Water and Environmental Research Institute of the Western Pacific
Annual Technical Report
FY 2002

Introduction

The Water & Environmental Research Institute of the Western Pacific or WERI is one of 55 similar water research institutes set up by U.S. Congressional legislation at each Land Grant University in the United States and in several territories. The institute is now in its 28th year of operation.

WERIs mission is to seek solutions through research, teaching, and outreach programs, to issues and problems associated with the location, production, distribution, and management of freshwater resources. WERI provides technical expertise, and conducts vigorous research and both undergraduate and graduate teaching programs aimed at improving economic conditions and the quality of life for citizens of Guam and regional island nations. WERI also runs a state of the technology water analytical laboratory and geographical information systems facility.

WERI administers and carries out research, training, and other information transfer programs under a variety of federal and local funding sources, but the institute was created specifically to administer Department of Interior (US Geological Survey) money under Section 104-B of the National Institute of Water Research (NIWR) 104-B Program. WERI has responsibility for 104-B money on Guam, in the Commonwealth of the Northern Mariana Islands (CNMI) and in the Federated States of Micronesia (FSM). In the 2002-2003 period, WERI faculty were involved as Principal Investigators on twenty-one research and training projects. Funding sources for these projects included US Geological Survey, US Weather Service, NASA, local agencies such as Guam Environmental Protection Agency, Guam Bureau of Planning, and Guam Airport Authority, Commonwealth Utility Corporation, CNMI and direct appropriations from the Guam legislature.

Currently WERI has a fulltime director who is also a UOG faculty member, four regular research faculty, one adjunct research faculty, a water analysis laboratory manager and technician, two office staff, as well as six graduate research students who are completing their MS degree in the Environmental Sciences program. During the 2002-2003 interval, WERI faculty and staff taught eight graduate courses and four undergraduate courses in the Environmental Science MS program and the undergraduate pre-engineering curriculums respectively. At the same time WERI faculty were first or second authors on thirteen refereed journal articles or conference proceedings, four technical reports, and nine professional presentations. Currently WERI faculty members serve as committee members on, or chairs of about twenty MS research theses in the Environmental Sciences and Biology graduate programs.

NON USGS Funded Projects

NASA Ground Based Radar Rainfall Estimation Project: Guam TRMM Validation

NATIONAL WEATHER SERVICE Pacific ENSO Applications Center

GUAM WATERSHED PROJECTS FUNDED BY GUAM ENVIRONMENTAL PROTECTION AGENCY

Development of Strategies for the Reduction of Nitrate Contributions from Septic Tanks into the Northern Guam Aquifer

Potential Impact of Current Landscaping Practices in the Tumon Basin on the Nutrient Status of Tumon Bay

Restoring the Northern Guam Watershed by identifying Groundwater Nitrate-Nitrogen Anomalies and their Sources

Contaminant and Restoration Assessment of Agana Swamp and Adjacent Waters

GUAM BUREAU OF PLANNING

Contaminant and Restoration Assessment of Agana Swamp and Adjacent Waters

GUAM AIRPORT AUTHORITY

Hydrogeological Services for Drilling of Exploratory Wells

DIRECT LOCAL FUNDING

Guam Hydrologic Survey Modeling Guams Northern Guam Aquifer Nutrient Inflows into Tumon Bay

Water Resources Monitoring Program In Cooperation with Hawaii District, USGS

COMMONWEALTH UTILITY CORPORATION CNMI

Hydraulic Modeling of Saipans Water Distribution System

Research Program

The Water and Environmental Research Institute (WERI) Advisory Council is the body, which determines research goals and priorities for WERI in general and the USGS 104B program in particular. The Research Advisory Council (RAC) for Guam consists of representatives from all Guam governmental agencies involved with water resources development or regulation, members of U.S. Federal agencies, military organizations on Guam that deal with water resources issues and members of the university research community. The RAC for the Federated States of Micronesia and the Commonwealth of the Northern Mariana Islands consist of representatives from various government departments that deal with water resources, representatives from local colleges, private sector engineers, environmentalists, and planners.

WERI held RAC meetings in May thru July 2001. Twenty one (21) people attended the Guam meeting, eighteen (18) people attended the CNMI meeting and twelve (12) people attended the FSM meeting. The RAC groups examined the previous years research priorities and discussed changes to keep the listings up to date.

In late August, a Request for Proposals (RFP) was sent out by FAX and mail to the three regions: Guam, CNMI, and FSM. RFPs were sent to all regular members of the three RACs as well as to several agencies and institutions that had expressed interest during the previous year. A total of fifty four (54) RFP mailings or Faxes were issued together with a copy of a) 104-B proposal guidelines, b) an example of a well-written 104-B proposal, and c) the list of critical water resource needs for their region.

Seven (7) proposals, Two (2) for Guam, Three (3) for the FSM, and three (3) for the CNMI were submitted. Review panels were selected for each of the regions. These panels were made up of researchers not submitting proposals or from others highly regarded in the water resources area of each of the regions. The submitted proposals were e-mailed to the members of the appropriate review panels. Each panel member had the list of critical needs and a scoring procedure that had been agreed upon at earlier RAC meetings. They were advised to work independently. Following a three-week interval, reviews were returned to WERI and re-evaluated by the Director. The Director made no changes to the individual ratings by the review panel members. All of the projects that were submitted were highly rated and were funded.

Groundwater Infiltration and Recharge in the Northern Guam Lens Aquifer during the record- breaking 1997-1998 ENSO event

Basic Information

Title:	Groundwater Infiltration and Recharge in the Northern Guam Lens Aquifer during the record- breaking 1997-1998 ENSO event
Project Number:	2002GU1B
Start Date:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	NA
Research Category:	Climate and Hydrologic Processes
Focus Category:	Groundwater, Climatological Processes, Hydrology
Descriptors:	Northern Guam Lens Aquifer, well heads, rainfall, sea level, cross-correlation, well-head prediction, time-lag response, ENSO
Principal Investigators:	Mark Lander, Mark Lander

Publication

PROJECT SYNOPSIS REPORT

Project Title

Groundwater Infiltration and Recharge in the Northern Guam Lens Aquifer during the record-breaking 1997-1998 ENSO event.

Problem and Research Objectives

The Northern Guam Lens Aquifer is comprised of Plio-Pleistocene limestone units deposited atop a volcanic basement. Typical heads range from about 3 to 5 feet above sea level, with the maximum thickness of the lens ranging up to about 150 feet. Continuously draining into the ocean, the water in the lens is replenished by rain, which, averages about 100 inches per year, but is highly variable on both long and short time and space scales. Guam draws some 80% of its drinking water from the freshwater lens in the aquifer, using some 45 million gallons per day, a bit more than half of the most recent estimate of 70-80 million gallons per day of sustainable yield. In order to identify appropriate techniques and management practices to sustain aquifer development while protecting water quality, groundwater scientists and engineers need a better understanding of aquifer dynamics. In particular, it is necessary to better understand the factors that control the rates and amounts of water taken into storage, the residence time of water in the aquifer, and the quantities that can therefore be extracted in given times and places without degrading the quality of the water. The responses of well levels to rainfall events provide important clues regarding the rate at which water descends through the vadose zone, the amount of time that it is retained in phreatic storage, and therefore the amount that may ultimately be available for exploitation by various techniques.

Variations in rainfall and sea level are the most direct and important causes of variations in well levels. Observations from 3 wells in the Agana Argillaceous Member of the NGLA indicate that the combined variations in sea level and rainfall in real time or near-real time account for up to 66% of the variance of water levels in the wells—the sea level accounting for the larger share of this variance near the coast, and the rain accounting for the larger share of the variance at well locations further inland. Multi-year variations of rainfall appear in the well levels at time lags up to nearly two years.

One of the most intense El Niño events of the past century occurred in 1997. Associated with this event there was a record number of very intense typhoons in the western North Pacific during 21997. Annual rainfall throughout Micronesia was heavy. Guam was struck by a devastating typhoon (Paka) in December of 1997. The following year, 1998, there was a record drought throughout Micronesia, with many places recording the lowest annual rainfall total. Rainfall gradually returned to normal in 1999-2001, with the annual amount at Guam increasing each year. The large spike of rainfall in 1997, followed by the extreme dryness of 1998 (Figs. 1 and 2), offered a unique opportunity to study the response of the northern Guam lens aquifer to such a dramatic natural event; especially the previous finding of a long-term lag of approximately 18 months to pass large variations of large-scale rainfall through the aquifer.

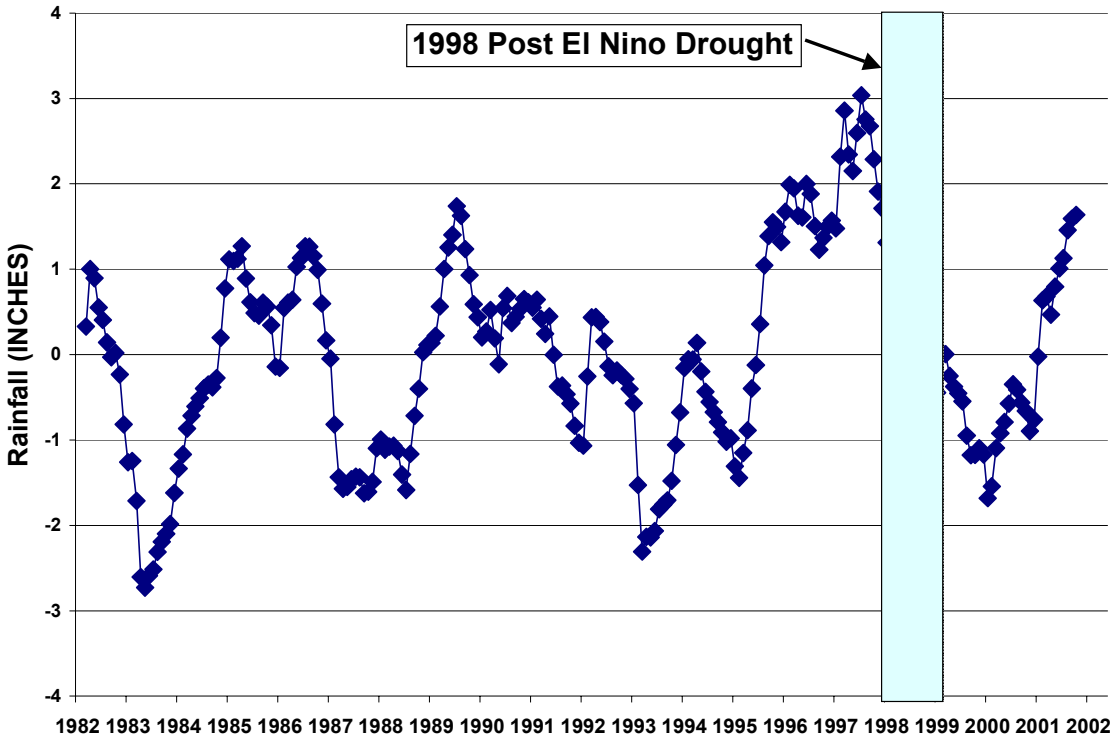

Figure 1. Monthly rainfall anomalies at Andersen Air Force Base. Blue box indicates the extreme dryness that followed the 1997 El Niño.

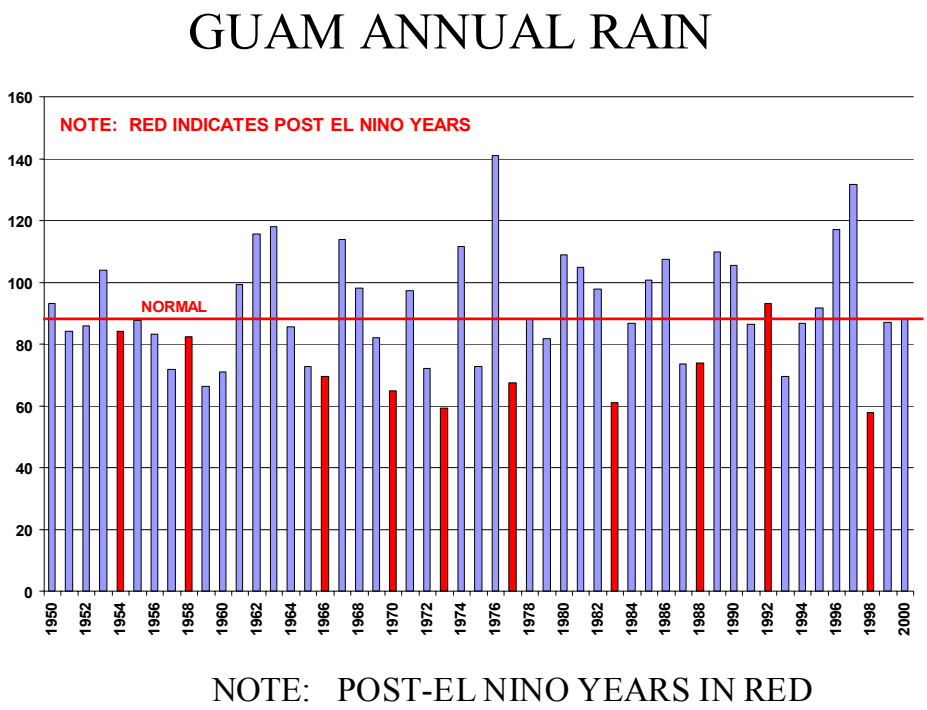

Figure 2. Time-series of Guam annual rainfall at the Guam International Airport. Note the high rainfall in 1997 followed by record low rainfall in 1998.

Methodology

Removing the tidal signal in the well time-series

The correlation of well water levels with the daily and monthly mean sea level is in general a function of distance from shore. All water level time series of the NGLA exhibit statistically significant cross-correlations with the time series of the daily average tide (expressed in feet above mean sea level). The tidal signal is transferred rapidly into the aquifer, and cross-correlations are highest at zero time lag for all periods investigated (daily to monthly). At some wells, the variations of sea level account for upwards of 50% of the variance of the time series of daily and monthly average water levels.

The linear cross correlation value is used to remove the tidal signal from the well water level time series. The cross correlation coefficients between the sea level and the water level of a given well can be used in a linear regression to predict the value of one variable given the value of the other. The best prediction that a linear regression can yield is given by

$$(A_i)^* = (r)\,(s_A/s_B)\,(B_i)' + \bar{A} \qquad (1)$$

where: $(\ )^*$ indicates the predicted value;
$(\ )'$ indicates departure from the mean value;
subscript i indicates the i^{th} value of the time series;
s_A and s_B are the standard deviations of variables A and B respectively;
r is the cross-correlation coefficient between variables A and B; and,
the over-bar indicates the mean value of the indicated time series.

Using Equation (1), the water level may be predicted from the sea-level time series. An adjusted well-level time series that is not correlated with the sea level may be obtained by subtracting the i^{th} term on the right-hand side of equation (1) from the i^{th} raw value of the well-level time series. In this manner, the well-level time series is "de-tided". Note that the well water level time series may be similarly adjusted to "de-rain" the time series, or to remove the component of any variable that has a non-zero cross-correlation with the water level. In this report, the sea-level signal was always removed first in order to evaluate the relationship of the remaining "de-tided" time series to the rainfall. Maximum correlations of water level with rainfall tended to occur at a time lag, whereas maximum correlations of water levels with sea level were always simultaneous at the frequencies examined (daily and monthly).

Using rainfall and tide to predict water levels

The "de-tided" water level time series may be cross-correlated with any other time series (such as time series of rainfall) to form a multiple linear regression equation of the form:

$$(A_i)^* = (r_{A:B})\,(s_A/s_B)\,(B_i)' + (r_{A:C})\,(s_A/s_C)\,(C_i)' + \bar{A} \qquad (2)$$

where: ( )* indicates the predicted value;
( )′ indicates departure from the mean value;
subscript i indicates the i^{th} value of the time series;
s_A, s_B, and s_C, are the standard deviations of variables A, B and C respectively;
$r_{A:B}$ is the cross-correlation coefficient between variables A and B;
$r_{A:C}$ is the cross-correlation coefficient between variable A (signal of B removed) and variable C; and,
the overbar indicates the mean value of the time series.

Such an equation derived to predict the level in well BPM1 from the rain and tide

$$(BPM1_i)^* = 0.5281\,(TIDE_i)' + 0.02227\,(RAIN_i)' + 2.723 \qquad (3)$$

yields a predicted time series for BPM1 that explains 66% of the variance of the raw time series. An investigation of the analysis of the variance explained by the rain and the tide (and the inter-relationships among other variables, such as the wind and the tide) at several well sites occurs in a later section.

Integrated anomalies

All of the variables examined in this report (rainfall, the Southern Oscillation Index or SOI, sea level, and water levels) were subjected to an analysis wherein the long-term annual or monthly mean of the variable is removed and the anomalies of each variable are added in sequence to create a time series of the running total. These running totals, or "integrated anomalies," sharply highlight long-term deficits or surpluses. The running totals of all the variables show prominent long-term deficits and surpluses that are clearly inter-related.

Residual analysis

Using the multiple linear regression equations, the well heads at several of Guam's observation wells was predicted (e.g., Fig. 3). The residuals of this prediction were examined, and it was found that they were not random, but had a slowly varying component of periods of over-prediction and under-prediction. Shifting the residual time series by 18 months provided a nearly perfect match with similar periods of rainfall surpluses and deficits (Fig. 4). Incorporating a time-lag component of 18 months for the rainfall in the regression equation increased R from +.63 to +.76 (Fig. 5)

The large variations in rainfall from 1997 to 1998 was seen in the well heads of the Northern Guam Lens Aquifer (Fig. 6). Note that the prediction equation using

simultaneous anomalies of rainfall and sea level is not as good as an equation that incorporates an 18-month time-lag component.

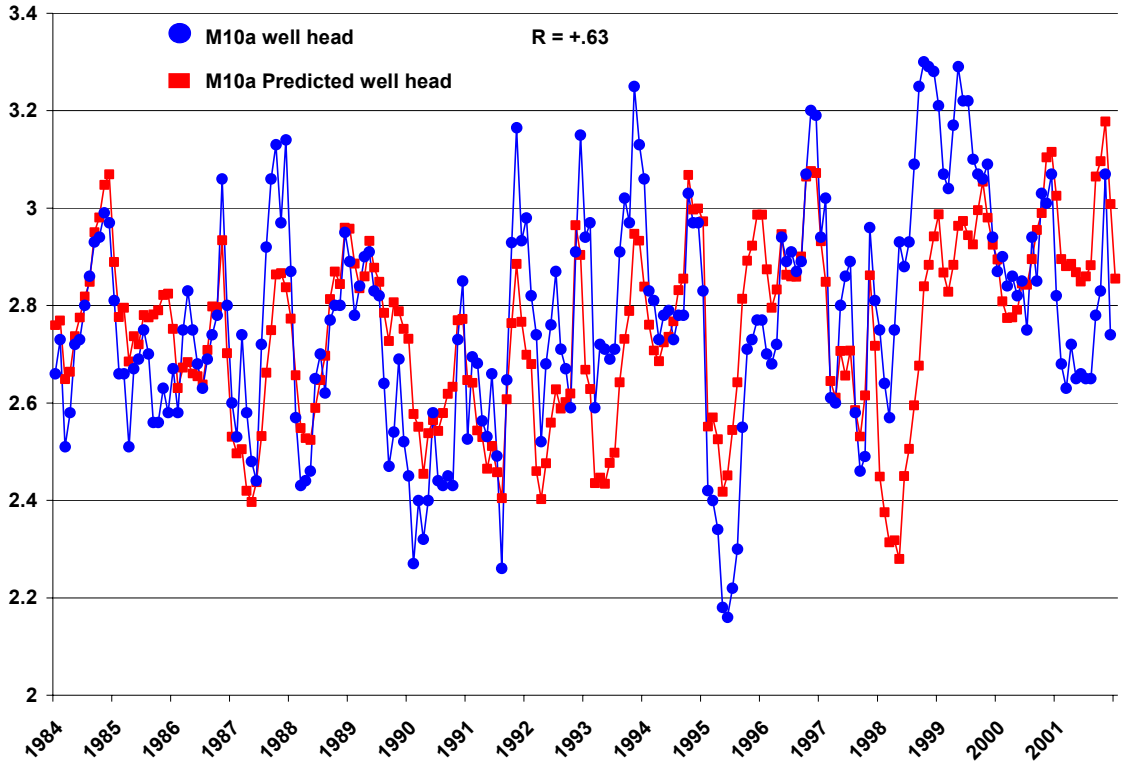

Figure 3. Prediction of well head from rainfall and tidal variations

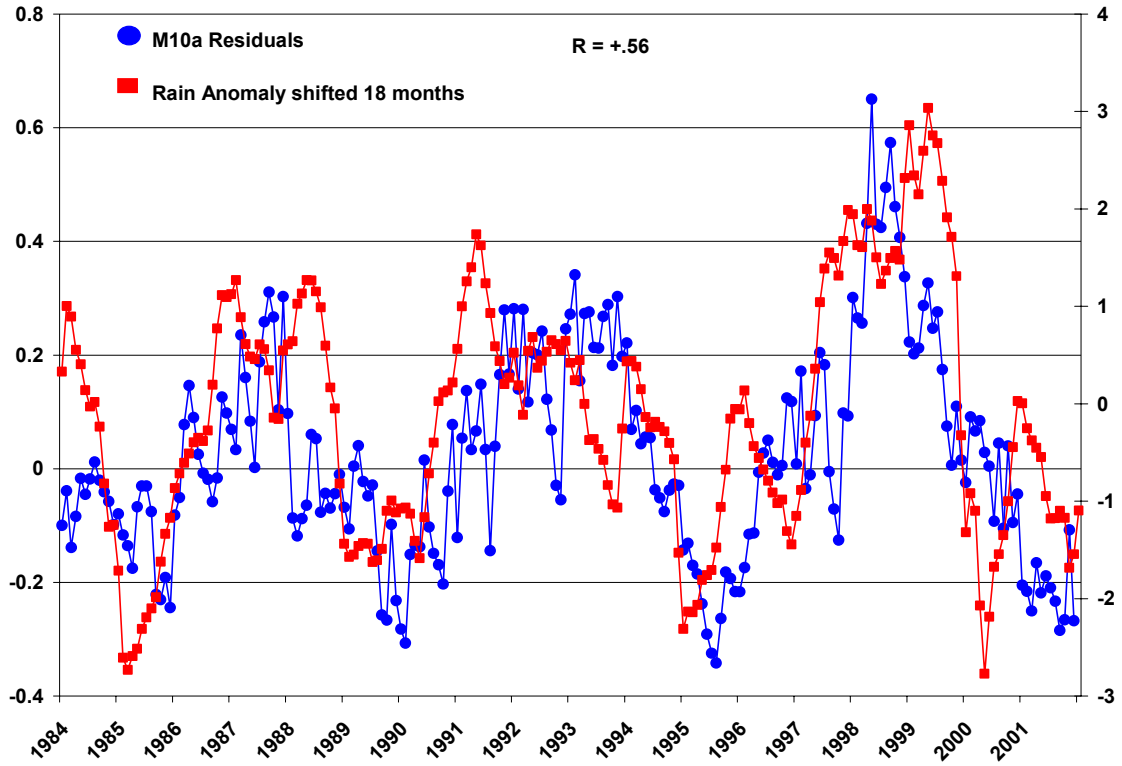

Figure 4. Residuals of well head prediction in Fig. 3 (shifted 18 months) versus rainfall anomaly.

