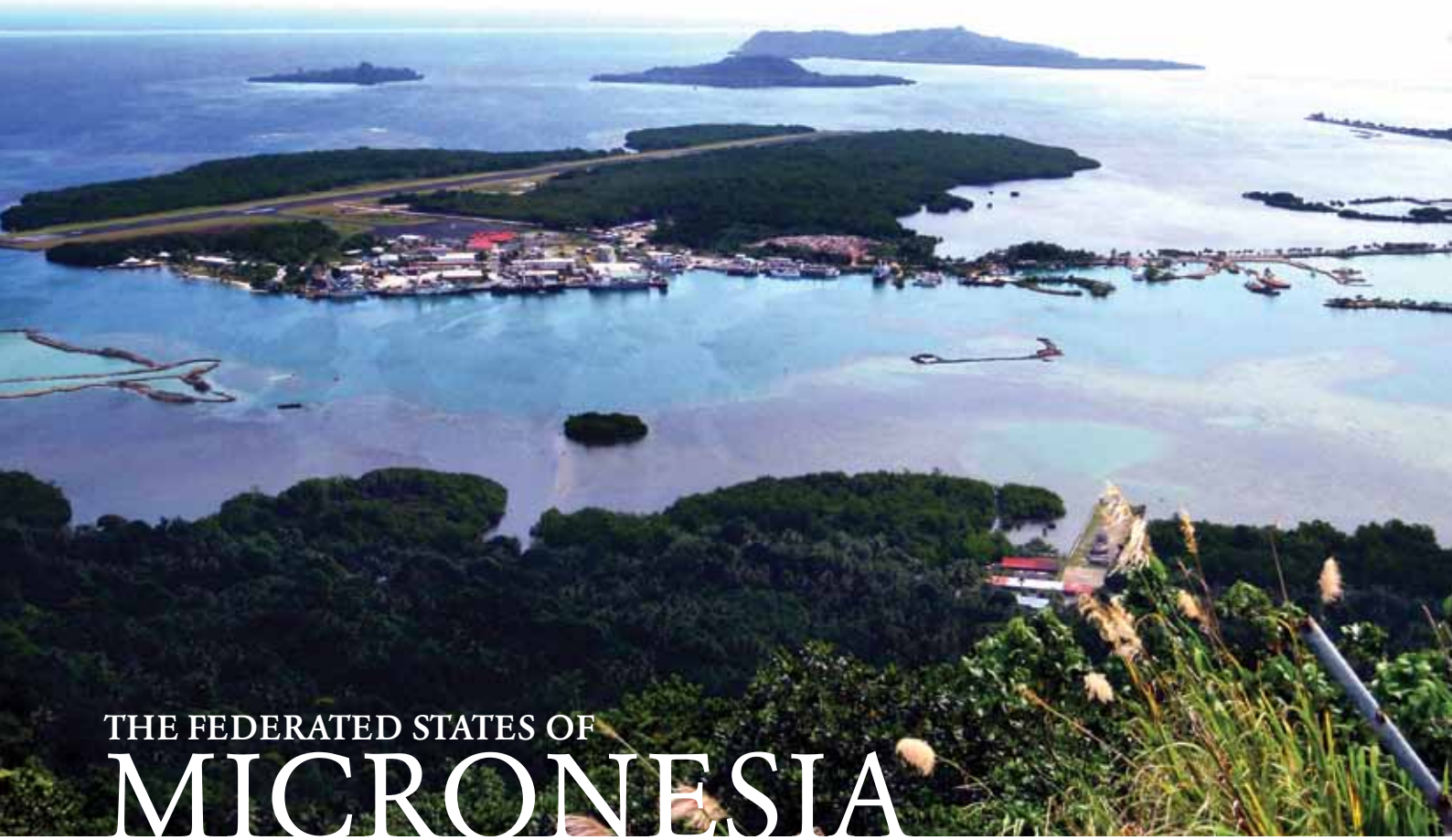


THE FEDERATED STATES OF MICRONESIA

Kolonia Airfield

1. COUNTRY INTRODUCTION

Description:

The Federated States of Micronesia (FSM) comprises of 4 major island groups and FSM State's of Pohnpei, Kosrae, Yap and Chuuk, with a total population projection of 107,839 in 2010, with the state of Chukk accounting for 49% of the population and the state of Pohnpei accounting for 32% of the population (FSM Division of Statistics). They consist of 607 islands spread out over more than 2.5 million sq. km which vary geologically from high mountainous islands to low lying coral atolls and volcanic outcroppings.

Economy:

Key economic sectors are agriculture (predominantly subsistence farming), agro-forestry, fisheries including processing, and some tourism, 18,000 - 20,000 visitors per year (FSM Division of Statistics). GDP is not equally distributed between the four states, with Pohnpei and Chuuk having a higher portion of the FSM GDP, with Yap and Pohnpei having the highest GDP per capita. As with many of the Pacific Island States, geographical isolation and poorly developed infrastructure are major impediments to long term development, with 80% of people dependent on subsistence or semi-subsistence livelihoods. The highest source of revenue is grants (compact grants and other grants, 60% of revenue), followed by tax 21%, and fishing access licences 10%.

Water Availability:

Surface water comprises of both small and large streams that drain mountainous catchments, of limited aerial extent, on the high islands of Pohnpei and Kosrae. On the smaller volcanic islands only limited surface water supply is available following rainfall, drying up some days or weeks after the rainfall reduces or ceases. Groundwater on these smaller volcanic islands is abstracted as a reliable water source from small, dispersed zones of semi consolidated sediments, weathered volcanics, and weathered schists. Groundwater from these environments is suitable for multiple, low to medium yielding wells. On the raised coral atolls and low lying atoll islands,

groundwater is most often abstracted from the freshwater lens by shallow hand-dug wells from coral sand and silts. Rainwater harvesting is concentrated mainly on the outer islands and in rural areas. Bottled water is a relatively common form of potable water consumption in the developed areas of FSM due to the poor quality of the domestic supply.

Island Vulnerability:

The island groups of Yap, Chuuk and their adjoining outer islands have limited and fragile potable water supply relying predominantly on groundwater abstraction for water supply needs. Water supplies on these islands are prone to impacts from typhoons, extended drought, landslides, tidal erosion and storm surges.

The islands of Pohnpei and Kosrae are geographically quite different, rising to over several hundreds of metres, with very high rainfalls and significant runoff, resulting in regular flooding, although not always damaging. Increasing frequency and intensity of droughts is perceived to be one of the main risks to water supplies in FSM. Siltation of the fringing reefs as a result of deforestation and subsequent erosion coupled with pollution from livestock is considered a growing issue, with damage to traditional marine food supplies and their environment. Urbanisation, pollution and waste management, poorly planned development, inappropriate farming practices, over-exploitation of marine resources and destruction of habitat have also been identified as concerns by stakeholders. The country's fragmented composition of small islands and its dependence on subsistence agriculture, fishing and tourism contributes to its vulnerability to natural and man-made disasters.

Power generation:

The only hydropower plant in FSM is located on the island of Pohnpei, the Nanipil Hydro Electric Plant, which has a capacity of 1.7 Megawatts. This is a supplementary power supply to the main diesel generation plant. Limited streamflows, competing with potable water supply needs severely restricts its operation. All other islands draw energy entirely from diesel electric plants.

Health:

Major health concerns are associated with water related diseases, especially cholera (resulting in an epidemic in Pohnpei in 2000), leptospirosis, hepatitis and amoeba, which are all endemic. The introduction of drinking water safety planning and improved security of potable water will decrease the incidence of water related diseases.

