



INTRODUCTION TO PROGRAMS AND RESEARCH ACTIVITIES

By

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WERI

**WATER AND ENVIRONMENTAL RESEARCH INSTITUTE
OF THE WESTERN PACIFIC
UNIVERSITY OF GUAM**

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WERI

Water & Environmental Research Institute of the Western Pacific at the University of Guam



The Water & Environmental Research Institute of the Western Pacific, or WERI, is one of 55 similar water research institutes established by U.S. Congressional legislation at each Land Grant University in the United States and in several territories. The institute is now in its 30th year of operation.

WERI's 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 various regional island nations. WERI also runs a state of the technology water analytical laboratory and geographic 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) funds under Section 104-B of the National Institute of Water Research (NIWR) 104-B Program. WERI has responsibility for 104-B monies on Guam, in the Commonwealth of the Northern Mariana Islands (CNMI), and in the Federated States of Micronesia (FSM).

In FY-2005 WERI faculty were involved as Principal Investigators on fourteen research and training projects with a combined budget of about \$1,317,000: \$278,000 from seven 104-B projects, \$81,000 from three other federal agencies, \$125,000 from Federal sources awarded through local agencies, and \$833,000 from local grants and direct funding from the Guam legislature.

Currently WERI has a fulltime director who is also a UOG faculty member, five regular research faculty, two adjunct research faculty, a water analysis laboratory manager and technician, two office staff, as well as five graduate research students who are completing their MS degree in the Environmental Sciences program. During the year 2005, WERI faculty and staff taught seven graduate courses and three 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 14 refereed journal articles or conference proceedings, and 4 water institute technical reports. Currently WERI faculty members serve as committee members on, or chairs of 6 MS research theses in the Environmental Sciences and Biology graduate programs.

See us on the web at:

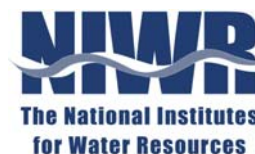
www.uog.edu/weri



ACTIVE PROJECTS

Water & Environmental Research Institute of the Western Pacific at the University of Guam

US GEOLOGICAL SURVEY WATER INSTITUTE PROGRAM



GUAM:

**Response of Well Heads of the Northern
Guam Lens Aquifer to Rainfall and Sea
Level Fluctuations at Daily Resolution**

**Watershed Land Cover Change Detection
in Guam**

FSM:

**Hydrological modeling of atoll islands
in the Federated States of Micronesia**

**Management of the Nanpil River
Watershed, Pohnpei Island,
The Federated States of Micronesia**

**Integrating Environmental Education
into Pohnpei's Primary School Curriculum**

CNMI:

**Polychlorinated Biphenyls (PCBs)
and Organochlorine Insecticides
in Biotic Components
of Tanapag Lagoon, Saipan**

**Development of Optimum Operational
Management Strategies for the Saipan
Water Distribution System**

OTHER FUNDED PROJECTS

NATIONAL WEATHER SERVICE

Pacific ENSO Applications Center

NATIONAL SCIENCE FOUNDATION

**Modeling of Fine-Grained Till Deposits by
the Laurentide Ice Sheet**

GUAM BUREAU OF PLANNING

**Development of a Geographic Information
System (GIS) Based Erosion Potential
Model for Southern Guam**

GUAM DEPARTMENT OF AGRICULTURE

**Heavy Metals and Abiotic Components of a
Guam Reef Flat Impacted by Leachate
from a Municipal Dump**

DIRECT LOCAL FUNDING

Guam Hydrologic Survey

Water Resources Monitoring Program



Response of Well Heads of the Northern Guam Lens Aquifer to Rainfall and Sea Level Fluctuations at Daily Resolution



Funded by:
US Geological Survey, Water Institute Program
P.I.
Mark Lander

Funding: \$19,958

This project will make an in-depth study of the response of the wellheads of the Northern Guam Lens Aquifer (NGLA) to rainfall and sea-level fluctuations at daily resolution. A characterization of the observed responses has immediate applicability to ongoing modeling efforts of WERI and USGS researchers of NGLA wellheads with SUTRA. One of the weaknesses of the SUTRA simulations is computation of water movement through an unsaturated zone more than 100 m thick. It is hoped that the analysis of the observed response of the wellheads to short-term variations of rainfall and sea level will help to calibrate the model, and determine the rate and time-lags at which the rainfall moves through the thick unsaturated zone of the NGLA. A goal of both the observational studies and the modeling studies is to elucidate the geological and hydraulic properties of the NGLA to better manage the resource.

The project includes an intensive study of newly acquired daily values of wellhead, rainfall, and sea level. Data has been obtained for other wells that were not available in previous research efforts. Recent acquisition of rainfall, sea level, and wellhead data at daily resolution -- plus the acquisition of data for several more wells than were used in previous studies -- will allow a more in-depth analysis of the well hydrograph responses to variations in the rainfall and sea level. A major effort will be required to properly inspect and organize all data for ready analysis and inter-comparison. The known timing of extreme short-term variations of rainfall and sea level will help to validate each time series.

The immediate objective of the project is a set of statistical model predictions of the daily value of the head at each selected well using the values of the daily rainfall and daily sea level. The parameters of the statistical model that optimize these predictions will give insight into the

hydraulic and geological properties of the NGLA.

