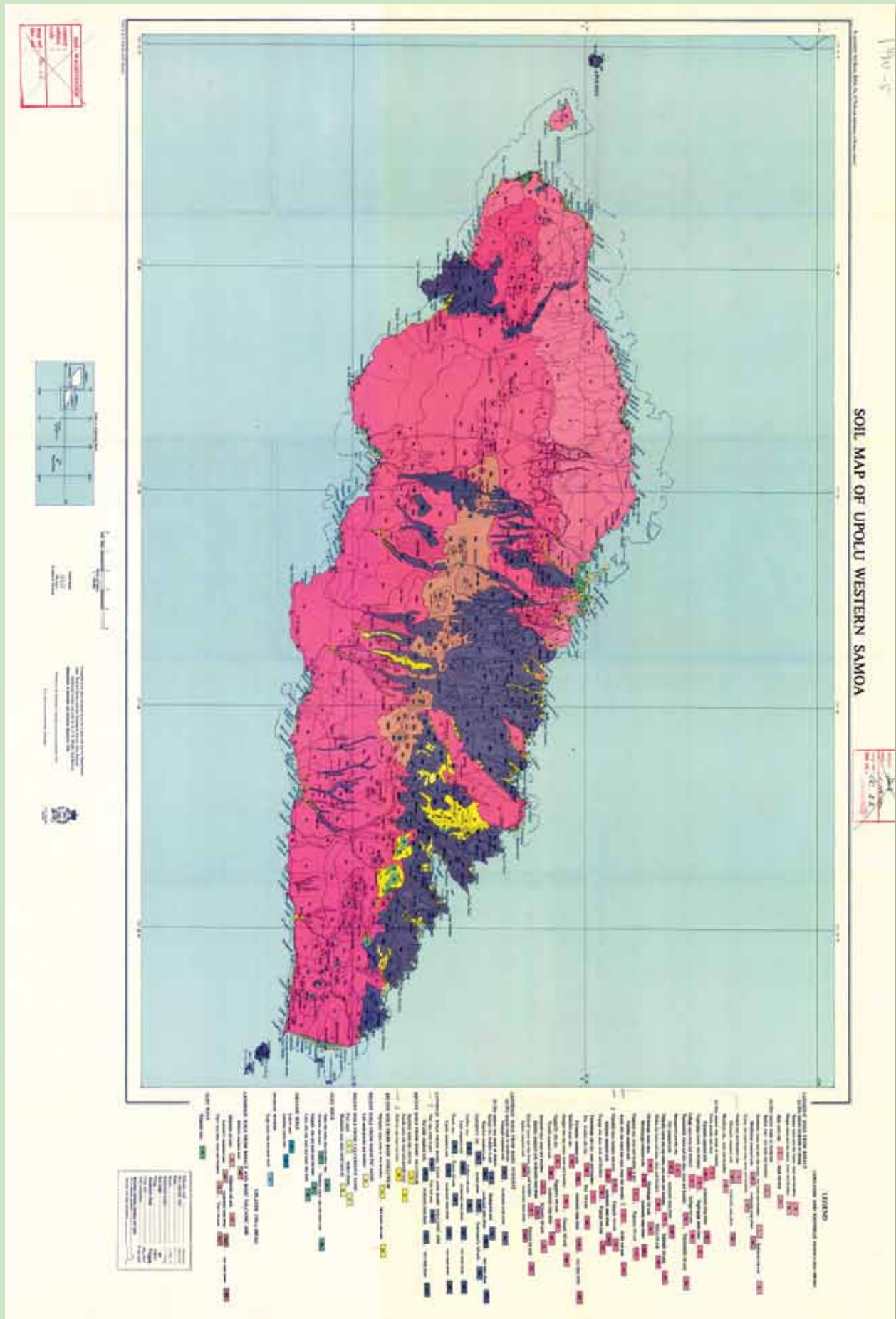
Map of Samoa



Source: CIA World Factbook, 2011



Soil Map of Upolu



Source: Wright 1962

Land Classification Map of Upolu (1962)



3. CLIMATIC

Samoa's climate is divided into 2 seasons. The hot/wet season begins from November and runs through until April while the cooler and drier period is between May and October. The temperature can range from 10.5^o Celsius (at Afiamalu in the high mountains) to 35^o

Celsius (at Apia) varying 1-2^o Celsius between the seasons. The annual rainfall ranges from 2,000mm in dry areas to 5,500mm in the mountains. The wetter areas are generally at altitude on the south east sides of the islands with it being relatively drier in the north west.

3.1 Rainfall data

Available rainfall data is limited, where much of the historical data has not been archived nor is easily accessible. Whilst the recently collected

rainfall data is accessible in TIDEDA database, the historical data is often stored in other data formats such as excel, or as paper charts or tabulations. Under Pacific HYCOS support, the Ministry of Natural Resources and Environment's Water Resources Division (MNRE –WRD) has commenced the rescue of the historic data and is digitising the older charts and tabulated data. A total of 13 automatic gauges were installed on Upolu and Savaii which will in time contribute to the collection of valuable rainfall totals and intensity data. The Samoa Meteorological Service operate a number of stations and has recently been involved in rescue of historic rainfall data, originally recorded on charts, to an electronic database. Additional raingauge upgrades are proposed in the near future.

