

**Water and Energy Research Institute of the Western Pacific
Annual Technical Report
FY 1999**

Introduction

The Water & Environmental Research Institute of the Western Pacific or WERI celebrates its 25th birthday this year. Since 1975, WERI has provided technical expertise aimed at developing and managing water resources and thereby improving the economic conditions and quality of life for citizens of Guam and the western Pacific region. The institute continues to seek solutions through research, teaching, professional training and outreach programs to technical problems associated with the location, production, distribution, and management of freshwater resources. A complete listing of WERI faculty and staff is contained in Table 1. During the period March 1, 1999 - February 29, 2000, WERI faculty published 29 refereed journal articles, abstracts, technical reports, and conference proceedings while carrying on eight NIWR 104-B projects, six other Federally sponsored projects, and five locally funded projects. Of these nineteen separately budgeted institute projects, four were predominantly information transfer efforts. In addition, during that time WERI faculty taught fifteen regular university graduate and undergraduate courses. In fact, the WERI research program covered all the costs of materials, equipment, supplies, and other expenses associated with all UOG courses, as well as offering numerous professional training workshops throughout the region. WERI continued to provide services to the University, the people of Guam, and the region at fraction of what consultants would charge for comparable deliverables. Table 2 contains a listing of all courses taught by WERI faculty during the reporting period March 1, 1999 to February 29, 2000. The WERI state-of-the-science water analytical laboratory is totally self-sustaining and pays for a significant portion of WERI's operating expenses. WERI's reputation on island is now such that our technologic expertise is continually being tapped by the governor's office, legislature, various commissions, the private business sector, the media and/or the general community. In fact the 25th Guam Legislatures re-authorized on a permanent basis two annual appropriations from the 24th Guam Legislature for WERI to manage long-term water monitoring and water data collecting on island. Recently, the Western Association of Schools and Colleges (WASC) accreditation team highlighted WERI by name three times in its exit presentation and status report, and highly commended its recent record of achievements.

Table 1 WERI Faculty and Staff

POSITION	PERSONNEL
Director	H. Galt Siegrist, Jr., Professor of Geology, Penn State Univ.
Regular UOG Faculty	Gary R.W. Denton, University of London, Associate Professor of Toxicology Leroy F. Heitz, Univ. of Idaho, Prof. of Civil Engineering John W. Jenson, Oregon State Univ., Associate Prof. of Hydrogeology Shahram Khosrowpanah, Colo. State Univ., Prof. Hydraulics & Engineering Mark Lander, Univ. Hawaii, Assist. Prof. Meteorology
Research Faculty & Associates	Charles P. Guard, Univ. Hawaii, Meteorology & Climatology John Jocson, Univ. Guam, Groundwater Modeling and Computers
Water Lab Staff	Harold Wood, Ft. Hayes State, Chemist & Lab Mgr. Crispina Tagudin, Central Luzon State Univ., Lab Tech III

Office Staff	Norma C, Blas, Clerk Typist II, Purchasing & Payments Mgr. Dolores Santos Secretary II, Payrolls & Research Budgets Mgr.
Graduate Assistants	Colette Beausoliel, Arizona State Univ. Lucrina Concepcion, Univ. Guam Tomas Nadeau, Univ. Guam Mauryn Quenga, Cornell Univ. Karel-Gustaaf Smit, Univ. Arizona Alex Soto, Univ. Philippines Danko Taborosi, College of Charleston David Vann, College of Charleston
Undergraduates	Nathan Habana Pedro Bay-Asen

Table 2 Courses Taught by WERI Faculty

COURSE	CREDITS AND FACULTY
Graduate Courses in Environmental Sciences Program	
Environmental Science: Geology/Engineering	(3-credits Heitz, Jenson, Khosrowpanah, & Siegrist)
Environmental Impact Assessment	(1-credit, Khosrowpanah)
Aquatic Toxicology (3-credits, Denton & Wood)	
Environmental Contamination & Toxicology	(3-credits, Denton and Wood)
Hydrology (3-credits, Heitz)	
Principles of Hydrogeology	(3-credits, Jenson)
Geology of Pacific Islands	(3-credits, Siegrist)
Environmental Science Internship	(2-credits, Staff)
Environmental Science Seminar	(1-credit, Siegrist)
Reef Limestone Petrography	(2-credits, Siegrist)
Geology & Geomorphology of Coral Reefs	(4-credits, Siegrist)
Water Resources of Pacific Islands	(2-credits, Staff, CCEOP Course)
Instrumental Analysis for Environmental Scientists	(3-credits, Denton & Wood)
Hurricanes and Typhoons: An Overview of Tropical	Cyclones (3-credits, Lander)
Application of Remote Sensing to Weather and Climate	(3 credits, Lander)
Tropical Climate and Climate Variability	(3 credits, Lander)
Undergraduate Courses	
Engineering Orientation	(1-credits, Heitz)
Engineering Graphics	(3-credits, Heitz)
Engineering Statics	(3-credits, Khosrowpanah)

Research Program

During the period March 1, 1999 - February 29, 2000, WERI faculty published 29 refereed journal articles, abstracts, technical reports, and conference proceedings while carrying on eight NIWR 104-B projects, six other Federally sponsored projects, and five locally funded projects. Of these nineteen separately budgeted institute projects, four were predominantly information transfer efforts. A summary table of the actual and percentage contributions to the WERI budget of these project categories is as follows:

Sources	Average Annual last two years	Average % of WERI Budget last two years
United States Geological Survey 104-B Annual allotment and competitive programs	\$279,000	29.1%
Other Federal grants	\$210,000	21.9%
EPA, NOAA, NASA, NRCS, DOI, CZM		
Annual Appropriation from Government of Guam		42.7%
24-161 (Guam Hydrologic Survey)	\$230,000	
24-247 (Comprehensive Water Monitoring Program) matched 1:1 by USGS	\$180,000	
Contracts and water laboratory analyses	\$60,000	6.3

The following tables lists Recently Approved and New Research Projects, Recently Submitted New Research Proposals, and Recently Approved Information Transfer Proposals.

A. Recently Approved New Research Projects

Funding Agency	Title	PI	Total Budget
USGS 104-B	Nutrient levels in freshwater seeps, springs and subterranean flows of Tumon Bay and their potential impact on the growth and proliferation of the green alga <i>Enteromorpha clathratus</i>	Denton, Jenson Wood	\$67,900
USGS 104-B	Erosion and sedimentation processes in southern Guam	Khosrowpanah Heitz	\$26,550
USGS 104-B	Evaluation how groundwater infiltration and recharge in the northern Guam lens aquifer is affected by rainfall intensity	Lander Jenson	\$20,680

USGS 104-B	The assessment of fecal indicator potential and kinetics of caffeine and several caffeine metabolites in environmental waters	Wood Suleman	\$16,890
USGS 104-B	Determination of rainfall erosivity factors for the Federated States of Micronesia by accounting for climate variability	Khosrowpanah Heitz	\$22,860
USGS 104-B	Quality of formula preparation water and incidence of waterborne diseases associated with artificial infant feeding in Chuuk State, Federated States of Mirconesia	Wood Meyshine	\$17,800
USGS 104-B	Implementation of the SWIG2D Groundwater/ Saltwater intrusion code for MATLAB, for application to island aquifer modeling on Guam and Saipan	Jenson	\$16,950