Environment and Tourism:

The biodiversity and natural heritage of FSM is both globally significant as well as considered to be the foundation for the country's long term economic self-sufficiency. The islands of FSM contain over 1,000 plant species, with at least 200 species that are found nowhere else. Its reefs, which provide both coastal protection as well as being an important source of livelihood for a majority of the local population, are home to nearly 1,000 species of fish and more than 350 species of hard coral. The reported decline in biodiversity has been linked to factors such as increased centralisation and urbanisation of the population, placing additional pressures on the environment. Maintaining the water resources, habitats and ecosystems that nurture biodiversity is crucial for sustaining economic interests such as fishing, agriculture and tourism.

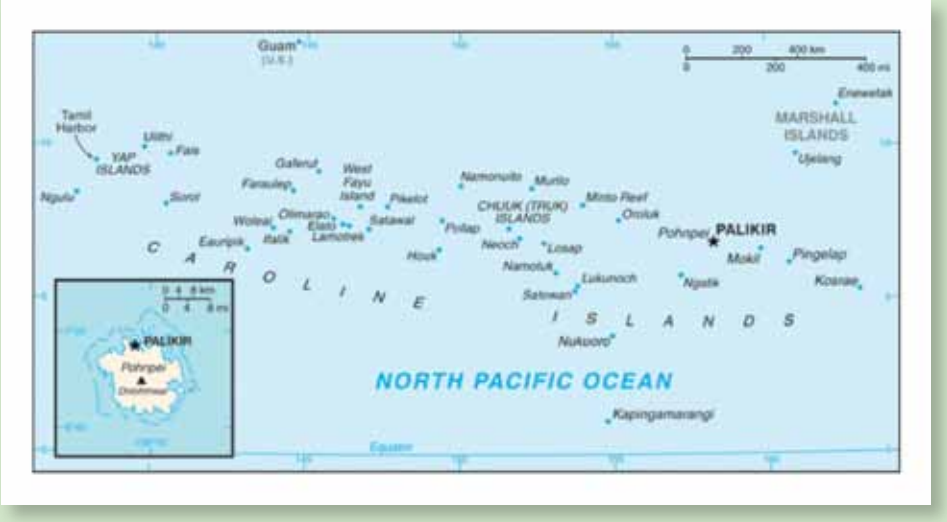
Pollution from improperly located wastewater disposal such as from pig pens that discharge directly or indirectly into the rivers and coastal areas threatens the aquatic environment with consequences for public health, the watershed ecosystem and the economy.

Tourism is fairly evenly spread across the year with small peaks in the periods January - March and then again in July – August.

2. GEOGRAPHIC

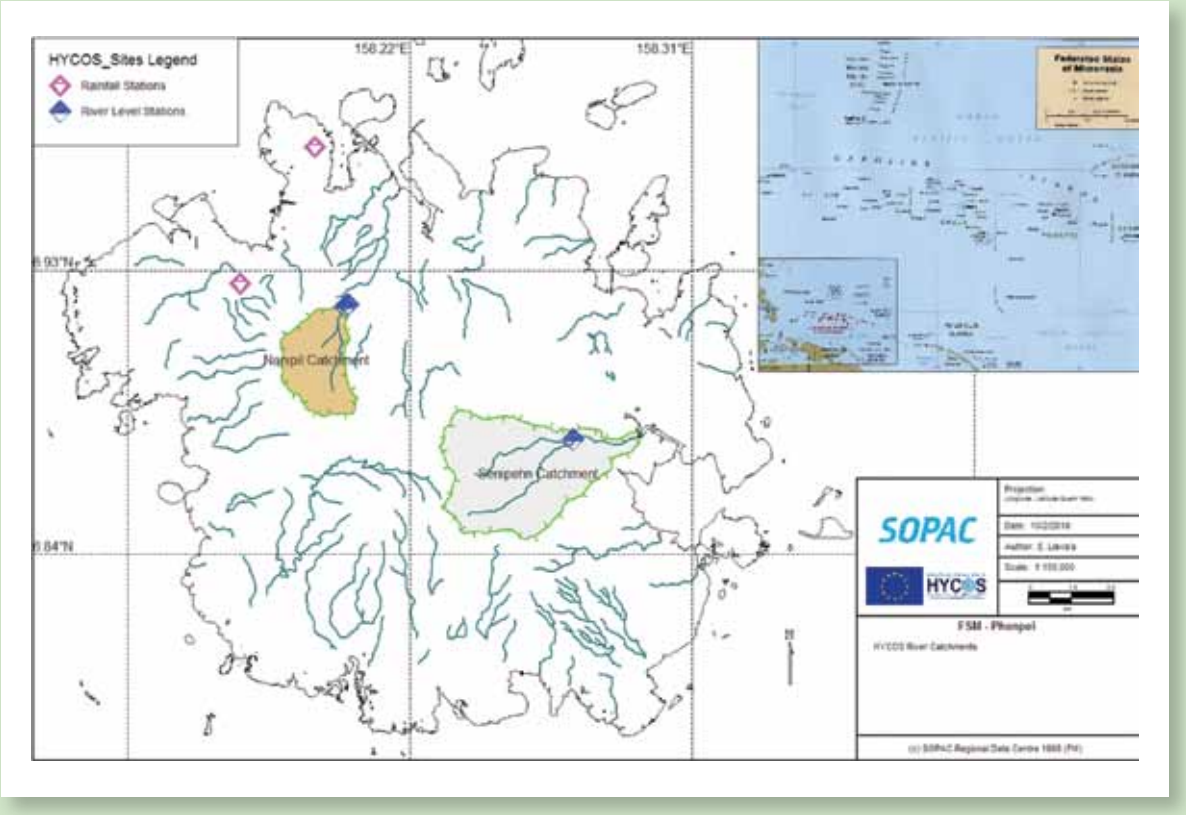
The main island group of FSM and national capital, Pohnpei, was formerly named The Caroline Islands. Pohnpei's highest point is Mt Nanloud found in the central interior of the island. Many of the river catchments start from Mt Nanloud and radiate out around the island. It is a very high peak for a small Pacific Island having an altitude of 772 metres or 2,532 feet.