Of particular interest will be to document the well responses to pulses of heavy rainfall, and the nearly step-function drops of sea level that occur after the close passage of typhoons. There are several historical pulse occurrences of substantial rainfall and several rapid changes of sea level in response to typhoons and also to El Niño. The response of the wells to these extreme events will be benchmark tests of any numerical model simulation of the NGLA. The ultimate objective is to use the information gained from the statistical models to enable researchers to develop appropriate boundary conditions for the numerical simulations of the aquifer, and to calibrate the model to reproduce the observed behavior. This study will provide baseline information for identifying the physical properties of the aquifer, and their implications for numerical simulation of the NGLA and for Guam's water management plan. The project thus directly supports four of the Guam Advisory Council's stated needs in Water Quality and Water Quantity:

- Develop water budgets for Guam's surface and groundwater watersheds.
- Develop a three dimensional groundwater flow model for the Yigo-Tumon trough aquifer for use in water quantity studies
- Continue studies to determine the response of the Northern Guam Lens to various rainfall events
- Re-evaluation of the North Guam Aquifer sustainable development estimates will also be evaluated.



Watershed Land Cover Change Detection in Guam



**Funded by:
US Geological Survey, Water Institute Program**

**P.I.s
Yuming Wen
Shahram Khosrowpanah
Leroy Heitz**

Funding: \$35,822

Land cover change (LCC) has been a subject of concern for the past century, particularly the past few decades around the world. Although many of the changes have been recorded qualitatively through the use of comparative photography and historical reports, little quantitative information has been available at watershed scale. It is currently possible to detect land cover change and determine trends in ecological and hydrological condition at watershed scale using advanced geo-spatial technologies. Satellite remote sensing, spatial statistics, geographic information systems (GIS), and global positioning system (GPS) can be used to identify LCC of watersheds. These technologies provide the basis for developing landscape composition and pattern indicators as sensitive measures of environmental change and thus, may provide an effective and economical method for evaluating watershed condition related to disturbance from human and natural stresses.

Landsat observations have evolved from an experimental system in the 1970s to a feasible system to ensure our ability to explore, characterize, monitor, manage, and understand changes in the Earth's surface. Land cover has been derived from a multi-date satellite imagery database which incorporates Landsat Multi-Spectral Scanner (MSS) imagery from the early 1970s to early 1990s, Landsat Thematic Mapper (TM) imagery from early 1980s to current, Landsat Enhanced Thematic Mapper Plus (ETM+) from early 1999 to current at local and/or regional scale. Recent surveys indicate that land cover/use changes have a direct and enormous effect on water quality and environmental change. Watershed water quality and ecosystem are threatened constantly by both human impacts like forest fires and development

and also natural phenomena like storms and droughts. In addition, the combined uses of GIS, remote sensing and GPS tools have been highlighted with respect to their advantages in watershed applications.

Spatial and temporal modeling of changes in wetlands and badlands in Southern Guam watersheds was identified as one of the highest priority research needs for Guam on the Guam Advisory Council meetings of November 15, 2004 and October 4, 2005. Four (4) temporal Landsat images from 1970s, 1980s, 1990s and 2005 (with about ten years interval) will be obtained to measure changes of watershed land cover for over three decades in Guam. Topographic map of 1978 for Guam and recent IKONOS imagery will be used as auxiliary information to improve land cover classification accuracy. Ten (10) meter digital elevation model (DEM) data has been used to delineate the watersheds in Guam. There are 14 watersheds in Southern Guam. The study area will focus on these watersheds in Southern Guam. The main objectives of this project are listed as follows.

- Search and obtain Landsat imagery for different dates;
- Preprocess the images such as georeference, projection and georectification;
- Conduct classification to extract land cover information from the satellite images;
- Compare the spatial and temporal land cover information to detect changes;
- Provide change detection maps.



Hydrological modeling of atoll islands in the Federated States of Micronesia



Funded by:
US Geological Survey, Water Institute Program

P.I.'s

John W. Jenson
Yuming Wen
Don Rubenstein
Funding: \$42,873

This project is a direct response to the need for “research directed toward the development of an accurate and practical groundwater evaluation model for the low islands” identified at the WERI Advisory Council Meeting in Pohnpei on October 11, 2005. Water shortages pose a grave concern to the inhabitants of atoll islands. The small size, unique geology, and high solar isolation on atoll islands combine to subject entire populations to the stresses of drought, and difficult, expensive, and sometimes untimely aid operations. Under normal conditions, water demand is met by rooftop rain catchment. Prolonged droughts, such as those associated with El Niño, exhaust water storage tanks and reduce island water supply to extremely limited alternatives. Tropical storms or typhoons can also destroy or severely damage rain catchment facilities.

At such times groundwater is the only alternative to importation. On most islands, groundwater is not utilized or the use of it is not systematic, however. Atoll aquifers have thin freshwater lenses immediately underlain by saltwater. High permeability and near sea-level elevation make the aquifer susceptible to saltwater intrusion and even depletion of the freshwater lens during times of limited or no recharge. The unique characteristics of atoll island aquifers, such as disproportionately thick transition zones between freshwater and saltwater, render traditional coastal aquifer models inappropriate. Moreover, sophisticated numerical models, such as are built for research purposes, are expensive and impractical for public or private sector planners and resources managers. The development of simple and elegant models to support groundwater resource assessment and management is needed by FSM resource managers to aid them in establishing sustainable and prudent groundwater extraction, protection and land use practices. The goal of this project is

to produce a model consisting of two components. The first will be a steady-state GIS-based analytical model using hydrological and geological data assembled this past year during the first phase of this project. The second model will be a three-dimensional, dynamic computer model which will simulate freshwater lens response to changing levels of recharge, extraction, and tidal and sea-level fluctuations. The dynamic model will be used to calibrate the simpler analytical model, enhancing its accuracy. Based on the more sophisticated model, appropriate correction factors will be integrated into the analytical model to develop a user-friendly and reliable, Excel Spreadsheet-based tool for water resource managers. The model will also incorporate supply and demand related to the availability and production of rainwater catchment and agricultural water uses.