B. Recently Submitted New Research Proposals

Agency	Title	PI	Requested Budget
USEPA	Restoration of the northern Guam watershed by identifying groundwater nitrate-nitrogen anomalies and their anthropogenic sources	Quenga Jocson	\$50,000
USEPA	Re-estimating sustainable yield of the northern Guam aquifer using new data sets	Joscson Quenga	\$35,000
USEPA	Spatial variability of contaminants from urban surface runoff and septic tanks in northern Guam	Khosrowpanah Heitz	\$30,000
USEPA	Levels and distribution of PCB in Agana Swamp, the Largest wetland on Guam	Denton	\$85,000
Commonwealth N. Mariana I.	Typhoon Vulnerability	Guard Lander	\$67,000

C.. Recently Approved Information Transfer Proposals

USGS 104-B	Development of a Western Pacific rooftop rain catchment system web site	Heitz	\$6,520
USGS 104-B	Effect of water education, increased training in operation and maintenance, and improved water quality analysis on water consumption within a small water-supply system	Jonas	\$9,600
USGS 104-B	Student activity guides, teacher manuals, and learning supplies for the new CNMI-developed island ecology/resource management textbook	Furey	\$10,995
USGS 104-B	Water conservation and reclamation project: model school	Benavente Mathis	\$55,000

Following is a list of initiatives that WERI faculty and staff have identified. These initiatives are designed to build on existing programs and increase our involvement in the community at large.

Future Weri Initiatives

- **Improve upon WERI's already state-of-the-science water analytical facilities and equipment.**
- **Expand our existing research and analytical facilities on the Lower Campus.**
- **Increase from six to ten, the number of WERI-funded Environmental Sciences graduate students working on water resource and related environmental concerns for their MS thesis.**
- **Develop stronger links with water professionals throughout the region, but especially in the CNMI, our new partner in the USGS NIWR Program.**
- **Grow the undergraduate Pre-Engineering (B.S.) Program.**
- **Develop stronger collaborative educational programs with colleagues at UOG, particularly those involved in the Environmental Science Masters Program..**
- **Substantially increase our efforts in the community and with elected officials and other policy makers to improve their technical understanding of water resource and related environmental issues.**

Basic Project Information

Basic Project Information	
Category	Data
Title	Island Karst Hydrology of Guam and its Incorporation into a General Carbonate Island Karst Model
Project Number	C-09
Start Date	08/01/1998
End Date	07/31/2000
Research Category	Ground-water Flow and Transport
Focus Category #1	Groundwater
Focus Category #2	Geomorphological and Geochemical Processes
Focus Category #3	Models
Lead Institution	Other

Principal Investigators

Principal Investigators			
Name	Title During Project Period	Affiliated Organization	Order
John Jenson	Associate Professor	Other	01
John Mylroie	Professor	Other	02
James Carrew	Professor	Other	03
Ivan Gill	Professor	Other	04
Robert Carruth	Professional Staff	US Geological Survey	05
Joseph Troester	Professional Staff	US Geological Survey	06

Problem and Research Objectives

Up to now, hydrogeologists and engineers working on karst water resource and environmental problems on Pacific carbonate islands have had to interpret and predict aquifer behavior based on conceptual models developed almost exclusively from studies of Atlantic/Caribbean carbonate islands. Such models however, are of limited applicability for Pacific carbonate islands because of differences in climate and tectonic history. The work on Guam described here is the first attempt to critically evaluate the applicability of existing karst aquifer conceptual models and genetic theories to a Pacific carbonate island (Mylroie et al., 1999). The project has therefore focused from its beginning in August 1998 on documenting the karst features of Guam and comparing them with analogous features on Atlantic/Caribbean carbonate islands. Two years of field work and supporting laboratory analyses have culminated in the first comprehensive inventory of the karst features of Guam, including its sinkholes, coastal springs and seeps, caves, fractures and faults (Taborosi, 2000). These features have been

classified according to their presumed origins, in order to more accurately predict their consequent hydrologic properties. Insights gained on Guam are supporting the development of the Carbonate Island Karst Model (CIKM), a general conceptual model of carbonate island aquifers (Myroie et al., in review; Myroie and Jenson, 2000a, b, c). These products will facilitate more reliable interpretations and predictions of aquifer properties not only on Guam, but on similar island and coastal carbonate aquifers elsewhere. Hydrogeologists and engineers equipped with such information will be better able to design appropriate groundwater production and aquifer protection strategies for islands where limestones form the predominant aquifers.

Methodology

Beginning during the first year, the Guam-based members of the project team mapped karst features along the coast and interior of northern Guam by field traverse, aerial reconnaissance, and analysis of existing aerial photographs. During May 1999 the full research team assembled on Guam to visit these sites, install instrumentation, and collect samples and data for subsequent laboratory analysis. In flowing fractures along the coast, for example, we installed temperature sensors to determine the feasibility of inferring fresh water spring discharge hydrographs from temperature changes that reflect the difference temperatures of fresh groundwater and seawater. We also collected rock core samples from caves and quarries for paleomagnetic and thin-section analysis, mapped selected caves, and documented the characteristics of selected carbonate units and karst environments on Guam. Members of the summer field team also made a reconnaissance excursion to Saipan to identify field sites with significant geologic histories that must be examined in detail to construct a more complete general model of carbonate island karst aquifers. The work in the Pacific was followed by similar fieldwork on Isla de Mona, Puerto Rico, as well as at selected sites on the main island of Puerto Rico. Samples and data collected on Guam, Isla de Mona, and Puerto Rico are currently being evaluated. Maps and spatial analyses are being constructed for publication as well as to support fieldwork during the coming year. During the final field season (June 2000) the entire team visited Saipan (10-14 June) to examine the fundamental geologic units and major karst features in order to make initial assessments of their hydrologic properties. These assessments will support the anticipated extension of the project to Saipan, which exhibits features more complex than those found on Guam (such as perched and semi-confined aquifer conditions). The team is currently on Guam (through June 21st) to visit recently discovered and newly accessed sites, as well as to critically examine descriptions and interpretations of key sites from the first field season.