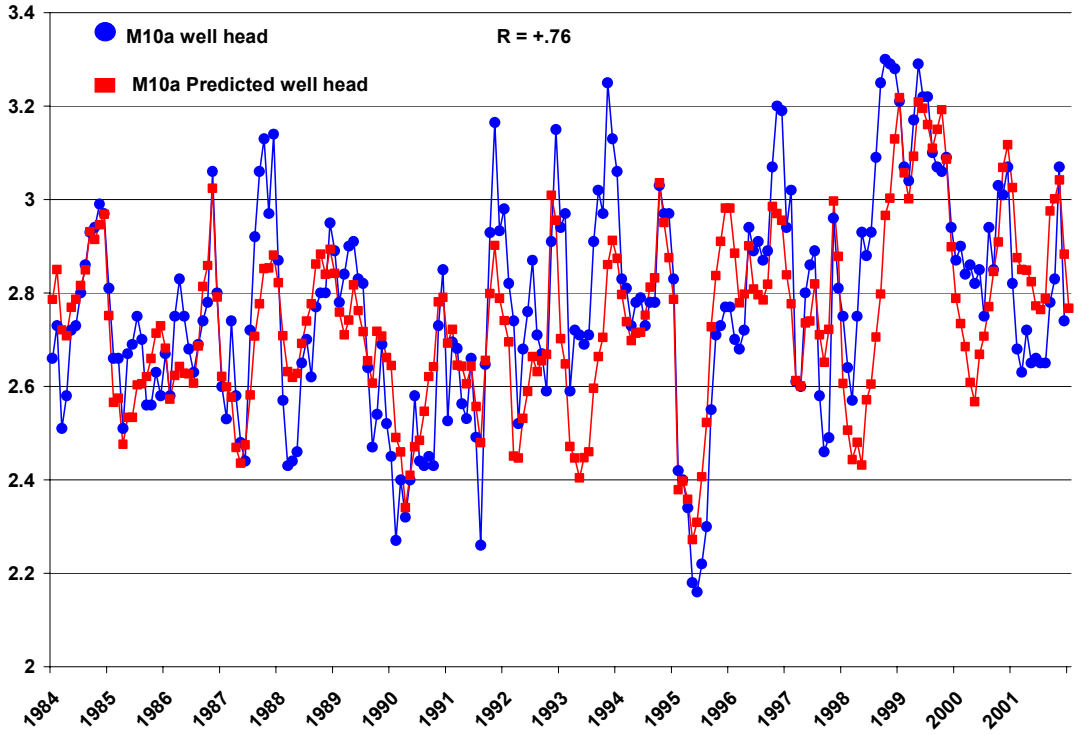

Figure 5. Predicted well head using rainfall and tidal signal plus a component from the rainfall anomalies at an 18 month time lag. Note the increase of R from +.63 in Fig. 3 to +.76.

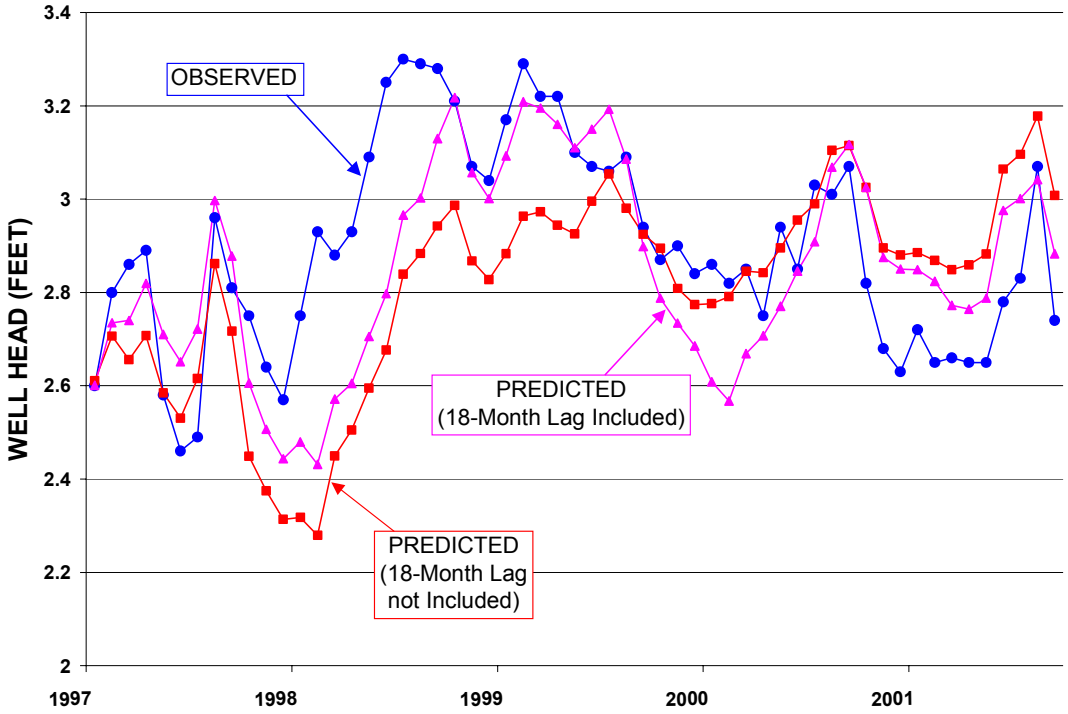

Figure 6. Well head time series showing the effects of the 1997-98 ENSO event. Note that inclusion of an 18-month time lag into the rainfall variable produces a better fit.

Principal Findings and Significance

The well heads of the northern Guam Lens Aquifer rise and fall with in concert with variations in both rainfall and sea level. The variance explained in the well heads by the combination of variations of rainfall and sea level approaches 70% for some wells. Analysis of the residuals of the predictions of well heads using variations in rainfall and sea level show a non-random sequence of under-predictions and over-predictions. The non-random variations in the time series of the residuals are highly correlated to similar deficits and surpluses of rainfall, but at an 18-month time lag. The huge differences in annual rainfall in 1997 and 1998 track into the well heads. The same 18-month time lag is noted. This project is still underway, and a comprehensive report will be forthcoming as a Master's Thesis and accompanying Technical Report in the Fall of 2003.

A rainfall climatology for Saipan: distribution, return periods, and inter-annual variations.

Basic Information

Title:	A rainfall climatology for Saipan: distribution, return periods, and inter-annual variations.
Project Number:	2002GU3B
Start Date:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	NA
Research Category:	Climate and Hydrologic Processes
Focus Category:	Climatological Processes, Water Quantity, Hydrology
Descriptors:	rainfall, rainfall distribution, rainfall rates, extreme events, return periods, long-term variation of rainfall, El Niño, typhoons
Principal Investigators:	Mark Lander, Mark Lander

Publication

PROJECT SYNOPSIS REPORT

Project Title

A rainfall climatology for Saipan: distribution, return periods, and inter-annual variations

Problem and Research Objectives

There are very few locations on Saipan where rainfall has been measured in a consistent manner for any appreciable length of time. A continuous 30-year daily rainfall record is often considered sufficient to compute baseline monthly and annual averages, and to make accurate estimations of the recurrence intervals of heavy rainfall events. Water resource managers of Saipan's groundwater and design engineers responsible for building structures to accommodate heavy rainfall require as input accurate rainfall statistics. Unfortunately, Saipan does not have a daily rainfall database that is anywhere close to 30 years for any location, and most of Saipan's rainfall databases are extremely piecemeal.

Research objectives of this project are to develop a rainfall data base for Saipan (using nearby island rainfall data as a proxy when Saipan data is missing or incomplete). From this data base the following aspects of the rainfall on Saipan are examined: (1) general rainfall statistics; (2) a summary of the annual distribution of rainfall, (3) an examination of the return periods of short-term high-intensity rainfall events, (4) the effects of tropical cyclones on the weather and climate of the island, and (5) an examination of inter-annual and inter-decadal variations in mean annual rainfall.

The CNMI and Guam are in an ENSO core region that features very dry conditions in the year following El Niño, and an increase in the level of threat from typhoons during an El Niño year. The long-term variations of rainfall on Saipan are very similar to those on Guam. As on Guam, the mean annual rainfall on Saipan varies substantially among locations on the island. As a first approximation, the heaviest rain tends to be at the higher elevations -- at Guam it occurs on the eastern slopes of the southern mountains and, at Saipan, it appears as if the mean annual rainfall is heaviest at stations in the central high ground (e.g., Capitol Hill and Mount Tagpochau).

The causes extreme daily rainfall events are typhoons, monsoon squall lines, and other so-called mesoscale weather systems that produce rain amounts that are largely independent of the island topography. The highest-intensity extreme rainfall events are caused by typhoons. This may be true for all intervals, from the peak 15-minute rainfall to the peak 24-hour rainfall. Because of typhoons, the probability distribution of 24-hour rainfall events is mixed (e.g., without typhoons, the return-periods for daily rainfall in excess of 10 inches would be much longer). Inter-annual variations of Saipan's rainfall are closely linked to the El Niño/Southern Oscillation (ENSO) phenomenon. To some extent, the occurrence of typhoons in Guam and in the CNMI is also linked to ENSO. Large inter-decadal variations in rainfall (and also in the distribution of typhoons) is noted. The causes of these remain a mystery.

Methodology

Data Base Development

Much of Saipan's rainfall database must be constructed, or assumed to be similar in character to that of nearby Islands such as Guam where reliable daily and monthly rainfall time-series exceed 30 years. Guard and Lander (2001) have constructed 30-year rainfall records for Saipan from existing data on Saipan (Table 1) and from analogies to the properties of the rainfall on Guam. The site selected for the construction was the Saipan International Airport (SIA). Despite having a shorter data record than the Saipan Loran station, SIA is an active site, is likely to remain an active site, and is concurrent with satellite imagery so that recent climatic knowledge can be used in the construction process.

Table 1. Name, elevation (feet), location, length of record (years), and the completeness (%) of record for the daily rainfall databases on Saipan.

Name of Site	Elevation (ft)	Location (lat/long)	Length (yrs)	% Complete
Post-War period				
Saipan International Airport	215	15°7'N-145°43'E	11/88-present	100%
Saipan Loran Station	10	15°8'N-145°42'E	01/54-12/78	64%
Capitol Hill	827	15°13'N-145°45'E	12/94-present	100%
Capitol Hill Fischer-Porter Rain Gauge	825	15°13'N-145°45'E	01/79-12/83	~60%
Saipan No. 2 (near CUC)/ Saipan Naval Station	499	15°13'N-145°44'E	02/60-07/63	83%
Kagman Community Center	80	15°12'N-145°47'E	01/84-10/84	~90%
Japanese period				
Garapan	N/A	15°12'N-145°43'E	01/32-12/37	100%
Chalan Kanoa	N/A	15°08'N-145°44'E	01/24-12/37	100%
Marpi	N/A	15°11'N-145°44'E	01/24-12/37	100%
Tanapag	N/A	15°11'N-145°43'E	01/24-12/37	100%
Mt. Tanabako (near bird Island Overlook	206.3 m (679 ft)	15°14'N-145°46'E	01/32-12/37	100%

Two independent methods were used to develop a database for SIA. The first entailed the acquisition of all available Saipan and regional data to derive a complete, continuous long-term SIA database. The possible length of the database was determined to be 47 years. The second method was more statistical, utilizing the close correlation between 11 years of SIA data and 11 years of smoothed Guam International Airport data. This technique provided an algorithm from which a representative SIA daily rainfall database could be derived. Mr. Charles Guard performed the former method and Dr. Mark Lander performed the latter.

Because of the poor daily rainfall data record available for Saipan, a method was needed to construct a representative 30-year daily rainfall record. The method selected was to partially use characteristics of the more complete Guam rainfall record as a proxy for the Saipan record. To do this, relationships between the Andersen Air Force Base, National Weather Service Finagayan, and Naval Air Station/National Weather Service Tiyan locations on Guam and the Saipan International Airport location were determined through correlation analyses, and consideration of monsoon activity, typhoon activity, and ENSO influences. The commercial rainfall databases for Guam and Saipan had several gaps that were filled in by obtaining the data from National Climatic Data Center publications and from military records. Monsoon activity was taken from a study by Lander and Guard (1997) in which Guard determined the frequency distribution of strong, moderate, and weak monsoon surges affecting Guam from 1954 to1995. Because of the large scale of monsoon and ENSO activity, it was assumed that monsoon activity and ENSO influences acted on Saipan in a manner similar to Guam. This large scale behavior accounts for the close correlations found between SIA data and smoothed Guam data from 1989-1999 (Fig. 1). Typhoon activity was compensated for separately. In fact, the presence of typhoon activity in the Guam and the Saipan databases (unsmoothed data) acted to lower the rainfall correlations between the two islands. A single typhoon event can account for 10-15 percent of the total annual rainfall. The short period of record overlap between Saipan International Airport and Capitol Hill was used to assess relationships during lighter rainfall--trade wind and thunderstorm--regimes. The longer record of the Coast Guard Loran Station was used considerably in the construction of the International Airport record. Fortunately, the rainfall characteristics of the Loran Station location and the SIA location were found to be similar, although the SIA is around 5 percent drier.

The annual rainfall for the derived 47-year SIA database is 73.45 inches. This compares favorably with the 74.00 inches derived by the Pacific ENSO Applications Center for SIA from a shorter period of SIA rainfall. Decadal rainfall trends for the derived database were compared with those of Guam long term databases. When differences due to typhoon rainfall were compensated for, the Guam and SIA trends were found to be similar. However, SIA demonstrated greater decadal variation than Guam when the tropical cyclone rainfall is added. The decadal averages for SIA are:

1950's (6 years)	60.51 in
1960's	88.19 in
1970's	68.11 in
1980's	80.04 in
1990's	66.48 in

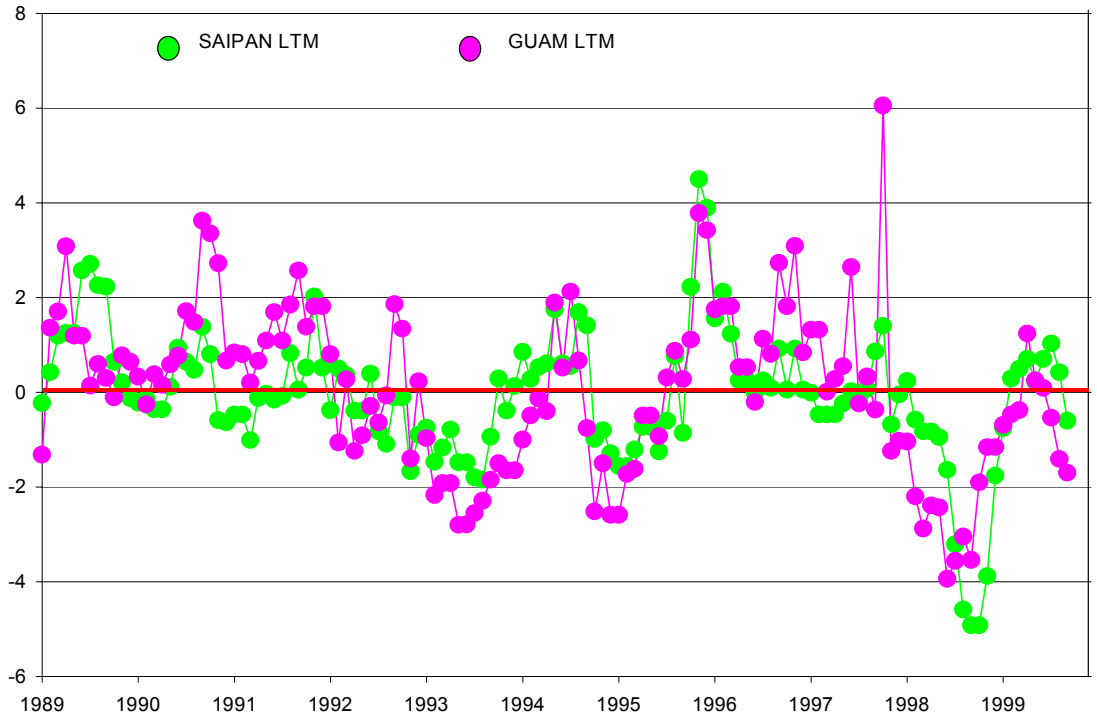

Figure 1. A five-month moving average of the monthly rainfall anomalies at Saipan (green dots) and at Guam (purple dots). The strong coherence between the rain on Guam and Saipan is largely a function of both locations reacting similarly to the status of ENSO, and receiving heavy rainfall from the same large-scale weather systems such as the monsoon. The driest year of record in this time series is 1998 at both Guam and Saipan. The drought in 1998 was a typical, but extreme, follow-on drought to a major El Niño (1997 was one of the strongest El Niño events ever recorded). The strong coherence of the long-term rainfall surpluses and deficits on Guam and Saipan enable one to use Guam's longer period of rainfall measurement to make some reasonable inferences of the character of the rainfall on Saipan based on the statistical properities of the rainfall on Guam.

Spatial Distribution of annual rainfall

The distribution of rainfall on the island of Saipan is affected to some degree by the topography, and the mean annual rainfall totals among recording stations on Saipan differ by as much as 15 inches (380 mm). The region in the vicinity of Saipan's international airport receives the lowest annual total of about 75 inches (1900 mm). The highest measured annual average of approximately 90 inches (2300 mm) occurs at Capitol Hill, and extends along the high ground from Marpi to Mount Topachau. In order to arrive at an annual rainfall distribution chart for Saipan, the rainfall at recording stations was first compared to simultaneous readings at Capital Hill – the wettest among all of Saipan's rain recording sites. Normalizing the stations to Capital Hill (where Capital Hill = 1.00) resulted in the distribution of Fig. 1.

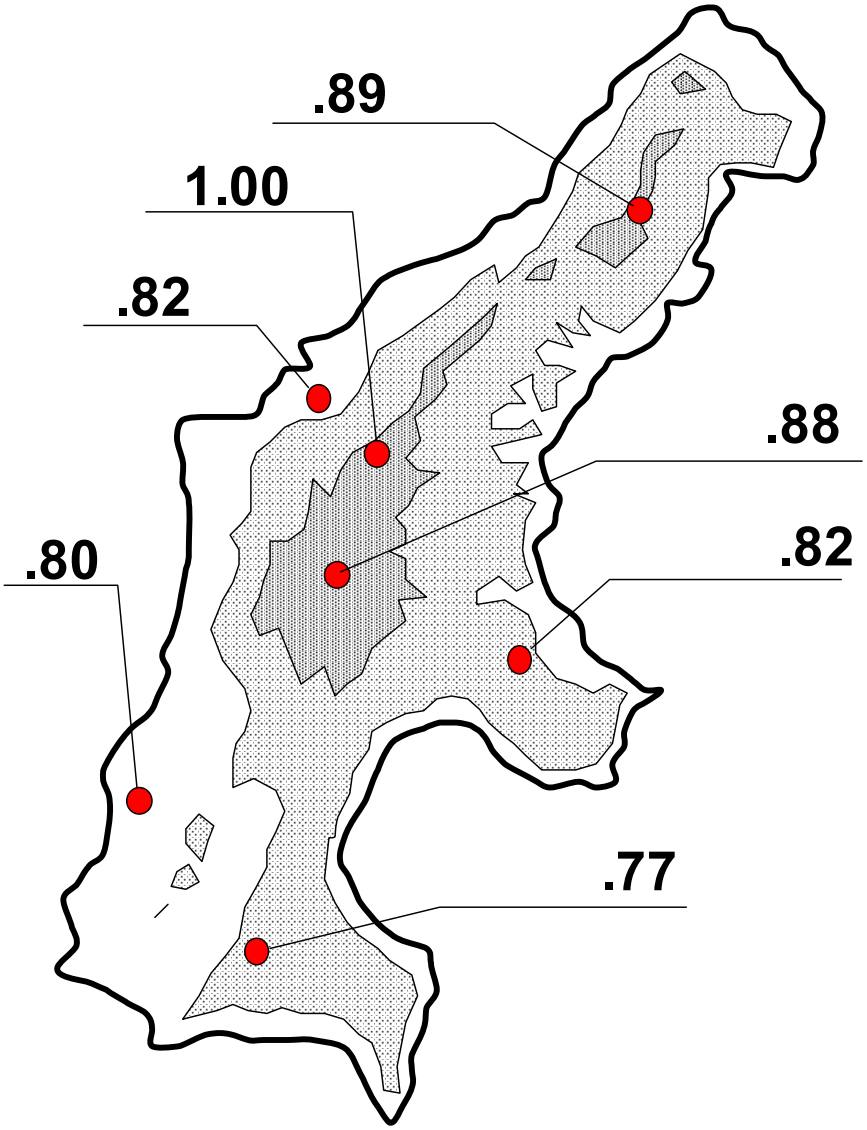

Figure 2. Rainfall at several sites on Saipan normalized to the rainfall at Capital Hill, where the annual rainfall at Capital Hill = 1.00.

The next step was to convert the percentages in Fig. 2 to actual rainfall in inches per year. The data for sites in Fig. 2 are based on the post-war rain records. Some other stations have been added based on inter-comparisons of stations in the Japanese record of 1924-37. This process resulted in the annual rainfall amounts shown in Fig. 3. Contours are drawn using this data to arrive at the presentation in Fig. 4.

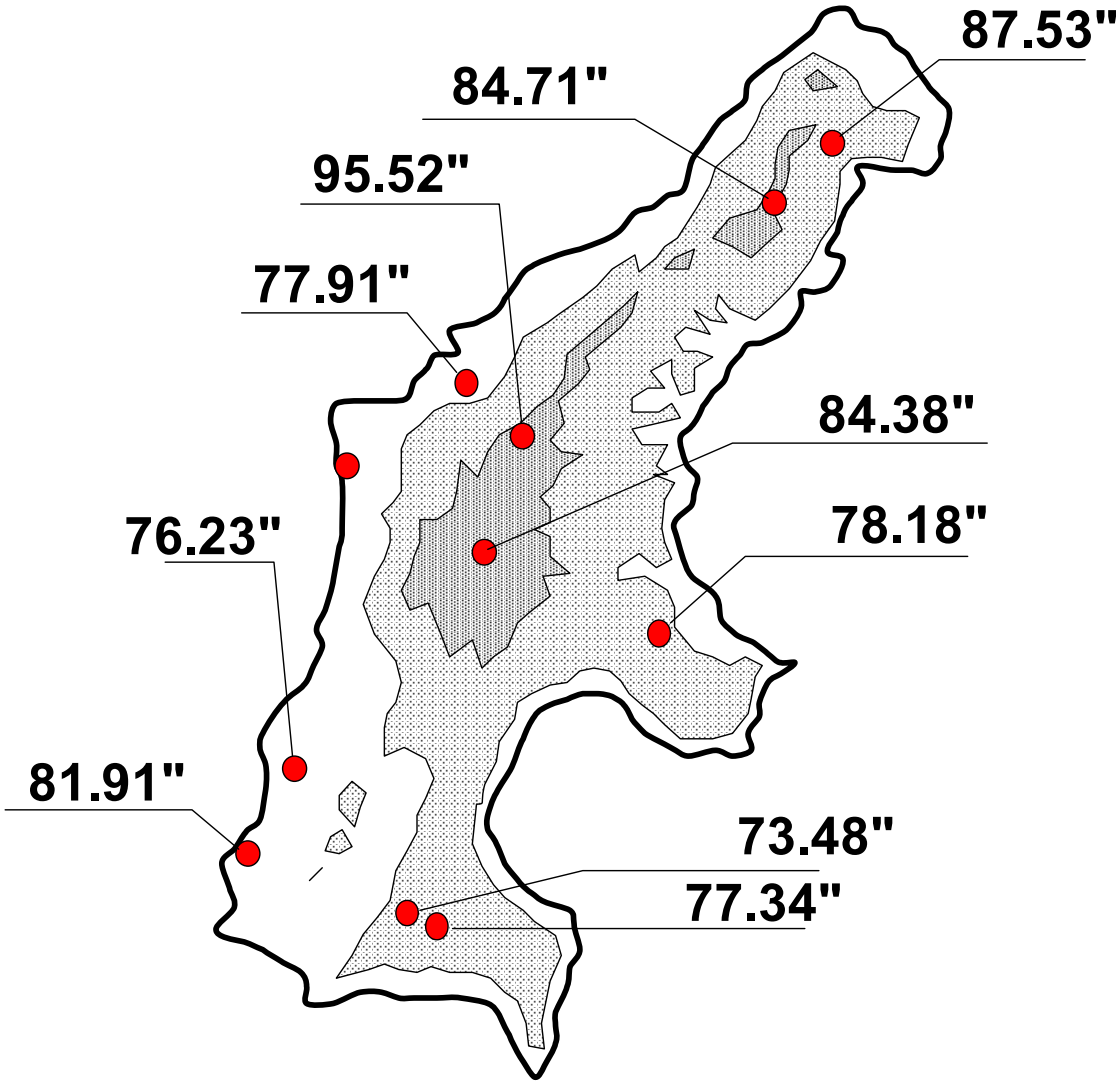

Figure 3. Mean annual rainfall at selected sites on the island of Saipan.