List of Pacific HYCOS supported Rainfall Stations

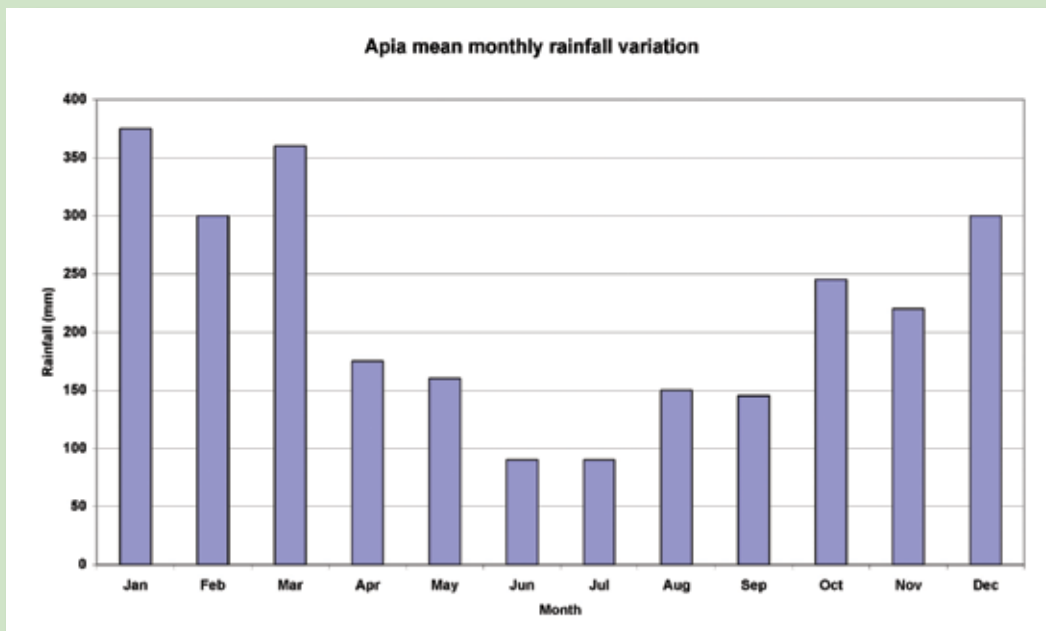
No	Station	Elevation (m)	Location and coordinates	Period of observations	Average rainfall
NA	Apia	2	Apia Met Office 13° 48' 54" S 171° 46' 52" E	1890 - Open	2610
1080200	Afulilo	361.1	13° 57' 48.411684" S 171° 33' 38.36268" E	11/1975* - open	NA
1160100	Togitogiga	470	13° 58' 26.929812" S, 171° 42' 44.51436" E	02/2009 – open	NA
1180100	Mulivai	170	13° 58' 46.69626" S, 171° 47' 22.58376" E	01/2009 – open	NA
1230100	Faleaseela	275.7	13° 54' 45.07398" S, 171° 57' 26.09388" E	01/2009 – open	NA
1250100	Olomanu	106.7	13° 52' 15.014892" S, 172° 2' 4.60068" E	09/2008 – open	NA
1280100	Mount Sigaele	617.3	13° 53' 38.553432" S, 171° 52' 31.73988" E	01/2009 – open	NA
1290100	Lanoto	NA	14° 0' 29.948436" S, 171° 29' 35.1888" E	01/2009 – open	NA
1320200	Vaisigano	NA	13° 52' 55.095" S 171° 45' 25.398" W	02/1975* -open	NA
1390100	Solosolo	260	13° 53' 46.819896" S, 171° 40' 4.20996" E	03/2009 – open	NA
2070100	Lata	NA	13° 44' 4.615044" S, 172° 31' 19.68024" E	03/2009 – open	NA
2140100	Asau	NA	13° 32' 55.637376" S, 172° 39' 38.86668" E	03/2009 – open	NA
2170100	Vaipouli	NA	13° 28' 8.800212" S, 172° 22' 53.94072" E	10/2008 – open	NA
2200100	Vaiaata	NA	13° 37' 48.61002" S, 172° 15' 32.91984" E	10/2008 – open	NA
1290100	Lanotoo	800.9	13° 54' 40.458924" S, 171° 49' 10.41672" E	1975*	NA

Monthly Climate Data for Apia

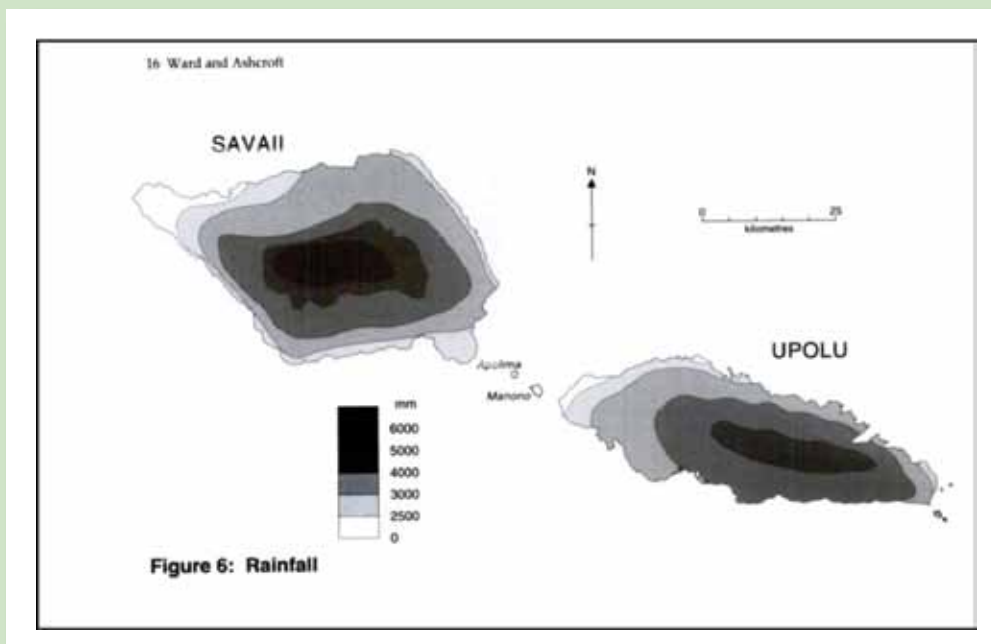
Observation Mean monthly	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	An- nual	Period
Temperature (°C)	26.7	26.8	26.8	26.7	26.4	26.2	25.8	25.8	26.1	26.3	26.4	26.7	26.4	1970-1990
Precipitation (mm)	375	300	360	175	160	90	90	150	145	245	220	300	2610	1890 open

Source: Samoa Meteorological Service

Long Term Average Monthly Precipitation Apia, Samoa 1890-Dec 2009



Samoa Annual Isohyetal Map



Source: Samoa Meteorological Service (after Ward and Ashcroft 1998)





Concrete road crossing, Sili River, Savaii Island

4. WATER RESOURCES

4.1 General Description

Samoa has on both Upolu and Savai'i an abundance of surface water streams and rivers which flow for much of the year. Generally reliable rainfall generates sufficient surface water flow for current water needs. During dry periods flows can decrease significantly and a lack of adequate storage reservoirs places stress on the water supply to meet potable water, as well as hydro electric generation and agricultural demands. These streams supply the majority of the public drinking water systems, especially for the capital city of Apia and its surrounds. A secondary water source that is used, though less developed, comes from groundwater. The variable and fractured rock environment from the dominating volcanics makes the development of the groundwater more problematic and more costly to access. However there is potential for development of this resource to contribute to future water supply needs. The growing tourism industry is placing additional stress on the existing water supplies. Small scale irrigation and village needs are supplied by gravity from the numerous streams found on both main islands. There is a reliance on rainwater harvesting where surface and groundwater supplies are limited.