Principal Findings and Significance

Significant findings and key work include the following. 1. Karst inventory of Guam. The karst inventory, including photo-documentation and survey of the island's caves and their hydrologic significance, has culminated in a masters thesis (Taborosi, 2000) and the submission of the first interpretive paper on the karst features of Guam (Myroie et al., in review). The paper also includes the first detailed description of the CIKM (Myroie and Jenson, 2000a, b, c) Data from the inventory have been compiled into GIS maps and other media for spatial analysis, and are being loaded onto the WERI web site (www.uog.edu/weri) to provide widespread access to the data. 2. Comparative field evaluations in the Caribbean and Saipan. a. Isla de Mona, Puerto Rico. Because Isla de Mona has a more established and simpler uplift history than Guam, it provides well-controlled examples of end-state conditions. These can be used to evaluate the types and degrees of karst development seen on Guam, where uplift has been more frequent and rapid. Puerto Rico provides an example of island karst on a large island, where the age of the limestones is similar to those of Guam, but the different sizes and histories of the islands has imposed fundamentally different hydrological conditions on the karst

development. Insights gained from a field investigation of Isla de Mona during June 1999 helped to constrain interpretations of related features on Guam.

b. North Coast Aquifer System, Puerto Rico. The island of Puerto Rico provides important clues regarding the evolution of karst in the large-island environment, which provides an end-member model against which to evaluate observations and conclusions drawn from work on smaller islands such as Guam. Work is underway on Puerto Rico to characterize the timing, distribution and geochemistry of dolomite in the Montebello Member of the Cibao Formation, and in the Lares Limestone. These two units comprise most of the lower aquifer system in the north coast of the Puerto Rico, and they show extensive karst features where exposed. From this work, we anticipate a new framework for the evolution of the Puerto Rico North Coast Aquifer System, as well as new data for dolomitization in the Caribbean and elsewhere. The mechanism of dolomitization and its timing have important implications for aquifer properties in the North Coast Aquifer of Puerto Rico in particular, and island aquifers in general. The stratigraphic and geographic distribution of dolomite in the aquifer systems can control porosity and permeability, and therefore patterns of groundwater flow. Preliminary results suggest that the dolomite in the North Coast Aquifer of Puerto Rico did not form until substantial uplift of the carbonate section had occurred. Presumably, the onset of dolomitization may be temporally related to the formation of the aquifer flow system and the development of karst topography on the uplifted carbonate highlands. This relationship may have parallels on oceanic islands and atolls where exposure of the carbonate rocks may occur as the consequence of eustatic fluctuation. This work was the basis for a Ph.D. dissertation project at the University of Puerto Rico.

c. History of exposure of the Miocene Aymamon Formation, Puerto Rico. We have found evidence of repeated exposure and karstification in outcrop and in cored sections of the Aymamon Formation, which have important implications for its aquifer properties. The exposure episodes have affected both the petrographic and hydrologic character of the rock, particularly in the production of significant porosity zones and impermeable layers. The resulting anisotropic permeability patterns affect recharge and flow patterns in the shallow, water-table aquifer, and suggest a strong relationship between paleoclimate, karst formation and aquifer properties. We anticipate that the results of this field investigation will reveal important insights regarding the evolution of karst in young limestone units and the inter-relationships between the resultant karst features, island size, climate, and other key variables that determine aquifer properties. This work was the basis for a master's thesis project at the University of Puerto Rico.

d. Saipan, Commonwealth of the Northern Mariana Islands. The limestone units on Saipan, although deposited at about the same time, and having subsequently undergone a tectonic history similar to Guam's, reflect a range of depositional environments not found on Guam. The hydrostratigraphy and lithologic properties of carbonate aquifer units on Saipan are unique and remarkably complex. Carbonate and volcanic units are interlayered, and structural features appear to influence aquifer properties to a greater degree than observed elsewhere thus far. The work conducted to date on Saipan indicates a more intensive investigation will reveal important new insights into the relationships between aquifer properties and aquifer history. Insights from these varied settings will provide the basis for a reliable general model for predicting the characteristics and behavior of carbonate island aquifers.

3. Spring hydrography from temperature measurement. The thermal contrast between warm tidal waters and cool discharging ground water at coastal discharge outlets from fractures and conduits appears to correspond to the observed halocline in these features, indicating temperature might be a proxy for degree of mixing and discharge. Promising early results suggest it might be possible to deduce pulses of storm-driven discharge of fresh water from temperature records (Gamble et al., 2000). This will enable the first systematic hydrographic data to be collected on Guam's coastal springs. Sites identified as promising during the 1999 field season are currently instrumented, and the research team is collecting data.

4. Petrographic analyses. Rock samples from Guam, Isla de Mona, and Puerto Rico have been evaluated at the petrographic laboratory at the University of Charleston. Analysis of more than 50 thin sections from samples collected on Guam during the 1999 field season indicates Guam's aquifer rocks on the plateau surface and coastal zones are much more pervasively altered than similarly placed rocks in the

Bahamas and Bermuda. This probably is the result of longer exposure and greater rainfall on Guam. The resultant porosity is complex, but the net result appears to be large-void porosity that probably transmits water rapidly, but by potentially circuitous paths not governed by primary bedding characteristics but by karstic pathways developed during subaerial exposure. We are now beginning study of 500-ft continuous core of the entire section of Guam's aquifer, in order to search for patterns of diagenesis that might correlate with surface sea-level stillstand indicators such as terrace levels and cliff-face grooves, which theory and previous work in the Atlantic-Caribbean suggest are zones of enhanced porosity. 5. Notching in uplifted carbonate rocks. Most of the horizontal notches cut into the cliff faces surrounded by the sea on carbonate islands have been interpreted as bioerosion notches. Lateral corrosion and cliff retreat may also produce notches, however. Interpreting the origin of the notches correctly is a key step in correctly characterizing the nature of groundwater flow and discharge in island karst and the concomitant development of island karst aquifer properties. We suspect many of the notches seen on Guam to be remnants of flank margin caves breached by cliff retreat. Detailed surveys of modern bioerosion notches and older notches of questionable origin began during the summer 1999 field season and will continue the summer 2000, along with petrographic analyses of the host rock and speleothems found in the notches. This work is the basis for a master's thesis project at Mississippi State University. 6. Reexamination of previously mapped lithology. The Argillaceous Member of the Mariana Limestone on Guam, a major rock unit that flanks the volcanic terrain at the southern end of the aquifer, exhibits distinctly different karst morphology and hydrologic properties from the "clean" limestone to the north. These distinctive attributes have up to now been assumed to be derived from terrigenous sediment from the nearby volcanic terrain having been incorporated into the limestone during deposition. Field examination of selected exposures during the 1999 field season suggests, however, that the insoluble material in the rock might merely have been brought into the interstices of pre-existing rock by weathering and vadose transport. If substantiated during the current year's work, this will require a thorough revision of current explanations and assumptions regarding the hydrologic properties of the unit, with important implications for future water resource development and management. At the more fundamental level, it will also require a reevaluation of current geological understanding of processes and rates of lateral transport of weathered volcanic materials onto adjacent limestone outcrops by mass wasting and stream flow. 7. Porosity enhancement by condensation corrosion in the vadose zone. Initial air temperature profile data from caves on Guam offer no evidence that the thermal regime of carbonate island caves would support the air flow and condensation necessary to support significant dissolution in the vadose zone. Condensation corrosion has been proposed as a process by which vadose caves could be enlarged over time. The absence of evidence for it on Guam and the other islands examined suggests that the evolution of vadose conduits must be explained in terms of hydrologic rather than atmospheric processes. This will help to bound the hydrologic characteristics that can be expected of conduits in the vadose environment.

Descriptors

Groundwater Hydrology, Karst Hydrology, Island Hydrology, Island Karst Hydrology

Articles in Refereed Scientific Journals

Mylroie, J. E., J. W. Jenson, D. Taborosi, J. M. U. Jocson, D. T. Vann, and C. Wexel, in review, Karst features on Guam in terms of a general model of carbonate island karst: *Journal of Cave and Karst Studies*.