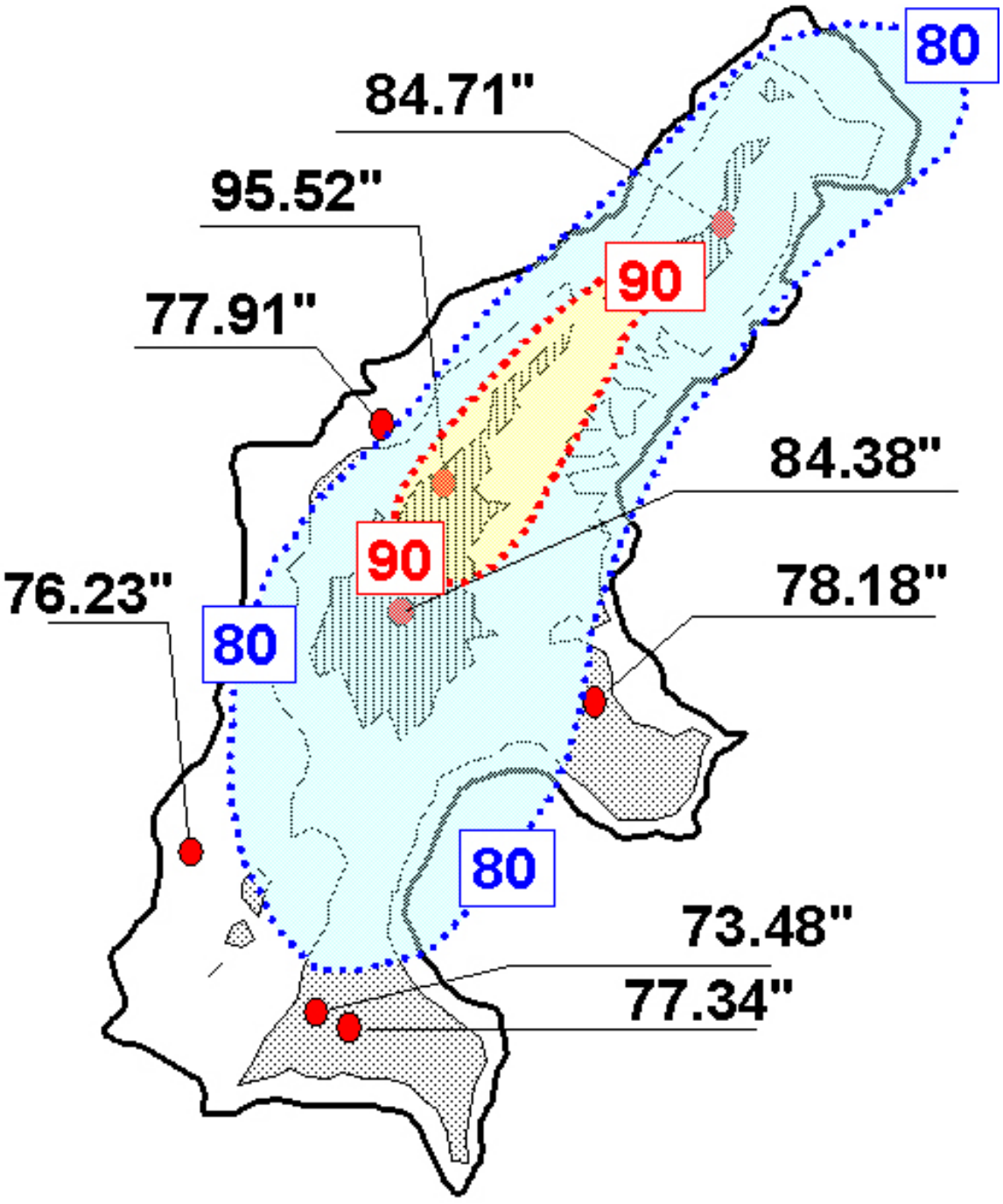

Figure 4. Contours of mean annual rainfall (in inches per year) on the island of Saipan based on the data in Figure 6. (Mean annual rainfall at selected post-war sites is indicated).

Return periods of short-term high-intensity rainfall events

Since the rainfall records on Saipan are so short and/or incomplete, calculations of return periods of extreme rain events may only be crudely estimated. The more complete record of rainfall on Guam allows for a comparison by proxy; however, the large-scale rainfall totals drop steadily with latitude (Fig. 5), and Saipan' annual rainfall is about 20 inches less than that of Guam (Fig. 6).

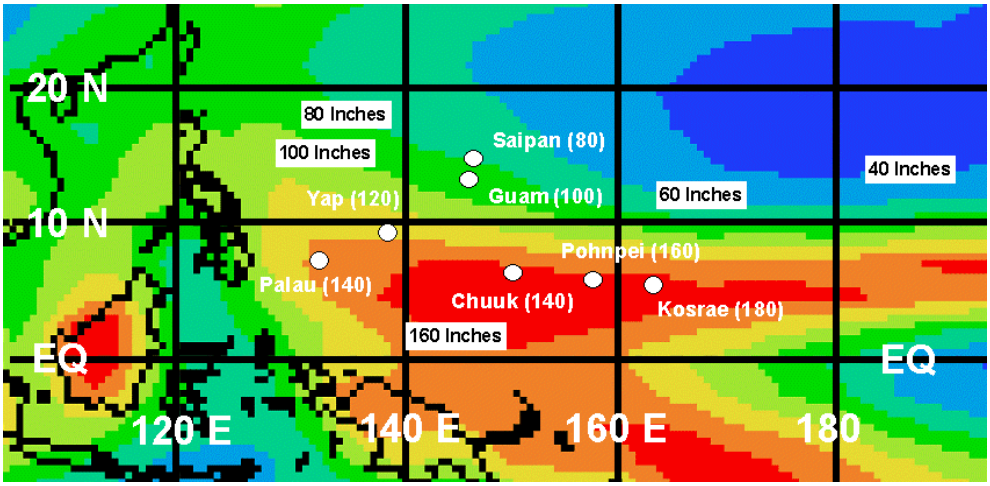

Figure 5. Mean annual over-water rainfall in Micronesia. Colors indicate rainfall pattern (amounts as labeled: red = 160 inches per year, orange = 140, yellow = 120, light green = 100, dark green = 80, teal = 60, light blue = 40, and within the blue there is a bit less than 40 inches of annual rainfall). Mean annual over-water rainfall at selected islands is indicated. Image adapted from figure on website URL http://orbit35i.nesdis.noaa.gov/arad/gpcp/

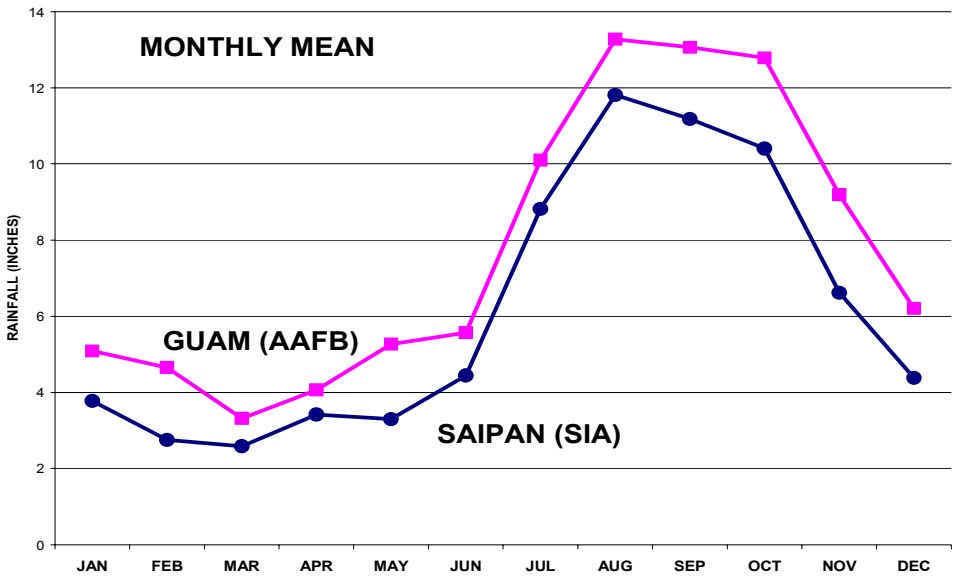

Figure 6. Monthly mean rainfall at Saipan International Airport and at Guam's Andersen Air Force Base (in inches). Note that in every month of the year, Guam (located further south) gets about 2 inches more rain than at Saipan.

Return-period calculations for Guam rainfall (Fig. 7) yield a mixed distribution, with typhoons causing all daily rainfall events in excess of 10 inches.

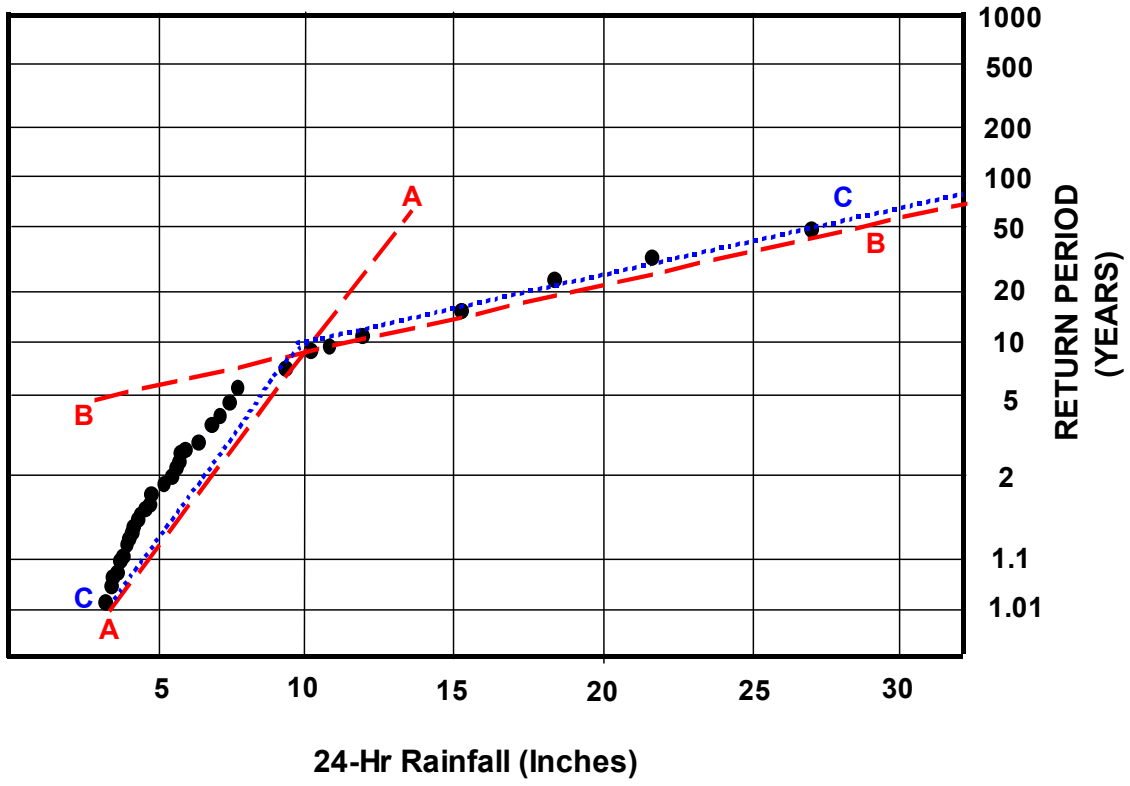

Figure 7. Return period for 24-hour rainfall totals computed for Guam. The change of slope of the lines that fit the individual realizations indicates that there is a mixed distribution of rainfall causes. This is indeed the case, as all rainfall totals in excess of 10 inches on this chart were caused by the direct passage of typhoons over the island. A conservative approach to estimating the return periods for 24-hour rainfall amounts on Guam would be to follow the blue curve "C-C" that has a breakpoint at the intersection of lines "A-A" and "B-B". The breakpoint value is 10 inches in 24 hours at the 10-year return period. Thus, one would estimate that at least one day in each year would have at least ~ 3.50 inches of rain. Similarly, the return period for 10 inches in 24 hours is 10 years, the return period for 20 inches of rain in 24 hours is 25 years, etc.

A similar return-period analysis of the extreme 24-hour rain rates using Saipan's more incomplete record (Fig. 8) yield a very wide range of possible values than center on the results for Guam.

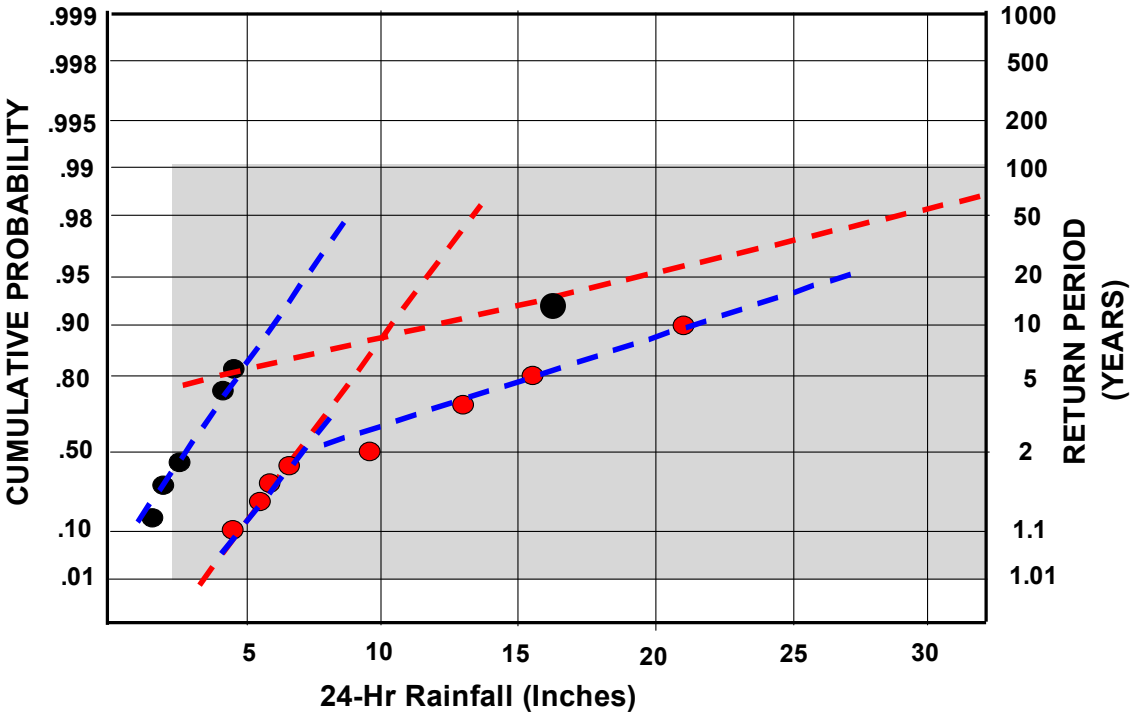

Figure 8. Method-of-moments (ranking method) computations of 24-hour return period extreme rainfall events using Saipan data. Black dots are from the record at Susupe, and red dots are from the record at Capital Hill. The Capitol Hill record contains an unusual number of typhoon-associated rainfall events that occurred in the 1990's. Guam's 24-hour return period curve is shown by the dotted red line.

Previous studies have shown that the return periods of extreme 24-hour rainfall events on Saipan to be a function of elevation, similar to the pattern of mean annual rainfall. The highest of extreme rainfall events on Saipan (as at Guam) are caused by typhoons. Data collected in typhoons on Saipan (Fig. 9) and on Guam (Figs. 10 and 11) show no topographical variation.

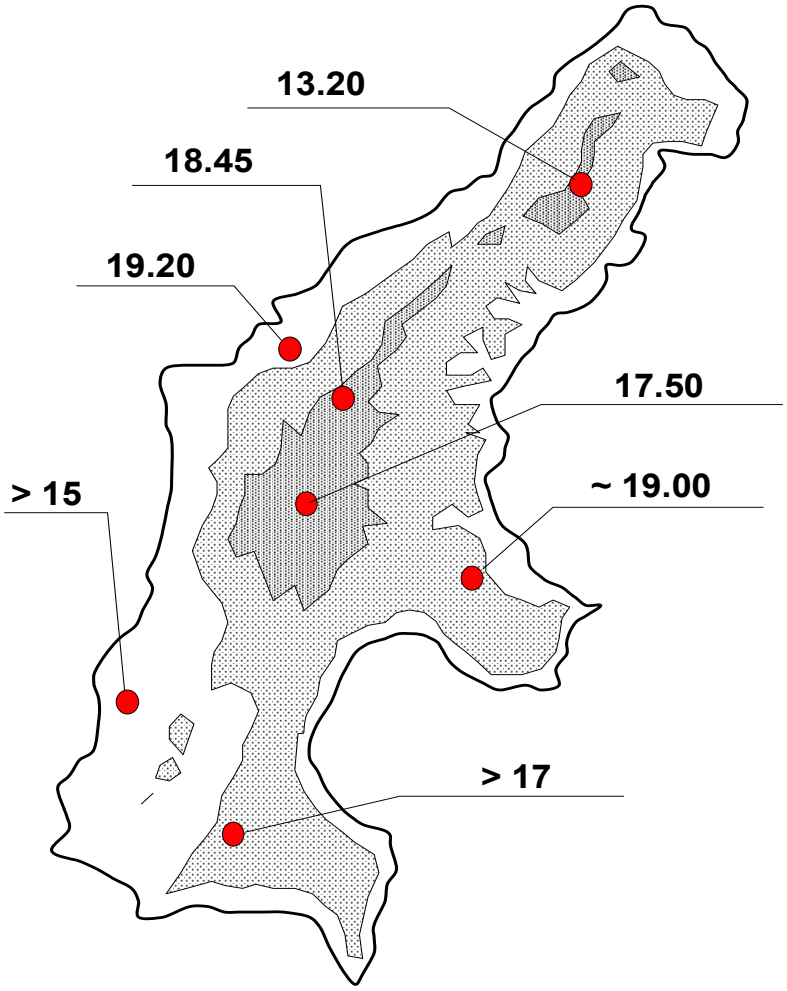

Figure 9. Twenty-four hour rainfall during Typhoon Steve, August 08, 1993. Note that the extreme rainfall totals are not a function of elevation. A similar distribution of heavy 24-hour rainfall was experienced on Saipan just one year later (not shown) during the passage of Typhoon Wilda by the island.

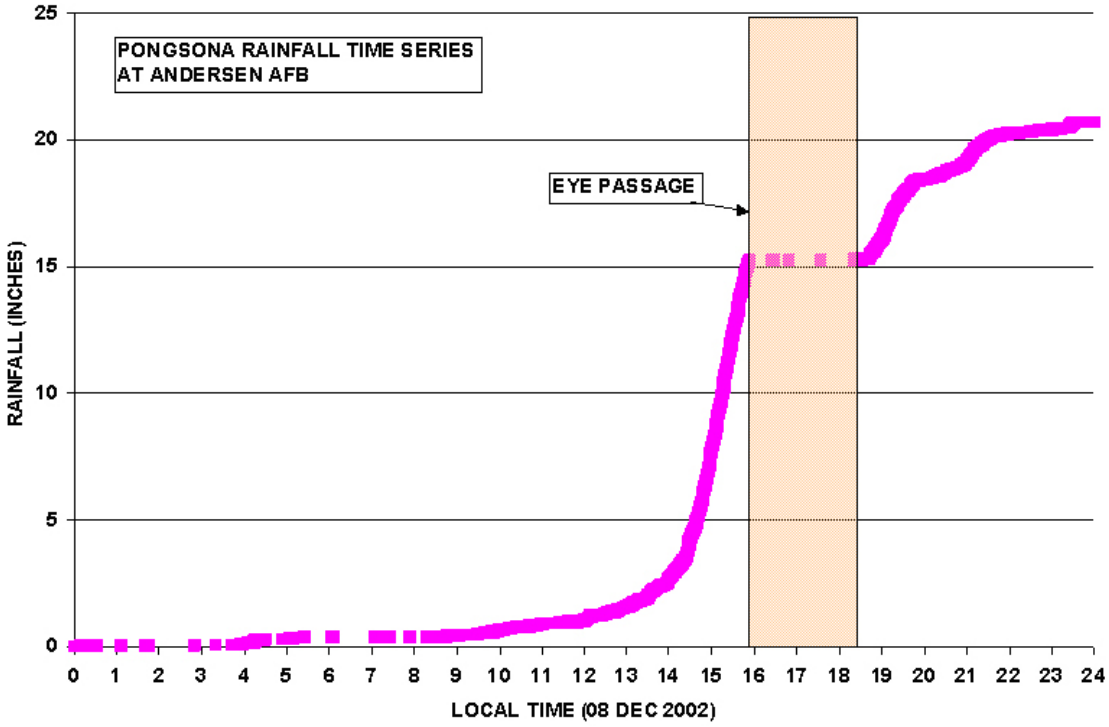

Figure 10. Time series of rainfall at Andersen Air Force Base during Typhoon Pongsona.

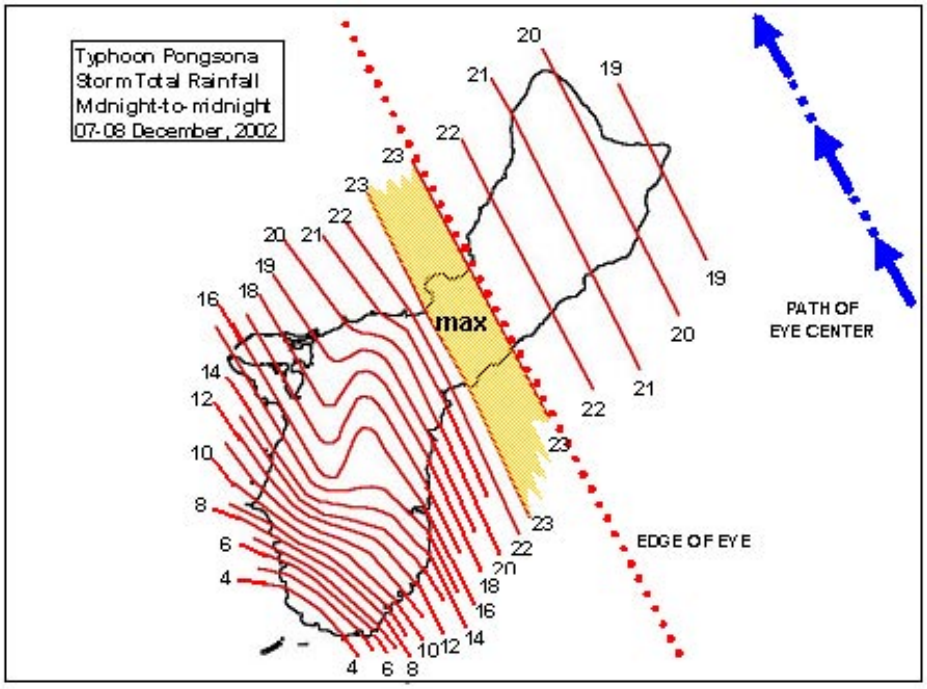

Figure 11. Analysis of 24-hour rainfall distribution in inches during the passage of Typhoon Pongsona over Guam.