Map of Federated States of Micronesia

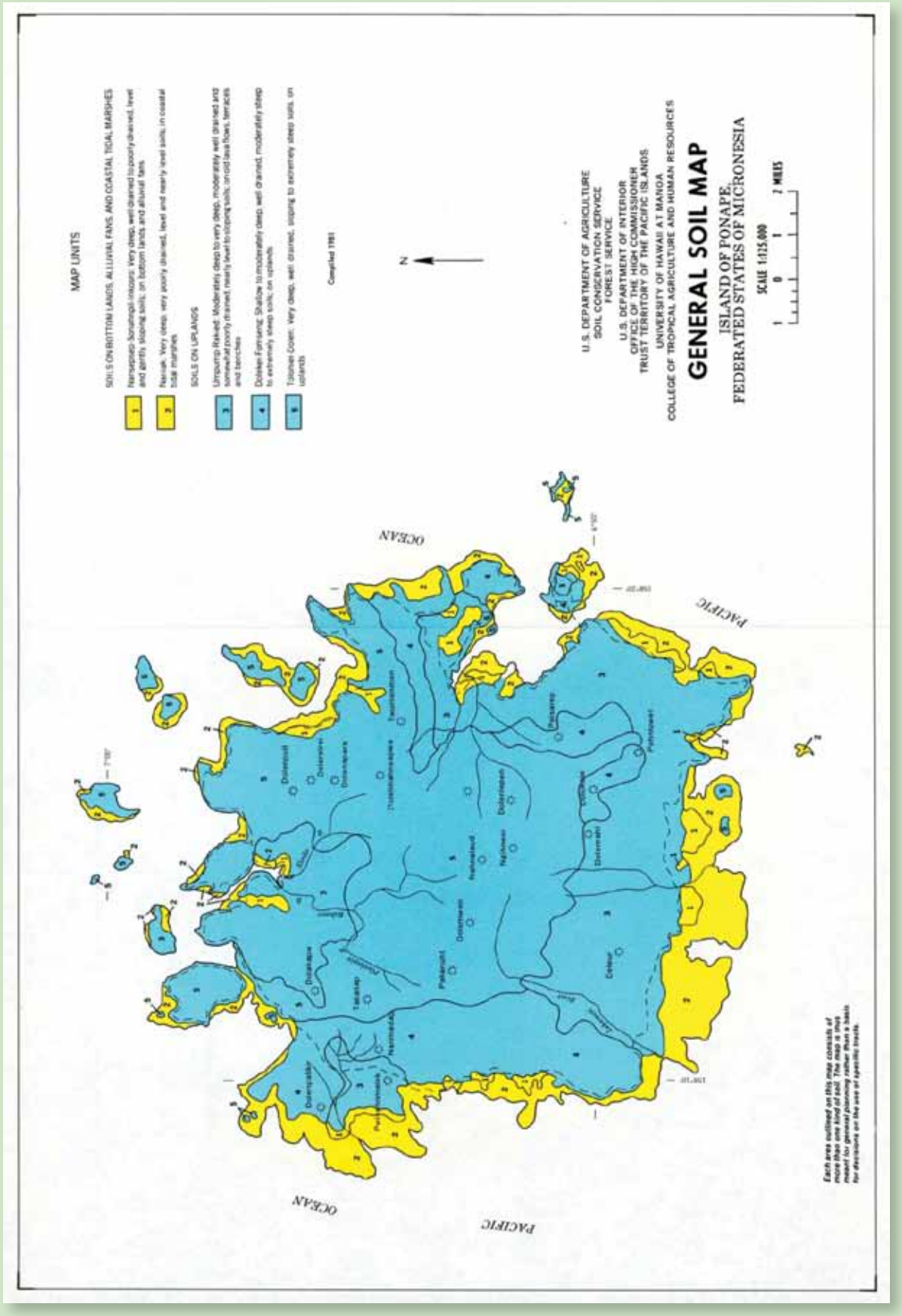


Source: CIA World Factbook, 2011

Map of Country showing HYCOS supported Catchments



General Soils Map of Pohnpei



Source: US Department of Agriculture, 1981

3. CLIMATIC

The climate of Pohnpei is tropical with heavy year-round rainfall, especially in the eastern islands, which are located on southern edge of the typhoon belt. Occasionally damage is experienced especially at roads and road crossings, bridges and in villages located adjacent to streams. The temperature is remarkably stable with the annual average of 27.3^{0}C, varying less than one degree. Apart from the National Ocean and Atmospheric Administration (NOAA) supported raingauge station in Kolonia, little long term rainfall is available. Data has been sourced where possible from NOAA for the preparation of the attached rainfall table as well as from the installed Pacific HYCOS rainfall stations. Total mean annual rainfall in Kolonia is 4,815 mm. The monthly figures are around 300 mm in the months of January to March and then increase and largely stabilise at 400 mm per month for the remainder of the year. Annual rainfalls on the islands highest mountain, Mt Nanloud commonly exceed 8,000 mm. The Western Environmental Research Institute, University of Guam (WERI) have collected rainfall data from several locations on Pohnpei including Mt Nanloud, but this data is short term and not readily accessible.

List of Pacific HYCOS Rainfall Stations

No	Station and number	Elevation	Location	Period of observations	Average rainfall#
1	Kolonia * Not available	10	Kolonia City 6° 57' 36" N 158° 12' 35" E	1900 to present	4815mm
2	Palikur # 16899997	90	National Government 6° 55' 31" N 158° 09' 55" E	Opened 2009	NA
3	Sokehs Rock # 16899994	160	Above Harbour 6° 58' 09" N 158° 11' 24" E	Opened 2009	NA
4	Senipehn # 16899998	40	Village 6° 52' 34" N 158° 16' 19" E	Opened 2009	NA
5	Nanipil# 16890000	110	Weir 6° 55'14" N 158° 12' 12" E	Opened 2010	NA

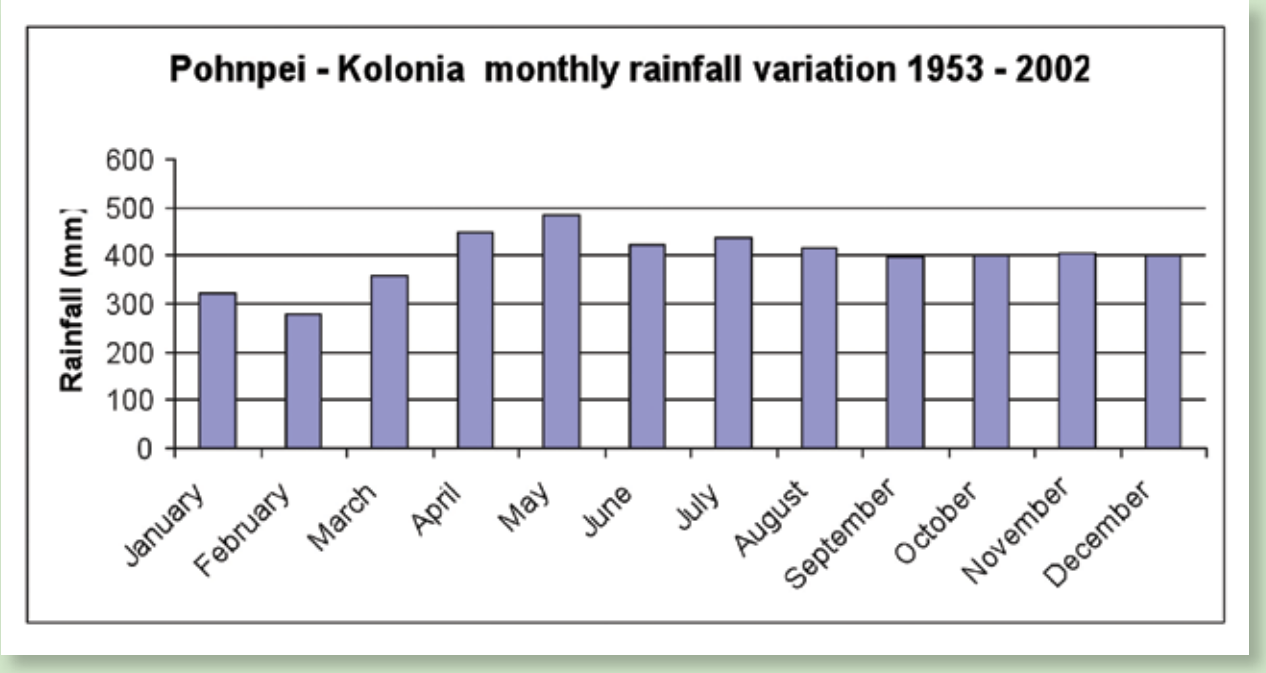
NA – Not Available - records are too short for any annual analysis
** NOAA station for Kolonia*
#Pacific HYCOS installed