The model will not only be practical, but will also contribute to a greater understanding of the hydrogeology and water use on atoll islands. The project will engage a multi-disciplinary team composed of a hydrogeologist, anthropologist, GIS specialist, and a graduate student in environmental studies. Use of the models will require some basic but readily deliverable training, which meets the interest of FSM state officials to better understand the conditions and processes that control the capacities and demands on atoll aquifers.

The construction of the models will require additional data collection with an emphasis on field-testing model parameters and predictions. The protocol is intended to aid island leaders in developing practical and comprehensive water resources plans. Outside of the models, the report will review general water-use practices to ensure that the proposed management plans are culturally and economically feasible.



Management of the Nanpil River Watershed, Pohnpei Island, The Federated States of Micronesia



Funded by:
US Geological Survey, Water Institute Program
P.I.'s
Shahram Khosrowpanah
Mark Lander
Leroy F. Heitz
Funding: \$38,837

The Nanpil Watershed is situated in the Sokehs and Nett Municipalities on the Northern side of Pohnpei Island. It is unique in many aspects. This area of approximately 3 square miles provides inflow to the Nanpil River that is the main source of the island's water supply. In recent years large areas of native forests and ecologically sensitive areas have been cleared for housing and road development projects and unmanaged agricultural activities (e.g., sakau/kava plots). These new development activities are now negatively impacting the biodiversity of much of the area, the headwaters and freshwater resources as well as the mangrove forests and coral reefs of Pohnpei Island. To implement any watershed management/protection plan requires having a better understanding of the physical and environmental components of the watershed. This includes how much rain the watershed receives, how much flow runs through the streams, what is the sediment load in the streams during the year, and how all these dynamic components are related to man's activities within the watershed. The lack of baseline information about the components of watersheds is a critical issue throughout the Federated States of Micronesia. When the political status of the Federated States of Micronesia with the United States changed from Trusteeship into Free Association in 1986, all the stream flow gages that were built and monitored by the US Geological Survey were deactivated and have remained effectively abandoned. Since 1986 there has been no information on how much flow runs through the streams and how much sediment is being carried to the reefs.

The objectives of this project are to: 1) install stream flow, sediment, and rain gages for selected sites within the Nanpil Watershed; 2) monitor the gages and develop a rating curve for the selected site; 3) develop a correlation between stream flow, sediment load and rainfall; and 4) develop a database of flow and sediment data for future use. This project will generate baseline information and correlations among the dynamic components of the Nanpil watershed environment. The baseline information will be used for future comparison between Nanpil watershed and the ongoing study of the Enipein Watershed. The findings will reveal the impact of the various activities such as land clearing, land slide/slope failures, and population growth on the quality of the watershed. This information will help various parties such as the Conservation Society of Pohnpei (CSP), Land Management, the Pohnpei Environmental Protection Agency (EPA), and local mayors to implement plans for protecting the watersheds in Pohnpei. Pohnpei's Public Utilities Commission (PUC) will be able to operate the water treatment plant more efficiently by knowing the level of the stream's turbidity and the available water in the stream. Also the information obtained in this project may be used by Pohnpei's Weather Service to enable them to provide flash flood warnings for the Nanpil River.



Integrating Environmental Education



into Pohnpei's Primary School Curriculum

**Funded by:
US Geological Survey, Water Institute Program
P.I.'s**

**Carla Schuk, Ben Namakin
Leinson Neth, Nick Donre**

While environmental education has been designated as a component of Pohnpei's curriculum, it has never been made an instructional priority in the classroom. Because of this, Pohnpei's citizens have only minimal knowledge about their environment and the impacts of their actions on it. Pohnpei is faced with a number of environmental issues from the upland forest down to the coral reef. Deforestation and sedimentation's effects on Pohnpei's drinking water are significant. Coastal water pollution, dredging, and over-fishing are other problems that Pohnpei is currently facing. CSP sees the need to provide local teachers with tools that will integrate environmental education into the current curriculum in order to educate kids about the issues we have and possible solutions to help mitigate these issues. CSP is dedicated to filling that gap and providing a sustainable system of environmental education in Pohnpei's primary schools.

CSP has developed an Environmental Resource and Activity Book (ERAB) for grades 1 through 8. The ERAB contains a resource guide for teachers, as well as activities that integrate information about Pohnpei's environment into curriculum subject areas. ERAB activities incorporate language arts, math, reading comprehension, visual arts, and science to enable teachers to cover environmental subject matter without creating increased curriculum requirements. About 30 percent of the activities deal with water and waste management. Through discussions with teachers and the Department of Education, it has been deemed impractical to try to teach environmental education as a new subject area.

With this in mind, CSP designed the ERAB with environmental lessons and activities that will compliment various subject areas in the existing school curriculum. The objectives of the ERAB project are;

1. To provide resources to teachers that will complement their curricula with messages of environmental awareness without creating new burdens and work demands.
2. To develop in the youth an awareness and understanding of the environment and ecology of Pohnpei, fostering a sense of stewardship towards environmental protection.
3. To collect local teachers' input for the ERAB and to produce a final draft for printing.
4. To train teachers in the use of the ERAB within the classroom in order to integrate environmental education into their current curricula.