In both typhoons Chataan (July 2002) and Pongsona (December 2002) on Guam, the rains recorded by newly installed electronic gages exceeded the 100-year event (Fig. 12). The 100-year event was exceeded at all intervals up to the 12-hour rainfall. It is thus possible that typhoon rains are responsible for the highest of extreme rainfall rates at all time intervals. Historically, typhoon rainfall has not been adequately measured. The typhoon frequency on Guam is approximately the same as it is in Saipan (Fig. 13), although during the 1990's Guam has experienced an unusual spate of typhoon strikes!

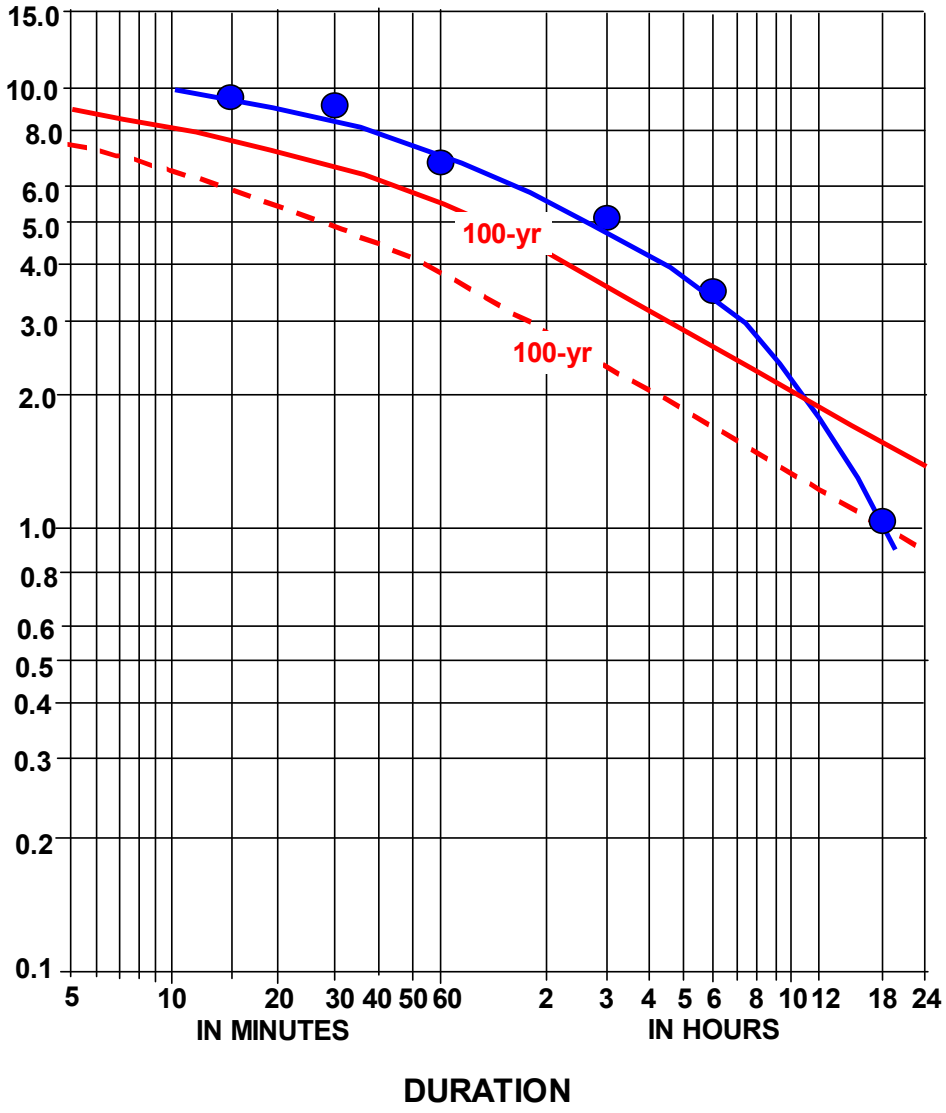

Figure 12. Peak short-term rain rates (blue dots) in Typhoon Pongsona over Guam. Note that the rates generally greatly exceed the existing values for the 100-year return period as found in the Guam Storm Drainage Manual.

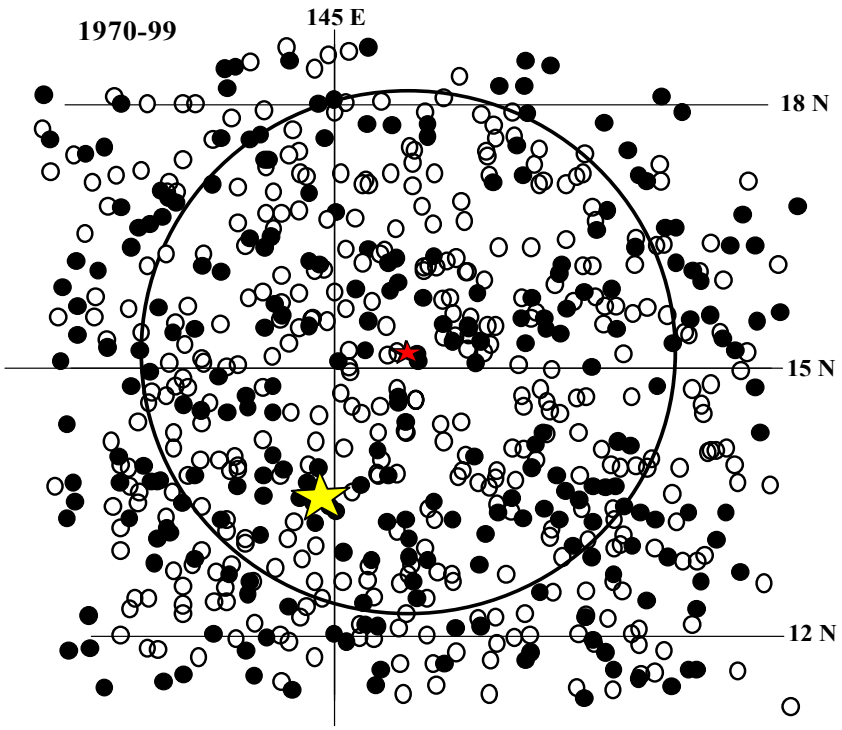

Figure 13. Six-hourly positions of all tropical storms (open dots) and typhoons (black dots) centered on Saipan (red star) for the period 1970-99. Despite Guam's recent spate of typhoon strikes in the 1990's, it appears that the typhoon distribution at Guam (yellow star) and at Saipan are roughly the same.

Inter-annual and inter-decadal variation

Saipan is located in a region of the world characterized by large-scale seasonal weather changes associated with the monsoons of the Eastern Hemisphere. For most of the year, the winds on Saipan are from the east, but during the summer and early autumn, the winds can become west to southwest for periods lasting up to one month. Generally, the swing of wind to the southwesterly is episodic and occurs in 3- to 10-day periods during which the winds may approach gale force. The number, strength and duration of episodes of southwest winds on Saipan is highly variable from year to year. The wind may become southwesterly on Saipan at any time of the year when a tropical cyclone passes to the north of the island. A monsoon index, and a wind rose chart have been prepared from the long-term records of the wind on Guam. Guam and Saipan share much of the same large-scale weather features such as episodes of the southwest monsoon, shear-line passages, hazardous surf events, and El Niño-related droughts. The behavior of the southwest monsoon (and the wind climate in general) on Saipan may have some slight differences that will be revealed when a study of the Saipan wind records are examined and compared with those of Guam. A monsoon index has not yet been prepared for Saipan because of the shorter length and fragmentary nature of its historical records of wind and rain.

There is intense pressure on the scientific community to predict the long-term fate of earth's climate (e.g., global warming); and further, to show the impact of such long-term climate change at regional scales (e.g., the tropical Pacific islands, Antarctica, and the world's grain belt). It has been suggested by some (e.g., Morrissey and Graham 1996) that the hydrologic cycle of the western Pacific may change in a warmer world in a manner that would see tropical islands in the northwest part of the basin (e.g., Yap, Palau, Guam and the CNMI) become drier while islands of the central equatorial and South Pacific (e.g., Kiribati southeastward through the Society Islands) become wetter. As research continues on the problem of long-term climate change, attention has recently been focused on climate fluctuations at periods of one to several decades. These inter-decadal climate variations are troubling because they may mask, or may be mistaken for, longer-term climate changes. A plethora of local and regional climate patterns have been defined, for example: the Pacific Decadal Oscillation (PDO) (Minobe 1997), the North Atlantic Oscillation (NAO) (Uppenbrink 1999), and the Southern Oscillation. Nearly all of these have prominent inter-decadal variations. Any projections of a change in the hydrologic cycle in the western Pacific in a warmer world must take account of the presence of susbstantial inter-decadal variations of rainfall, as observed on Guam.

The 50-year record allowed some assessment of inter-decadal variations in Guam's rainfall. The 1950s was a very dry decade, as indicated by the sharp downward slope of the running accumulations of rainfall anomalies shown in Fig. 14. The late 1960s to the mid-1970s were slightly drier than the long-term average, while the 1980s through the early 1990s were slightly wetter than the long-term average. The period 1960-65 was very wet as indicated by the sharp rise of the running accumulation of the rainfall anomalies shown in Fig. 14. The distribution of these long-term trends are consistent at both Tiyan and Andersen AFB (the two stations with the longest complete rainfall records on Guam), and at SIA. Superimposed on the long-term rise and fall of the integrated rainfall are sharp peaks and troughs that are primarily associated with ENSO:

the period from the end of the El Niño year through the year following El Niño tends to be very dry.

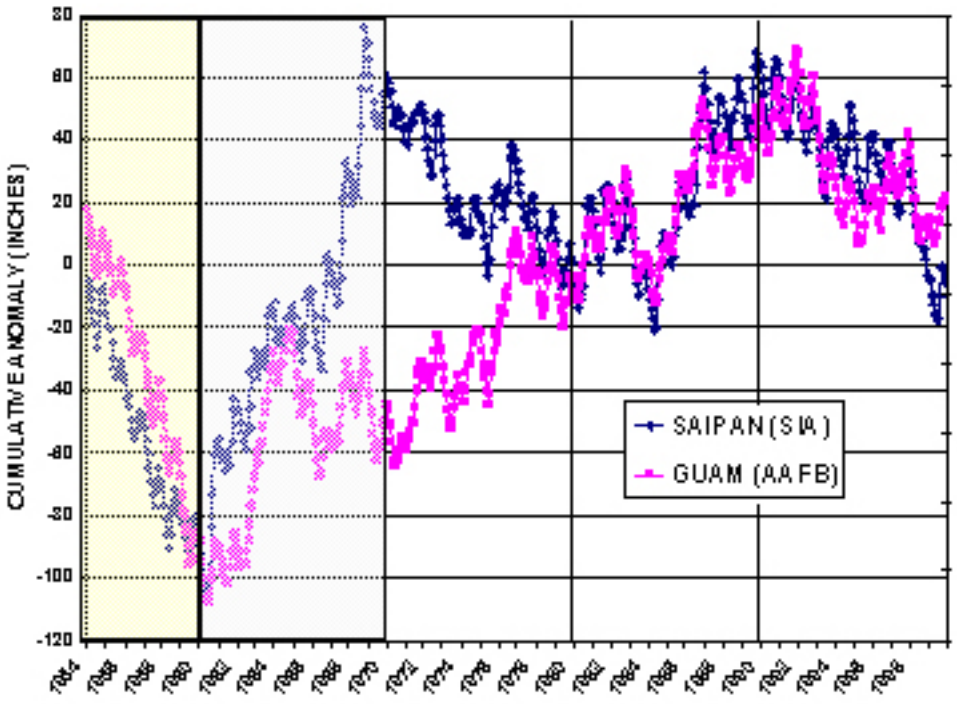

Figure 14. Running accumulations of the rank (lowest month = -305, highest month = +306) of each month's rainfall for the period 1954 to 2000 (annual cycle not removed). Complete records were available from Andersen AFB, Guam, and the constructed time series of the SIA. Prominent features include the extreme dryness of the 1950's (orange half-tone), a very wet period in the 1960's (light-blue half-tone), and recent overall dryness in the 1990's. Recent short-term prominent rainfall fluctuations include relative dryness from late 1992 through 1995, and a wet period during 1996 and 1997, followed by the driest year of record: 1998. These short-term fluctuations are related to El Niño

Principal Findings and Significance

The distribution of rainfall on Saipan is affected (to some degree) by the topography, and the mean annual rainfall totals among recording stations on Saipan differ by as much as 15 inches (380 mm). The region in the vicinity of Saipan's international airport receives the lowest annual total of about 75 inches (1900 mm). The highest measured annual average of approximately 90 inches (2300 mm) occurs at Capitol Hill, and extends along the high ground from Marpi to Mount Tagpochau.

The Saipan rain record is too short to develop accurate return periods of extreme rainfall events. The 24-hour extreme rainfall curve for Guam may be used as a proxy for the 24-hour extreme rain total on Saipan. Recent accurate measurement of rainfall in typhoons on Guam show extraordinary magnitudes that exceed existing 100-year values at all short-term intervals from 15 minutes to 12 hours. More rain records need to be collected in typhoons to produce reliable tables of return periods for short-term extreme rain events. In any case, it is suggested that the extant tables for Guam extreme rains be used at both Guam and Saipan (albeit with the provisos that typhoons may cause higher rain rates than previously thought, and that the frequency of direct typhoon strikes on Guam has recently been much higher than that on Saipan). The return periods of extreme rain rates should be considered uniform across the topography.

Inter-annual variations of Saipan's rainfall are closely linked to the El Niño/Southern Oscillation (ENSO) phenomenon. To some extent, the occurrence of typhoons in Guam and in the CNMI is also linked to ENSO. Large inter-decadal variations in rainfall (and also in the distribution of typhoons) are noted. The causes of these remain a mystery.

Impact of Ordot Dump on Water Quality of Lonfit River Basin in Central Guam

Basic Information

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End Date:	2/28/2003
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Congressional District:	NA
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Focus Category:	Water Quality, Toxic Substances, Solute Transport
Descriptors:	Point-Source Pollution, Priority Pollutants, Landfill Leachate
Principal Investigators:	Mohamed Golabi, Gary Denton, Harold Wood

Publication

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PROJECT SYNOPSIS REPORT

Project Title

Impact of Ordot Dump on Water Quality of Lonfit River Basin in Central Guam

Problem and Research Objectives

Guam's only municipal solid waste disposal site is centrally located in the village of Ordot and has been in use for over fifty years. Lacking in the conventional technology built in to modern day sanitary landfills, the site is essentially an open dump covering ~20 acres of the upper Lonfit River valley. The dump was operated by the US Navy at the end of WWII and transferred to the Government of Guam shortly thereafter. Although slated for closure more than 20 years ago, it still receives around 200 tons of solid waste per day from the civilian community. Early records of the types of materials disposed of at the Ordot Dump are nonexistent but are suspected to include the same array of toxic chemicals found at other military dumpsites on island. Today, there is some control over the bulk disposal of industrial chemicals, waste oil, and metallic waste at Ordot Dump. However, household waste is rarely screened and is known to contain a variety of hazardous substances, both biological and chemical. Leachate streams occur in several places around the perimeter of the dump and course their way down gradient into the Lonfit River and out into Pago Bay. Their chemical composition is largely unknown and their impact on the local environment in terms of ecology, agriculture, and human health remains to be investigated.

The objectives of this project were to characterize the primary biological and chemical contaminants in leachate water emanating from the Ordot Dump and trace their respective movements down the watershed and out into the ocean. This was accomplished by examining surface water and soil interstitial waters at discrete locations between the dump and the coast to determine the distribution and abundance of primary contaminants and identify their differential mobilization rates in surface and subsurface environments.

Methodology

Leachate samples were collected from two separate locations on the southern face of the dump and sent off-island for a one-time analysis of all priority pollutants listed under *Guam Water Quality Standards* (GEPA 2001). The high cost of this analysis precluded further testing.

Surface water samples were taken at monthly intervals from five sites along the Lonfit/Pago river systems between the dump and the ocean. These were analyzed for total coliforms and fecal indicator bacteria (*E. coli* and *Enterococci*), nutrients (NOx, NH_4-N and orthophosphate-P) and heavy metals (Ag, Cd, Cr, Cu, Fe, Hg, Mn, Ni, Pb and Zn). Samples for nutrient and heavy metal analyses were withdrawn directly into 50 ml polypropylene syringes and filtered through in-line 0.45 μm filters into 100-ml plastic vials.

Monthly subsurface water samples were taken from five sites around the western edge and southern toe of the dump. These were collected using suction cup lysimeters buried

to depths of 2, 4 and 6 feet below ground level. Samples were removed from the lysimeters under vacuum and analyzed for bacteria, nutrients and metals without further treatment.

All surface and subsurface water samples were stored on ice in the field. In the laboratory, those required for heavy metal analysis were acidified with analytical grade nitric acid (100 µl/l00 ml). All bacteria and nutrient analyses were performed within 6 h and 24-h of collection respectively.

All bacteria counts were made using the Idexx Quantitray® technique. Total coliforms and *E coli* were incubated at 35°C with Colilert® media to their respective color and fluorescent endpoints. *Enterococci* were incubated in Enterolert® at 41°C to a fluorescent endpoint.

Nutrient determinations were made using a multi-channel Flow Injection Analyzer (FIA) (Quickchem 800: Lachat Instruments). The analytical methods were those recommended by the manufacturer and are essentially the same as those described in *Standard Methods,* Part 4500 (APHAWW 1992) with modifications for flow injection analysis. The heavy metal analyses were carried out by conventional flame and flameless atomic absorption spectrometry.

Principal Findings and Significance

Leachate:

The biological and chemical contaminants detected in the leachate samples are listed in Table 1 together with the appropriate surface water and safe drinking water quality standards for Guam. Especially noticeable are the extremely high counts of fecal indicator bacteria, which exceeded the Guam recreational water quality standards by at least three orders of magnitude. Presumably, these elevated numbers reflect unsanitary human wastes (e.g. disposable diapers) and animal carcasses placed in the dump as well as fecal contributions from the large populations of rodents, stray dogs and wild pigs in the area.

Of the 27 chemical contaminants detected in the leachate samples, 12 were found at levels that exceeded one or both of the water quality standards. Nutrient levels were particularly high, especially NH_4-N. In fact, the pungent small of ammonia was very noticeable at one of the leachate collection sites. Copper and Pb were also high in one of the samples compared with their respective surface water quality standard. Both metals are relatively toxic to aquatic organisms. Levels of all detectable metals were several orders of magnitude over and above those normally encountered in uncontaminated river waters (Denton *et al.* 1998).

It is interesting to note that relatively few organic solvents were found in the leachate and no pesticides other than p-dichlorobenzene. Likewise, no PCBs, PAHs, dioxins or furans were detected in either sample.

Bacteria:	Units	Results	Guam Water Quality Standards	
			Surface Waters [a]	Drinking Water
Bacteria:				
Total Coliforms	MPN Index/100 ml	2,419,200	-	0
E. coli	MPN Index/100 ml	137,400	126	0
Enterococci	MPN Index/100 ml	298,100	33	0
Nutrients:				
NOx	µg/l	604	100-500 [b]	10, 1 [c]
NH_4-N	mg/l	503	3.08 [d]	-
Ortho-P	µg/l	166	25-100	-
Metals (total):				
Aluminium	µg/l	1600 - 4,500	1000	50-200
Antimony	µg/l	9.7	-	6
Arsenic	mg/l	0.007 - 0.046	0.15	0.01
Barium	µg/l	85 - 240	-	2000
Boron	mg/l	1.6 - 5	-	-
Chromium	mg/l	0.017 - 0.210	0.210 [e, f]	0.1
Copper	mg/l	0.023 - 0.092	0.012 [f]	1.3
Iron	mg/l	0.68 - 2.9	3.00	0.3
Lead	µg/l	4.7 - 45	3.20	15
Manganese	µg/l	290 - 340	-	50
Nickel	mg/l	0.050 - 0.110	0.052 [f]	0.1
Vanadium	µg/l	26 - 62	-	-
Zinc	mg/l	0.083 - 21	0.11 [f]	5
Pesticides:				
p-dichlorobenzene	µg/l	3.4	-	75
Organic Solvents:				
Acetone	µg/l	17	-	-
Benzene	µg/l	3.1	-	5
Ethylbenzene	µg/l	7.3	-	700
Tetrahydrofuran	µg/l	10	-	-
Toluene	µg/l	18	-	100
cis-1,2-Dichloroethane	µg/l	1.1	-	5
m,p-xylenes	µg/l	8	-	-
o-Xylene	µg/l	3.6	-	-
Others:				
Cyanide	mg/l	0.007 - 0.016	0.0052	0.2
Phenolic Compounds	mg/l	0.074 - 0.155	-	-

a = GWQS for freshwaters only; b = as nitrate nitrogen; c = as nitrate nitrogen and nitrite nitrogen respectively; d = Criteria Chronic Concentration (CCC) at pH 7.0
e = CCC for Cr^{3+} only; f = CCC estimated at total hardness of 100 mg/l; dashes indicate no standards currently available

Table 1: Priority pollutants detected in leachate from Ordot Dump (Dec. '03)

Surface Waters:

The results of the bacterial analysis of surface waters from the Pago-Lonfit River systems are shown in Table 2. As expected, counts for the fecal indicator bacteria, *E. coli* and *Enterococci,* were highest at site 1 near the point of convergence between the river and a major leachate stream. However, these quickly diminished within a few hundred meters downstream and, for *E. coli*, were mostly below the recreational water quality standard at sites 2 and 3. In contrast, the recreational water quality standard for *Enterococci* was exceeded at all sites almost all of the time.

Station #	Distance from Discharge Point (m)	MPN Index/100 ml		
		Total Coliforms	*E. coli*	*Enterococci*
		mean (range)	mean (range)	mean (range)
Leachate Stream	0	2,419,200	137,400	298,100
1	10	38,820 (17,329 - 92,080)	1,553 (391 - 5,012)	4,661 (907 - 17,239)
2	500	11,460 (4,352 - 24,192)	43 (5 - 259)	146 (20 - 703)
3	1,500	1,189 (4,160 - 24,192)	59 (10 - 233)	180 (30 - 816)
4	4,500	17,902 (8,050 - 24,810)	277 (51 - 1,609)	132 (5 - 631)
5	5,000	18,882 (5,850 - 26,130)	441 (20 - 5,794)	153 (20 - 1850)

mean calculated as geometric mean

Table 2: Bacteria in surface waters of the Lonfit-Pago River system (Oct. '02 – May '03)

In general, fecal indicator bacterial counts were poorly correlated with one another both in space and time (Figure 1.). This suggests that they have very different survival times and reproductive capabilities in the environment.