Limited historical surface water monitoring is available from the Samoa Water Authority,

SWA. Prior to 2005 hydrological monitoring was undertaken by the Samoa Meteorological Service. A lack of raw water abstraction metering to date prevents accurate assessment of water availability and withdrawal against low flow yields and residual flows.

4.2 Major Floods and Droughts

Samoa experiences instances of both floods and drought, floods having a more rapid and less predictable onset, whilst the onset of drought is much slower and often more widespread, with significant impacts for communities. Floods can cause devastation in urban areas and due to very rapid runoff from the steep mountain catchments, allows for very short lead in and prediction times. Due to hydrological data collection programs not being active in the past, floods or droughts have not been measured apart from a few low flow discharge measurements on select streams. Associated with floods is the risk of debris slides and elevated levels of sediment, which can threaten communities and exacerbate flooding and land degradation in the urban and downstream areas.

4.3 Socio-economic characteristics

The surface water streams in Samoa have significant socio-economic benefits and the current and expected future demands placed on these streams may compromise traditional

use. Historically the streams have always been part of traditional life providing domestic and stock water, fishing limited irrigation water, and recreation. The potential for increased hydroelectric power generation or irrigation will directly compete with existing and more traditional use of this water source. In many cases this development involves abstraction directly from the river or by water transfer through tunnels, pipes and channels into another catchment with corresponding reduced riparian flow left in the parent stream. The future potential for hydro power development may be limited to mini and micro hydroelectric power generation. The Samoa Electric Power Corporation (EPC) currently operates stream flow stations in Tafitoala, Lotofaga, Fausaga, Seugagogo and Faleata. A number of water catchments are protected in the form of national parks and reserves.

5. HYDROLOGICAL INFORMATION

In the past hydrological monitoring and assessment was undertaken by the Samoa Meteorological Service with development aid assistance programs. Training was irregular and unstructured, based on periodic country visits by various specialists over a comparatively short period. Preserved datasets are generally short, fragmented and of limited value. More recently, 2005, as part of the European Union funded Water Sector Support Programme, WaSSP, Samoa's Ministry of Natural Resources and Environment, Water Resource Division (MNRE-WRD) was established and has assumed responsibility for water resource assessment and management. In 2008 the Pacific HYCOS Project provided training and support to MNRE-WRD, over a three year period, with the re-

establishment of surface water hydrological stations to help establish a program of sustainable water resources monitoring in Samoa. Additional financial support for the water sector has come from the European Union funded Water Sector Support Program (WaSSP).

5.1 Hydrological Stations

Hydrological stations have operated for varying periods in Samoa however the resulting data is generally incomplete or is un-processed. The attached table indicates the sites known to Pacific HYCOS which have data archived on the Samoan TIDEDA Hydrological database.



List of Hydrological Observation Stations 2008

No.	Station and number	Location and coordinates	Catchment Area (km ²)	Observation Period	Observation Items
1	Vaipu 1080001	Road Bridge 13° 57' 48.9879" S, 171° 34' 54.30072" E	18.2	Open	WL, Q
2	Mataloa 1150001	Togitogiga 14° 0' 49.01508" S, 171° 43' 3.66744" E	34.9	06/07/2009 - Open	WL, Q
3	Salauseu 1190002	Taftoala 13° 58' 39.333" S, 171° 48' 9.7812" E	11.8	10/07/2009 - Open	WL, Q
4	Leafe 1210003	Lotofaga 13° 58' 9.068376" S 171° 51' 1.99188" E	25.6	15/12/09 - Open	WL, Q
5	Faleaseela 1230001	Faleaseela 13° 55' 14.75616S 171° 57' 54.80388" E	16.78	29/09/1990 - Open	WL, Q
6	Fuluasou 1290001	Fuluasou East 13° 51' 56.0124" S 171° 46' 15.3516" E	NA	01/1991 – 04/2001	WL, Q
7	Fuluasou 1290002	Fuluasou Middle 13° 53' 6.0324" S 171° 49' 41.3004" E	NA	03/1996 – 04/2001	WL, Q
8	Fuluasou 1290003	Fuluasou West 3° 53' 9.771324" S 171° 49' 49.33668" E	4.4	31/05/2008 - Open	WL, Q
9	Vaisigano 1320001	Alaoa West 3° 52' 22.897056" S 171° 45' 20.0304" E	37.2	04/07.2008 - Open	WL, Q
10	Vaisigano 1320002	Alaoa East 13° 52' 28" S 171° 45' 16" E	37.2	01/1990 - 04/2009	WL, Q
11	Vaisigano 1320005	Tiapapata 13° 54' 3.3912" S 171° 46' 32.1168" E	37.2		WL
12	Vaisigano 1320006	Alaoa Middle 13° 52' 56.3988" S 171° 46' 57.864" E	37.2	03/1991 – 03/2001	WL
13	Vaisigano 1320007	Malolelei 13° 54' 3.3912" S 171° 46' 32.1168" E	37.2	May - June 1985	WL
14	Vaisigano 1320008	Alaoa East (Pump Pro) 13° 52' 50" S 171° 45' 15" E	37.2	01/12/2008 - Open	WL, Q
15	Vaisigano 1320009	Alaoa Middle (new site location)		01/05/2009 - Open	WL
16	Mulivai 1440002	Tiavea SWA 13° 59' 12.926544" S 171° 30' 28.81404" E	10.9	21/11/2008 - Open	WL
17	Seugagogo 2020001	Seugagogo 13° 44' 42.192024" S 172° 19' 27.64668" E	22.6	7/08/2009 - Open	WL
18	Faleata 2020002	Faleata 13° 43' 28.27308" S 172° 18' 53.85708" E	11.6	07/08/2009 - Open	WL
19	Fatalele 2170001	Vaipouli 13° 28' 7.064652" S 172° 22' 58.1736" E	1.6	26/07/2008 - Open	WL

Dates indicate data availability; very significant gaps of many years are evident in all of the datasets

Review and assessment of the historic hydrological data has identified that only limited confidence can be placed in the historic data. The more recently collected data under the Water Sector Support Programme, WaSSP and Pacific HYCOS provides greater quality assurance for these priority sites. Water level hydrographs only, are presented, where confidence in determining discharge calculations are limited due to a shortage of discharge measurements at medium to high flows. The range of discharge measurements undertaken at selected sites have been presented in a table along with the maximum level recorded at the respective station to give an indication of data collected.