Monthly Climate Data

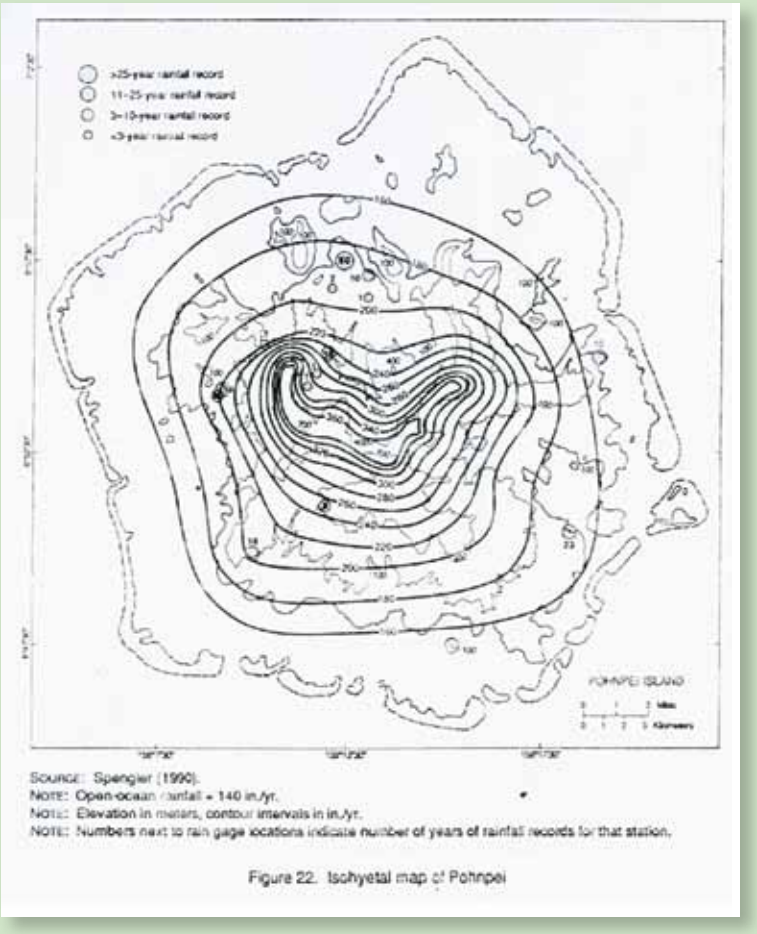
Observation Item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	An-nual	Period for the Mean
Temperature (°C)	27.2	27.3	27.5	27.3	27.1	27.3	27.2	27.4	27.2	27.4	27.5	27.2	27.3	Jan 1996 – Dec 2008
Precipitation (mm)	312	267	356	452	493	432	439	427	409	411	411	406	4815	1953 - 2002

Source: NOAA: www.weatheronline.co.uk/weather

Monthly rainfall variation for Kolonia (NOAA)



Annual isohyetal map of Pohnpei



The isohyetal map for Pohnpei, below, is shown with data displayed in inches. The orographic effect of the high mountains is quite evident with a general concentric pattern around Mt Nanloud and its adjacent peaks. A maximum rainfall zone of 360 inches (9,144 mm) is shown, exceeding the commonly reported 8,000 mm. Longer term records are required to allow verification and to identify the extremes. Mt Nanloud is a virtual cloud forest with mist and rainfall being experienced on most days of the year.

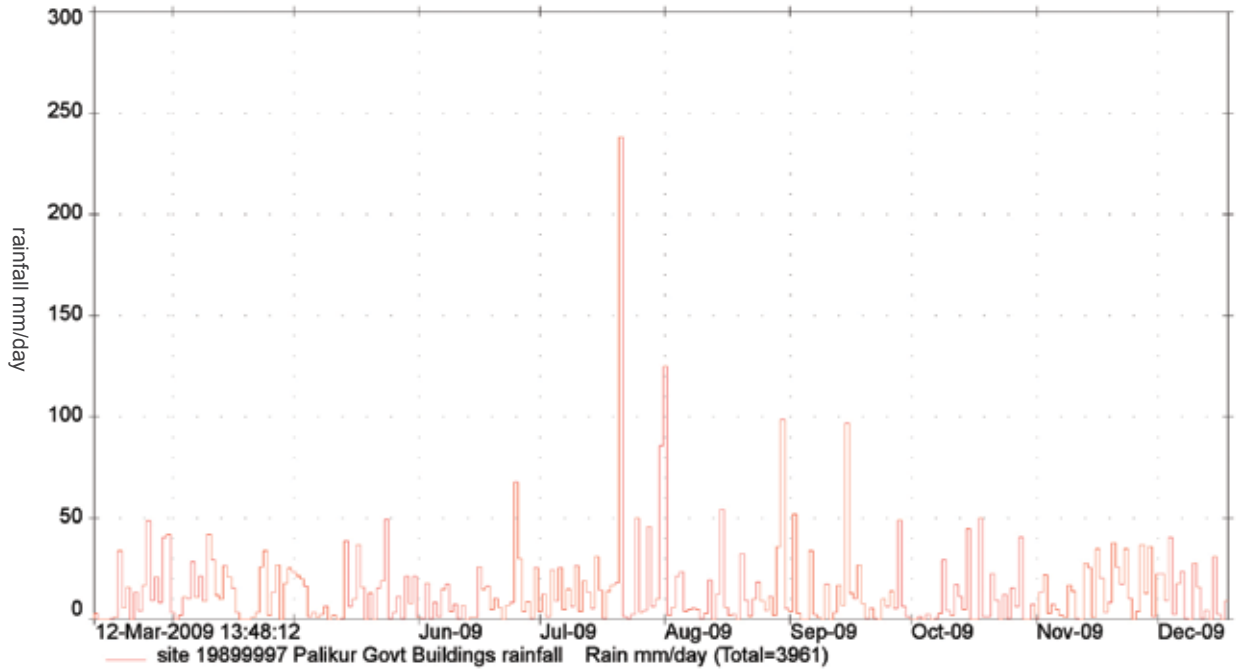
Source: Spengler 1990

Stream gauging, Nanpil

Rainfall intensity data

HYCOS has been unable to source any high quality rainfall intensity data for Pohnpei. Whilst the limited data collected from the Pacific HYCOS supported rain gauges is of high quality, being logged down to a 1 second time step, it is currently of insufficient length. The following plot of daily rainfall from the Palikur Pacific HYCOS rain gauge clearly shows the regular nature of the rainfall at this location and is typical on the island of Pohnpei. For this limited dataset, rainfall was experienced on 247 out of 280 potential rain days in 2009. Close to 4,000 mm was measured in only 9 months with an average of 16 mm being expected on any one rain day. Rainfall intensities from this limited dataset show values of 55 mm in one hour and 25 mm in 15 minutes occurring for a particular storm event. Longer term data sets will allow intensities and frequency data to be better defined to assist with design data. This data will be extremely useful in time for design of infrastructure such as roads, bridging, culverts and drainage works and for any rainfall runoff modelling. WERI hold additional data from their automatic rain gauges which were deployed for a few short years and have been since removed. These stations are not shown due to uncertainty of their exact locations.

Daily rainfall data from the Palikur automatic rain gauge



Nanpil stream water supply intake weir

4. WATER RESOURCES

4.1 General Description

The study catchments selected for the Pacific HYCOS project are the Nanipil and Senipehn in Pohnpei. These are two significant streamflow catchments both rising in the high mountains of Pohnpei. The Nanipil stream is significant as it supplies water to Kolonia's water supply system and to the Nanipil hydroelectric plant. The flow is supplemented 1 km below the intake by inflow from a significant tributary stream. The Nanipil catchment has some scattered housing, with the dominant land use being for food production, with garden cultivation and forest harvesting. Some sakau (Kava) is grown in the catchment for local supply and export.

The Senipehn is the largest catchment on Pohnpei, it is a quite pristine natural catchment, also with few houses and where land use is limited to forest harvesting and small gardens. Both catchments are considered very stable and covered in old growth forest carrying very little sediment even at very high flows. Whilst Pohnpei's water resources can be described as generally abundant, with rain falling on most days of the year, availability is compromised close to the population centre of Kolonia during times of sustained low rainfall due to poor catchment and local water storage. Volcanic structures, covered by shallow soils, with dense forest cover, on steep to moderate catchment slopes, leads to rapid runoff and poor catchment storage characteristics. The National Government offices and residences located at Palikur extract groundwater for their water needs from several groundwater boreholes due to poor and limited surface water availability in this area. With respect to catchment erosion, most can be considered stable due to the dense forest and low levels of agricultural development. This cannot be said of the Enipein catchment in the south of the Island where a high level of cultivation for sakau (kava) production for domestic consumption and export is undertaken, resulting in increasing levels of sediment runoff.