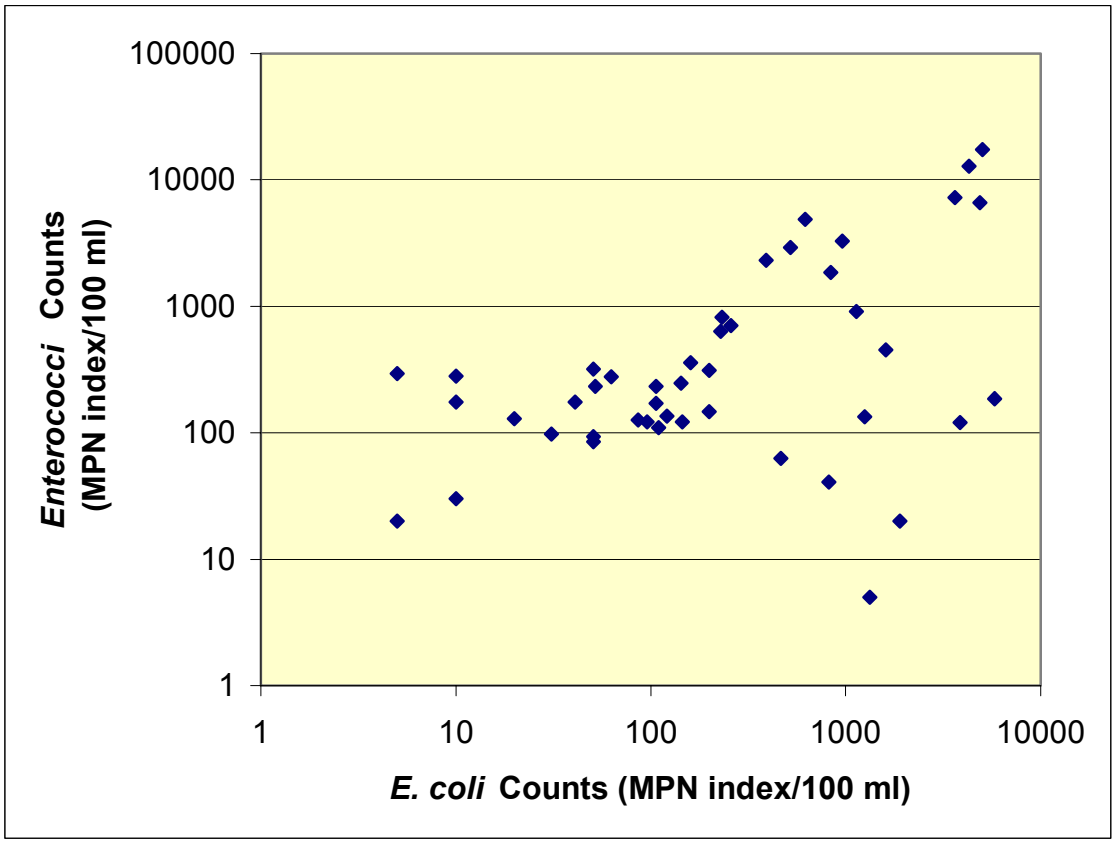

Figure 1: Relationship between *E. coli* and *Enterococci* counts in surface waters of the Lonfit-Pago River System (Oct. '02 – May '03)

On occasions, relatively high fecal indicator bacteria counts were encountered at sites 4 and 5 in the lower reaches of the Pago River and likely reflect seepage from residential septic tanks in the Pago Bay area. There is also a small sewage treatment plant (aerated sludge system) nearby that services 15 or so houses and allows the effluent to percolate

into the ground (Ed Reyes, Guam Waterworks Authority, pers. com.). The data geometric means for both fecal indicators at these sites exceeded the Guam recreational water quality standards.

Nutrient enrichment attributable to runoff from the dump was only evident at site 1 and only for inorganic nitrogen (Table 3). Levels determined further downstream were reasonably typical of groundwater impacted streams on Guam (Denton *et al.* 1998) except at the coast (site 5) where unusually high levels of NOx and NH_4-N were occasionally detected. Such findings again point towards the domestic wastewater inputs in the lower Pago basin area.

The absence of detectable levels of soluble inorganic phosphorus immediately downstream from the dump was unexpected considering the elevated concentration determined in leachate. Presumably, this nutrient is rapidly scavenged from the water column by iron as it changes oxidation state and precipitates out of solution as the hydrated ferric oxide.

Site #	Distance from Discharge Point (m)	Nutrients (µg/l)		
		NOx-N	Ammonia-N	Orthophosphate-P
		median (range)	median (range)	median (range)
Leachate	0	604	503	166
1	10	2,976 (1,350 - 3,380)	42.2 (41.1 - 43.2)	all <1.0
2	500	358 (229 - 487)	3.1 (1.3 - 6.3)	all <1.0
3	1,500	208 (111 - 305)	3.1 (1.7 - 5.2)	all <1.0
4	4,500	359 (151 - 567)	<1 (<1 - 2.8)	all <1.0
5	5,000	1140 (130 - 10,000)	18 (1.4 - 24.5)	all <1.0

Table 3: Nutrients in surface waters of the Lonfit-Pago River system (Oct. '02 – May '03)

Elevated heavy metal levels in the leachate stream were quickly diluted as they entered the Lonfit River at site 1 and were at normal baseline levels at all sites further downstream (Table 4). Iron and Mn were typically the most common elements detected and were generally followed in decreasing rank order of abundance by Cu>Zn>Pb>Cr and Ni. Levels of Cd, Hg and Ag were consistently below the limits of analytical detection at all sites so far examined.

In all probability, much of the soluble heavy metal load in the leachate stream rapidly partitions out onto suspended particulates upon entering the watershed and ultimately ends up in bottom sediments. These contaminated sediments would be gradually mobilized downstream and dumped in the Pago River estuary and adjacent waters.

It is suggested that sediment cores taken at strategic locations along the Pago-Lonfit River systems and out into Pago Bay would provide a more realistic measure of heavy metal distribution and abundance in this area. Such a sampling program would also provide a better understanding of the potential impact of these contaminants on the biota, particularly the suspension and deposit feeders and those organisms living in intimate contact with bottom deposits.

Metal	Site # (distance from leachate stream)				
	Leachate (0 m)	1 (10 m)	2 (500 m)	3 (1,500 m)	4 (4,500 m)
	mean (range)	mean (range)	mean (range)	mean (range)	mean (range)
Fe	1404 (680 - 2900)	87.0 (12.0 - 646)	16.8 (4.7 - 33.3)	15.8 (3.8 - 27.8)	14.9 (4.2 - 36)
Mn	314 (290 - 340)	272 (83.3 - 966)	21.5 (8.3 - 52.3)	24.3 (7.3 - 73.8)	27.4 (6.6 - 384)
Cu	46.0 (23.0 - 92.0)	5.6 (1.7 - 31)	0.5 (0.2 - 2.0)	0.4 (0.2 - 1.4)	0.4 (0.2 - 2.2)
Zn	1320 (83 - 21,000)	2.8 (1.2 - 6.2)	0.1 (0.1 - 0.5)	0.1 (0.1 - 0.3)	nc (<0.1 - 1.1)
Pb	14.4 (4.7 - 45.0)	nc (<0.3 - 4.0)	nc (<0.3 - 0.3)	nc (<0.3 - 1.0)	nc (<0.3 - 1.4)
Cd	all <0.1	all <0.2	all <0.2	all <0.2	all <0.2
Hg	all <0.1	all <0.3	all <0.3	all <0.3	all <0.3
Ag	all <0.1	all <0.1	all <0.1	all <0.1	all <0.1
Cr	59.7 (17.0 - 210)	2.0 (1.1 - 5.0)	nc (<0.3 - 0.9)	nc (<0.3 - 0.6)	nc (<0.3 - 0.8)
Ni	74.2 (50.0 - 110)	12.9 (2.7 - 33)	all <0.6	all <0.6	all <0.6

Table 4: Heavy metals in surface waters of the Lonfit-Pago River system (Oct. '02 – May '03)

A study of this nature should also include the chemical analysis of biotic representatives, particularly key organisms of ecological and economic importance. This would facilitate the identification of critical contaminant pathways and permit a realistic assessment of any potential health risks to those who harvest any of the aquatic resources in this area for food.

Subsurface Waters:
Bacterial counts in soil pore waters down gradient of the Ordot Dump were surprisingly low considering the extremely high numbers present in leachate (Table 5). Even total coliform counts rarely exceeded 200 per 100 ml sample and were mostly around 2 or less per 100 ml sample.

Soil Depth (feet)	No. Samples	MPN Index/100 ml		
		Total Coliforms	*E. coli*	*Enterococci*
		median (range)	median (range)	median (range)
2	32	2 (<2 - 4740)	<2 (<2 - 20)	<2 (<2 - 400)
4	30	2 (<2 - 7016)	<2 (<2 - 11)	<2 (<2 - 31)
6	36	2 (<2 - 4838)	<2 (<2 - <10)	<2 (<2 - 10)

Table 5: Bacteria in soil pore waters down gradient from Ordot Dump (Oct. '02 – May '03)

Both fecal indicator bacteria were rarely encountered at counts over 10 per 100 ml sample. Whether this is because bacteria in leachate from the dump are physically trapped in the overlying surface soil layers, or consumed by other soil microbes, or both, remains to be established. In any event, the data imply little to no subsurface movement of bacterial pathogens from the dump into the watershed.

It is interesting to note that the frequency with which *E. coli* and *Enterococci* were detected in soil pore water samples was depth related with the fewer detections at six feet than at two feet (Figure 2). In contrast, total coliforms were encountered in

approximately 50% of the samples collected at all three depths. It is also noteworthy that *Enterococci* were detected more often than *E. coli* at all soil depths.

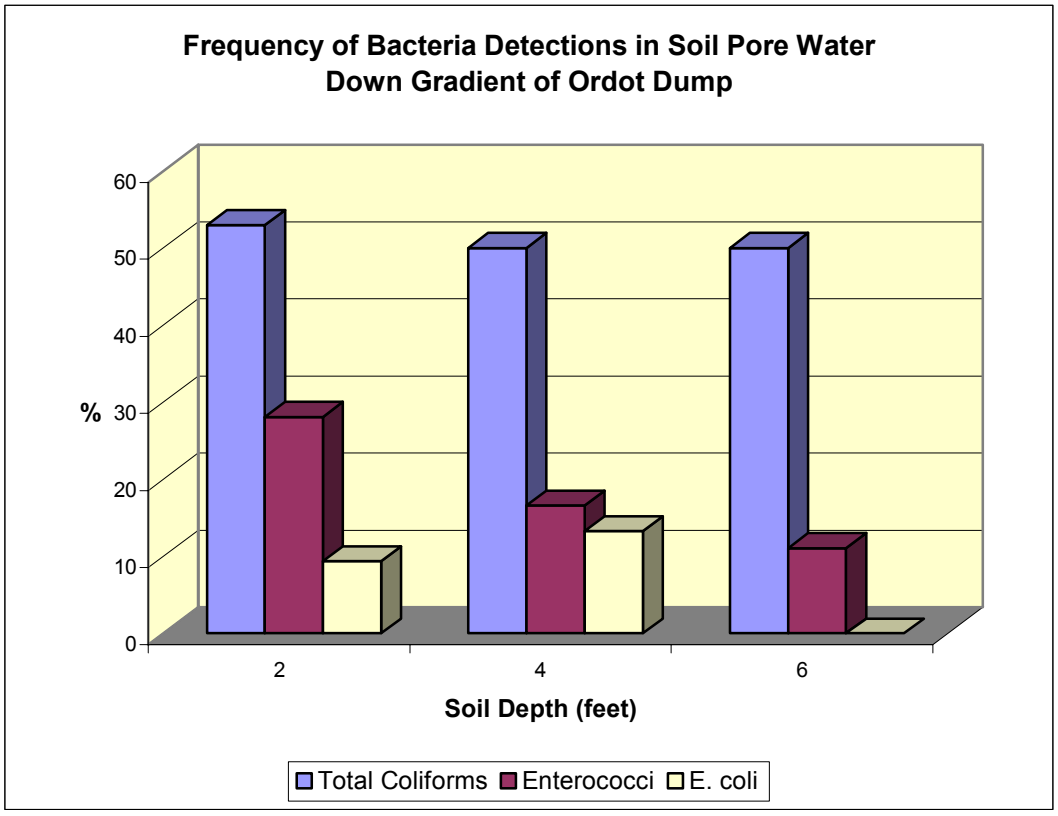

Figure 2: Frequency of bacteria detections in soil pore water down gradient from Ordot Dump (Oct. '02-May '03)

Nutrient levels found in soil pore waters are summarized in Table 6. NOx enrichment was evident in the majority of samples from the shallower depths and occasionally at the deepest level. These findings highlight the mobility of the nitrate anion down through the soil profiles and could account, at least in part, for the relatively lush vegetation growing further down the watershed.

Soil Depth (feet)	No. Samples	Nutrients (µg/l)		
		NOx-N	Ammonia-N	Orthophosphate-P
		median (range)	median (range)	median (range)
2	3	1,270 (339 - 8,124)	5.8 (2.9 - 6.0)	2.9 (1.0 - 16)
4	5	5,990 (10 - 9,510)	32 (2.9 -141)	18 (1.0 - 49)
6	8	740 (5 - 35,455)	11 (4.3 - 35)	8.5 (1.0 - 59)

Table 6: Nutrients in soil pore waters down gradient from Ordot Dump (Oct. '02 – May '03)

Ammonia-N and orthophosphate-P levels were generally low and indicative of a fairly well aerated soil environment at all depths. Both nutrients showed some indication of depth-dependency with the highest levels occurring in samples from the deeper lysimeters. It seems unlikely that the low pore water bacteria counts noted above were related to a nutrient deficiency.

Heavy metal levels in the soil pore water samples have yet to be completed. However, the data thus far collected suggest all elements of interest are at, or close to, the limits of analytical detection with the possible exception of Al, Fe and Mn.

Concluding Remarks and Recommendations:
The results of this preliminary investigation show that leachate streams from the Ordot Dump transport substantial quantities of nitrogen, phosphorus and essential trace elements to the middle reaches of the Lonfit River. The extremely high fecal indicator bacteria content of the runoff also suggests that it could be a major source of human pathogens to the area. The biological impact of relatively high concentrations of certain potentially toxic heavy metals in the leachate requires further evaluation, particularly in the immediate downstream region of the watershed. Edible aquatic resources and potentially useful bioindicator species should be the primary focus of such studies. The subsurface movement of NOx, Al, Fe and Mn from the dump into the watershed is probably considerable. The latter metals could have a significantly negative impact on plant growth down gradient from the dump and warrant further investigation. Concentrations of PCBs, chlorinated pesticides (other than p-dichlorobenzene), PAHs, furans, dioxins, Hg, Cd, and the majority of organic solvents currently classified as priority pollutants by the USEPA, were undetectable in dump leachate and are not considered to be of any immediate importance. However, the continued and regular surveillance of all priority pollutants emanating from the dump is strongly recommended in order to identify any future quantitative and qualitative changes in contaminant concentrations.

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Inventory of Karst Features Relating to Past and Present Groundwater Flow on Tinian, CNMI, in Terms of the Carbonate Island Karst Model

Basic Information

Title:	Inventory of Karst Features Relating to Past and Present Groundwater Flow on Tinian, CNMI, in Terms of the Carbonate Island Karst Model
Project Number:	2002GU5B
Start Date:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	NA
Research Category:	Ground-water Flow and Transport
Focus Category:	Groundwater, Models, Water Supply
Descriptors:	Island karst, karst models, Mariana Islands
Principal Investigators:	john jenson

Publication

1. Stafford, Kevin _, John E. Mylroie, John W. Jenson, 2002, A Preliminary Report on the Karst Geology of Tinian and Rota., Water and Environmental Research Institute of the Western Pacific, Technical Report No. 96, University of Guam, Mangilao, Guam, p. 25.

PROJECT SYNOPSIS REPORT

Project Title: Inventory of Karst Features Relating to Past and Present Groundwater Flow on Tinian, CNMI, in Terms of the Carbonate Island Karst Model

Problem and Research Objectives

This project consisted of a survey of the karst features that control the input, transport, and discharge of fresh water from the limestone units covering the island of Tinian. Specific work included mapping and cataloging of karst surface features, caves, and coastal discharge features. In addition to obtaining such data to support sustainable development of Tinian's aquifer, the project provides new data by which to develop a more accurate and complete conceptual model of carbonate island karst aquifers in general. Karst research begun on the relatively uncomplicated aquifers of Atlantic-Caribbean islands has recently been completed on Guam and extended to Saipan. This project extended the work to Tinian. Tinian is unique in that it is a composite island (i.e., a carbonate island with the volcanic core of the island exposed near the center) with relatively compact shape and simple topography. This makes it ideal for testing certain hypotheses regarding the evolution of island karst aquifers.

Methodology

The study employed the classical methods of geological field investigation, including surface traverse and mapping, mapping of caves, and photo-documentation of key features both above and underground. Previous maps of the general geology (Doan et al., 1960) showed numerous faults and fractures. The relationship of structural features to sinkholes and coastal discharge features is now being systematically examined.

Principal Findings and Significance

The project began with an exhaustive literature and data search, which assembled all of the historical scientific and engineering publications related to the island. Many such documents are archived at the University of Guam's Micronesian Area Research Center. Much unpublished data also resides in the field offices of the USGS and Commonwealth Utility Corporation on Saipan and Tinian, and is accessible to support the project. All such data will be catalogued and put into a database to support the maps and diagrams that will be produced from the field study. These are being used to identify clues regarding the specific pathways by which water moves into and through the aquifer. Generalizations regarding such relationships will be incorporated in the Carbonate Island Karst Model, a general conceptual model for karst aquifers on small carbonate islands.

The project is the next logical step toward to eventually completing a comprehensive survey of the island, as for Guam and Saipan. A technical report is currently being prepared from work done in Summer 2002. The results of additional field work in December 2002 and January 2003 will be incorporated in a final report that will be published in Summer 2003. The final report will contain the full set of maps and photographs from the survey, including sinkholes, caves, coastal springs, and other significant karst features. It will also document and explain the relationships between these and structural features mapped in the current study as well as by previous workers.

Slow Sand Filter Conceptual Design Package forThe Federated States of Micronesia

Basic Information

Title:	Slow Sand Filter Conceptual Design Package forThe Federated States of Micronesia
Project Number:	2002GU6B
Start Date:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	NA
Research Category:	Engineering
Focus Category:	Treatment, Water Supply, Surface Water
Descriptors:	Streams, Water Quality Control, Slow Sand Filter
Principal Investigators:	Shahram Khosrowpanah, Leroy F. Heitz

Publication

1. Khosrowpanah, Shahram, and Leroy Heitz, 2003, Slow Sand Filter Conceptual Design for the Federated States of Micronesia, FSM, Water and Environmental Research Institute (WERI), University of Guam, Report No. 101, 60pp.
2. Khosrowpanah, Shahram, 2003, Application of Slow Sand Filtration Technology for Islands in the Federated States of Micronesia, 21st Annual Pacific islands Environment Conference, USEPA, Koror, Republic of Palau.

PROJECT SYNOPSIS REPORT

Project Title

Slow Sand Filtration Conceptual Design Package for the Federated States of Micronesia, FSM

Problem and Research Objectives

The lack of clean drinking water is a significant problem for residents of the high, volcanic island of the Federated States of Micronesia (FSM) (US EPA, 1986). The island of Pohnpei in the Federated States of Micronesia (FSM) suffered severe outbreaks of cholera in April 2000, which resulted in 20 deaths, and over 3,000 infected people. The epidemic started at Enipein, a remote village of the island where there is no potable water supply and no proper sanitation facilities (PUC, 2001). At the conclusion of a three-day symposium that was held in Pohnpei on the cholera epidemic, lack of proper water and food sanitation were defined as the sources of spread of the disease (Cholera Symposium, Pohnpei 2001). A similar outbreak occurred in Chuuk in 1983. Again, contaminated water supply systems were suspected as a source of spreading the disease. In both states the water systems suspected of spreading the disease are supplying raw untreated surface water to the consumers. Simple filtration and chlorination could do much to improve the sanitation of these systems.

The objective of this project was to put together the findings of earlier Kosrae Slow Sand Filter Pilot studies and to develop detailed conceptual construction drawings, operation recommendations, and construction costs for small slow sand filtration plants. The resulting recommendations and drawings will be planned around and sized appropriately for use by the many small community water supply system throughout the FSM.

The specific objectives were to:

1) Collect information on several potential sites for use of slow sand filtration technology in Kosrae and Pohnpei. This information includes the location, water demand, source of inflow, and the turbidity levels of the source water.
2) Develop detailed conceptual structural drawings of a slow sand filter plant for a typical site in FSM. These drawings include details of structural requirements, and complete descriptions of required inflow and outflow piping systems, filter and underlain systems, and filter controls. The design packages cover (various) potential sites in FSM with construction cost estimates for each site.

3) Develop an operation manual on how to operate the recommended slow sand filter system. This manual will include information on when the filters need to be scraped, how to backfill the filters, and how to control the inflow and out flow from the filter.

Methodology

The project objectives were accomplished by site visitation and development of conceptual construction-drawings for three different sizes of SSF for the FSM.

Phase I. Site Visitation

Pohnpei state has approximately 14 small community water supply systems that deliver untreated water to each community. Kosrae State has three village water supply systems delivering untreated water to village residents. The same situation exists in the other community water supply system in the FSM. Most of these small systems include a pipe that brings water from a small diversion structure at the sources to a large storage tank followed by a gravity feed distribution system to the village houses.

A site visitation was made to all Pohnpei and Kosrae community water supply systems. Two sets of data were collected. The first set of data was the estimation of the needed flow for user consumption. The second set of data deals with the physical characteristics of potential locations for a slow sand filter plant. As mentioned earlier the size of the slow sand filters depends upon the water demands. For example, to provide 1.6 million gallons a day for the Toful municipality in Kosrae requires a filter bed area of approximately one third of an acre. So, it was important to have a site that can physically accommodate the filters. In addition, topographic considerations were evaluated in order to determine the need for excavation that could increase the cost of construction.

Based on the needed flows three flow rates; 150, 60, and 20 gpm were selected for slow sand filter design.

Phase II. Design and construction cost estimates

From the information in phase 1, we developed a conceptual construction-drawing package for a typical slow sand filter that can be applied to water systems in the FSM. This package includes a complete set of structural drawings of the facilities for producing 150, 60, and 20 gpm-filtered water. These drawings as shown in Figures 1 and 2 show inflow and outflow pipes to the plant, the under drain system that lies beneath the filter bed media, and the required flow control systems. Basic structural details are also provided. While these plans will not be final construction drawings, they will useful for those seeking to secure funding to construct an actual facility. These plans will also greatly reduce the workload and thus the expense of producing final construction drawings for each project.

A completed construction cost estimate has been provided for the conceptual filter design. The construction cost that shows the unit cost of each component of the slow sand filters has also been compiled. A sample of these estimates is shown in Table 1, 2 and 3.

Principal Findings and Significance

The principal investigators of this project have completed two previous studies using a slow sand filter pilot plant that was constructed on the island of Kosrae. The hydraulic loading rate, the bacteria removal rate, and sediment removal was determined during the first study, FY 2000. The results of the second study that was completed in FY 2001 indicated that the local basalt media could perform as well as the imported sand media. This study brings together the results of the two previous pilot studies into a design of an actual full sized filter that includes a detailed conceptual construction-drawing package for three different flow rates 150, 60, and 20 gpm. As mentioned earlier, Figures 1 and 2 show the inflow and outflow to the plant, the under drain system that lies beneath the filter bed media, and the required flow control systems. A typical slow sand filter facility normally consists of two identical filter tanks that supply the community with treated water. During the time when filter scraping is required, one filter will be shut down and scraped while the other remains in service. However, to reduce the operational manpower and project cost we developed a conceptual construction-drawing package with one filter. The extra water from the filter will be stored in a storage tank for the time that filter needs to be scraped. This will avoid a supply discontinuity in providing drinking water for community.