Recent actions by MNRE-WRD have resulted in the digitising of Vaisigano, Faleaseela and Fuluasou catchments which will allow improved access to the application of this data.

5.2 Study Catchment Introduction

Two catchments, the Vaisigano and Faleaseela demonstrate some of the better examples of hydrological data available for Samoa, where long term data is available. Both catchments located on the island of Upolu, have stations at control weirs, which offer stability to the rating curves, however improvements to these ratings with

discharge measurements at medium to high flows is required. The Vaisigano River is important in the north of Upolu as it is used for water supply for Apia and hydro-electric generation. It flows through a highly urbanised area where flooding can cause significant problems. The Faleaseela to the east of Upolu, is largely a rural river, has agricultural uses and supplies water to the south west of Upolu.

5.2.1 General Description

Both study catchments rise on the high mountain spine of Upolu, and both are perennial streams, of which there are many on the volcanic island. The upper catchments of the streams are forested, with lower clearings of pasture land for cattle farming, this terrain is interspersed in places with deep incised and very rugged gorges. Data collection commenced on these streams in the early 1970's, with a need for data for water supply purposes. The Faleaseela in the west is in an area of reduced runoff where the localised geology favours infiltration to the fractured rock aquifers. As evidenced on the attached map, there are fewer perennial streams in this area but there are a number of gravity springs on the mid to lower slopes of the mountains.

Location of study catchments





Local house, Upolu

Characteristics of selected river stations and their sub-catchments.

	Name of River and Station number	Subcatchment Area (km ²)	Highest peak	Lowest point	Land use
1	Vaisigano at Alaoa East 1320002	11.154	820m	0m	Agriculture and forest
2	Vaisigano at Alaoa West 1320001	9.295	900m	0m	Agriculture and forest
3	Vaisigano at Alaoa Middle 1320009	13.6	1100m	0m	Agriculture and forest
4	Faleaseela at Faleaseela 1230001	16.78	400m	0m	Agriculture and forest

5.2.2 Measured Hydrological data

The only long term hydrological data available in Samoa is for the Vaisigano and Faleaseela streams, this data was sourced from the NIWA Pacific TIDEDA backup database, in the form of instantaneous data and gaugings. The original datasets in chart and paper tabulation format, are held by MNRE WRD. There is a structured program underway to digitise and archive this information to the TIDEDA database. The digitising of these paper records are understood to be now completed, (L. Simanu pers comm. 2011). Where discharge measurements are available only at low flows, rating curves have not been developed.

In addition to the catchment mapping, an assessment was made on the catchment gradients. This is included for the main branch and secondary branches where present.

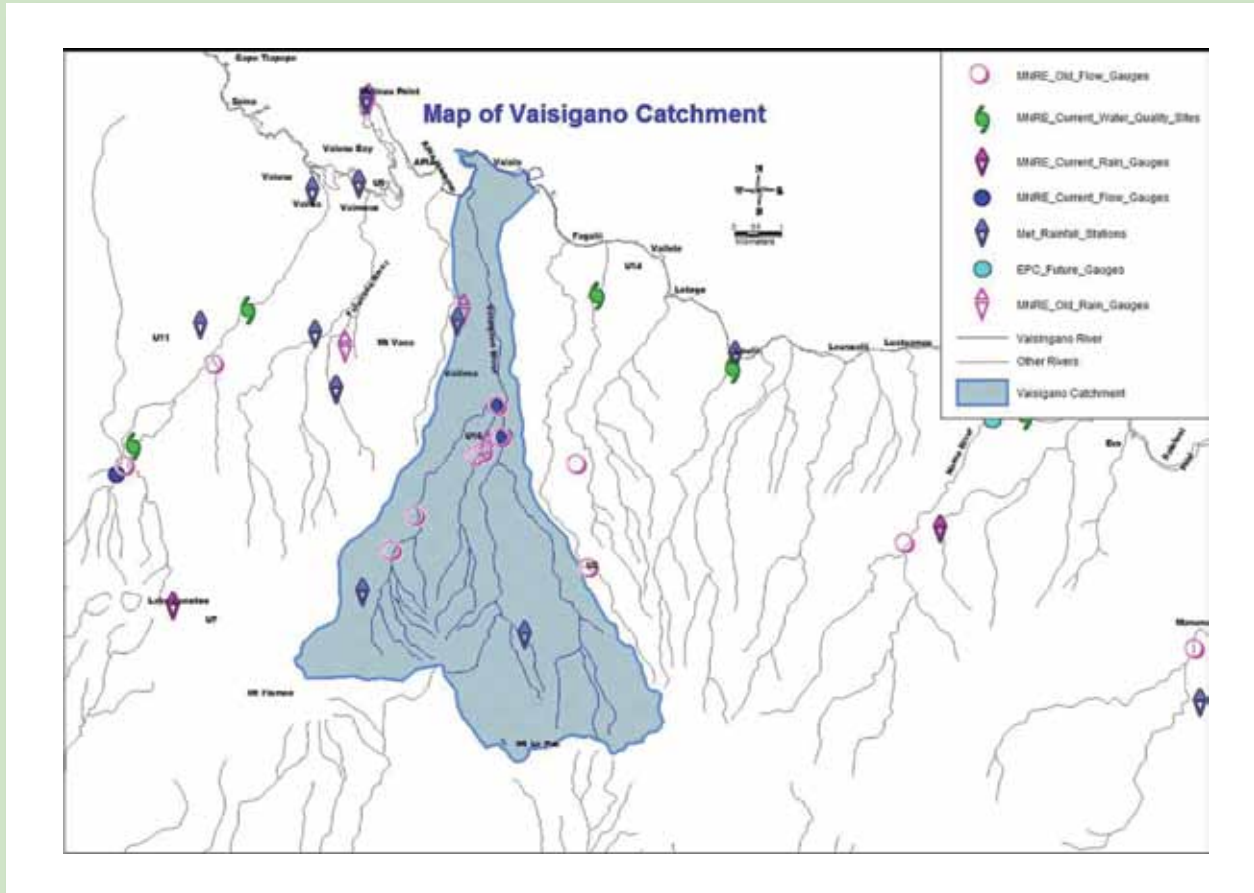
Catchment 1 – Vaisigano at Alaoa East

The Vaisigano River was identified as one of the major catchments under the Pacific HYCOS project for support, and is of significant interest to the Water Sector Support Programme, WaSSP, Samoa Water Authority (SWA), and Electric