4.2 Major Floods and Droughts

Due to the short term nature of the available hydrological datasets, limited information is available on floods or droughts for Pohnpei and within the HYCOS study catchments of Nanipil and Senipehn catchments. The 6 month dry period from January to June 1982 is the longest dry period recorded in the 23 years of record available for the Nanipil Stream. During this period in 1982, the Nanipil Stream mean daily flows were as low as 0.6 cubic foot per second (cusecs) or 17 litres per second and these were generally sustained for some months, severely compromising water supply. With its current population of around 6,000 people (FSM Division of Statistics, 2010), a similar event would be significant without a supplementary supply. The highest floods evident are in January 1992 when a daily mean discharge of 1200 cusecs or 34 cubic metres per second (cumecs)

or 2,936 million litres per day (ML/day) was measured. The flood peak would have been very much higher than this but the instantaneous flow data is unavailable. This demonstrates the highly variable nature of the stream flows, where floods are characteristically very flashy, compromising bridging, culverts and river crossings. During these flash flood events lives are at risk where people attempt to cross swollen rivers and streams. Such river and stream crossing is common place in FSM, for access to villages, garden produce to market and children travelling to schooling, where foot bridges have not been built. It is uncertain if any specific flood analysis has been undertaken on this river.

4.3 Socio-economic characteristics

Current demands on the water resource for all but the north of Pohnpei are limited to very small scale agriculture, villages and schools. The capital city of Kolonia draws its water supply from the northern part of the island, resulting in the resource being highly committed especially during sustained dry periods. The streams are also used for activities such as food preparation washing of cooking and food items and household laundry as well as a fishery resource for freshwater species. Piggeries are frequently located next to streams and close to water use areas contributing to point source pollution and degraded water quality. Potential exists on much of the island for increasing levels of small irrigated agriculture, micro hydro and small scale tourist resort development. Some streams offer tourism potential for river boating, rafting, bush walking and waterfall and eco-tourism experiences.

5. HYDROLOGICAL INFORMATION

Hydrological data has been collected by a range of administrations commencing with the German regime in 1900 and progressing to the United States Geological Survey (USGS) which ceased collecting data in the early to mid 1990's. FSM does not have a National Hydrological Service as such and any recent hydrological monitoring and assessment was undertaken by the USGS. Data collection activities were undertaken on periodic country visits over a comparatively short period. Consequently datasets are short, fragmented and of limited value apart from those on the Nanipil Stream. There has been no regular data collection for some years apart from rainfall data collected by NOAA and some research activities undertaken by WERI on selected catchments in the 2000's. Until recently there was no National Hydrological Database and apart from the Nanipil, there appears to be no long term data sets exceeding more than a few years. Most of the data collected is understood to be held in the USGS archives in the USA in an imperial data format and on the original charts and was largely inaccessible for review. Van Der Burgh in the 1970's undertook some early analysis and a number of his reports and assessments are available through USGS website. The Pacific HYCOS Project implemented in FSM in 2009 with support at a National Government level with the Department of Transport, Communication and Infrastructure (DTCI), a Government funded Department with no hydrological experience. Under HYCOS support, training was given and skills were developed, capital equipment purchased and pilot sites identified, installed or reinstated in order to support sustainable water resources monitoring for pilot river basins. More recently Pacific HYCOS has rescued the accessible USGS stream data for one site to the FSM TIDEDA database system. The FSM TIDEDA database also hosts the recently collected data from the installed or refurbished sites under Pacific HYCOS.

5.1 Hydrological Stations

The USGS and Van Der Burgh list a number of sites that operated in the 1970's. Apart from the reports published at the time, little is known about these sites and 20 – 30 years of abandonment makes them very difficult to locate. Pacific HYCOS selected two pilot catchment basins, the Nanipil and the Senipehn, for upgrading and installation of new generation hydrological monitoring equipment.

List of Pacific HYCOS Hydrological Observation Stations

No	Station and number	Location and coordinates	Catchment area A (km^2)	Observation period	Observations
1	Nanipil 16897600	above intake 6° 55' 13" N 158° 12' 15" E	7.6	1972 – 1994 2009 open	WL, Q
2	Nanipil 16899995	at PUC Dam (intake) 6° 55'14" N 158° 12' 12" E	7.9	2010 open	WL & RF
3	Senipehn 16899999	at footbridge 6° 52' 34" N 158° 16' 19" E	14.0	2010 open	WL, Q & RF

5.2 Study Catchment Introduction

5.2.1 General Description

The FSM Island State of Pohnpei has in general an abundance of surface water streams and rivers which in general radiate out from the islands high and wet interior. The northern most streams, especially the Nanipil, supply the majority of the public drinking water especially for the capital city of Kolonia. A secondary potable water source, and less developed, comes from groundwater, a network of boreholes found in the Palikur area. The groundwater source is used for the National Government offices as well as domestic supplies in the immediate area, and where surface water flow is limited. The Nanipil Dam forms the intake structure for the hydro power station and potable water supply, though its water storage capacity is limited. Abundant rain generally brings sufficient surface water flow, though supply can be compromised during periods of extended dry or El Niño events. In addition to the local domestic needs, additional demand is placed on the storage by the fish processing industry at Koror's Port. The quality of supply is generally good but is at risk from poor sanitation and agriculture practices located close to water sources within the catchment. Tourism to date is comparatively underdeveloped and is limited to a few small hotels in Kolonia.

5.2.2 Measured Hydrological data

The only long term data available in FSM is for the Nanipil Stream. The data is sourced from the USGS water web site in the form of daily mean discharges filed in cubic feet per second (cusecs). The original data including streamflow measurements is not readily available. The attached graphs are restricted to the average flow for the stream on that particular day, and do not represent a measure of flood flows. The peak flood flow will therefore be considerably higher than those that are indicated. In recent years, WERI engaged with the Conservation Society (CSP) of Pohnpei to undertake the hydrological data collection program on the Nanipil, Senipehn and Enipehn Streams plus some raingauges, the data has not been available to Pacific HYCOS or DTCI. Support funding for WERI has ceased but it is understood that CSP still collect and archive some data in spreadsheets formats, where there is no hydrological database system.

Pacific HYCOS funded the installation of two high quality and long term hydrological stations on the Nanipil and Senipehn streams, measuring water level and rainfall. This work was carried out in 2009, with the assistance of the Department of Transport, Communications and Infrastructure (DTCI), where DTCI are the government department responsible for maintaining these sites and the national hydrological database. The TIDEDA national hydrological database set up by HYCOS is limited at this stage to water level and rainfall information. Rating curves have yet to be developed over a full range of flow conditions and currently only very limited discharge measurements have been undertaken. In addition to the catchment mapping, an assessment was made on the catchment gradients.

Nanpil stream, East branch

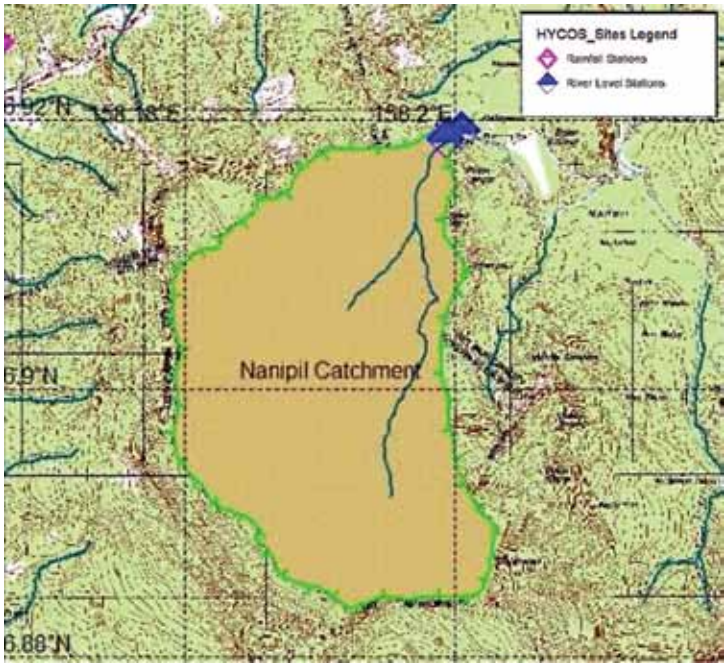
This is included for the main branch and secondary branches where present. Gradient or channel slope forms an important parameter in hydrology especially hydrological modelling. Recent hydrological data is recorded in SI units, where DTCI have elected to utilise the metric system for hydrological measurements.