Book Chapters

Dissertations

Ramirez, W., 2000, Dolomitization and the Evolution of the North Coast Aquifer System, Puerto Rico, University of Puerto Rico. Taborosi, D., 2000a, A Karst Inventory of Guam, M.S. Thesis, University of Guam, Mangilao, Guam. Matos, R., 2000, Controls on Porosity in the Aymamon Limestone, North Coast Aquifer System, Puerto Rico, University of Puerto Rico.

Water Resources Research Institute Reports

Myroie, J. E., J. W. Jenson, J. M. U. Jocson, and M. Lander, 1999, Karst Geology and Hydrology of Guam: A Preliminary Report, Technical Report #89, Mangilao, Water & Environmental Research Institute of the Western Pacific, University of Guam.

Conference Proceedings

Gamble, D. F., J. L. Myroie, and J. W. Jenson, 2000, The Use of Cave Air and Water Temperatures to Assess the Guam Aquifer: Annual Meeting of the Association of the American Geographers, Pittsburgh. Jenson, J.W., 1999, Toward a suitable conceptual model of the Northern Guam Lens Aquifer: Karst Modeling, Karst Waters Institute Special Publication 5, Charlottesville, VA, p. 58. Jocson, J. M. U., Jenson, J.W., and Contractor, D.N., 1999, Hydrologic insights from a finite-element model of the Yigo-Tumon sub-basin, Northern Guam Lens Aquifer: Karst Modeling, Karst Waters Institute Special Publication 5, Charlottesville, VA, p. 174. Myroie, J. E., and J. W. Jenson, 2000a, Guam and the Carbonate Island Karst Model: Theoretical and Applied Karstology, v. 11. Myroie, J. E., and J. W. Jenson, 2000b, The Carbonate Island Karst Model: Mississippi Water Resources Conference, April 18-19, 2000, Raymond, MS. Myroie, J. E., and J. W. Jenson, 2000c, Guam and the Carbonate Island Karst Model: Friends of Karst Meeting, July 2000, Cluj, Romania. Myroie, J. E. and Vacher, H. L., 1999, A conceptual view of carbonate island karst: in Palmer, A. N., Palmer, M. V., and Sasowsky, I. D., eds., Karst Waters Institute Special Publication 5, p. 48-57. Ramirez, W. and Gill, I., 1998, Dolomitization of the Montebello Member, Cibao Fm. and Lares Limestone, northern Puerto Rico: Caribbean Geological Conference, June 1999, Kingston, Jamaica. Ramirez, W. and Gill I., 1999, Dolomitization in the North Coast Aquifer System, Puerto Rico: Symposium of Caribbean Geology, Feb. 1999, Mayaguez, Puerto Rico. Taborosi, D., 1999, Karst inventory of the Northern Guam Lens Aquifer: Karst Modeling, Karst Waters Institute Special Publication 5, Charlottesville, VA, p. 244.

Other Publications

Taborosi, D (2000), Karst Features of Guam, WERI Technical Poster 1. Taborosi, D. (2000), Karst Inventory of the Northern Guam Lens Aquifer, WERI Technical Poster 2 Taborosi and Vann, 2000, Geologic Formations of Guam, WERI Technical Poster 3

Basic Project Information

Basic Project Information	
Category	Data
Title	Development of Design Parameters for Household Rainwater Catchment Systems for the Island of Saipan
Project Number	B-04
Start Date	03/01/1999
End Date	02/28/2000
Research Category	Engineering
Focus Category #1	Water Supply
Focus Category #2	Water Use
Focus Category #3	Models
Lead Institution	Other

Principal Investigators

Principal Investigators			
Name	Title During Project Period	Affiliated Organization	Order
Leroy Heitz	Professor	Other	01

Problem and Research Objectives

The island of Saipan in the Commonwealth of the Northern Marianas Islands (CNMI), although blessed with abundant rainfall, is plagued with fresh water supply problems. In many portions of the island high chloride levels make the municipal water supply undesirable for drinking purposes. In other areas problems with inadequate pressure and “water hours” are a normal occurrence. The 1997-1998 El Niño induced drought further exacerbated these conditions. In some rural areas of the island no municipal water supply is available at all and those living on rural ranches are forced to truck-in their supplies of fresh water. To overcome these adverse conditions many people have turned to rainwater catchment systems (RWCS). These types of systems, which consist of a roof catchment surface, guttering, and a storage tank, are used successfully to supply water throughout Micronesia and in other portions of the Pacific and in fact all over the world. At this point in time there is no source of information for sizing the various components of RWCS for the CNMI. In order to optimize water production and either private or governmental expenditures for these systems it is important that all components of the systems be sized properly to work together. Tank size, and guttering lengths, must be coordinated with the physical size of the structure, the size of family to be served and the uses that will be made of the water. Along with these factors the variability of rain falling on the island from season to season and from year to year must also be considered. The objectives of this research project were to: 1.) Update information on water consumption for households presently served by the municipal water system and for those in rural areas not served by the public system. 2.) Develop

design criteria for the components of the RWCS for both urban and rural systems, 3.) Prepare a brochure containing the design criteria developed in objective 2 in a manner that is comprehensible to those who will be financing, installing and maintaining rain water catchment systems.

Methodology

This project was divided into three phases as described below: Phase I: The first step was to do a thorough literature search on individual household water use on Saipan. Next researchers consulted with officials at the Commonwealth Utility Corporation to determine what kinds of use rates customers on the existing municipal system experience. Members of individual households throughout the island were interviewed to determine their water use patterns. Tabulations of roof sizes, percentage of roof surface drained by gutters and size of existing storage tanks were made for both rural houses and for those houses served by the municipal supply. This data was analyzed in order to develop a common set of use rates for Saipan. Four sets of use rates were developed in a manner similar to those developed in previous studies for Yap and Chuuk state in FSM. Phase II: Phase II of the proposed research was used to develop design criteria for the components of the RWCS. This phase of the study included: 1. Development of a typical 45-year daily rainfall record for Saipan at the airport. 2. The rainfall data along with the use rates being developed in Phase I were used in an operational model of a RWCS to explore various RWCS component sizing and water use options. 3. The information developed in component 2 were used to develop design criteria for individual RWCS. Phase III: In this phase, the researchers will prepare a brochure containing the design criteria developed in part 2. These criteria will be translated in such a way that it is comprehensible to those who will be installing and maintaining rain water catchment systems. The brochure will be distributed to all Commonwealth governmental agencies dealing with rainwater catchment systems. This brochure will be made available in locations where components of RWCS's are sold and at governmental offices dealing with water supply and financing of rain catchment system. A series of workshops will be held to be sure that those most interested in using the information will be trained in how to interpret the charts and tables in the brochure. The brochure will also serve as another module in the existing WERI audiovisual training series on water resources development.

Principal Findings and Significance

The major result of this project thus far has been a representative sampling of over 100 households on the Island of Saipan to determine water use patterns by islands residents. This data was entered into a database and was used in developing water use criteria for RWCS. A second major accomplishment thus far is the development of a synthetic long term (45 year) record of rainfall for one gage station in Saipan. In the past, the available rainfall records were scattered and all very short term. This is the first effort to consolidate this data into one usable long term record. Other researchers doing work in Saipan are already using this data for their investigations. Upon completion of the project, the other major result will be the development and dissemination of criteria to be used in the design of new or refurbishing of existing individual RWCS on the island of Saipan. We will carry out a thorough information dissemination effort to assure that the results of the study are available to those who will be financing, constructing, and maintaining the systems.