In the spring of 2006, CSP will form a task force of education professionals from the Department of Education and local teaching staff, to edit and produce a final draft of the ERAB. Participating teachers will pilot some of the activities within their classrooms to ensure that they have appropriate instructions and match the abilities of the students. This process will be followed by a series of teacher trainings in the summer of 2006 that will introduce the ERAB to teachers and provide them with an opportunity to practice using the activities. The teachers will participate in role-playing to practice using the activities and lessons, as well as having an opportunity to ask any questions they may have. The three training sessions will be divided by grade levels: (1) for teachers of grades 1-3; (2) for teachers of grades 4-6; and (3) for teachers of grades 7-8.

Polychlorinated Biphenyls (PCBs) and Organochlorine Insecticides in Biotic Components of Tanapag Lagoon, Saipan



Funded by:
US Geological Survey, Water Institute Program
P.I.'s
Gary R. Denton, Harold Wood
Michael Trianni
Funding: \$50,615

Tanapag Lagoon borders the western shore of central Saipan. It harbors a rich diversity of marine life and supports a variety of commercial and recreational activities. Over the last quarter century, Tanapag Lagoon has become heavily impacted by the activities of man. Primary sources of anthropogenic disturbance in these waters include a power station and commercial port, two small boat marinas, a sewer outfall, several garment factories, auto and boat repair shops, wood shops, government vehicle maintenance yards, a commercial laundry, and an acetylene gas producer. There are also a number of old military dumps and disposal sites in the area as well as a 50-year-old municipal dump that served as the island's only solid waste disposal site until its closure a little over two years ago. Several streams and storm drains discharge into the lagoon during the rainy season and provide a mode of transport into the ocean for any land-based contaminants from these and other facilities. Overflows from sewer lines are also commonplace at this time of the year and the whole area is inundated by storm water runoff during periods of prolonged wet weather.

Until recently, the availability of information concerning the distribution and abundance of major contaminant groups in this area was extremely limited. The turning point came in 1998 when WERI scientists conducted a detailed assessment of heavy metals, PCBs and PAHs in surface sediments from the southern half of the lagoon and identified areas of enrichment around the port, the small boat marinas, and the dump. Subsequently, dominant ecological representatives (algae, seagrass, seacucumbers, bivalve mollusks and fish) were collected for chemical analysis from strategic locations within the lagoon in order to determine the impact of these perturbations on resident biota. All samples have since been analyzed for heavy metals and archived specimens await analysis for other contaminant groups of concern. This

project will screen the archived collection for PCBs and organochlorine insecticides (e.g. DDT and related compounds). These ubiquitous contaminants are of interest because of their persistence, high bioaccumulation capacity and endocrine disruptive influence. Virtually nothing is known of their distribution and abundance in biota from Tanapag Lagoon despite PCB 'hotspots' being previously identified inland. The study will therefore add significantly to the existing contaminant database required for future trend monitoring purposes in the lagoon. Moreover, it will provide valuable information on levels of a potentially harmful group of organic chemicals in key indicator organisms and identify potential health risks (if any) associated with the unrestricted consumption of edible species. Overall, the program will provide the necessary foundations for the future assessment and regulation of pollution problems in the area. Such information is vital for the overall protection and sustainable development of aquatic resources in Saipan's coastal waters.

The analytical work will be carried out at the Water and Environmental Research Institute (WERI), Water Quality Laboratory, at the University of Guam, where adequate support facilities, infrastructure, essential chemicals and items of equipment (including GC-MS plus accelerated solvent extraction and solvent reduction systems) necessary for the study are present. All analyses will be conducted on freeze-dried samples to compensate for water losses incurred during storage of the achieved collection. Previously determined wet to dry weight ratios will be reported with the data along with extractible lipid weights (%).



Development of Optimum Operational Management Strategies for the Saipan Water Distribution System



Funded by:
US Geological Survey, Water Institute Program
P.I.'s
Shahram Khosrowpanah
Leroy F. Heitz
Mariano Iglecias
Funding: \$23,694

The Government of the Commonwealth Northern Marianas Islands (CNMI), has invested a large amount of funds to improve Saipan's water distribution system, but delivery problems still exists. A stated goal of the CNMI government is to provide 24-hour water to all residents served by the Commonwealth Utility Corporation (CUC) water system. This goal will be unattainable until the CUC has a complete knowledge of their water delivery capabilities and operation.

Over the years the CUC water distribution system has grown and new wells have been added to the system. This physical expansion has been well documented but improvements in the hydraulic characteristics and delivery capabilities of the entire system have never been fully examined.

The Saipan water distribution system has been divided into 12 sub-regions. Each region is expected to operate somewhat independently. However, due to inadequate inflow to the system, system leakage, and lack of knowledge of system behavior, the system is unable to provide 24-hour water services to all customers. WERI researchers have developed computerized models of each of the 12 sub-regions of the CUC water system using the Haestad WaterCad water system modeling program. They also, developed a Source, Transmission and Storage model of the Saipan Water System. This includes a Skeleton of the existing 12-region water system models that are joined together at the boundary points. The next step needed is to examine various system operational schemes in order to find an optimum way to transfer water from sources to the customers.

The benefits expected from the project include a better understanding of the adequacy of the

existing pumps and well systems, the adequacy of existing storage facilities to provide for daily fluctuating demands, the ability of the well and storage system to provide sufficient flows, and a more in depth understanding of the most efficient means to move water from water supply rich regions to those that have supply shortages in order to maintain delivery of 24 hour water to all areas in the system.