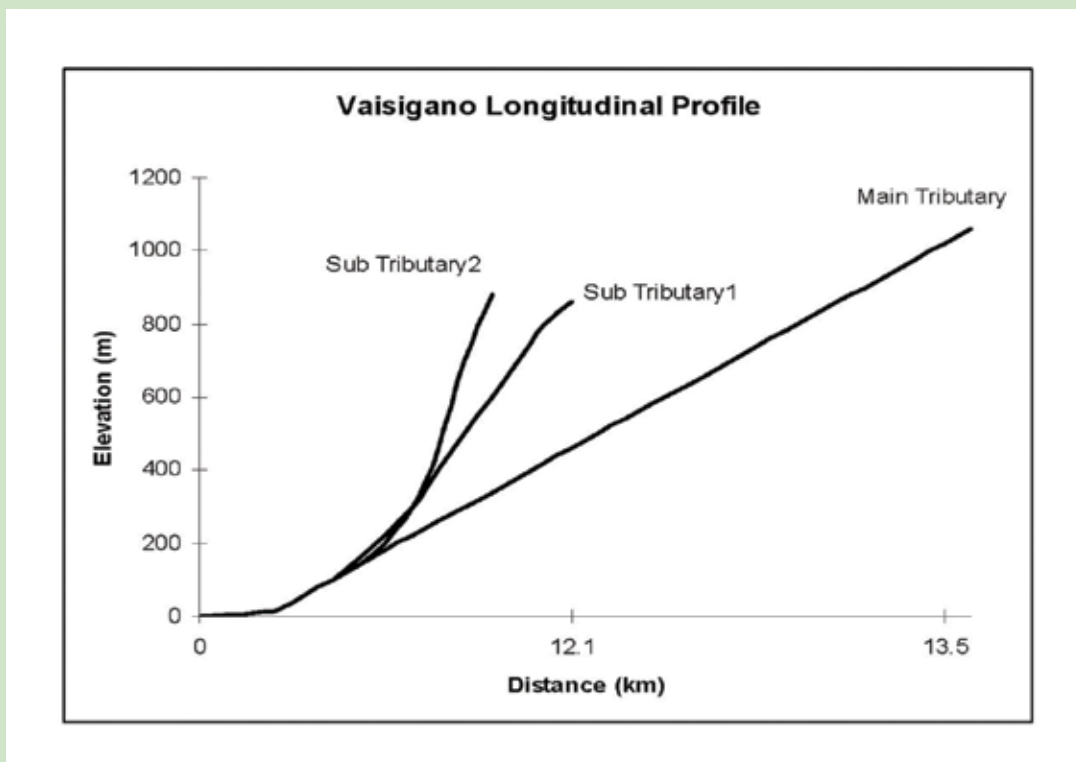
Power Corporation (EPC), due to its importance and the demands placed on it, as well as its propensity to flood. The Vaisigano River flows to the north from the high mountains, down through the lower valley to the Apia urban area to meet the Pacific Ocean. The old hydrological site at Alaoa East measured river flows mid stream between two SWA intakes and below an EPC power station, involving inter basin water transfer. This site is very insensitive to low flows due to the very wide control weir. Water levels were measured in a stilling well using a Stevens A71 chart instrument and more recently a shaft encoder instrument was installed. Due to this limiting location, Pacific HYCOS in cooperation with SWA funded the installation of a new site, upstream of the power station and water off-takes, to better monitor the natural catchment resource.

During extreme weather conditions the river has quite often flooded to high levels, causing serious erosion, damage to properties in the riparian zone and nearby businesses, with significant disruption to the town's traffic flow. The total catchment area is 37.18 square kilometres and is one of Samoa's largest and most destructive rivers.

Map of Vaisigano Catchment



Vaisigano Catchment profile





Apullio Hydro dam

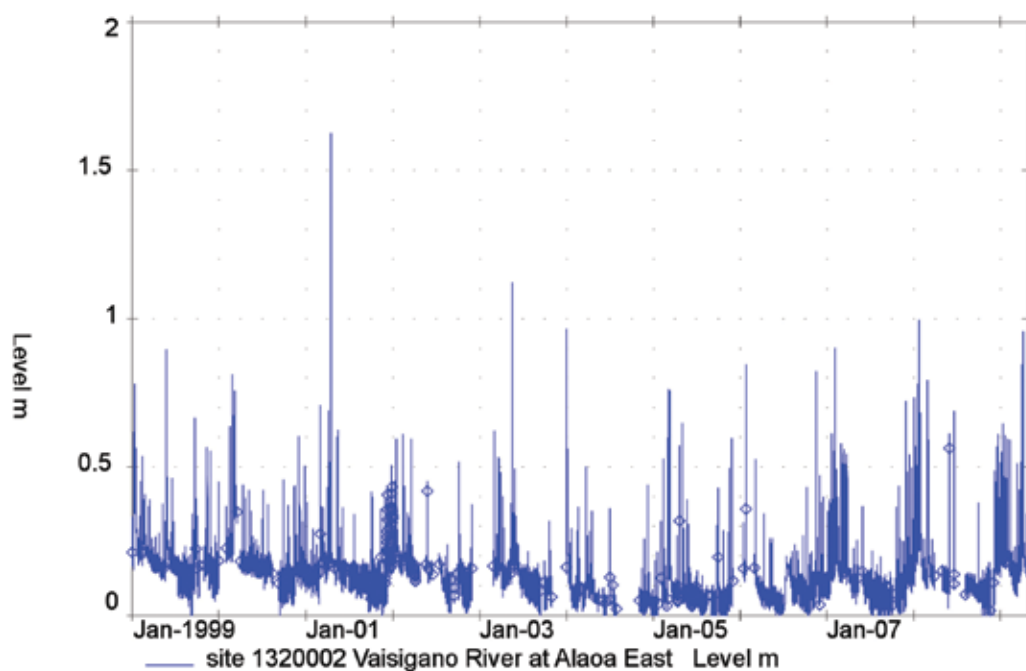
List of available discharge measurements for Vaisigano, Alaoa East, Station No. 1320002