To increase the length of the time between filter scraping the inflow water should be have relatively low in turbidity. This requires having a settling basin before the water inflows to the filters. Flow controls and water distribution to the filter beds has been kept as simple as possible to avoid problems with long-term maintenance of the facility. There are two valves that controls the flow, one located at the inflow, and one located at the outflow of the filters. The function of the inflow valve will be to control inflow and also for shutdown of the filter during scraping times. The outflow valve will be used to control the flow rate through the filter. As shown in Figure 2, the filter has two piezometers. The piezometers will indicate the head loss through the filter's media and thus will serve to warn those operating the filter when scraping will be required. The filter media will be of local crushed basalt or imported sand. The imported sand will be more expensive but it will eliminate the washing requirements. According to the Kosrae pilot study, the performances of local and imported sand are the same; with the exception that local sand requires extensive washing. This washing is for removing small sized particles that will clog the filters.

A completed construction cost estimate has been provided for the conceptual filter design. The construction cost shows the unit cost of each component of the slow sand filters for 150, 60, and 20 gpm. Tables 1, 2, and 3 show the detail costs for three size slow sand filters.

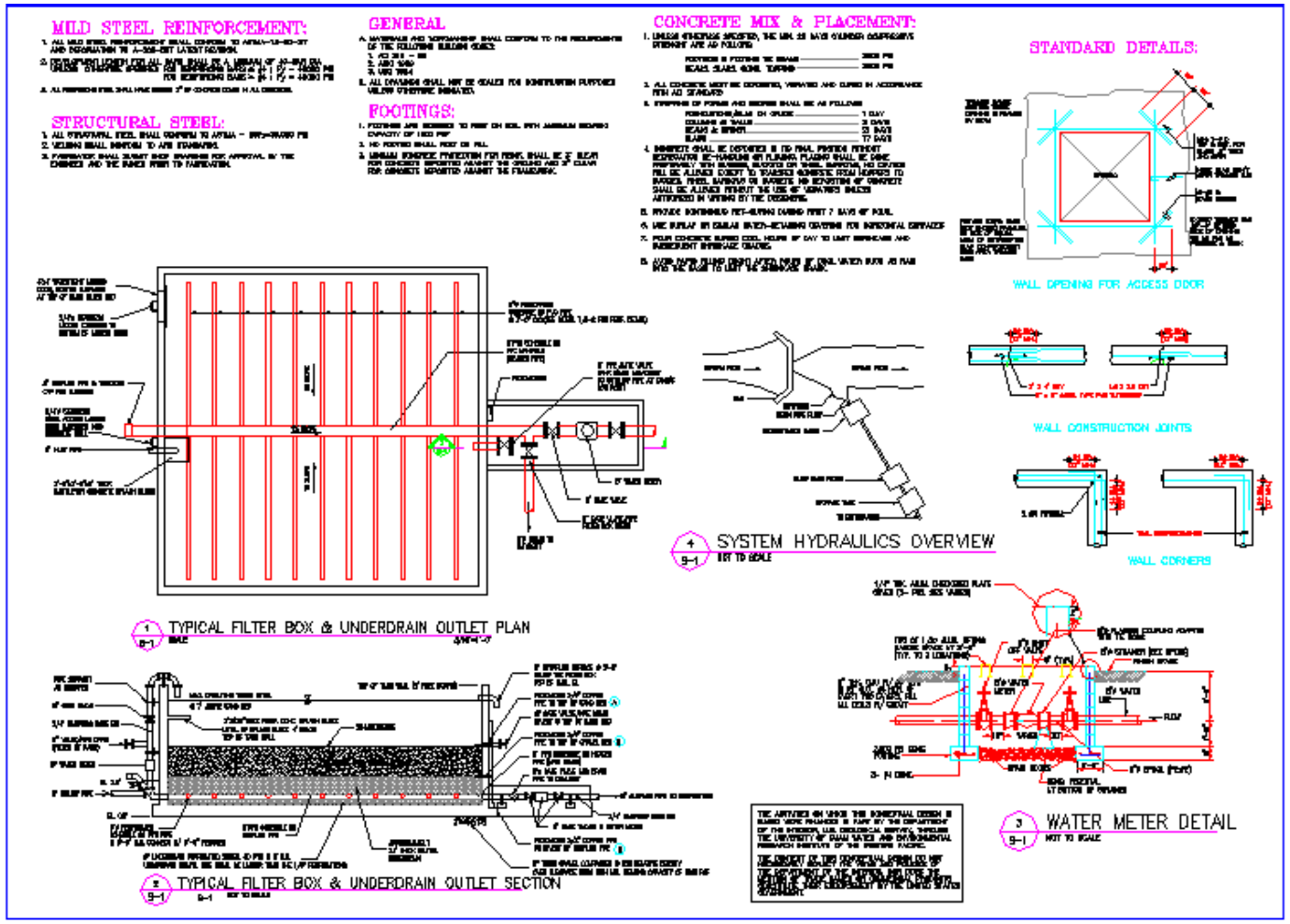

Figure 1. Slow Sand Filter Conceptual Design: Box Filter, under drain outlet, and System Hydraulics

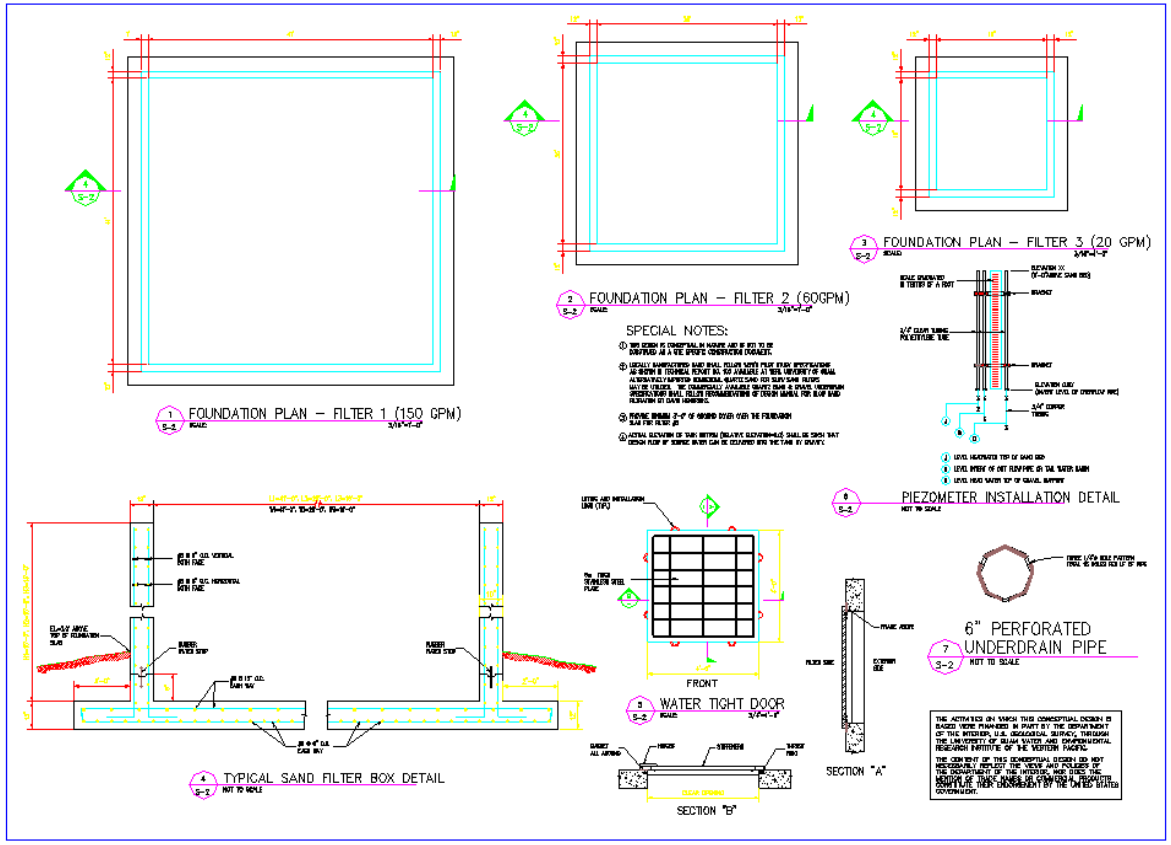

Figure 2. Slow Sand Filter Conceptual Design: Foundation Plan, Filter Box Detail, and Piezometer Installation detail for 150, 60, and 20 gpm filter capacity

Table 1. Cost Estimate for Slow Sand Filter with 150 gpm Capacity

SLOW SAND FILTER BUDGETARY CONSTRUCTION COST ESTIMATE (150 GPM CAPACITY)					
COST ESTIMATE PROVIDED BY MASOUD & COMPANY (JANUARY 2003)					
NO.	ITEM	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	8" SCHEDULE 80 PVC PIPE	80	FT	$19.94	$1,595.00
2	8" PVC SCHED. 80 COUPLING	8	EA	$56.25	$450.00
3	8" PVC SCHED. 80 ELBOW 90 DEGREE	3	EA	$65.00	$195.00
4	6" SCHEDULE 80 PVC PIPE PERFORATED	600	LF	$25.00	$15,000.00
5	6" PVC SCHED. 80 COUPLING	20	EA	$31.25	$625.00
6	6" PVC SCHED. 80 ELBOW 90 DEGREE	5	EA	$40.00	$200.00
7	6" TO 8" PVC SCHED 80 REDUCER	15	EA	$62.50	$937.50
8	8" GATE VALVE BRASS	6	EA	$687.50	$4,125.00
9	8" SCHEDULE 40 GALVANIZED PIPE	80	LF	$29.11	$2,328.57
10	8" MJ 90 DEGREE ELBOW	4	EA	$225.00	$900.00
11	8" SOLID SLEEVE JOINT	8	EA	$225.00	$1,800.00
12	4'X4' SS WATER-TIGHT DOOR & FRAME	1	EA	$3,562.50	$3,562.50
13	MAGNETIC TAPE	1	LS	$250.00	$250.00
14	STRUCT. STEEL REINFORCED CONC. (3000 PSI, GRADE 40 STEEL)	174	CY	$312.50	$54,386.57
15	TRENCH BEDDING SAND	1	LS	$1,500.00	$1,500.00
16	GRAVEL BASE COURSE	46	CY	$45.00	$2,083.33
17	COMPACTION	1	LS	$1,250.00	$1,250.00
18	TRENCHING/BACKHOE/EXCAVATOR	1	LS	$22,400.00	$22,400.00
19	3/4" HOSE BIB	2	EA	$6.25	$12.50
20	LOCALLY MANUFACTURED SAND FILTER (commercial sand quartz @ $462/cy	249	CY	$150.00	$37,355.56
21	LOCALLY MANUFACTURED GRAVEL FOR UNDERDRAIN	125	CY	$120.00	$14,942.22
22	PIZOMETERS	3	EA	$435.00	$1,305.00
23	WATER METERS 8"	2	EA	$1,250.00	$2,500.00
24	PIPE ADHESIVE, PLUGS, MISC. FITTINGS	1	LS	$500.00	$500.00
25	FENCE & GATE	400	LF	$56.25	$22,500.00
26	STAINLESS STEEL LADDER	2	EA	$1,800.00	$3,600.00
27	MISC. CONCRETE STRUCTURES, OPEN CHANNEL, WIER, ETC.	1	LS	$4,500.00	$4,500.00
28	SMALL TOOLS & MISC. EQUIPMENT	1	HR	$1,400.00	$1,400.00
29	LABOR	1920	HR	$15.00	$28,800.00
30	SUPERVISION	240	HR	$30.00	$7,200.00
31	LAND SURVEYING DURING DESIGN AND CONSTRUCTION PHASES	1	LS	$2,500.00	$2,500.00
32	SITE SPECIFIC DESIGN AND CERTIFICATION	1	LS	$4,500.00	$4,500.00
33	CONSTRUCTION PERMITTING, FEES	1	LS	$900.00	$900.00
	SUBTOTAL				$246,103.76
	OVERHEAD, TAX, & CONTINGENCIES @ 25%				$61,525.94
	GRAND TOTAL				$307,630

Table 2. Cost Estimate for Slow Sand Filter with 60 gpm Capacity

SLOW SAND FILTER BUDGETARY CONSTRUCTION COST ESTIMATE (60 GPM CAPACITY)					
COST ESTIMATE PROVIDED BY MASOUD & COMPANY (JANUARY 2003)					
NO.	ITEM	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	8" SCHEDULE 80 PVC PIPE	80	FT	$19.94	$1,595.00
2	8" PVC SCHED. 80 COUPLING	8	EA	$56.25	$450.00
3	8" PVC SCHED. 80 ELBOW 90 DEGREE	3	EA	$65.00	$195.00
4	6" SCHEDULE 80 PVC PIPE PERFORATED	380	LF	$25.00	$9,500.00
5	6" PVC SCHED. 80 COUPLING	14	EA	$31.25	$437.50
6	6" PVC SCHED. 80 ELBOW 90 DEGREE	5	EA	$40.00	$200.00
7	6" TO 8" PVC SCHED 80 REDUCER	10	EA	$62.50	$625.00
8	8" GATE VALVE BRASS	6	EA	$687.50	$4,125.00
9	8" SCHEDULE 40 GALVANIZED PIPE	80	LF	$29.11	$2,328.57
10	8" MJ 90 DEGREE ELBOW	4	EA	$225.00	$900.00
11	8" SOLID SLEEVE JOINT	8	EA	$225.00	$1,800.00
12	4'X4' SS WATER-TIGHT DOOR & FRAME	1	EA	$3,562.50	$3,562.50
13	MAGNETIC TAPE	1	LS	$250.00	$250.00
14	STRUCT. STEEL REINFORCED CONC. (3000 PSI, GRADE 40 STEEL)	110	CY	$312.50	$34,259.26
15	TRENCH BEDDING SAND	1	LS	$1,500.00	$1,500.00
16	GRAVEL BASE COURSE	29	CY	$45.00	$1,316.67
17	COMPACTION	1	LS	$1,050.00	$1,050.00
18	TRENCHING/BACKHOE/EXCAVATOR	1	LS	$14,140.00	$14,140.00
19	3/4" HOSE BIB	2	EA	$6.25	$12.50
20	LOCALLY MANUFACTURED SAND FILTER (commercial sand quartz @ $462/cy	100	CY	$150.00	$15,022.22
21	LOCALLY MANUFACTURED GRAVEL FOR UNDERDRAIN	50	CY	$120.00	$6,008.89
22	PIZOMETERS	3	EA	$435.00	$1,305.00
23	WATER METERS 8"	2	EA	$1,250.00	$2,500.00
24	PIPE ADHESIVE, PLUGS, MISC. FITTINGS	1	LS	$500.00	$500.00
25	FENCE & GATE	400	LF	$56.25	$22,500.00
26	STAINLESS STEEL LADDER	2	EA	$1,800.00	$3,600.00
27	MISC. CONCRETE STRUCTURES, OPEN CHANNEL, WIER, ETC.	1	LS	$4,500.00	$4,500.00
28	SMALL TOOLS & MISC. EQUIPMENT	1	HR	$1,400.00	$1,400.00
29	LABOR	1210	HR	$15.00	$18,150.00
30	SUPERVISION	150	HR	$30.00	$4,500.00
31	LAND SURVEYING DURING DESIGN AND CONSTRUCTION PHASES	1	LS	$2,500.00	$2,500.00
32	SITE SPECIFIC DESIGN AND CERTIFICATION	1	LS	$4,500.00	$4,500.00
33	CONSTRUCTION PERMITTING, FEES	1	LS	$600.00	$600.00
	SUBTOTAL				$165,833.11
	OVERHEAD, TAX, & CONTINGENCIES @ 25%				$41,458.28
	GRAND TOTAL				$207,291

Table 3. Cost Estimate for Slow Sand Filter with 20 gpm Capacity

SLOW SAND FILTER BUDGETARY CONSTRUCTION COST ESTIMATE (20 GPM CAPACITY)					
COST ESTIMATE PROVIDED BY MASOUD & COMPANY (JANUARY 2003)					
NO.	ITEM	QUANTITY	UNIT	UNIT COST	TOTAL COST
1	8" SCHEDULE 80 PVC PIPE	80	FT	$19.94	$1,595.00
2	8" PVC SCHED. 80 COUPLING	10	EA	$56.25	$562.50
3	8" PVC SCHED. 80 ELBOW 90 DEGREE	5	EA	$65.00	$325.00
4	6" SCHEDULE 80 PVC PIPE PERFORATED	240	LF	$25.00	$6,000.00
5	6" PVC SCHED. 80 COUPLING	8	EA	$31.25	$250.00
6	6" PVC SCHED. 80 ELBOW 90 DEGREE	5	EA	$40.00	$200.00
7	6" TO 8" PVC SCHED 80 REDUCER	8	EA	$62.50	$500.00
8	8" GATE VALVE BRASS	6	EA	$687.50	$4,125.00
9	8" SCHEDULE 40 GALVANIZED PIPE	80	LF	$29.11	$2,328.57
10	8" MJ 90 DEGREE ELBOW	4	EA	$225.00	$900.00
11	8" SOLID SLEEVE JOINT	8	EA	$225.00	$1,800.00
12	4'X4' SS WATER-TIGHT DOOR & FRAME	1	EA	$3,562.50	$3,562.50
13	MAGNETIC TAPE	1	LS	$250.00	$250.00
14	STRUCT. STEEL REINFORCED CONC. (3000 PSI, GRADE 40 STEEL)	70	CY	$312.50	$21,759.26
15	TRENCH BEDDING SAND	1	LS	$1,500.00	$1,500.00
16	GRAVEL BASE COURSE	18	CY	$45.00	$830.00
17	COMPACTION	1	LS	$1,050.00	$1,050.00
18	TRENCHING/BACKHOE/EXCAVATOR	1	LS	$6,300.00	$6,300.00
19	3/4" HOSE BIB	2	EA	$6.25	$12.50
20	LOCALLY MANUFACTURED SAND FILTER (commercial sand quartz @ $462/cy	38	CY	$150.00	$5,688.89
21	LOCALLY MANUFACTURED GRAVEL FOR UNDERDRAIN	19	CY	$120.00	$2,275.56
22	PIZOMETERS	3	EA	$435.00	$1,305.00
23	WATER METERS 8"	2	EA	$1,250.00	$2,500.00
24	PIPE ADHESIVE, PLUGS, MISC. FITTINGS	1	LS	$500.00	$500.00
25	FENCE & GATE	400	LF	$56.25	$22,500.00
26	STAINLESS STEEL LADDER	2	EA	$1,800.00	$3,600.00
27	MISC. CONCRETE STRUCTURES, OPEN CHANNEL, WIER, ETC.	1	LS	$4,500.00	$4,500.00
28	SMALL TOOLS & MISC. EQUIPMENT	1	HR	$1,400.00	$1,400.00
29	LABOR	760	HR	$15.00	$11,400.00
30	SUPERVISION	95	HR	$30.00	$2,850.00
31	LAND SURVEYING DURING DESIGN AND CONSTRUCTION PHASES	1	LS	$2,500.00	$2,500.00
32	SITE SPECIFIC DESIGN AND CERTIFICATION	1	LS	$3,500.00	$3,500.00
33	CONSTRUCTION PERMITTING, FEES	1	LS	$450.00	$450.00
	SUBTOTAL				$118,819.78
	OVERHEAD, TAX, & CONTINGENCIES @ 25%				$29,704.94
	GRAND TOTAL				$148,525

An Alternative Model for Enhancing Access to Safe Drinking Water in Less-Wealthy Areas: A Low Cost, Equity-Oriented & Participatory Source Water Protection Plan for Chuuk, Federated States of Micronesia

Basic Information

Title:	An Alternative Model for Enhancing Access to Safe Drinking Water in Less-Wealthy Areas: A Low Cost, Equity-Oriented & Participatory Source Water Protection Plan for Chuuk, Federated States of Micronesia
Project Number:	2002GU11B
Start Date:	3/1/2002
End Date:	1/28/2003
Funding Source:	104B
Congressional District:	NA
Research Category:	Water Quality
Focus Category:	Water Quality, Education, Management and Planning
Descriptors:	Source Water Protection, GIS & Remote Sensing, Education, Basins, Non-Point Pollution, Planning
Principal Investigators:	John Byrne, William Smith, Young-Doo Young

Publication

1. Smith Jr., William James, 2003, THE HUMAN RIGHT TO WATER:FROM THEORIES OF GLOBAL NEOCOLONIAL COMMODIFICATION, TO LOW COST, LOW TECH AND PARTICIPATORY ALTERNATIVE PRACTICE IN CHUUK STATE, FEDERATED STATES OF MICRONESIA, Ph.D. Dissertation, Center for Energy and Environmental Policy, School of Urban Affairs and Public Policy, University of Delaware, Newark, Delaware, 413
2. Smith Jr., William James, 2003, Applying the Human Right to Water in Micronesia Utilizing Geographical Analysis: Multi-scale Source Water Protection, 99th Annual Meeting 5-8 March 2003, Association of American Geographers, Washington D.C., 75.

PROJECT SYNOPSIS REPORT

Project Title

An Alternative Model for Enhancing Access to Safe Drinking Water in Less-Wealthy Areas: A Low Cost, Equity-Oriented & Participatory Source Water Protection Plan for Chuuk, Federated States of Micronesia.

Problem and Research Objectives

Problem

The people of Chuuk State, Federated States of Micronesia suffer from inadequate access to safe water. In the case study sub-basin on the island known as Fefan, as in most of Chuuk, waterborne diseases are the primary concern. This is confirmed by the investigators vis-à-vis on-site surveys, a detailed literature review, and extensive interviews of local managers and regional scientists. Although technology exists to mitigate waterborne disease, such technologies are often not appropriate for least wealthy areas such as Chuuk due to concerns regarding cost, decentralization of technology and management across many small islands, difficulties concerning maintenance, level of Western education needed to operate in the long run, as well as environmental and cultural appropriateness. This scenario is worsened in Chuuk by a lack of governmental capacity for spatial analysis of the environment for the purposes of mapping community environs, inventorying their sources of water and pollutants sources, and laying the foundation for source water protection. On a village scale this is compounded by the fact that little outreach occurs from the government regarding environmental health education. Because decision-making in Chuuk is made mostly at the village, rather than state or federal scales, whatever capacity is built at the state scale has little impact without a deliberate attempt to translate gains into education that can be delivered to communities, leaders and schools. Thus, a simultaneous multi-scale approach to these problems is necessary.

Research Objectives

Objectives were to form a coalition capable of incorporating local knowledge of culture, technology and environment together with Western scientific understanding in order to:

1. Build capacity for spatial analysis and environmental management (especially of water resources) on a Chuuk State scale by working with the Chuuk State Environmental Protection Agency;
2. Work with locals at a village/sub-basin scale to find low tech, low cost and appropriate ways to mitigate the impact of waterborne disease, utilizing existing resources and environmental education whenever possible.
3. To bolster the capacity of the Chuuk Environmental Protection Agency to perform environmental health outreach as noted in objective #2, vis-à-vis the capacity built by achieving objective #1.

Methodology

In order to reach objectives 1 through 3 the Micronesian Source Water Protection Coalition was formed. Founding members include the Chuuk EPA, Bill Raynor of The

Nature Conservancy, William James Smith, Jr. of the Center for Energy and Environmental Policy at the University of Delaware, and civil society in Chuuk.