The project will be split into two phases. The first phase will be to finalize the skeleton of each Saipan's sub-water system. We will work closely with CUC Engineering staff to be sure all included components such as pipes, tanks, wells, and reservoirs are correctly modeled and match field data. The second phase will determine the optimum system operation. This phase will be accomplished in close consultation with CUC staff engineers. First the model will be operated in steady state mode and the response of the system during critical times will be examined to determine if the system can meet the required demands and if not what changes in either operation or physical make up of the system would be required to solve the problems. Next the model would be operated in extended time simulation mode to examine storage tank operations. The response of the storage tanks during critical times will be examined to determine if all of the tanks are operating in an optimal manner and if not what changes in either operation or physical make up of the system would be required to improve tank operations.



PROJECTS COMPLETED MARCH 2006



**Water & Environmental Research Institute
of the Western Pacific at the University of Guam**

US GEOLOGICAL SURVEY WATER INSTITUTE PROGRAM



GUAM:

**Heavy Metals in Biotic and Abiotic
Components of a Guam Reef Flat Impacted
by Leachate from a Municipal Dump**

**Anthropogenic Impact On Nitrogen Cycle
In Tumon Bay Using 15N, And 14 N
Isotopic Ratio Methods**

**Development of A Digital Watershed Atlas
for Guam**

FSM:

**Watershed Management for Enipein
Watershed, Pohnpei Island, the Federated
States of Micronesia**

**Geologic Study, Map Development, and
Water Resources Analysis of Fais Island,
Yap State, FSM**

**FSM atoll groundwater resource
inventory**

CNMI:

**Development of a Source, Transmission and
Storage model of the Saipan Water System**



Heavy Metals in Biotic and Abiotic Components of a Guam Reef Flat Impacted by Leachate from a Municipal Dump



**Funded by:
US Geological Survey, Water Institute Program
P.I.**

**Gary R.W. Denton
Harold R. Wood
Funding: \$31,627**

Pago Bay is a fringing reef flat on the eastern shore of central Guam. It harbors a rich diversity of marine life and supports a variety of scientific, commercial and recreational activities. For the past 50 years, leachate streams emanating from Guam's only municipal dump have been making their way down the Lonfit River and out into Pago Bay. Chemical characterization of the leachate streams has identified heavy metals as the contaminants of primary concern both from an ecological and human health perspective. Specific elements flagged as exceeding toxicity thresholds include arsenic, chromium, copper, iron, lead, manganese, mercury, nickel, silver and zinc. Currently, nothing is known about the movement of these potentially toxic elements into the biotic components of Pago Bay. In view of the commercial, recreational and scientific importance of this area, such a study is long overdue. This study established baseline levels of the aforementioned metals in biotic and abiotic components of the bay with emphasis on sediments, bioindicator species and dominant fisheries resources traditionally harvested for food.

Surface sediment samples were collected at ~100-m intervals along the entire length of the bay and at ~100-m to 200-m intervals along five, approximately equally spaced transect lines running perpendicular to the coast. Biota sampling focused on dominant groups with high bioindicator potential that are either sessile

or are restricted in their movement. Potential candidates include algae, seagrasses, seacucumbers, bivalves and gastropod mollusks. These organisms generally have little or no regulatory capacity for some or all of the contaminants in question and hence their tissue levels mirror biologically available amounts derived from their immediate surroundings. They were collected largely on an opportunistic basis from within the six regions delineated by the sediment transects.

The analytical work was carried out at the Water and Environmental Research Institute (WERI), Water Quality Laboratory, at the University of Guam, where adequate support facilities, infrastructure, essential chemicals and items of equipment necessary for the study were present. The analytical procedures followed established methods developed by USEPA and NOAA. Quality control and quality assurance procedures were rigidly adhered to.

Overall, the study established a reliable database with which future findings may be compared and evaluated; delineated areas of contaminant enrichment within the study area, and identified potential hot spots. Further, it assessed the degree of contamination in Pago Bay by reference to levels reported for clean and polluted environments elsewhere in the world. Potential health risks (if any) associated with the long-term consumption of edible resources surveyed were also evaluated.



Anthropogenic Impact On Nitrogen Cycle In Tumon Bay Using ^{15}N , And ^{14}N Isotopic Ratio Methods



Funded by:
US Geological Survey, Water Institute Program
P.I.
Dr. Maika Vuki

Funding: \$35,264

Algal blooms along Tumon Bay in Guam are a major concern. Tumon Bay is the tourist hub for the island of Guam and the increasing pollution due to nutrient enrichment and subsequent algal bloom is an eyesore and could potentially have negative impact on the tourism industry on the island.

Early studies have clearly shown the excessive growth of green alga *Enteromorpha clathrata*. One of the possible nutrient sources for this algae comes from freshwater springs that discharges in the form of springs and seeps along the entire bay area. These spring waters flow from aquifers of the northern lens of the island. The levels of nitrates are significantly high enough in these springs to sustain algal population along the estuary. However, the increasing stands of algal bloom may be due to the rapid industrialization along the bay area.

The critical question is what are the major sources of enrichment along the estuary. Clearly the input from the catchment that discharges to the entire bay will need to be considered. Previous studies have focused on determining the levels of nitrogen containing nutrients and phosphate in the receiving waters and the intertidal water zone along the bay. While these data have been useful in confirming the enrichment status, they lack clarity as to the origin of the pollutants. Human impact through fertilizer applications, construction work, commercial operation such as restaurants, shopping malls, certainly have an impact but there is limited data on the extent and its role in the increase of algal growth.