Site	Minimum gauged		Date	Maximum gauged		Date	Max level recorded (m)	Date	No Q meas
	Level m	Flow m ³ /s		Level m	Flow m ³ /s				
Vaisigano Alaoa East 1320002	0.018	1.170	10/09/1987	0.500	2.978	24/10/1998	1.620	29/09/1990	51

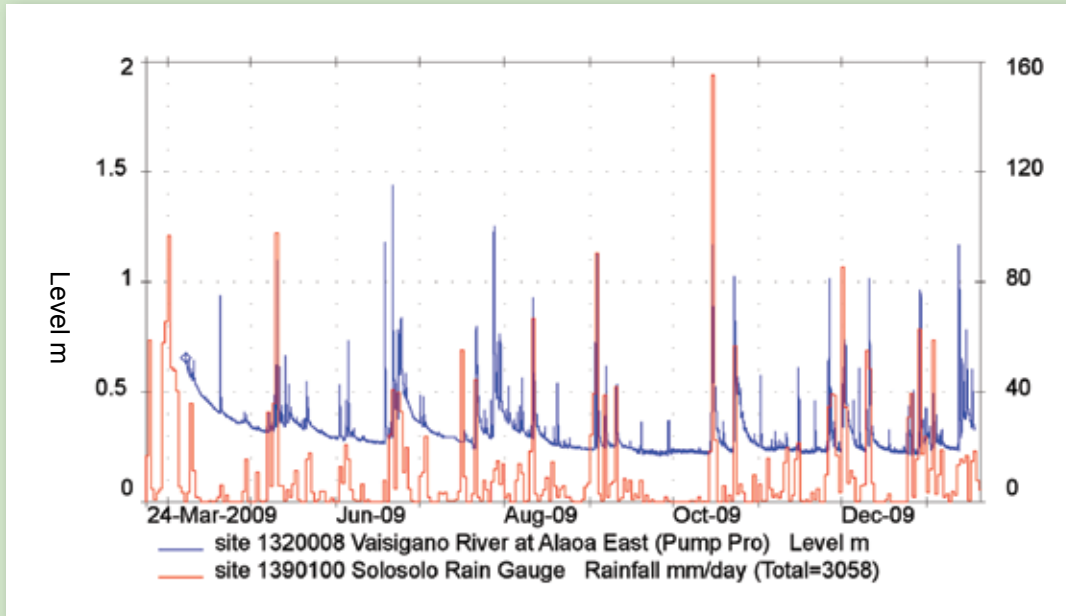
Dates indicate data availability; very significant gaps of many years are evident in all of the datasets

The following graph of the long term data is from 1999 - 2009. Whilst the site was installed in the 1970's data is still mostly held on the original paper chart and in paper tabulations. Reprocessing of chart data has commenced and with intention that it will be digitally stored in the database.

Long Term Variation of Water Level (Instantaneous), Vaisigano River, Alaoa East Station No. 1320002

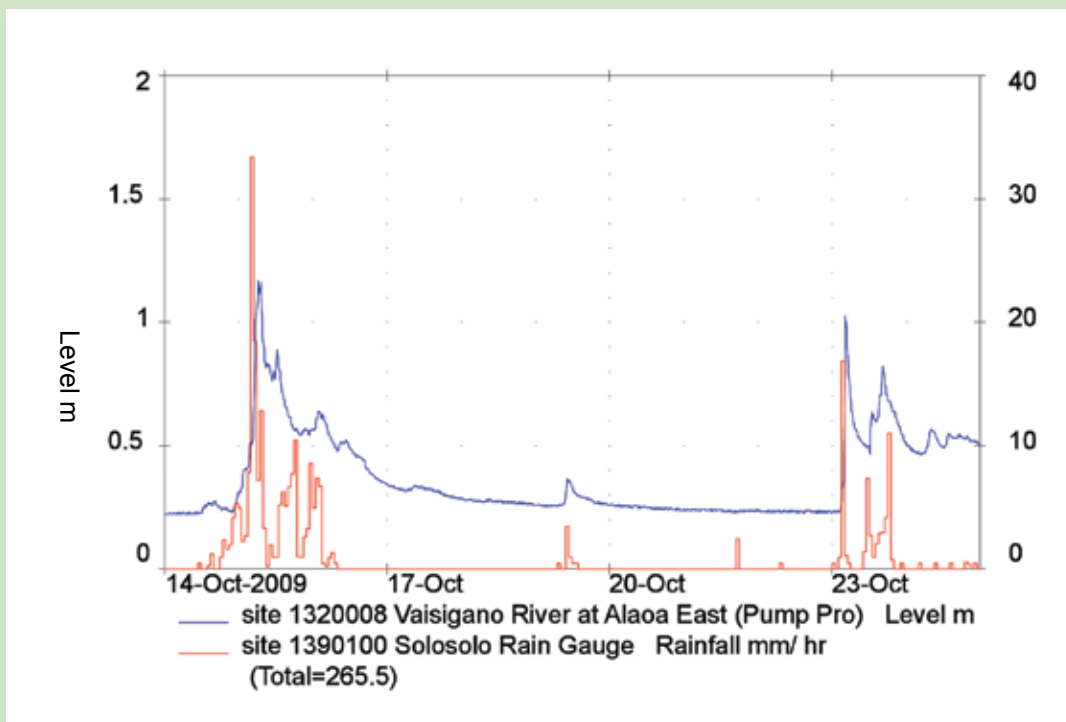


Water level and rainfall new upstream Vaisigano site (Pacific HYCOS) Station No. 1320008



The attached graph showing rainfall and stream flow level is from data collected by the Pacific HYCOS project. The frequency of data allows the response time to specific storms to be assessed in some detail. The limitations on older chart recorders was that clocks could be in error, data was manually extracted and response timing of rainfall and stream level events for highly responsive catchments was poorly defined at the chart scales used. This graph shows an hourly time step, which can be reduced to 15 minutes if required for rainfall runoff modelling purposes.