5.2.2.1. Catchment 1 – Nanipil, above intake

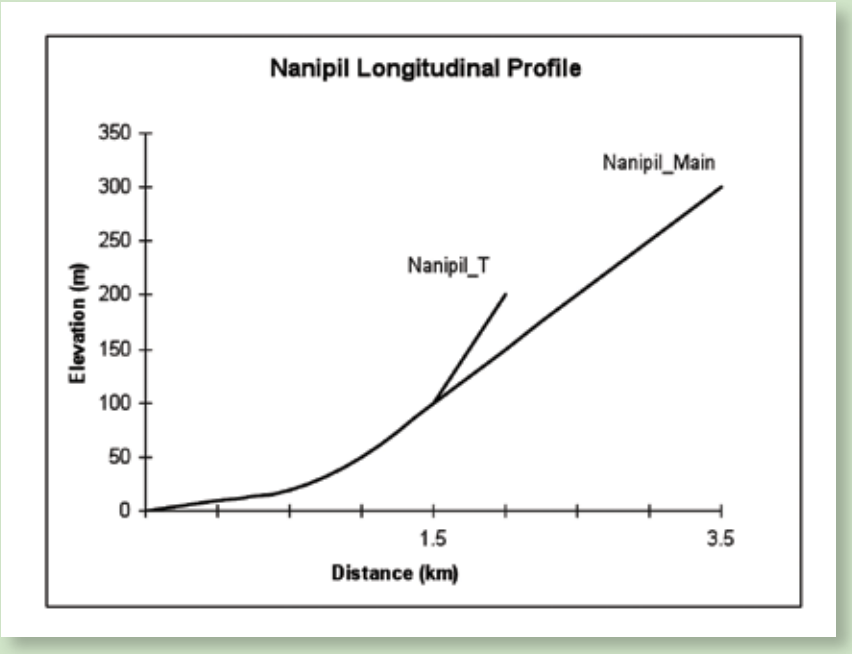
The Nanipil Catchment fronts the northern slopes of Mt Nanloud and flows to the north and east, its upper slopes are very steep and densely forested. There are no raingauges in the mid to upper catchment, although they are proposed.

The Catchment has been mapped to the intake weir for the Pohnpei Public Utilities Corporation PUC water supply and hydro electric power plant. The catchment is relatively stable and following rainfall rises very rapidly. From the weir it falls steeply to the Nanipil hydro electric plant located at the confluence of the Nanipil east branch. This catchment was selected due to its importance to Kolonia for water supply, energy and subsistence food production, and is also the Pacific IWRM GEF demonstration catchment. The catchment also has the longest rescued hydrological dataset on Pohnpei.

Nanipil catchment, only the west branch is monitored



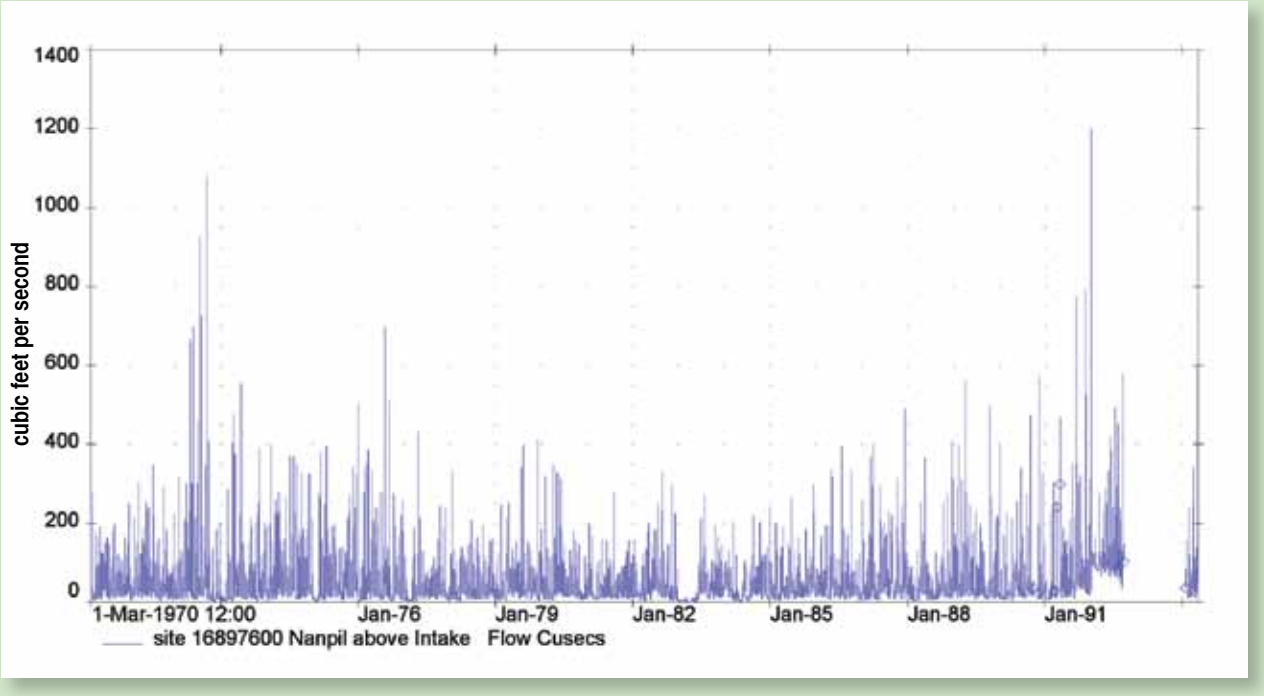
Nanipil and tributary stream, longitudinal profile