Descriptors

Water Harvesting, Water Use Data, Rainfall-Runoff Models, Rainfall

Articles in Refereed Scientific Journals

Book Chapters**Dissertations****Water Resources Research Institute Reports**

Heitz et al (2000) Rooftop Rain Catchment Assessment on Saipan, WERI Tech Rept in Prep

Conference Proceedings**Other Publications****Basic Project Information**

Basic Project Information	
Category	Data
Title	The Application of Slow Sand Filtration Technology For Kosrae State, Federated States of Micronesia:colon; A Pilot Project
Project Number	B-07
Start Date	03/01/1999
End Date	02/28/2000
Research Category	Engineering
Focus Category #1	Treatment
Focus Category #2	Water Supply
Focus Category #3	Surface Water
Lead Institution	Other

Principal Investigators

Principal Investigators			
Name	Title During Project Period	Affiliated Organization	Order
Shahram Khosrowpanah	Professor	Other	01
Leroy Heitz	Professor	Other	02
Harold Wood	Professional Staff	Other	03
Bruce Howell	Professional Staff	Other	04

Problem and Research Objectives

Surface water is widely used throughout the high islands of the FSM and particularly in Kosrae as a major source of drinking water. In all cases this water is heavily contaminated and unfit for human consumption without treatment. Studies by the Hawaii Department of Health (1991) indicates that Kosrae has one of the highest incidences of water related diseases in the world. Steps were taken in 1984 to reduce this high rate of disease with the construction of the Tofol–Lelu diversion and treatment system. This system, the largest water system in Kosrae, serves approximately 2,500 people. The facility consists of a low dam intake and a rapid sand filter. The problem is that the rapid sand filter is undersized and has never been fully operational since its construction. The filter system is very complex and has been plagued with breakdowns due to the harsh tropical environment and the lack of training in maintenance and operation of such a complex system. To improve the quality of Kosrae's drinking water the ongoing study has been funded by the USGS and the Kosrae State Government to assess the feasibility of adopting Slow Sand Filtration (SSF) technology for the treatment of surface water on the island of Kosrae. To accomplish the objective of this study, a pilot study has been undertaken with the following specific objectives: a) to determine if slow sand filtration technology can be used to produce an attractive finished water that meets Kosrae State Water Regulation for drinking water, b) to determine the effectiveness of local basalt sand as a filter media, c) to determine if it is necessary to cover filters to prevent problems with algae growth, and d) to determine the design criteria for a full-scale slow sand filtration plant.

Methodology

This project was divided into three phases as described below: Phase I. Planning, design, and construction of the pilot plant. A pilot plant consisting of four test cylinders has been constructed near the Tofol stream in Kosrae. Each plant includes a PVC pipe 13 feet long, 12-inch diameter with 5.5 feet of sand media sitting on 1.8 feet of gravel bed. A weir, regulating the inflow to the each cylinder at approximately 230 ml/min, is located at the top of the plant. Each cylinder is equipped with three piezometers, sampling taps, and outflow weir that prevents the creation of negative pressure across the filter media. Two of the filters have a locally sand material that has been prepared according to typical SSF specifications. The other two have commercially prepared sand media that is imported from off island. Phase II. Monitoring and testing. The ongoing testing, that was started in May and will be continued until end of August of this year, includes: 1) coliform spiking to determine the filter bed maturity, 2) daily inflow/outflow turbidity measurement to determine the filter turbidity removal's rate, 3) daily head loss measurement across the filter bed to determine the scrapping time for the filters, 3) daily measurement of the inflow dissolved oxygen for alga growth, and 4) daily inflow/outflow temperature measurement to determine the filter bed maturity. Phase III. Evaluation. The pilot plant performance will be evaluated base on the results of Phase II. The criteria for evaluating pilot plant performance will be based on criteria such as: 1. The ability of the plant to removal coliform bacteria: We are seeking removal of at least 90 to 99% of coliform bacteria. 2. The ability to reduce the turbidity of feed waters: We are seeking filtered water turbidities of less that 1 NTU. 3. Fairly long filter run times: We are seeking filter run times of one to two months between scrapings. The difference in performance of each of four filter materials tested will be carefully evaluated. A final set of design recommendations and criteria for the actual slow sand filter will be developed from the pilot plant data.

Principal Findings and Significance

The construction of the pilot plants has been completed. The monitoring and testing of the pilot plant performance presently is on going. The testing will be continued until August of this year. The results will be carefully evaluated to determine the feasibility of applying this technology to a full-scale plant in Kosrae. There is a great interest in applying SSF technology to other islands in the FSM. This is especially true on Pohnpei Island where a recent Cholera outbreak is being blamed partially on unsanitary conditions in rural surface water supplies. In light of these needs we plan to explore the possibility of transferring the technology to other islands in the FSM as well as other parts of the Western Pacific.

Descriptors

Streams, Water Quality Control, Slow Sand Filter

Articles in Refereed Scientific Journals

In preparation.

Book Chapters

Dissertations

Masters Thesis Colette Beausoliel

Water Resources Research Institute Reports

In preparation.

Conference Proceedings

Other Publications

Basic Project Information

Basic Project Information	
Category	Data
Title	The Evaluation of Several Chemical Indicators of Fecal Pollution in Relationship to Standard Microbiological Indicators
Project Number	B-02
Start Date	06/01/1999
End Date	02/28/2000
Research Category	Water Quality
Focus Category #1	Water Quality

Focus Category #2	None
Focus Category #3	None
Lead Institution	Other

Principal Investigators

Principal Investigators			
Name	Title During Project Period	Affiliated Organization	Order
Gary Denton	Associate Professor	Other	01
Naushadalli K Suleman	Associate Professor	Other	02
Harold Wood	Professional Staff	Other	02

Problem and Research Objectives

The traditional microbiological indicators of fecal pollution are problematic, especially in tropical waters because of the ambiguous nature of these indicators. It has been well established that the coliforms, especially *Escherichia coli*, and the fecal streptococci are only obscurely associated with fecal pollution in these tropical waters. Several sites were chosen to represent the variety of recreational waters analyzed by the Guam Environmental Protection Agency for their recreational water reports. These included marine sites and fresh water river sites. Some of these sites are perennially positive for indicator bacteria and others were chosen that tend to be positive less often. One of the sites was a river that has a sewage treatment plant outfall. The study also included an evaluation of a proprietary most probable number (MPN) method (Idexx QuantiTray) for performing total coliforms, *E. coli* and *Enterococcus*.