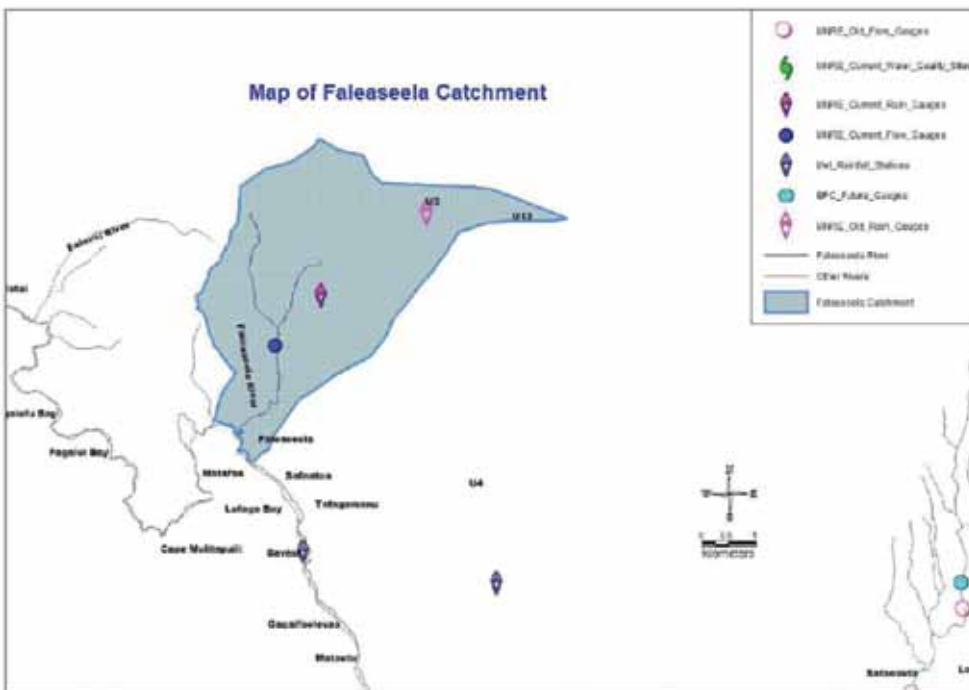
Relationship of hourly rainfalls with an adjacent raingauge to assess runoff for two select storms, in the highly responsive catchment of Vaisigano.



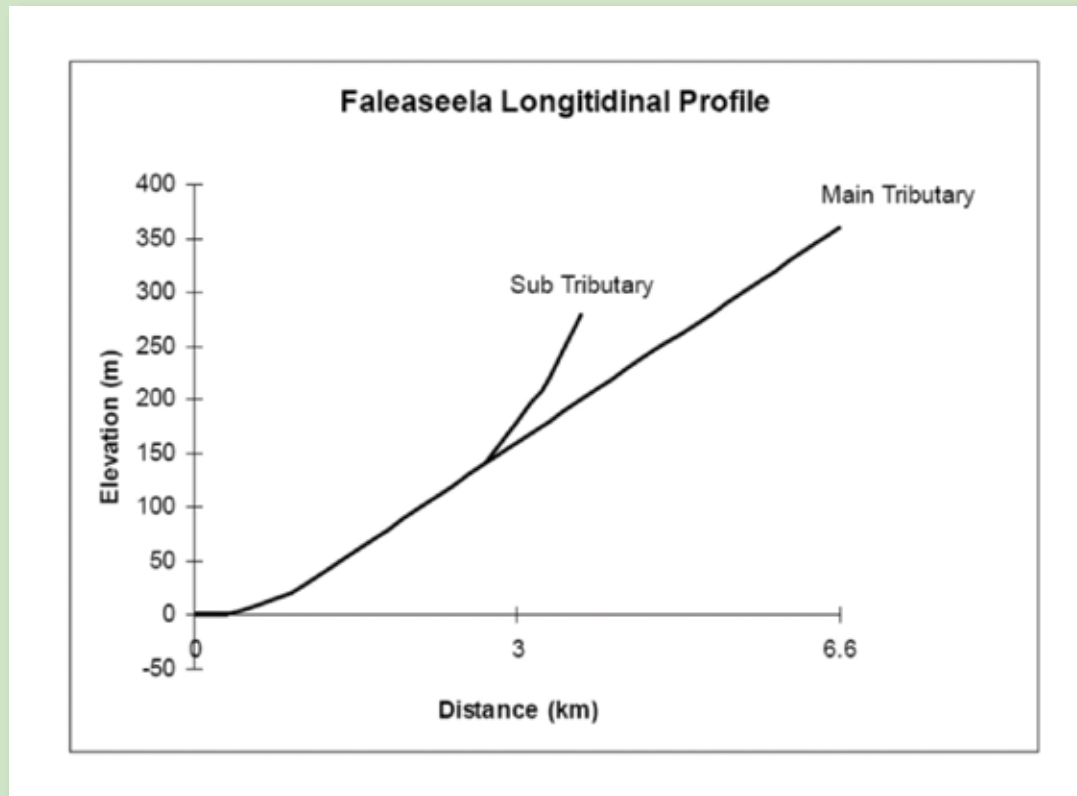
Catchment 2 – Falaeseela

The Falaeseela River is of significance to the Samoa Water Authority and was included under the Pacific HYCOS project. The Falaeseela river flows to the south from the high mountains, down through the lower valley to the Falaeseela Village meeting the Pacific Ocean. The site has a concrete weir and measures river levels. The site is quite sensitive to low flows due to the shaped control weir. Water levels were previously measured in a stilling well using a Stevens A71 chart instrument, more recently a shaft encoder instrument was installed. The mid catchment contains a SWA intake at a significant, but unmeasured, spring from the volcanics. The total catchment area is 16.8 square kilometres.