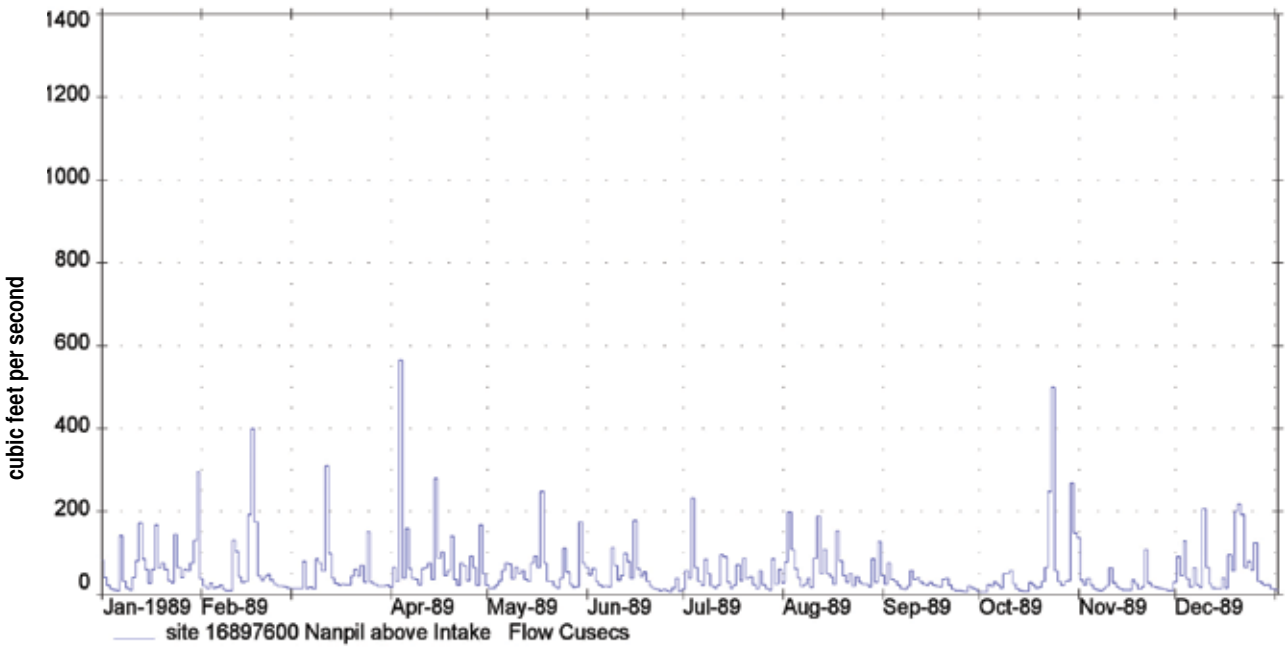
Historical Data

The following river flow graphs demonstrate the type of data collected and what is readily available from the closed USGS site some distance upstream of the control weir. The original site has been located and comprised of an old corrugated iron stilling well approximately 500 metres upstream of the weir. The quality of the data is unknown but the record is fairly complete. There is no rainfall data included in this data as it was not available from the USGS website.

Long Term Variation of daily mean discharge Nanipil above Weir (USGS)



Annual Pattern of daily mean discharge for 1989 Nanipil above Weir (USGS)



Pacific HYCOS

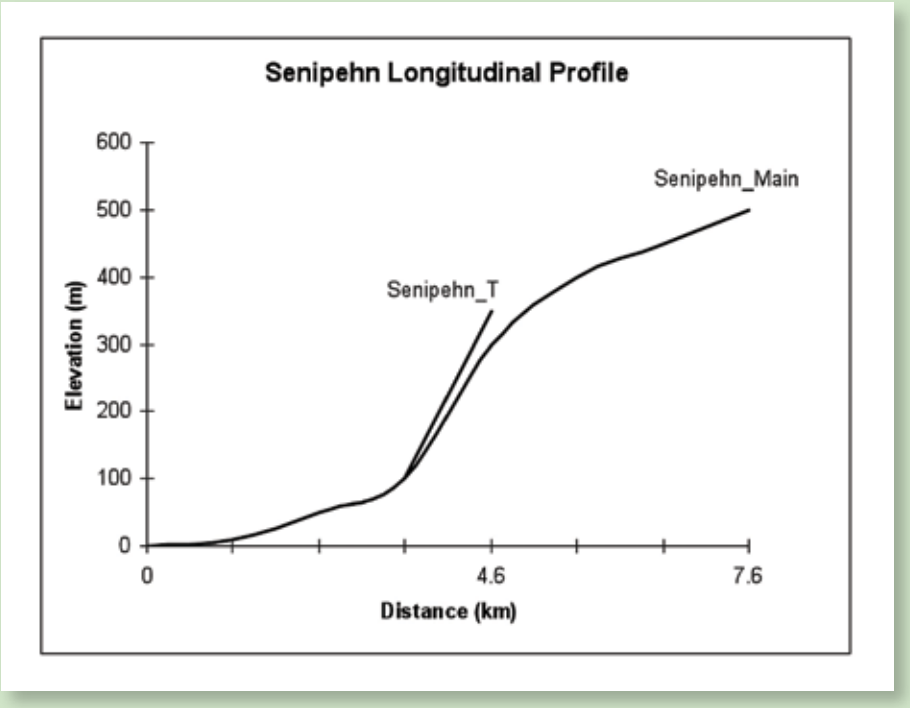
Pacific HYCOS installed a new Nanipil site in 2009, downstream of the original location closer to the weir and only limited data is available to date. An additional station was installed by Pacific HYCOS. This station was mounted to the weir, over the original stilling well, and is used to measure water levels and rainfall only. It is uncertain if this stilling was ever used previously for data collection and there is no evidence of a water level gauge board being installed at the weir. This water level only station is to enable the Pohnpei Public Utilities Corporation (PUC) to better manage the intakes and abstraction for potable water and hydro-electric power generation and to enable long term data to be collected on spills for an assessment of riparian flows. The raingauge was installed at the weir in May 2010 with upper catchment raingauges proposed for installation by DTCI in 2011.

5.2.2.2. Catchment 2 – Senipehn at Footbridge (South Branch)

This is a new site installed under Pacific HYCOS to measure outflows from the Senipehn Catchment. The catchment was selected for its stability as a natural and undeveloped catchment and as a gauge against the Enipehn Catchment to the south which has high levels of cultivation for agricultural use for food and especially kava production. WERI have measured flows and suspended sediment from this catchment. The Senipehn site is located at a significant steel suspension foot bridge 1.6 km upstream of the highway crossing. The stream is very stable and can be gauged at most river discharges with high flows being measured from the bridge. The catchment is steep and covered with almost 100% old growth forest with a very small sediment loading and as for most rivers on Pohnpei, it rises extremely rapidly. With close to 9 months of rainfall data being collected since the site was installed, over 3,000 mm was measured.

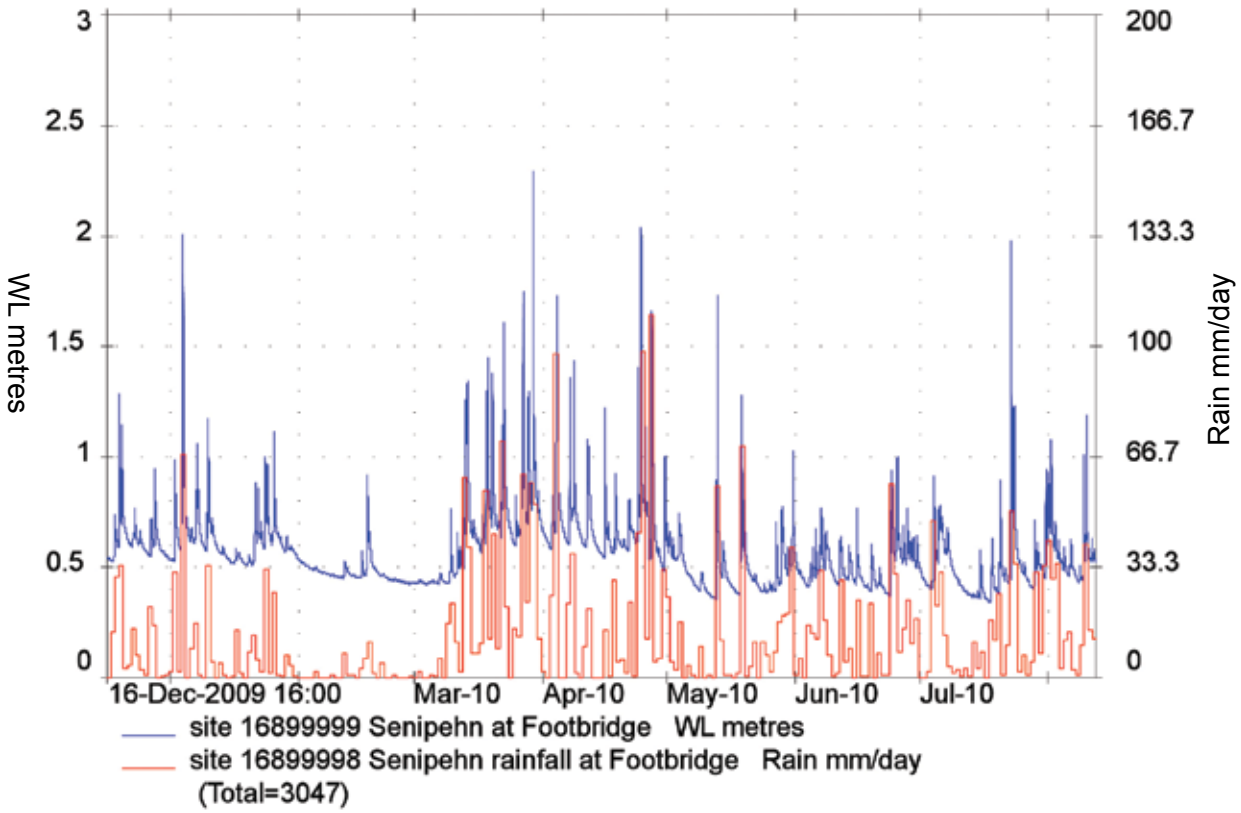
Senipehn catchment map, only the south branch is monitored