Methodology

Samples were taken at the chosen sites for their weekly recreational water reports. Samples were taken in sterile 1 liter bottles and subjected to a variety of bacteriologic assays. These included membrane filtration using mTEC media and QuantiTray Colilert[®] 18[®] (Idexx) assays. Both of these test for *Escherichia coli*. The QuantiTray system is a method for doing a MPM using 97 wells. *Enterococcus* were likewise analyzed using two methods, a membrane filtration using mEI media and QuantiTray[®] assays using Enterolert[®] media and 97 well Quantitrays (Idexx). *Clostridium perfringens* (CP) were assayed on mCP media as both total and spores. At the same time as bacteriologic sampling, a one liter bottle of water was collected for fecal sterol assay. This assay was performed by filtering the suspended solids onto a tared glass filter and dried under vacuum. The filter was extracted into a chloroform:dichloromethane mixture, evaporated to near dryness and taken up in toluene:hexane. The toluene:hexane solution was cleaned up on a florisil:silica column. The fraction containing sterols was evaporated to dryness and taken up in dichloromethane and derivatized to silane derivatized with BSTFA + TMCS, 99:1 (Sylon BTF). After evaporation to dryness the sample was made up in a solution of α -cholestane (internal standard) in dichloromethane. The derivatized extracted was analyzed by gas chromatography-mass spectrometry using a selected ion storage method to decrease background and increase sensitivity.

Principal Findings and Significance

Early results demonstrated a very good correlation between the two E. coli methods and the two Enterococcus methods. The correlation between the membrane filtration method for E. coli and the Colilert method demonstrated better correlation when incubated at a higher temperature (41 or 45 deg C), especially in marine waters. In addition, the marine samples requires a ten times dilution in both the Colilert and the Enterolert methods. By using a higher incubation temperature for the Colilert method, dilutions of less than ten could be used. Because of these results, the Guam Environmental Protection Agency has decided to use these methods in their recreational water surveillance program. Although these methods are somewhat more costly than the membrane filtration methods, they are considerably less labor intensive. Clostridium analysis demonstrated that in most samples that the majority of the organisms were in the spore stage. For later samples, the Idexx methods and the mCP method for total Clostridium perfringens were used. Samples for fecal sterols were found to generally correlate with the bacterial analysis. The method is limited in sensitivity because the method used suspended solids and only a limited sample could be filtered to obtain the solids. Sensitivity could be increased by other methods to process more water, multiple filters or centrifugation. Alternatively, sampling of the sediments could be done. Sediment sampling is essentially a look back in time, as the results reflects levels when the sediments were deposited. The suspended solids in the water tends to reflect the present time, as do the bacterial results. Analysis for fecal sterols is technically difficult Sampling and analysis continues to increase the size of the data set.

Descriptors

Bacteria, Indicators, Tropical Waters, Fecal

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Water Resources Research Institute Reports

In preparation

Conference Proceedings

Other Publications

Basic Project Information

Basic Project Information	
Category	Data
Title	Contaminant Assessment of Sediments in Tanapag Lagoon, Saipan
Project Number	B-05
Start Date	06/01/1999

End Date	05/31/2000
Research Category	Water Quality
Focus Category #1	Water Quality
Focus Category #2	Toxic Substances
Focus Category #3	Sediments
Lead Institution	Other

Principal Investigators

Principal Investigators			
Name	Title During Project Period	Affiliated Organization	Order
Gary Denton	Associate Professor	Other	01
Harold Wood	Professional Staff	Other	02
Brian Bearden	Professional Staff	Other	03

Problem and Research Objectives

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, the southern near-shore section of Tanapag Lagoon has become heavily impacted by the activities of man. Primary sources of anthropogenic disturbances include a commercial port (Saipan Harbor), a sewer outfall, a municipal dump and a small boat marina. The area is also inundated by storm water runoff from the adjacent commercial and industrial sectors of the community during prolonged periods of wet weather. The effects of these perturbations on the indigenous biota within the lagoon are largely unknown. Likewise, fundamental data describing the abundance and distribution of persistent and potentially toxic pollutants within the system, is also lacking. Mindful of these shortcomings, a contaminant assessment of surface sediments within the Lagoon was undertaken. The objectives of the study were: 1. To determine the presence and abundance of PCBs, PAHs, and a range of heavy metals (Ag, As, Cd, Cr, Cu, Hg, Ni, Pb, Sn, and Zn), in bottom sediments from strategic locations within Tanapag Lagoon. 2. To map concentration contours for each contaminant within the area and highlight specific point sources and areas of enrichment. 3. To assess the degree of sediment contamination in Tanapag Lagoon by reference to levels reported in clean and polluted environments elsewhere and with special reference to other tropical regions of the world, including Guam. 4. To develop criteria for distinguishing between clean and contaminated sediments within the Lagoon. 5. To initiate the provision of a sound database with which future levels of contamination may be compared and evaluated. 6. To provide information of value for the upgrading of Saipan's marine water quality monitoring program

Methodology

Near shore sampling stations were selected at 100-m intervals, along transect lines running approximately parallel and perpendicular to the coast between Muchot Point and Flores Point. The distance between stations was reduced to 50-m in the vicinity of known or suspected point sources of contamination. Sediments from the outer lagoon were collected along three equally spaced transect lines (~1400-m apart) running seaward toward the barrier reef, between Muchot Point and Flores point. Sampling stations were located 500-m, 1250-m and 2250-m from the shore along each transect

line. Forty-one sampling stations were visited in all and were located using digital-orthophoto-imagery maps with reference to prominent landmarks, compass bearings on fixed points of reference and GPS. All sediment samples were taken to a depth of 15 cm using hand-held aluminum corers. Three such sediment cores were collected from within a 3-m diameter circle at each station. The charged corers were sealed with Teflon lined, plastic end-caps, wrapped in aluminum foil, labeled, and stored on ice prior to being deep frozen for air transportation back to Guam. In the laboratory, individual sediment cores were thoroughly mixed in a glass bowl with a Teflon spatula following the removal of large rocks, shells and other such bulky materials. Sub-samples for heavy metal analysis were placed in acid cleaned polyethylene vials and dried to constant weight, at 60°C, while those for PCB and PAH analysis were air-dried, in the dark, in shallow aluminum pans. Upon drying, the sediments were disaggregated and only that fraction passing through a 1-mm screen was analyzed for chemical contaminants. Separate air-dried sub-samples were put aside for the analysis of specific physicochemical properties (e.g., particle sizes distribution, organic carbon) and petrographic description. Residual sediments were stored in pre-cleaned glass jars, at -20 degrees C, for further analysis as necessary. The analytical procedures were developed in accordance with established SW-846 protocols developed by USEPA for the physical and chemical evaluation of solid wastes, in addition to methods recommended by NOAA for the National Status and Trends Program for Marine Environmental Quality. Congener specific analysis was carried out for PCBs and PAHs using the common 20 and 16 congener calibration standards for each chemical group respectively. Quality control and quality assurance procedures were rigidly adhered to. The data was incorporated into a GIS and analyzed using the computer program, "ArcView 3D Analyst" to develop contours of equal contaminant concentration within the Lagoon.