Map of Falaeseela Catchment



Faleaseela Catchment Profile



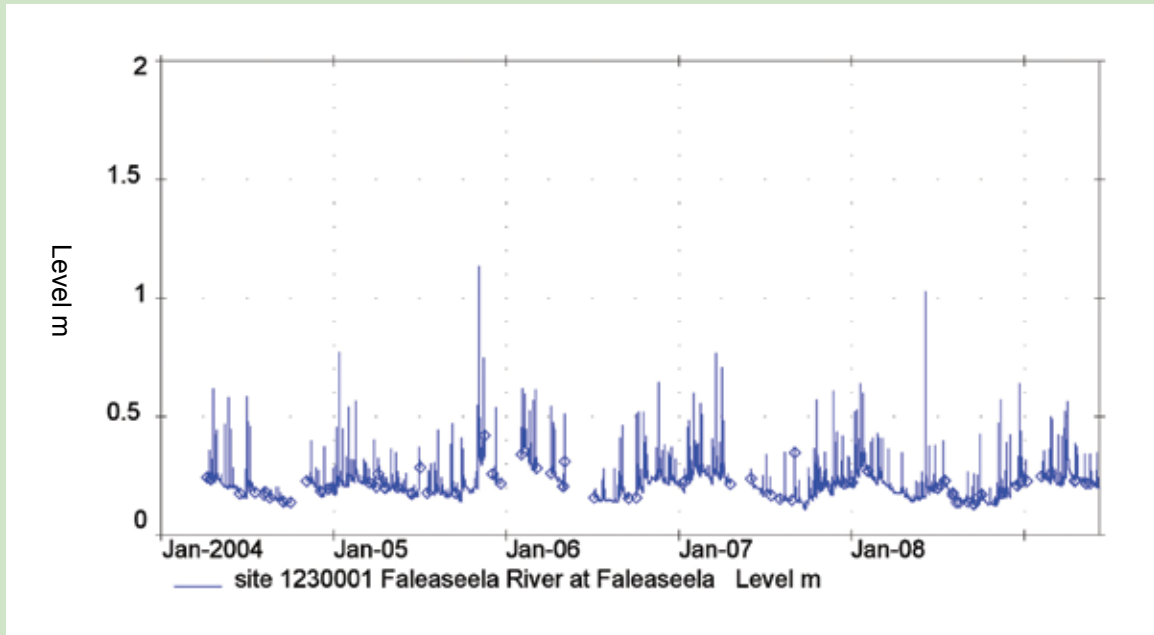
List of available discharge measurements, Faleaseela Station No. 1230001

Site	Minimum gauged		Date	Maximum gauged		Date	Max level recorded (m)	Date	No Q meas
	Level m	Flow m ³ /s		Level m	Flow m ³ /s				
Faleaseela at Weir 1230001	0.136	0.101	1/10/2004	0.342	0.797	2/02/2006	1.13	6/11/2005	36

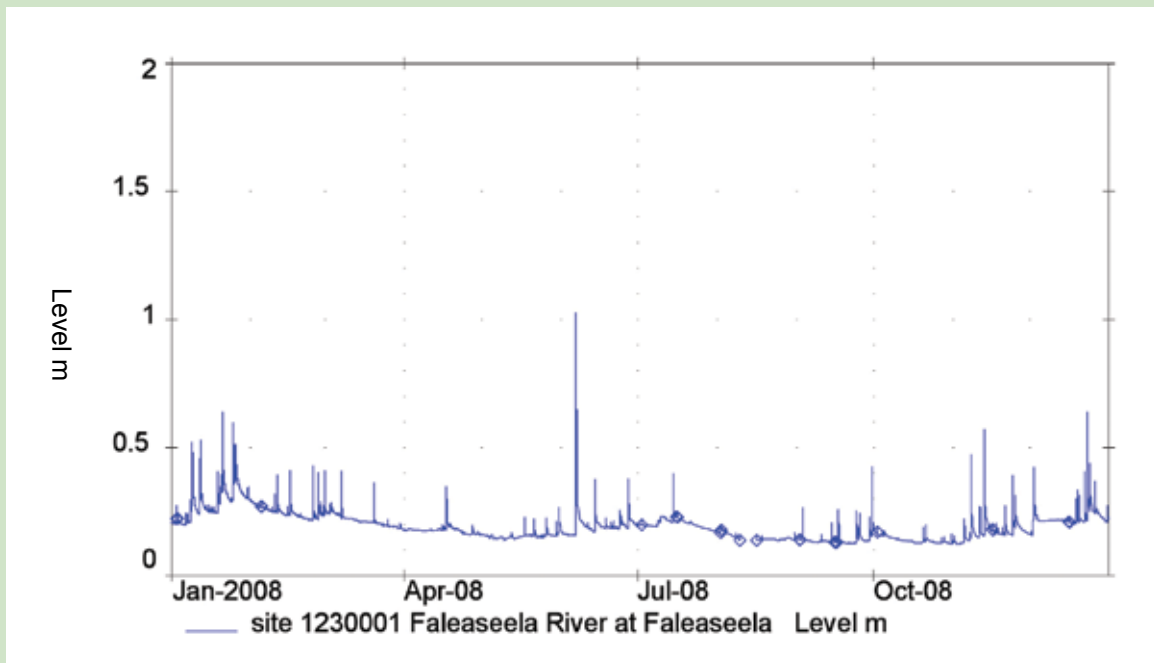
Note; significant gaugings are uncalculated and are not on the database



Long Term Variation of Water Level (Instantaneous) Faleaseela River, Station No. 1230001



Annual Pattern of Water Level Faleaseela River, Station No. 1230001





Field team preparing for discharge measurement below EPC Power Station, Vaisigano at Alaoa East

6. COMMENT

In general the usable river hydrological data available for Samoa is limited due to poor and fragmented records, with discharge measurements mainly at low flows. The data that is available is useful for the basic calibration of catchment models and for analysis of some individual storm or drought sequences. A minimum of 10 years of consistent and continuous data is needed for hydrological statistics with any confidence to be derived. MNRE and their staff have shown an excellent level of commitment in recent times to the collection of hydrological data and it is hopeful that by 2015 some robust datasets will have been collected. These datasets will assist government and stakeholders alike to make a more informed assessment on the development and sustainability options of the nations water resources.

7. PHOTOGRAPHS



Where the Vaisigano River meets the ocean, after a small rainfall event showing very turbid water



MNRE Field team undertaking water quality observations Vaisigano River at the new site No. 1320008





Samoa Water Authority water treatment plant at Alaoa east



Training in data rescue techniques for chart digitising using TIDEDA



Samoa Electricity Authority Vaisigano Hydro Power Plant



MNRE field team undertaking a streamflow measurement in heavy rain upstream of the Falaseela Weir, 20 metre waterfall beyond



SWA water intake off the Vaisigano River