Senipehn and tributary stream, longitudinal profile



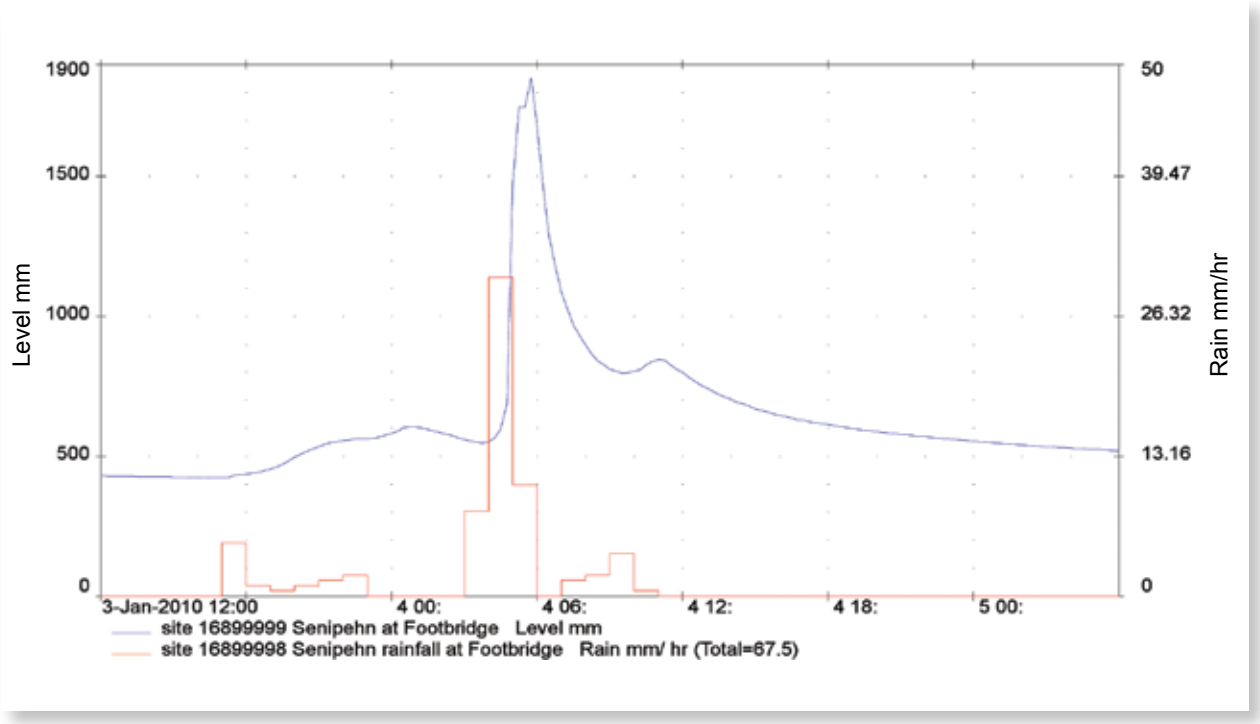
Nan Modal ruins

Variation of instantaneous water level with daily rainfalls



The following hydrograph, with daily rainfall, demonstrates the rapid response of the Senipehn stream to rainfall events. Rainfalls and flow are very closely correlated, where a significant intense rain event will result in a corresponding flow event within a short period of time. In this case a 50mm rain event over 3 hours corresponded with a rapid 1.5 metre rise in the stream level within an hour, dropping almost as quickly on cessation of the rainfall. This demonstrates the highly responsive nature of these steep mountainous catchments.

Hydrograph with daily rainfall plotted for Senipehn



6. COMMENT

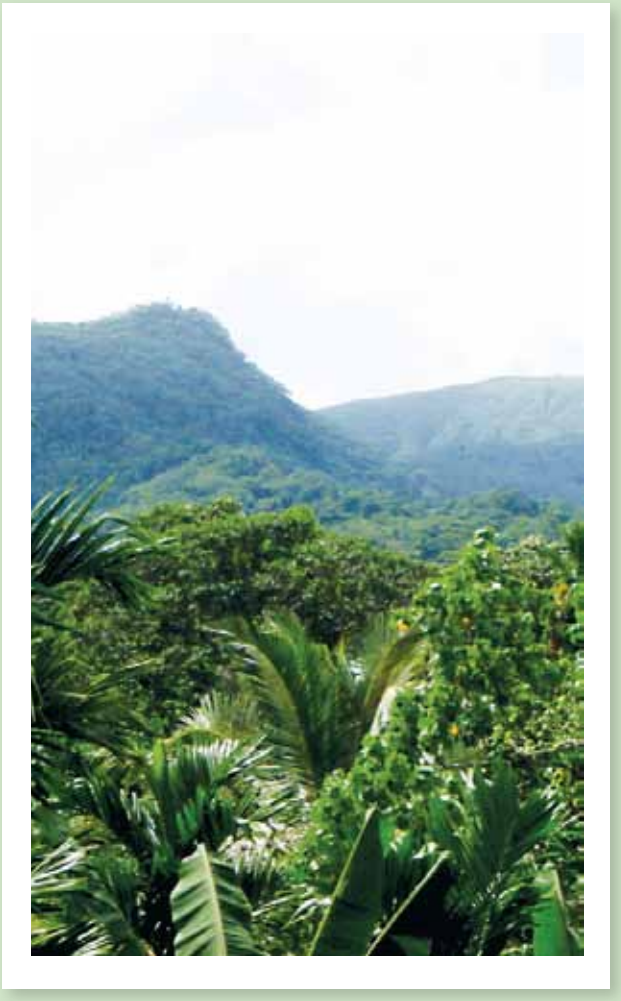
Little hydrological information is available in any of the States of FSM for any long term or regional hydrological analysis for either surface or groundwater. The USGS hold much of the historic data however this has been difficult to access. The very limited existing data is useful for the basic calibration of catchment models for some individual storm event or drought sequence. It will be some time before long term consistent datasets can be collected to enable flow analysis or statistical analysis to be undertaken to better assess Pohnpei's water resources, and then only for the re-established sites. It is well recognised that a minimum of 10 years of consistent and continuous data is needed for hydrological statistics to be derived, 20 years is better. DTCI have shown a good level of commitment to this data collection program and it is hopeful that by 2015 some robust datasets will have been collected to allow for a more informed assessment of the water resources and this to be available to the broad range of stakeholders especially for Integrated Water Resources Management and long term planning.

Nanipil River above intake weir, typically a dominant cobbled steep bed surrounded by dense old growth forest, The river is highly responsive to rainfall with rises of 2 metres in 30 minutes being recorded.

7. PHOTOGRAPHS

Construction activities installing sensor line, Senipehn River December 2009 looking downstream. This river is equally responsive to heavy rain as the Nanipil. . Note the well armoured bed, dense indurated volcanic boulders typical of Pohnpei Rivers with little fine material.

Photograph 4 - Nanipil hydro, 1.7 megawatts, generation is very compromised by a limited water resource supplying potable water for Kolonia also.



Typical Pohnpei mountain environment looking towards Mount Nanloud in the middle distance, Senipehn River

Nanipil Weir and hydro electric intake finalising water level recorder, gauge board and raingauge

DTCI staff undertaking discharge measurement from the foot bridge at Senipehn

Servicing automatic raingauge on Sokehs Rock above Kolonia