Principal Findings and Significance

Chemical data found in sediments from Tanapag Lagoon during the present study were summarized and compared to earlier unpublished findings for sediments taken close to the Puerto Rico dump (Division of Environmental Quality, Saipan). Levels normally encountered in clean reef sediments were included for comparative purposes. Also sediment quality guidelines (SQGs) recently proposed by Macdonald and co-workers (Ecotoxicology, 5: 253-278, 1996) for Florida's coastal waters were compared. These researchers estimated SQGs for a wide range of contaminants using existing biological effects data. From their extensive database, two SQGs were derived, a threshold effects level (TEL) and a probable effects level (PEL). These guidelines were formulated with the intention of delineating three ranges of contaminant concentrations that were rarely ($< \text{TEL}$), occasionally ($> \text{TEL}$ to $< \text{PEL}$) and frequently ($\geq \text{PEL}$) associated with adverse biological effects. Levels of all three contaminant groups in sediments from Tanapag Lagoon decreased with increasing distance from the shore. Moderate to heavy enrichment of arsenic, copper, lead, mercury, tin, and zinc was evident in sediments taken close to the Puerto Rico dump and adjacent to the docks. However, the number of TEL exceedences were limited to four stations for arsenic; two stations for copper, lead and zinc, and one station for mercury. PCB concentrations were relatively high in sediments from the southwest point of Puerto Rico dump but did not exceed the TEL. Levels were also appreciably lower than those found in the same vicinity by DEQ in the late 1980's (see Table). Elsewhere, PCBs were uniformly light in sediments at all stations. Likewise, PAH levels were light to moderate throughout the study area and only exceeded the TEL at one station off the northeast face of the dump. No PEL exceedences were found for any contaminant at any of the 41 sampling stations. A comparative analysis of the data with levels found elsewhere suggests that the mid- to outer-reaches of Tanapag Lagoon are relatively clean by world standards.

Descriptors

sediment quality, coastal waters, heavy metals, PCBs, PAHs

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Water Resources Research Institute Reports

Denton et al (2000) Saipan Lagoon Sediment (In Preparation)

Conference Proceedings

Other Publications

Basic Project Information

Basic Project Information	
Category	Data
Title	Creation of a 50-Year Rainfall Data Base, Annual Rainfall Climatology, and Annual Rainfall Distribution Map for Guam
Project Number	B-03
Start Date	06/01/1999
End Date	02/28/2000
Research Category	Climate and Hydrologic Processes
Focus Category #1	Climatological Processes
Focus Category #2	Hydrology
Focus Category #3	Water Quantity
Lead Institution	Other

Principal Investigators

Principal Investigators			
Name	Title During Project Period	Affiliated Organization	Order
Charles Guard	Research Associate	Other	01
Mark Lander	Assistant Professor	Other	02

Problem and Research Objectives

Since the early 1950s, there has been considerable interest in the rainfall on Guam, as is apparent from the over-60 rain gauge sites established and maintained by various US agencies. Unfortunately, the length of record of most of the sites is short, in many cases incomplete, and in some cases unreliable. The purpose of this study was to build a 50-year data base and an annual rainfall distribution map for Guam.

Methodology

Commercial databases were used for initial data collection, but they contained many data gaps. The authors, often going to original documents, were able to recover much of the missing data. The study used the longest, most reliable records to establish baseline relationships. Eventually, rainfall values were constructed to fill the remaining gaps. On several occasions, typhoons blew away rain gauges, and the rainfall had to be reconstructed. In some data-void areas, vegetation types and soil permeability characteristics were used to assess relative wetness and dryness in order to establish rainfall gradients and patterns. NEXRAD radar data were also used to identify common cloud distribution patterns, especially over the adjacent waters. Annual data were plotted for each year from 1950 through 1999. As more and more information was revealed about the rainfall distribution patterns from the analyses, reanalyses were conducted for each map to fine-tune the annual rainfall distribution. Each investigator performed this process independently. The analyses were very similar, and discrepancies were resolved into a single consensus analysis. The mean annual rainfall map was developed by selecting rainfall values at 150 points on Guam that included all of the rain gauge sites. The 50-year values for each of the 150 points were then averaged to derive 50-year values. These rainfall values were then plotted at the appropriate 150 locations, and an analysis was conducted in the same manner as for the individual annual analyses.

Principal Findings and Significance

An average annual rainfall distribution map was developed for Guam for the 50-year period. The map shows that the major rainfall patterns are generally oriented north-northeast--south-southwest, with maximums and strong rainfall gradients located along the western and southern mountains. Another maximum lies in the central part of the north end of the island. Rainfall minimums lie in the center of the island, southwest of Mount Santa Rosa, south of Ritidian Point, and over extreme southern Guam. Again, these are oriented in a general northeast-- southwest manner, along the Island's axis of orientation. This analysis indicates that earlier rainfall distribution studies for Guam have greatly oversimplified or incorrectly analyzed the Island's rainfall distribution patterns and gradients.

Descriptors

Rainfall, climatology

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Water Resources Research Institute Reports

Guard & Lander (2000) 50-yr Annual Rainfall Distribution for Guam, WERI Tech Report (in Prep)

Conference Proceedings

Other Publications

Information Transfer Program

WERI's mission involves a large information transfer/dissemination component. Key elements include written forms such as newsletters, 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. Our audience includes water managers and engineers, politicians, school teachers, students and ordinary citizens. It is important that WERI make this information available in as widely distributed form as possible. Many of the water quality and quantity problems that exist in the western pacific are do to lack of education and knowledge in the water resources areas.

Basic Project Information

Basic Project Information	
Category	Data
Title	Teacher Workshops for the Federated States of Micronesia
Description	Hold workshops and revise teachers handbook on Island water resources.
Start Date	03/01/1999
End Date	02/28/2000
Type	Audio-Visual Productions
Lead Institution	US Geological Survey

Principal Investigators

Principal Investigators			
Name	Title During Project Period	Affiliated Organization	Order
Shahram Khosrowpanah	Professor	Other	01
Leroy Heitz	Professor	Other	02

Problem and Research Objectives

Generally, throughout the Federated States of Micronesia (FSM) there is a need for improved water supplies. This is evidenced by a high incidence of disease related to unsanitary conditions (inadequate water quality) and potable water shortage in times of low rainfall or drought (inadequate water quantity). There are a number of reasons for these deficiencies in island water supplies. Among them are lack of funds to improve facilities and lack of knowledge of how to improve them. This lack of knowledge is especially apparent in the general population. This includes school children as well as adults. The overall objective of this project was to increase the knowledge of island water supplies among high school students in the FSM. As these students mature, they will be more apt to develop, use, and maintain island household and community water supply systems in an intelligent and responsible manner. In order to meet this overall objective we held teacher training workshops in the FSM. The objectives of these workshops were to: 1.) assure that those teaching the students have the necessary background in island water resources and an understanding of the previously developed island water supply curriculum, and 2.) to gain feedback from the teachers in order to improve the previously published curriculum that had been developed by WERI.

Methodology

We held two 2 day workshops at the island centers of Chuuk and Pohnpei States of the FSM. The workshops were designed to use a variety of teaching strategies to include: a) Use of multi media to include: videos, slides and overheads b) Traditional lectures c) Student led classroom sessions & Discussion groups The materials and activities covered in these workshops included: 1) DAY 1 a) Program introduction and basic concepts of island water resources b) Detailed discussions of WERI's Island water resources curriculum package c) Concepts of supplying water through centralized water distribution systems d) Rooftop rain water catchment systems 2) DAY 2 a) Hands on exercises in developing lessons from the curriculum handbooks b) Discussions on improvements that could be made to the curriculum and workshops to make the island water resources training program more effective

Principal Findings and Significance

In 1993 and 1994 researchers at WERI developed a video, set of slides and a classroom teaching guide on island water supplies. The slides and teaching guide were directed at high school students. The intent being to instill a consciousness of water supply problems and their solution in this group of people who will be the next generation of decision-makers and who are also in a position to intelligently observe and comment on water use practices in their homes and communities. The principle findings of this project were: 1) The Island Water Supply Curriculum was being used in the classroom in FSM. 2) After using the curriculum the teachers had many very good suggestions for improving the content and delivery of the materials. The revised curriculum has been completely revised and updated using the suggestions provided by the teachers. Copies of the revised student workbooks will be distributed to all of the high schools throughout FSM. The benefit of the project is an increased understanding of rural and centralized water supplies by teachers in the school systems of the FSM. These teachers can now pass along this information to their students who will develop an increased understanding of what sources of water are available and what their most appropriate uses are. They will understand methods of development of water sources that will maximize the quantity of water available as well as ways in which water quantity can be improved. Hopefully, the understanding of these factors will lead to improvements in island water supplies, the end result being a decrease in diseases related to poor water quality and an increase in the amount of potable water available for use during drought or periods of low rainfall.

Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Water Resources Research Institute Reports

Conference Proceedings

Other Publications

Revised Teachers Manual for Chuuk and Outer Islands

Basic Project Information

Basic Project Information	
Category	Data
Title	Teacher Workshops for the Federated States of Micronesia
Description	This project held teacher training workshops and edited and reprinted WERI's highly successful high school teaching supplement titled "Water Supply for Remote Tropical Islands"
Start Date	03/01/1999
End Date	02/28/2000
Type	Audio-Visual Productions
Lead Institution	Other

Principal Investigators

Principal Investigators			
Name	Title During Project Period	Affiliated Organization	Order
Shahram Khosrowpanah	Professor	Other	01

Problem and Research Objectives

Generally, throughout the Federated States of Micronesia (FSM) there is a need for improved water supplies. This is evidenced by a high incidence of disease related to unsanitary conditions (inadequate water quality) and potable water shortage in times of low rainfall or drought (inadequate water quantity). There are a number of reasons for these deficiencies in island water supplies. Among them are lack of funds to improve facilities and lack of knowledge of how to improve them. This lack of knowledge is especially apparent in the general population. This includes school children as well as adults. The overall objective of this project was to increase the knowledge of island water supplies among high school students in the FSM. As these students mature, they will be more apt to develop, use, and maintain island household and community water supply systems in an intelligent and

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Articles in Refereed Scientific Journals

Book Chapters

Dissertations

Water Resources Research Institute Reports

Winter, Stephen J., Campbell, B. L., Khosrowpanah, S., Heitz, L.F., 2000, Water Supply for Remote

Tropical Islands, A High School Teaching Supplement, WERI, University of Guam, Mangilao, Guam, 42pp.

Conference Proceedings

Other Publications

USGS Internship Program

Student Support

Student Support					
Category	Section 104 Base Grant	Section 104 RCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	3	N/A	N/A	N/A	3
Masters	1	6	N/A	N/A	7
Ph.D.	N/A	N/A	N/A	N/A	N/A
Post-Doc.	N/A	N/A	N/A	N/A	N/A
Total	4	6	N/A	N/A	10

Awards & Achievements

WERI faculty continued to be major and effective participants in law and policy making on Guam by serving as committee members and chairs on numerous governmental boards and by giving testimony at legislative oversight hearings.

Publications from Prior Projects

Articles in Refereed Scientific Journals

1. Heitz, L.F, S. Khosrowpanah & J. Nelson (2000) Sizing of surface water detention ponds for water quality improvement. *Journ. Amer. Water Resour.* 36(3):1-8.
2. Lander, M. A. & C. P. Guard (2000) Eastern Hemisphere Tropical Cyclones of 1967. *Monthly Weather Review* (in press)
3. Randall R.H. & H.G. Siegrist, Jr. (2000) Reefs of the Tarague Embayment, Northern Guam (*Atoll Res. Bull.* in press.)
4. Siegrist H.G., Jr. & R.E. Miller (2000) Trace element variation in a Miocene carbonate section from the Mariana Islands: Implications for sea level changes. *Journ. Geochem.* (in review).

Book Chapters

Dissertations

Water Resources Research Institute Reports

1. Denton, G.R.W., L.P. Concepcion, H.R. Wood, V.S. Eflin, & G.T. Pangelinan (1999) heavy metals, PCBs, and PAHs in marine organisms from four harbor locations on Guam. Univ. Guam, Water & Environ res. Instit. West Pac. Tech Rept 87:154p.
2. Guard, C. P. (2000) 50-year rainfall climatology and New Annual Rainfall Distribution Maps for Guam (WERI Tech Rept. in preparation)
3. Guard, C. P. (2000) A 50-year, partially Manufactured Rainfall Database for Saipan International Airport (WERI Tech Rept. in Preparation)
4. Heitz, L.F., (1999) Designing your rainwater catchment and storage system for rainwater catchment systems in Pohnpei State, FSM. Univ. Guam, Water & Environmental Research Institute of the Western Pacific, Water Info. Bull 5.
5. Taborosi D.F. & S. Khosrowpanah (2000) Environmental Impact Statement, Inarajan River Dam Project. WERI Tech Rept. (In press)

Conference Proceedings

1. Denton G.R.W. (1999) Urban runoff studies on Guam: a contaminant assessment overview. EPA 18th Annual Pacific Islands Conference, Saipan.
2. Foc, Y-S, L.F. Heitz, & H. Smith (1999) Hawaii rainwater catchment systems development: Draft Guidelines. Proc.9th International Rainwater Catchment Systems Conf. Petrolina, Brazil.
3. Guard, C. P., M. A. Lander (1999): The maximum winds on Guam during Super Typhoon Paka – further arguments for reassessing western North Pacific wind-pressure relationships. Proc. 23rd Conf, Hurr. and Trop. Meteor., Dallas, TX, January 1999.
4. Heitz L.F. (1999) Strategies to mitigate the nutrient environment in the Tumon and Agana Bays. EPA 18th Annual Pacific Islands Conference, Saipan.
5. Heitz, L.F., Y.-S. Foc & H. Smith (1999) Development of rooftop rainwater catchment system design criteria for Pohnpei State, Federated States of Micronesia., Proc. 9th International Rainwater Catchment Systems Conf. Petrolina, Brazil
6. Heitz, L.F. & G.R.W. Denton (1999) Automated sampling systems for pollution detection and unsightly algal blooms in Tumon Bay. The hotel connection 18th Ann. EPA Pac. Isl. Conf. Saipan.
7. Heitz L.F. (1999) Strategies to mitigate the nutrient environment in the Tumon and Agana Bays. EPA 18th Annual Pacific Islands Conference, Saipan.
8. Khosrowpanah, S. (1999) Water resources in the Pacific Islands. EPA 18th Annual Pacific Islands Conference, Saipan.
9. Lander, M.A., and C.P. Guard (1999) A look at global tropical cyclone activity: basin Intercomparisons and relationships with ENSO, QBO, and other large-scale climate features. Accepted for Proc. 23rd Conf, Hurr. and Trop. Meteor., Dallas, TX, January 1999.
10. Lander, M.A. (1999) Some Characteristics of tropical cyclone intensification as revealed by hourly digital Dvorak analysis. Accepted for Proc. 23rd Conf, Hurr. and Trop. Meteor., Dallas, TX, January 1999.
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