The results of this study are:

- Determination of the different forms of nitrogen compounds in the ground water system discharging into Tumon Bay. This involved determining the levels of nitrates, nitrites and ammonia in all the possible inputs including those that have been studied previously.
- Determination of the isotopic ratio of stable nitrogen isotopes, ^{15}N and ^{14}N at the different components of the nitrogen cycle (water, plants, fish, invertebrates) in order to discriminate the contribution of human or animal waste nitrogen from fertilizer and industrial nitrogen.
- Determination of the mechanism of nitrogen uptake through the different levels of the nitrogen cycle based on the data collected.
- Comparisons of the findings with previous data on the levels of nitrogen containing nutrients.

The results from this study will help to pinpoint the sources of nitrogen enrichment along the bay and assist the management in designing suitable measures for minimizing pollution. This study has also trained students at the University of Guam to conduct environmental analysis and deepen their appreciation for chemical processes pertaining to pollutants in the environment. It has also enhanced the institute and the chemistry department in training on new techniques of isotopic methods, that were used in this study.



Development of A Digital Watershed Atlas for Guam



Funded by:
US Geological Survey, Water Institute Program

P.I.'s

Shahram Khosrowpanah
Yuming Wen
Funding: \$35,052

Effective management of island water resources requires accurate information on the physical and environmental components of all the watersheds. There are sixteen (16) watersheds in southern Guam that contribute runoff to the streams and coastal areas. Protecting these watersheds from point and non-point sources of pollution requires a better understanding of the watershed topography, vegetation, soil properties, roads, land use and land cover information, badland and many other features. The watershed's features should be stored and formatted in such a way that it can easily be made available for any water resources study such as; watershed planning and management, estimating upland erosion, and evaluating the impacts of mans activities on the quality and quantity of the streams. In addition, the information should be stored in such a way that it can be easily updated and made available to all interested agencies and researchers.

During the 1990s, geographical information systems (GIS), with their ability to gather spatial data from different sources into an integrated environment, emerged as a significant tool for hydrologic modeling. Particularly, GIS provided a consistent method for watershed delineation using digital elevation models (DEMs). In this project, GIS and related technologies such as remote sensing and global positioning systems (GPS) will be used to collect, digitize, organize, model and analyze data on watershed characteristics. A geo-database was established to incorporate physical, environmental and socio-economic information on the watersheds. Remote sensing was used for data updates for the digital watershed atlas. GPS provided data updating for the GIS database, and was used for some data ground-truthing.

The overall objective of this project was to create an atlas of Southern Guam's watersheds that includes the watershed boundary with its physical and environmental components.

The specific goals of the project were to:

- 1) Form a core user group for atlas development. At the startup of the project, the researchers organized a committee with representatives from the Government of Guam and other related agencies. The role of this committee was to identify the digital elevation model (DEM) that should be used and what other information should be included in the atlas.
- 2) Development of the watershed layers. During this phase the layers that describe the physical characteristics of the southern Guam watersheds were assembled. This included
 - a) Acquisition of a standard Digital Elevation Model (DEM) set for the island,
 - b) Development of watershed boundaries for all major basins in South Guam;
 - c) Development of sub-watershed boundaries according to the consensus of the core group,
 - d) Development of stream maps for all the major streams,
 - e) Development of layers showing river mile locations for all major streams,
 - f) Development of stream profiles (graphs of elevation vs. river mile) for all major rivers, and
 - g) Development of slope and slope aspect maps for all of South Guam.
- 3) Development and acquisition of existing layers identified as being important by the consensus of the core group. All layers were projected into one common projection system.



Watershed Management for Enipein Watershed, Pohnpei Island, the Federated States of Micronesia



Funded by:
US Geological Survey, Water Institute Program
P.I.'s
Shahram Khosrowpanah
Mark Lander
Funding: \$39,067

The Enipein Watershed which is situated in the Kitti Municipality in the South of Pohnpei Island is unique in many aspects. This area of approximately 10 square miles is home to unique native forests; a spectacular web of rivers, streams and fresh water swamps; and extensive mangrove forests, sea grass beds and coral reefs. According to the Conservation Society of Pohnpei (CSP) many of Pohnpei's 110 endemic plants and 13 endemic bird species along with thousands of other terrestrial and marine creatures are found in this area. One of its most astounding features is the unique occurrence of Pohnpei's only stand of the endemic plant, Pwuh (Ragraea berteriana), mainly used to make mwaramwars (leis). The Enipein Watershed Basin is also unique because it encompasses part of the Pohnpei Watershed Forest Reserve, the whole of the Enipein Mangrove and Marine Sanctuary/Park, and the Nahtik Marine Protected Area. However, with a growing population and need for cash, the Enipein watershed's fragile habitats and invaluable resources are becoming highly threatened.

In recent years large areas of native forests and ecologically sensitive areas have been cleared for housing and road development projects and unmanaged agricultural activities (e.g., sakau/kava plantations). These new development activities are now negatively impacting the biodiversity health of the area, the headwaters and freshwater resources as well as the mangrove forests and coral reefs. To implement any watershed management/protection plan requires having a better understanding of the physical and environmental components of the watershed. This includes how much rain the watershed receives, how much flow runs through the streams, what is the sediment load in the streams during the year, and how all these dynamic components are related to man's activities within the watershed. The lack of baseline information

about the components of watersheds is a critical issue throughout the Federated States of Micronesia.

When the political status of the Federated States of Micronesia with the United States changed from Trusteeship to Free Association in 1986, all the stream flow gages that were built and monitored by the US Geological Survey were halted and have remained effectively abandoned. Since 1986 there has been no information on stream flow and how much sediment is being carried to the reefs.