In order to reach objective #1 the Coalition applied for and won a Conservation Grant from ESRI. We installed the GIS from ESRI and utilized GPS and satellite data from the USGS grant to customize a training program for the Chuuk EPA staff (there was no GIS in Chuuk). The training program involved 1 trainer to 5 trainee mentoring that incorporated local examples on the desktop and in the field. Training in spatial analysis was mainly focused on source water protection (see William James Smith, Jr.'s dissertation resulting from this study at http://www.philippinefamily.net/fsmswpp.html for the details). Another primary focus was the production of environmental outreach materials and report making utilizing the technology. Simultaneously, Smith hand digitized vital base-line GIS data from high resolution IKONOS 1 and 4 meter imagery in Chuuk Lagoon, and L-Sat imagery for Chuuk as a whole.

Capacity building through development of a
GIS and GPS-based decision support system

ESRI's grant provided the GIS software necessary for improving capacity regarding spatial analysis of the environment and public health. An important underlying concept for this partnership idea was addressing in part the need to literally be *at* places across Chuuk to conduct environmental analysis by enhancing "desk-top analysis." In addition, GIS and GPS are flexible technologies. Thus, once basic skills are learned they can be applied creatively to address a variety of local issues with local data. GPS is especially important in this regard, as it allows data collection "on the fly" that can represent such things as:

- Physical features;
- Conservation areas;
- Locations of surveys within natural features;
- Inventories of resources, sources of pollution, or hazards;
- Patterns of water quality sample results interpolated from discrete points; and
- Patterns of the spread of waterborne disease, etc.

This data and tool-set can be applied at multiple scales, and thus, was an excellent companion to the research at the state and village scales. Partnering is also buoyed by such technology, as data and information become easier to share. In all these ways decision-making is supported through this tool-set if locals can take master it, avoid expensive upgrades, and keep software compatible (a reason to use ESRI's ArcView 3.2).

In addition, scale is an important concept in basin management. Through the collection, storage, retrieval and display of data scale can be understood as an important facet of daily life in basin management and environmental analysis. Map making is key to this process, and while it bolsters the learning process for managers "on the desk-top," in the village products can breathe life and deeper understanding into environmental outreach materials. This can be accomplished by showing locals their environment at previously

unseen scales that support environmental processes they rely upon such as basin functions related to water quality.

The first basin delineations for Chuuk Lagoon were created utilizing re-rectified topographic maps and DEMs, as well as TINs. GIS data layers were created for Chuuk Lagoon by utilizing high resolution 4 meter color and 1meter panchromatic IKONOS satellite data, and L-Sat ETM data was to create land and reef layers for the entire state. Data created includes ArcView GIS Shapefiles of:

- All Chuuk State land
- All Chuuk State reef
- All lagoon beach
- All lagoon forest
- All lagoon grasslands
- All lagoon mangrove
- All lagoon streams (major)
- All lagoon sand
- All lagoon swamp
- All lagoon transportation (airport, boat ramps, paths, roads)
- All lagoon urban built

This aided in the source water study in Fefan by assisting in source water:

1. Delineation;
2. Inventorying; and
3. Addressing susceptibility

GPS enabled researchers to create layers informed by local knowledge for contributions to studies of water regarding:

- collection;
- treatment;
- storage; and
- consumption – including, our research demonstrates, untreated stream water.

Inventorying was conducted on a village scale, and the researcher created his own base-line data based upon the search for indicators of contamination -- as monitoring for the contaminants themselves was too resource intensive given fiscal and time restraints after a typhoon struck. Susceptibility was examined through a house-to-house survey of user's experiences and perspectives with a diverse set of sources of water and water collection, treatment, storage and collection technologies.

Environmental health, education and outreach

Logically then, an important part of capacity building that includes working with the grassroots is environmental outreach. Again, at the village and basin scale this can be done through schools, as well as through literature and posters at the community level, (which the team also has attempted). Local languages must be used in addition to a "universal" language such as English.

Focusing on a simple, direct and well-stated message that is portrayed in a light that is relevant by using local examples is important. To that end, local GIS/GPS products are excellent teaching aids. It is worth noting that "fancier" is *not* always better. Meanwhile, peer review involves people from the community the outreach is aimed at *during the process*, not just at the end, and should assist in keeping the material relevant and culturally appropriate to the village(s) and basin.

Selection of study area and techniques

Given the researcher's parameters for capacity building, the identification of regional concerns and gaps in knowledge, and formation of partnerships at the governmental and civil society scales, the MSWPC's selection of study area was a process that partners could easily agree upon. Criteria for the study basins were originally set for selecting multiple basins for comparative analysis, but devastation wrought by a powerful typhoon a week after the second training session ended made a multi-basin analysis of rural, mixed urban/rural, and urban environments impossible. The storm cost the team time by stranding a team member on an outer island for over a month, and also created terrible landslides that resulted in many deaths and community trauma. This also meant that indicators of threats to public health had to be used obtained vis-à-vis surveys of people and landscapes, as their was not an opportunity to arrange water quality monitoring over a significant period as previously envisioned. Criteria were set for a single rural basin that could more equitably represent most of Chuuk, rather than the one urban area with limited piped water.

Criteria for the primarily rural basin included the following:

1. Able to be visited during all visits;
2. Local participation must be possible, and given the post-storm context the basin, a basin of one of the team members seemed a good choice if all other criteria were met;
3. Likelihood of experience with waterborne disease outbreaks relatively high;
4. No treated water system exists or may ever exist, due to lifestyle and economy;
5. Possibility exists that stream water, perhaps untreated, is being consumed;
6. Must be able to extrapolate from this experience to others in the region for greater lessons to be garnered.

Given these criteria a basin was chosen in Fefan. The resulting study follows.

Field study techniques and equipment inventory

Day 1. *Survey* and at the same time *collect GPS* data for mapping of:
- Survey location
- Source water
- Potential contaminants

Day 2. *Cultural and physical GPS data collection* for mapping of:
- Culturally important places
- Potential contaminants (again)
- Secondary and unmapped tributaries

Supporting maps, satellite imagery, and equipment were used into the field. Researchers entered the study area from Weno via boat and then proceeded in Fefan on foot. Below is an inventory of equipment found useful for the field study:

- 2 Garmin76Map GPS units (marine environments) (basin shapefile from ArcView uploaded via third party freeware)
- Spare rechargeable batteries
- Binoculars
- Compass (GPS does not tell direction when you are still and it is a back up for safety)
- Camera
- Digital camera
- Video camera
- Waterproof notebook for taking notes in the rain with pencil
- Canvas and plastic bags for equipment

A five person team was employed that included Joe Konno, Julita Albert, Ismael Mikel, EPA staffer Elmut, and William James Smith, Jr. One person administered the survey for raw data from interviews or source water or pollutant inventorying, while one recorded answers in English. One utilized the GPS unit, while another recorded notes corresponding with GPS points. The remaining member handled the camera equipment and left their GPS on without taking points, so as to have a complete record of our tracks. The survey and GPS recorders used common names and times on their forms so it would be simple to understand which GPS data matched a given survey record.

Analysis of core data and information with delineation

The approach to the fieldwork is described in this section. Surveying mostly required hiking up the mountain slopes of the study area from home to home, beginning from the top of the basin, tracking the sources downward through communities.

Nine surveys were conducted on October 17 and 18, 2002. Respondents represent 89 persons on the island of Fefan in eastern Chuuk Lagoon in sub-basin "FefanJulita" (in the EPA GIS database), covering portions of Onnongoch, Fongen and a small part of Fein

villages. This basin is home to Julita Albert, one of the researchers, and she was kind enough to facilitate our traveling in the community. This population lives in a rural and small village context in relation to the "urbanized" areas of Weno. More information pertaining to lifestyles of the people in this basin can be derived from the data and information in the Appendix of the full dissertation.

The study area has a perimeter of 2.66 miles and an area of .37 square miles (basin delineation from USGS re-rectified quad including shallow reef) (Figs. 1, 2, 3, 4, 5 & 6). The population lives in a mostly forested basin, with the exception of the coastal area, wherein occurs the highest population density. In coastal areas the people of Fefan live on either side of the main road/dirt path, with mangroves on the outside and forest towards the interior that rapidly climbs fairly steep, but mostly inhabitable, slopes. There is a small portion of the population living in the Mangrove area. The geology is of volcanic origin, providing for a shallow ground water lens that is unconfined and therefore under fairly direct influence of activities on the landscape. As is the case with all of Chuuk State, precipitation levels are typically high, averaging close to 140 inches per year, so the assumption is that water *quality* is the most pressing issue, but at times quantity is also a problem due to El Nino events. Livelihoods mainly include fishing and sustainable farming of local foods such as taro and coconut.

Eight surveys were given in the village of Onnongoch and one in Fongen, in western Fefan. The lead respondents for families were:

- F01 Monica Kanas, female, age 31.
- F02 Pet Xyman, male, age 37.
- F03 Anna Ekom, female, age 70.
- F04 Skeichy Albert, male, age 50.
- F05 Elena Kanas, female, age 53.
- F06 Aniwisia Etin, female, age 57.
- F07 Teresia Roke, female, age 30.
- F08 Felixia Joseph, female, age 39.
- F09 Koson Andrew, female, age 64.

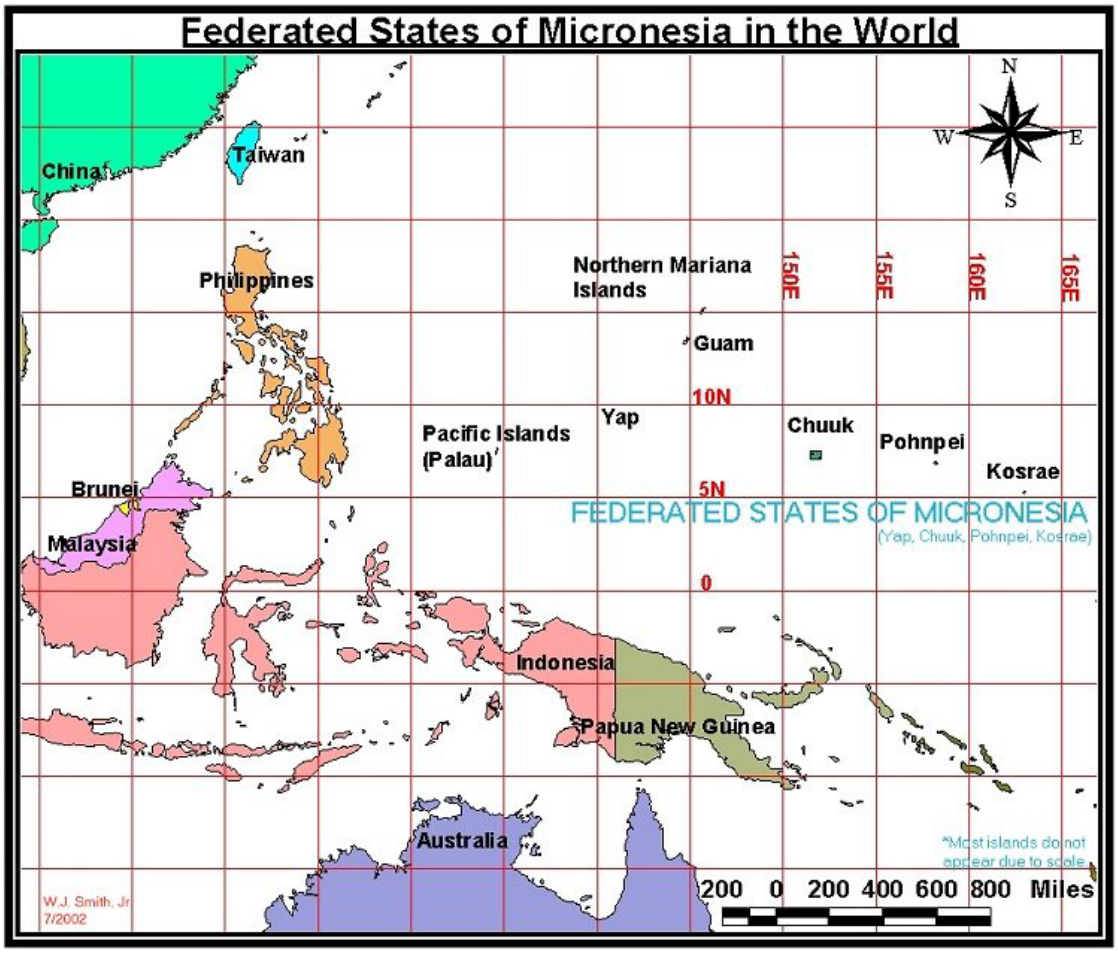

Figure 1. Location of Chuuk.

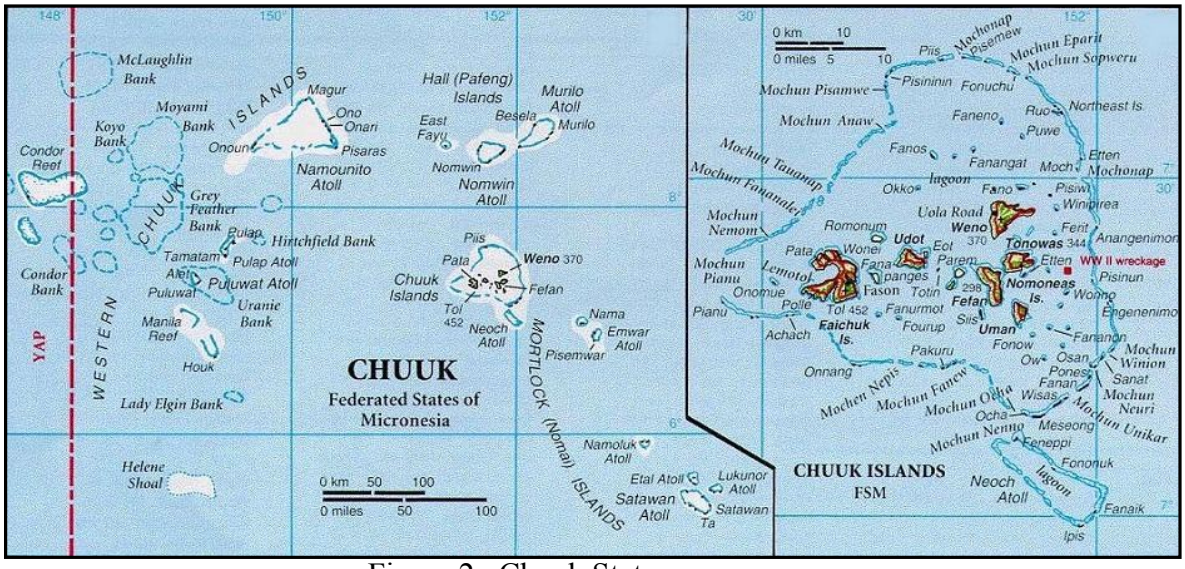

Figure 2. Chuuk State.

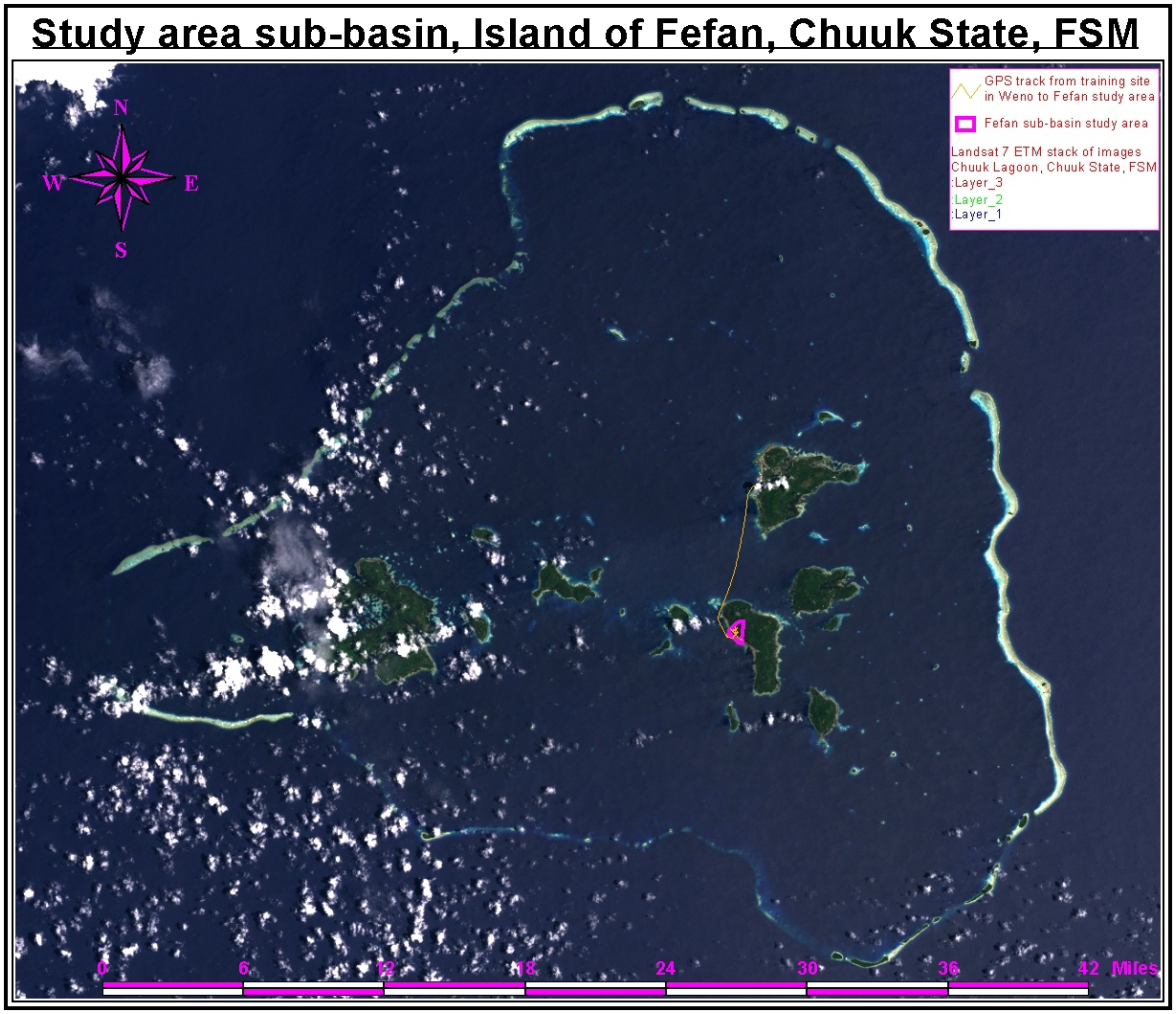

Figure 3. Chuuk Lagoon.

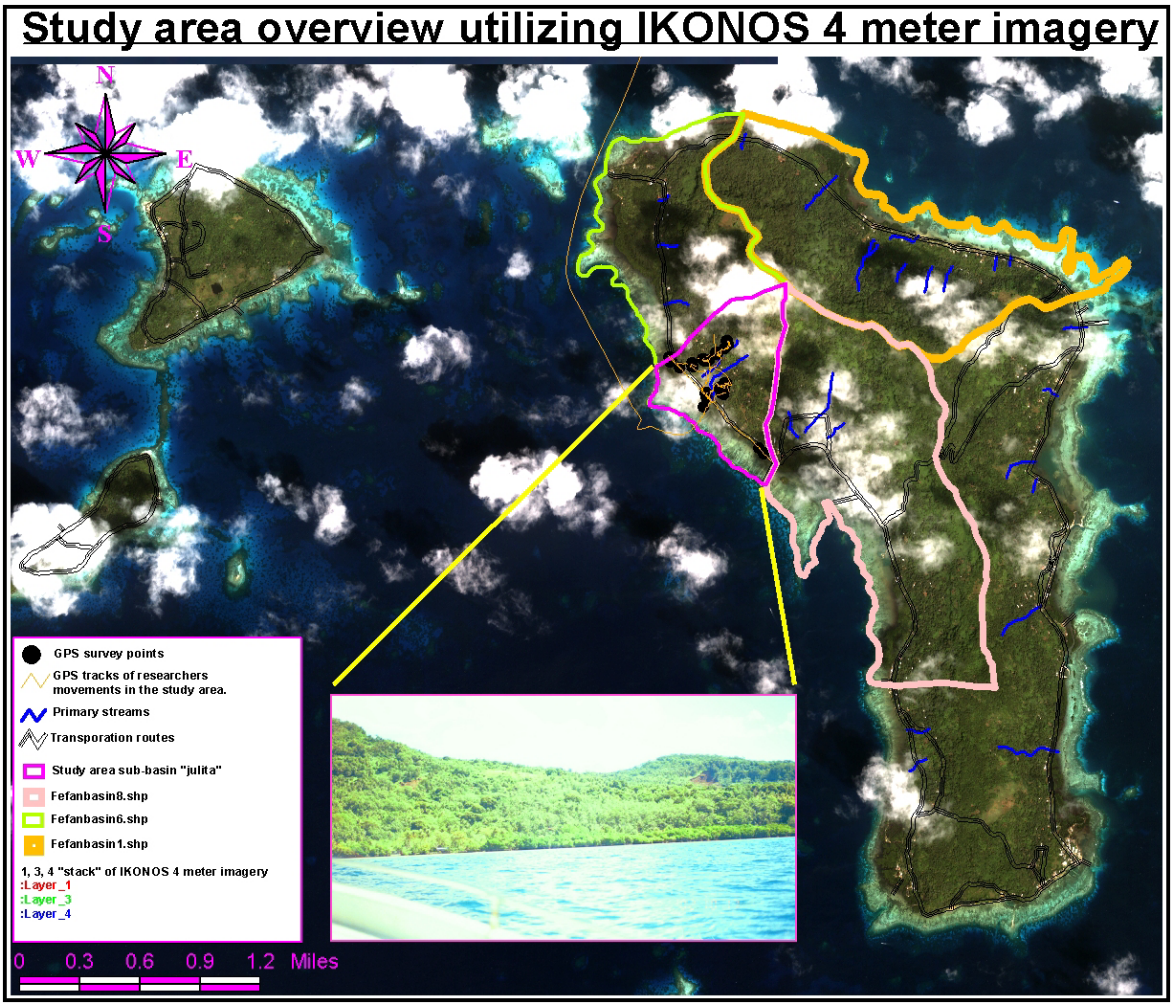

Figure 4. Study area on Fefan.