The objectives of this project were to: 1) install stream flow, sediment, and raingages for selected sites within the Enipein Watershed; 2) monitor the gages and develop stage discharge rating curves for selected sites; 3) develop a correlation between stream flow, sediment load and rainfall; and 4) develop a database for future use. The results of this project include development of baseline information and correlations among the dynamic components of the Enipein watershed environment. The baseline information will be used for future comparison between Enipein watershed and other watersheds that have less human activity such as those in Madolenihmw municipality. The results have revealed the impact of the various activities such as land clearing, land slides/slope failures, and population growth on the quality of the watershed. This information will help various parties such as the Conservation Society of Pohnpei (CSP), Land Management, the Pohnpei EPA, and local mayors to implement plans for protecting the watersheds in Pohnpei.



Geologic Study, Map Development, and Water Resources Analysis of Fais Island, Yap State, FSM



**Funded by:
US Geological Survey, Water Institute Program**

P.I.'s

John W. Jenson

Donald H. Rubinstein

Funding: \$39,838

This project assessed the physical resources and sociocultural factors that must be considered in order to develop a reliable source of potable water to meet the needs of the residents of the small (2.6 km²), remote island of Fais, Yap State, Federated States of Micronesia. Fais's resident population of about 320 people currently relies almost exclusively on rainwater catchments to meet its potable water needs. However, on average once a decade a major storm destroys or damages existing catchments, most recently in November 2003. Groundwater development is limited to one functional well that has demonstrated its potential to provide fresh water and the existence of a natural feature that has been used in past droughts to draw fresh water from the aquifer. Although these resources along with the potential for further groundwater development may establish an excellent emergency supply, the existing rainwater catchment system is operating at less than 25% of its potential. Bringing the catchment system up to its full potential and providing the means to maintain it may produce enough potable water to meet the needs of the people in all but the worst of droughts or storm events.

The socio-cultural portion of the project included an inventory of all catchment areas and storage volumes both in-use and potentially available. Along with a survey of water usage patterns and other demographics these data provided a basis for evaluating the effectiveness of the existing system, the potential of the system, and an estimate of future demand. Continued development of the groundwater on Fais for

dealing with emergencies was also explored. The small size and subsistence economy of Fais along with the prevailing traditional social organization and land tenure was considered in the technical recommendations for development and protection of groundwater. These recommendations were designed to be compatible with the island's social traditions, cultural values, and indigenous authority.

The size of the island and the physical constraints on the size and shape of the freshwater lens is also vital to the development projects that were proposed. Most existing wells provide saline water demonstrating that the prior estimations of the lens' properties and location are inaccurate. The refinement and completion of our map of the key karst features that constrain the drainage, storage and discharge of groundwater were key to understanding of future development of this resource. The study employed the classical methods of geological and anthropological fieldwork. The results included recommendations for appropriate development and management approaches that will ensure that water from the developed sources will be available when needed.

The project supported the second year of a graduate thesis project in Environmental Science at the University of Guam for a graduate research assistant was trained on a broad range of graduate academic topics, including hydrology, hydrogeology, cultural anthropology, environmental economics and management, and the use of databases and GIS.



FSM atoll groundwater resource inventory



Funded by:
US Geological Survey, Water Institute Program
P.I.'s
John Jenson
Yuming Wen
Funding: \$21,199

Atoll islands are uniquely vulnerable to drought. During the most severe droughts production from rooftop rain catchments ceases completely, and groundwater can become too saline for human consumption, or even disappear entirely as the shallow, thin groundwater lenses of the atoll islands become depleted. State officials and island leaders in the Federated States of Micronesia need reliable estimates of the amount and rates at which water can be extracted under drought conditions, and the rate at which the freshwater lens can be expected to recover as precipitation returns to normal. Such knowledge will enable more effective management of emergency water supplies during droughts and provide a basis for sustainable management.

The research team conducted a comprehensive literature and database search on the geology and hydrology of Pacific atoll islands, from which information was extracted and compiled into a GIS database. Using the geological and hydrological data they incorporated static (steady-state) analytical equations into a GIS model to calculate groundwater reserve and sustainability estimates for each atoll island in the database. During the summer field season the team visited Yap State, FSM, to substantiate the applicability of the GIS model by field checking the underlying assumptions and methodology against actual conditions on a representative atoll island. They interviewed residents to learn about their water use practices and needs.

Specific objectives of the literature/database search included collecting the following information for each of the atoll islands in the FSM:-

- Island locations, geographical dimensions, and hydrogeological data (e.g., hydraulic conductivity, water table response to tides) gleaned from previous studies by others.
- Land use information on each island, to include the proportion of each island covered by various types of vegetation, both natural and agricultural, and the evapotranspiration characteristics of the vegetation.
- Meteorological information for each island, to include historical rainfall records and regional estimates, where data on individual atolls are unavailable.
- Demographic information related to water use, such as population and daily water consumption, types of use, usage patterns, and responses to previous droughts.

Specific objectives for the GIS database and hydrologic model to be constructed for the project include the following:-

- Estimates of the steady-state groundwater reserve associated with rainfall over the range of interest—i.e., historically normal to historically low rainfall amounts.
- Estimates of the rate and amount of water that could be extracted from each island aquifer under drought conditions.
- Estimates of the rate at which island groundwater reserves can be expected to recover as rainfall returns to normal.