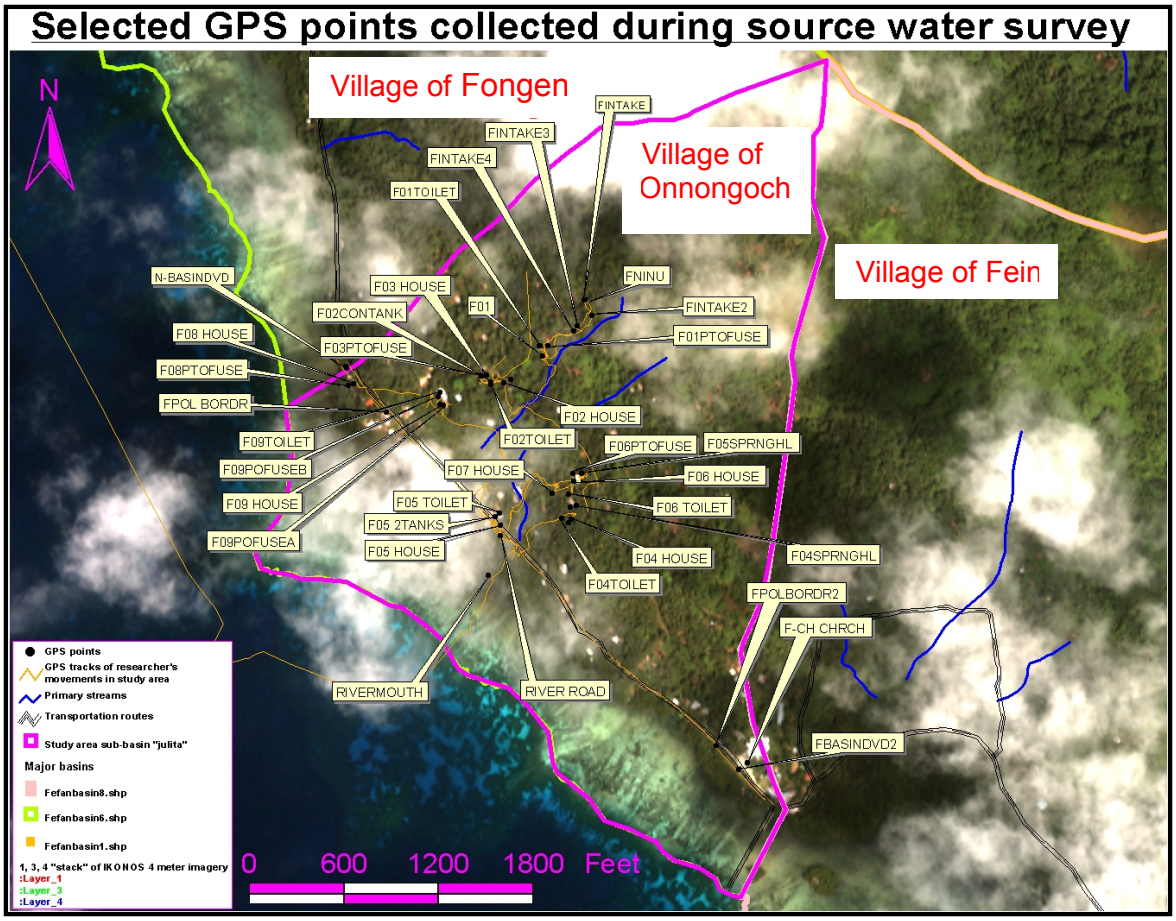

Figure 5. Source water survey of study area.

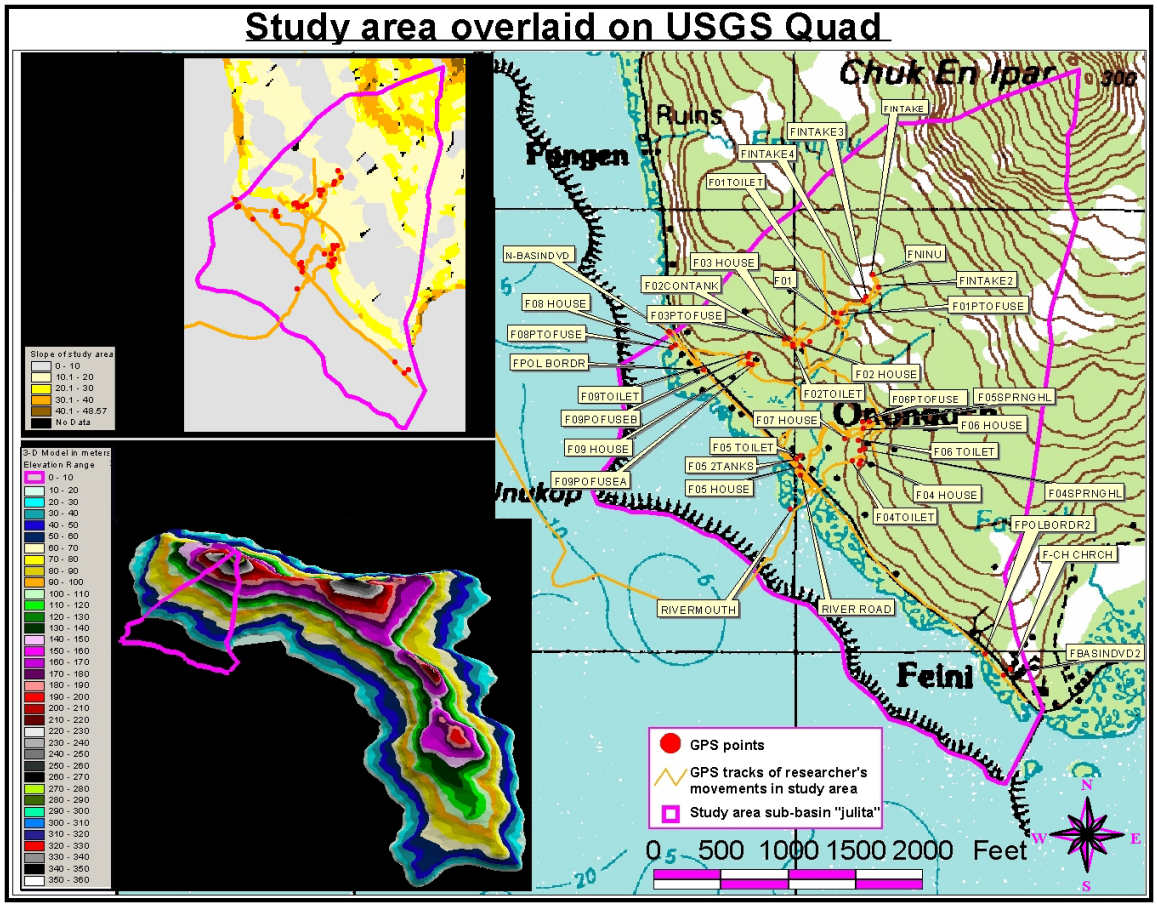

Figure 5. Study area slope and elevation.

Principal Findings and Significance

Full research and findings are found at the Micronesian Source Water Protection Coalition Web page at http://www.philippinefamily.net/fsmswpp.html. What follows are some of the findings and outputs of the research.

As is the case with EPA state guidelines for source water protection methodologies, the source water protection analysis was grounded in the process of:

1. Delineation;
2. Inventorying; and
3. Addressing susceptibility

This community outreach, combined with practicing with the GIS/GPS technology in the field, provided an output in terms of building capacity through improving Chuuk EPA skill-sets, as well as integrating staff knowledge with planning community outreach.

The types of GIS outputs have already been discussed, and will not be repeated here. However, it is important to note that an important output was supporting the capacity to create environmental health outreach materials and deliver them to the public. We used GIS/GPS to create basin-based water quality education that explained how to reduce vulnerability to waterborne disease. Included on posters and brochures posted publicly and shared with schools were local examples pollutants and also water collection, treatment, storage and delivery technology, and a guide as to how to use that technology, as well as for what purposes, to mitigate vulnerability to waterborne disease. The image files are too large to include here, so please see the posters and brochures we created that are downloadable at the MSWPC Web site. These outputs were delivered to the public vis-à-vis several community outreach efforts at schools and in the study area community.

Outreach is quite important, because our study discovered that villagers were vulnerable due to (not including complementary and vital hygienic reasons):

1. Drinking untreated stream water;
2. Not fixing broken rooftop catchments;
3. Not boiling water for drinking;
4. Boiling or using rooftop water for drinking, but not for brushing teeth, other food preparation (i.e. preparing taro or sashimi), or cooking that does not involve boiling; and
5. Poor basin management practices such as suspending pig cages above streams, dumping generators along streams for flood control, locating human waste near sources, etc. (on Weno many buried transformers were also just uphill of food and perhaps water). It is worth noting that "basin management" in an environment where regulation is weak *must* be participatory, and in Chuuk it must incorporated hygiene education.

Staff learned to integrate their GIS/GPS products with their outreach materials and short mock technical reports. Thus, both verbal and written communication skills for utilizing GIS/GPS were fostered, while practical Chuuk issues were examined.

Integrating spatial analysis skills at a state management scale, while at the same time studying source water vulnerability at a village scale, allowed the trainees to consistently focus their skill-building on the relevant local experiences of people they wish to assist.

During our studies it was discovered that rooftop catchments were not as numerous in the study area as anticipated, and were in need of maintenance through a local management team. Perhaps a church-based group would be a good idea, as people are turning back to dug-out springs and stream water that is at times untreated. In addition, the cholera scare of the 1980s is still remembered. However, we discovered that the environmental health message regarding when to boil water or use rooftop catchment water, and how to protect sources in the landscape from coming into contact with point and non-point sources of pollution is woefully inadequate.

From our research it has become clear that, rather than focus on centralized and high tech approaches to providing safe water only in areas where the relatively wealthy can afford to pay for "treated" water, a participatory and low tech and low cost approach should be adopted. It appears best to focus on basin-based source water protection education regarding how and where to dump hazardous materials, locate human waste in relation to sources of water, and allow for vegetative buffers and elevated surfaces around sources such as dugout springs for partial filtration. In addition, villagers need village scale education regarding for what purposes they should boil water, and this should be combined with hygiene education (a future hygiene study like this source water research would be helpful!). This education should be integrated formally through the school system to facilitate a semblance of fair or sustainable distribution of the knowledge in the long-term. Again, another idea worth exploring would be the use of church-based groups to maintain broken rooftop catchments. Lastly, their may be other less-wealthy world technologies that would better transfer to Chuuk than expensive and high tech ones. For example, the National Academies of Science have proven in no uncertain terms that wrapping saris (a garment worn in India) in a certain way around water collection vessels has the proven ability to strain out relatively large pathogenic microorganisms and prevent cholera. Such materials could also carry important environmental health messages.

The integration of basic basin management education for source water protection that uses local examples, understanding of how and for what purposes to boil water or utilize rooftop catchment water, and adopting hygienic practices, together, hold the most promise for reducing vulnerability to waterborne disease across rural basins in Chuuk. The role of environmental education in this endeavor is not simply as a support to technology, but is actually the most important factor in the sustainability of mitigating waterborne disease in the area. Without doubt, such environmental education can be well

supported through adoption of GIS/GPS tools by environmental managers. The Micronesian Source Water Protection Coalition has started Chuuk down this path, though a longer term partnership is vital to keep momentum moving forward.

Environmental health and basin-based source water protection education, as well as honing of low tech approaches are often not as glamorous endeavors as installing high technology, and they are not normally profitable. This may be a reason this approach is often ignored globally given the present paradigm of the commodification of water, and generally, academic researchers have trouble garnering grants for such projects because they do not represent "cutting-edge science." However, we are convinced that our research demonstrates that such approaches represent the primary way to equitably help most Chuukese avoid waterborne disease, protect the very young, old, and immunocompromised, and allow Chuukese to live longer and healthier lives. This type of approach to improving access to safe water deserves sustained support from within and outside the Chuukese community, and the lessons learned here likely hold relevance in many other parts of the less-wealthy realm.

Information Transfer Program

WERIs mission involves a large information transfer-dissemination component. Key elements include written forms such brochures and pamphlets, a website, technical reports, journal articles, newspaper columns, and book chapters. The audience for the results of USGS sponsored research is widely varied geographically and by education level. It is important that WERI make this information available in a very widely distributed form.

This project funded the design, layout and printing of three technical completion reports resulting from USGS funded research projects. One hundred (100) hard copies of each report were printed and the reports were prepared for publication on WERIs Web page.

It is very important that WERIs Web page be updated and optimized on a regular basis. To provide this a professional web maintenance firm was contracted to provide maintenance to the WERI Web page on a regular basis.

Because of Guams remote location it is difficult and quite costly for researchers to present their findings at technical conferences and symposiums. This project funded a portion of off-Island travel expenses for PIs and graduate students presenting refereed professional paper summarizing all or a portion of current or past 104-B research projects.

Water Quality Analysis and Water System Operation and Maintenance Training for Chuuk State FSM

Basic Information

Title:	Water Quality Analysis and Water System Operation and Maintenance Training for Chuuk State FSM
Project Number:	2002GU7B
Start Date:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	NA
Research Category:	Water Quality
Focus Category:	Education, Water Supply, Management and Planning
Descriptors:	Information Dissemination, Education
Principal Investigators:	Leroy F. Heitz, Gary Denton, Shahram Khosrowpanah, Harold Wood

Publication

PROJECT SYNOPSIS REPORT

Project Title

Water Quality Analysis and Water System Operation and Maintenance Training for Chuuk State FSM

Problem and Research Objectives

The need for effective information transfer on all aspects of water resources topics is immediate in the Federated States of Micronesia (FSM). This need arises from physical remoteness and political changes. Water resources training for all personnel working in water and wastewater industries is critical in the Federated States of Micronesia where waterborne diseases can reach world record levels.

Micronesia is an area where formal reports and professional publications are simply not effective information transfer vehicles. The most effective means of information transfer is one-on-one or small group discussions and presentations. Consequently, a training program was designed for the state of Chuuk with the objectives of (1) providing technical information on drinking water quality issues, and (2) training local personnel in pump station equipment, operation and maintenance.

Methodology

The methods used to meet both objectives of the training program included formal lectures, laboratory sessions, and field training in protocols of sampling and analysis, evaluating water quality data, and on-site maintenance of water pumping stations. Pertinent water resources issues were selected for discussion from the fields of water quality and water distribution systems. Lectures were augmented with detailed handouts, overheads, slide presentations and practical demonstrations. Emphasis was given to providing hands-on experience and training for both sessions of the training.

The instructional team of the Institute provided the water quality section of the training, and a consulting engineer provided the hands-on operation and maintenance section of the training. Twenty-five (25) students from Chuuk State Public Utility Corporation (CPUC) and Chuuk State Environmental Protection Agency (EPA) participated in this training.

Principal Findings and Significance

The significant accomplishments of this project were:

1. It provided technical understanding of water resources related issues such as water distribution systems, water quality sampling and analysis, and operation and maintenance of pumping stations to the participants who work at related water resources agencies in Chuuk State, FSM.

2. It facilitated the long-term development of a partnership between the Institute and water resources professionals in Chuuk State, FSM.

We consider that one of the critical water resources need for islands in the FSM is for practical hands-on education and field training on a number of water related issues. To date, WERI has made an impact in bringing improved technical self-sufficiency to the water resources professionals and water planners on Yap, Kosrae, Pohnpei, and now Chuuk. They are now more fully aware of the needs and practical application of stringent water quality sampling and water system operation and maintenance.

Regional Dissemination of a Locally-developed Integrated Island Ecology & Resource Management Textbook, Website, & Teachers Manual/Activity Guide

Basic Information

Title:	Regional Dissemination of a Locally-developed Integrated Island Ecology & Resource Management Textbook, Website, & Teachers Manual/Activity Guide
Project Number:	2002GU10B
Start Date:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	NA
Research Category:	Not Applicable
Focus Category:	Education, Ecology, Conservation
Descriptors:	Island, Ecology, Resource Management, Textbook, Website, Activities, Teachers Guide
Principal Investigators:	John Furey, Vince Riley, Craig Smith, Gerald Smith, Danny Wyatt

Publication

1. Furey, John F., 2002, Island Ecology & Resource Management: Commonwealth of the Northern Mariana Islands textbook project, in 2002 Pacific Education Conference Proceedings at American Samoa, Pacific Regional Education Laboratory, Honolulu, HI
2. Furey, John F. 2003,Website, http://www.crees.org/ecology/default.htm, 800p.

Project Title

Regional Dissemination of a Locally-developed Integrated Island Ecology & Resource Management Textbook, Website, & Teacher's Manual/Activity Guide

Problem and Research Objectives

Throughout the Pacific island region, human populations suffer from the combination of distressed social and financial economies, growing populations, and limited and fragile island resources. A locally-applicable program of integrated environmental education is critical to address these issues and the need has been widely expressed throughout the region in recent years. This project directly addressed this need.

"Experts" in the fields of environmental science and education are often recruited from non-island areas and lack needed foundational information of island ecology and island resource management regimes to adequately address local needs.

Regionally-applied two year professional contract programs--originally meant to automatically lapse and therefore provide professional opportunities to islanders who complete their collegiate studies and professional training--effectively cause an exporting of expertise, leaving little environmental and educational knowledge behind. Oftentimes, any reports that are left behind are written in such scientific "ese" as to be uninterpretable by many local program directors.

The Northern Mariana Islands made a concerted effort to address this problem since 1996 and developed a highly readable, regionally-appropriate, 800 page *Island Ecology & Resource Management: Commonwealth of the Northern Mariana Islands* textbook. The book was designed to be applicable throughout the region and permission to "cut & paste" from it is part of the book's purposes.

This project sought to, in part, address the above-identified problems through a concerted effort to regionally disseminate this comprehensive island ecology/resource management textbook/curriculum throughout the Western Pacific to encourage fellow island education and resource management entities to model it to address their own needs and to save years of start up and drafting and editing time.

Methodology

1. The Activity Guide/Teachers Manual for the *Island Ecology & Resource Management: Commonwealth of the Northern Mariana Islands* textbook is being revised and printed.

2. A website was established.

3. Travel to several Pacific Islands was undertaken by the PI to share the work and encourage regional adoption, revision, and transformation of the information into language and frameworks applicable to each island's needs.

Principal Findings and Significance

During the Pacific Education Conference held in 2002 at American Samoa, participants in the presentation made by the PI expressed their enthusiastic acceptance of the textbook CD's and the project in general. This was done in surveys conducted by the Pacific Regional Education Laboratory in Honolulu, HI. Similar positive responses were made following presentations conducted by the PI in Honolulu, HI, at Kosrae Island, at Ponape Island, at Chuuk Island and at Guam. The change of islands from Belau and Yap to instead Oahu and American Samoa was done to facilitate the presentation in American Samoa and take advantage of the opportunity to reach the large group of island education specialists gathered at this important annual conference. Through this conference venue and at the individual island visits, Compact Discs of the ecology textbook project were disseminated throughout the Pacific Region.

Although still in the "Under Construction" stage, the Website component of this project is developing well. A contract has been awarded and draft chapters are currently posted on the College Research Education and Extension Services' website at *http://www.crees.org/ecology/default.htm*. An updated, more complete, and more interactive site is currently being developed by NMC science and NMC Information Services staff and this project's contract firm of InfoSystems of Saipan.

The project procured key equipment, including two ruggedized notebook computers and a high quality multimedia projector, which provided critical assistance to the PI during the island visits and presentations and continue to be employed for college instruction at NMC. The computers are also being used to upgrade and finalize the project's activity guide and are used to "burn" the project's Compact Discs.

The significance of this environmental education regional dissemination project cannot be over-emphasized. Capacity building in both island resource management agencies and island educational departments is the most important task that water and environment institutions can undertake. This project reached audiences of more than 500 gathered education professionals at the 2002 Pacific Education Conference, key resource managers in Honolulu, and over 15 combined resource managers and educators each at meetings conducted on Kosrae, Ponape, and Chuuk. A recent meeting on Guam conducted by the UOG Marine Laboratory as part of the Western Pacific Regional Sea Grant Consortium effort also occurred and provided the opportunity to share the project and CD's with these gathered Marshallese, Ponapean, Belau, American Samoan, and Guam resource managers.

Information Management

Basic Information

Title:	Information Management
Project Number:	2002GU12B
Start Date:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	NA
Research Category:	Not Applicable
Focus Category:	Climatological Processes, Hydrology, Management and Planning
Descriptors:	Water Resources Mangement, Climatic Data, Rainfall Data
Principal Investigators:	Leroy F. Heitz

Publication

INFORMATION MANAGEMENT

WERI's mission involves maintaining and providing water resources related data to researchers, water resources managers, educators and the general population of the islands of the Western Pacific. This project was used to provide funding to maintain subscriptions to a wide variety of data sources dealing with meteorology, climatology and hydrologic data. These resources are maintained at WERI and made available to researchers, water managers, educators and the general public throughout the region. Communication and information exchange between experts in the area of water resources is vital to the improvements in the wise use of this resource.

Information Transfer

Basic Information

Title:	Information Transfer
Project Number:	2002GU13B
Start Date:	3/1/2002
End Date:	2/28/2003
Funding Source:	104B
Congressional District:	NA
Research Category:	Not Applicable
Focus Category:	Education, Water Supply, Water Use
Descriptors:	WAter Reources, Education, Information Transfer
Principal Investigators:	Leroy F. Heitz

Publication

WERI's mission involves a large information transfer-dissemination component. Key elements include written forms such brochures and pamphlets, a web site, technical reports, journal articles, newspaper columns, and book chapters. The audience for the results of USGS sponsored research is widely varied geographically and by education level. It is important that WERI make this information available in a very widely distributed form.

This project funded the design, layout and printing of three technical completion reports resulting from USGS funded research projects. One hundred (100) hard copies of each report were printed and the reports were prepared for publication on WERI's Web page.

WERI's Web page, shown below, is located at http://weriguam.org/home/index.htm, and is the Institute's focus for Information Transfer/ Dissemination.

WERI Web Page

It is very important that WERI's Web page be updated and optimized on a regular basis. To provide this a professional web maintenance firm was contracted to provide maintenance to the WERI Web page on a regular basis. This year the firm also worked on finishing up digitizing all old WERI technical completion report and is presently finalizing a database search engine for accessing the technical completion reports on line.

Because of Guam's remote location it is difficult and quite costly for researchers to present their findings at technical conferences and symposiums. This project funded a portion of off-Island travel expenses for PI's and graduate students presenting refereed professional papers summarizing all or a portion of current or past 104-B research projects.

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 RCGP Award**	**NIWR-USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	3	0	0	0	3
Masters	4	0	1	0	5
Ph.D.	0	0	0	0	0
Post-Doc.	0	0	0	0	0
Total	7	0	1	0	8

Notable Awards and Achievements

Publications from Prior Projects

1. 2000GU10B ("Erosion and Sedimentation Processes in Southern Guam") - Water Resources Research Institute Reports - Scheman, N.D., S. Khosrowpanah, M. Gollabi, and L. Heitz 2002, Identification of Erosion Process and Sources of Exposed patches in the Lasa Fua Watershed of Southern Guam: A Pilot Project, Report No. 99, Water and Environmental Research Institute (WERI), University of Guam,70pp.
2. 2001GU1342B ("Development of Monthly and Seasonal Rainfall Climatologies and Distribution Maps for Guam") - Water Resources Research Institute Reports - Lander, M.A., and C.P. Guard, 2003 Creation of a 50-Year Rainfall Database, Annual Rainfall Climatology, and Annual Rainfall Distribution Map for Guam. Water and Environmental Research Institute (WERI), University of Guam, Report No. 102, 75pp.
3. 2001GU1321B ("Investigation of the Use of Locally Available Materials for Slow Sand Filtration In Kosrae State, Federated States of Micronesia") - Water Resources Research Institute Reports - Khosrowpanah, Shahram, and Leroy Heitz, 2003, Slow Sand Filter Conceptual Design for the Federated States of Micronesia, FSM, Water and Environmental Research Institute (WERI), University of Guam, Report No. 101, 60pp.
4. 2000GU7B ("Determination of Rainfall Erosivity Factors for Selected Islands in the Federated States of Micronesia Accounting for Climate Variability") - Conference Proceedings - Sh. Khosrowpanah, & L. Heitz, 2002, Rainfall Erosivity Factors for Selected Islands in the Federated States of Micronesia, in Proceedings of the American Water Resources Association 2002 Spring Specialty Conference on Coastal Water Resources, New Orleans, Louisiana.
5. 2001GU1342B ("Development of Monthly and Seasonal Rainfall Climatologies and Distribution Maps for Guam") - Conference Proceedings - Sh. Khosrowpanah, & L. Heitz, 2002, The Application of Slow Sand Filtration Technology for Community Water Systems in Micronesia, in proceedings of 21st Annual Pacific Islands Environmental Conference, Koror, Republic of Palau.