Development of a Source, Transmission and Storage model of the Saipan Water System



Funded by:
US Geological Survey, Water Institute Program
P.I.'s
Shahram Khosrowpanah
Leroy F. Heitz
Ernesto L. Villarin
Funding: \$21,745

Water hours and low delivery pressure have long been a part of the daily lives of the people in the islands of the Western Pacific. In Saipan, Commonwealth Northern Marianas Islands (CNMI), large investments have been made in system improvements, but delivery problems still exist. A stated goal of the CNMI government is to provide 24-hour water to all residents served by the Commonwealth Utility Corporation (CUC) water system. This goal will be unattainable until the CUC has a complete knowledge of their water delivery capabilities and operation. Over the years the CUC water distribution system has grown and new wells have been added to the system. This physical expansion has been well documented but improvements in the hydraulic characteristics and delivery capabilities of the entire system have never been fully examined.

The Saipan water distribution system has been divided into 12 sub-regions. Each region is expected to operate somewhat independently. However, due to inadequate inflow to the system, system leakage, and lack of knowledge of the system behavior, the system is unable to provide 24-hour water services.

In the past WERI researchers developed computerized models of each of the ten sub-regions of the CUC water system using the Haestad WaterCad water system modeling program. This model includes a physical system description, details of water usage, and parameters describing system operation.

This model provided the next step needed which is to examine the entire system behavior when the main distribution lines for each of the sub-systems are connected.

The benefits from the project included a better understanding of the adequacy of the existing pumps and well systems, the adequacy of the existing storage facilities to provide for daily fluctuating demands, the ability of the well and storage system to provide sufficient flows, and a more in depth understanding of the most efficient means to move water from water supply rich regions to those that have supply shortages in order to maintain delivery of 24 hour water to all areas in the system.

The project was split into two phases. The first phase started from the 12-system water models previously developed of the Saipan Water System. These models were skeletonized to remove all but the major water sources, tanks and transmission components and joined together at the boundary points. Researchers worked closely with CUC Engineering staff to be sure all included components were correctly modeled.



Environmental Science Graduate Program University of Guam



The Environmental Science Program is designed to provide students with an appreciation of the interdisciplinary nature of environmental problems that exist in the world today and prepare them for professional employment, teaching, or advanced studies in diverse areas of environmental science, or related disciplines. The program also serves working professionals in local schools, government agencies and the private sector who are seeking career advancement and/or professional enrichment, e.g., educators, regulators, administrators and planners.

The interdisciplinary focus of the program is intended to train students to identify and understand environmental problems and exercise sound judgment in effecting their remediation. This is accomplished through a careful blend of core courses and electives in an integrated teaching-research approach. Students are required to conduct a research project and document their study in thesis form. They are encouraged to present their findings in a variety of forums (e.g., society meetings, conferences, workshops, seminars, peer-reviewed journals, technical reports, newsletters and the local newspaper). Students also have the opportunity to serve out an internship with a local environmental or engineering firm, or an appropriate Government of Guam or Federal Government Agency. This permits them to gain professional problem solving skills in the

environmental arena. Students who graduate from the MS program can, therefore, reasonably expect to enter professional employment in a variety of areas in the public and private sectors where an understanding of the complex interdisciplinary scientific, social, and political dimensions posed by environmental problems is increasingly necessary.

The Environmental Science Program strives to promote educational and service projects within island communities of the Western Pacific, and attract a broadly based group of scholars committed to seeking answers to the many environmental questions that are arising in developing island nations of the tropical Pacific Basin. Areas of faculty expertise center around three broad areas of concentration namely, biology-ecology, geosciences-engineering, and management. Further information may be obtained from the Program Chair, **Dr. Ross Miller**, telephone: (671) 735-2141, **e-mail: rmiller@uog.edu**.



Pre Engineering Program University of Guam



Engineers are society's problem solvers. They take the theoretical ideas of the scientist and bring them into reality in today's world for the benefit of mankind. Engineers are involved with projects that vary from the design and construction of transportation systems to the planning of the space stations of the future. Nearly all aspects of our lives are touched by the projects worked on by people in the various engineering fields.

WHAT IS PRE-ENGINEERING AT THE UNIVERSITY OF GUAM?

The University of Guam offers a program in Engineering Science that parallels the engineering programs offered during the first two years at major colleges and universities.

The first two years of engineering study places emphasis on learning the tools and theories and providing the background for all engineering fields. Rigorous studies in mathematics and the physical sciences are required of all students. Students are also required to take courses in the social sciences and humanities to round out their educational experience.

WHAT IF I AM NOT SURE IF I REALLY WANT TO BE AN ENGINEER?

Each fall semester the University of Guam offers a course titled "INTRODUCTION TO ENGINEERING". This course is designed to acquaint students to the engineering profession. Discussions are held on all of the various

engineering fields. Educational and professional registration requirements are also introduced. Various guest speakers relate their experiences in the real world of engineering. Finally, students get a taste of the problem-solving techniques used by engineering students and practicing engineers.

WHAT IF I HAVE A WEAK BACKGROUND IN MATHEMATICS AND THE PHYSICAL SCIENCES?

Engineering requires a strong aptitude for both math and science. For students with these kinds of aptitudes but with weaknesses in prior training, there are remedial classes available to help bring the student up to a competitive level. These students will require more than the normal two years to complete the Pre-Engineering Program.

WHERE CAN I GET MORE INFORMATION?

For more information on the Pre-Engineering Program, contact the University of Guam Counseling Center, the Dean of the College of Natural and Applied Sciences, or contact **Dr. Shahram Khosrowpanah** (khosrow@uog.edu) or **Dr. Leroy Heitz** (lheitz@uog.edu) at the Water and Environmental Research Institute of the Western Pacific, UOG Station, Mangilao, Guam 96923 (telephone number (671) 735-2685).