WATER AND ENVIRONMENTAL RESEARCH INSTITUTE

**Guam Hydrologic** Survey (GHS)

&

**Comprehensive Water Monitoring Program** (CWMP)

> **FY 2014 Annual Report**

November 2014

OF THE WESTERN PACIFIC UNIVERSITY OF GUAM

## GUAM HYDROLOGIC SURVEY (GHS) & COMPREHENSIVE WATER MONITORING PROGRAM (CWMP)

## FY 2014 ANNUAL REPORT

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

## **PROGRAM MISSION STATEMENT**

The Guam Hydrologic Survey (GHS) and the Comprehensive Water Monitoring Program (CWMP) were created in 1998 by the 24<sup>th</sup> Guam Legislature under Public Laws No. 24-247 and 24-161 respectively. The Water and Environmental Research Institute (WERI) was charged with administering the annual legislative appropriations necessary to drive these two programs and facilitate, direct and implement their primary objectives. Both programs are now an integral component of the WERI water resources research, information dissemination, education and training mission.

## **PROGRAM GOALS**

The purpose of GHS is to consolidate Guam's hydrological data gathered over the years by local and federal government agencies and consultants, and to conduct research on water related issues of local importance. GHS also funds a variety of water resource educational programs in various formats, including guest lectures and seminars at UOG and in the community, informational and training workshops for teachers and professionals from other government agencies, field trips and talks for schoolchildren, and the publication and distribution of educational posters, maps, and fact sheets.

The CWMP was created to collect data on saltwater intrusion and water lens thickness in Guam's sole source aquifer in the northern part of the island and stream flow and other parameters associated with surface waters in the south. The program builds on studies previously undertaken by the US Geological Survey (USGS) that were abandoned several years earlier because of a discontinuance of matching funds from the Government of Guam. The CWMP annual appropriations from the Guam legislature have facilitated the collaborative reinstatement of these studies with USGS under their 50-50 Federal/State-Territory cost-sharing program for water resource monitoring.

The foresight of the Guam Legislature in creating these two very important programs deserves special mention here. Through their efforts and continued support, we have consolidated and interpreted several vital water resources databases for Guam and revitalized the USGS water resources monitoring program. Our understanding of the complex physical, chemical and biological processes that influence Guam's water resources has broadened considerably and the increase in graduate student research opportunities provided by the programs has substantially added to the number of highly trained water resources professionals in the island's work force.

## **PROGRAM FUNDING**

GHS and CWMP appropriations written into each public law are \$204,200 and \$173,948 respectively. Local budgetary constraints saw a 6% reduction in funding support for both programs in FY'09, i.e., \$192, 309 and \$163,817 awarded for GHS and CWMP respectively. These shortfalls continued through FY'12. An additional 5% reduction was levied against each account by Governor Calvo in FY'12 and is continuing through FY'14. This reduces the total awards to \$182,694 for GHS and \$155,626 for CWMP. The information presented herein summarizes all GHS and CWMP program objectives and related activities undertaken in FY'14.

## **PROGRAM OUTCOMES FOR FY'14**

## GUAM HYDROLOGIC SURVEY (GHS)

In FY'14, GHS provided funding the continued maintenance, repair and upgrading of

instrumentation in the WERI *Computer Analysis and Geographic Information System* (CA-GIS) *Laboratory*. Almost every water research project carried out by WERI involves a GIS analysis and mapping component. The GIS laboratory provides the required hardware and expertise in GIS analysis and serves as a data archive for GIS generated databases. WERI also works closely with various Government of Guam and Federal Agencies in sharing GIS data that become available.



GHS provides limited stipends for research by graduate students working on their MS

Graduate students in WERI CA-GIS Laboratory

degree in Environmental Science and partial summer salaries to WERI faculty advising those students. It also pays for undergraduate field and lab assistants working on water resources projects on Guam, and the salary of one full-time Staff Hydrologist charged with operating WERI's complex and sophisticated database analysis and GIS facility.

## **GHS Sponsored Research Projects Completed in FY'14:**

1. Basement Map of the Northern Guam Lens Aquifer By far the single most important tool for successfully locating new wells that will deliver abundant high quality water from the Northern Guam Lens Aquifer is an accurate and precise map of the volcanic basement rock that forms the floor of the aquifer. The volcanic rock beneath the water-bearing limestone partitions the aquifer into semi-contiguous subterranean catchments, or basins. On the slopes of the basement rock standing above sea level, where the base of the aquifer thus lies above sea level, downward percolating fresh water becomes concentrated in basement valleys and at the base of the slopes, where it enters the lip of the fresh water lens. The rim of fresh water thus concentrated along the boundary of the volcanic basement and the water-table near sea level is underlain by volcanic rock rather than sea water. This *para-basal* water is thus



Sinking new NGLA wells

fresher, thicker and much less vulnerable to salt-water contamination than the *basal* water downstream, which floats on the underlying sea water and becomes progressively thinner and saltier until it discharges at coastal springs and seeps. Water flowing down the flank of the

volcanic slopes above sea level, designated *supra-basal* water, is the freshest of the water in the aquifer and is completely invulnerable to contamination by sea water.



Volcanic basement beneath limestone aquifer defines three groundwater zones: 1) the basal zone, where the fresh water lens is underlain by sea water, 2) the para-basal zone, where the fresh water is underlain by the volcanic rock, and 3) the supra-basal zone, where the fresh water moving down-slope toward the para-basal zone is lies above sea level.

The first detailed map of the basement topography was produced as part of the 1982 Northern Guam Lens Study. Beginning in 1998, with the establishment of the Guam Hydrologic Survey by the 24<sup>th</sup> Legislature, WERI began updating and revising the 1982 map based on new data and insights acquired by exploratory drilling, the emplacement of new monitoring wells, and other data obtained incidental to ongoing local aquifer development and military installation environmental remediation projects.

Most recently, the exploratory drilling program undertaken by the US Navy in 2010 in support of the anticipated military build-up provided additional new control on the elevation of the basement in crucial locations. Moreover, the new Guam Groundwater Availability Study led by the USGS Pacific Islands Water Science Center, in collaboration with WERI, has provided additional funding to update the database that supports the map. An accurate map of the basement topography is an essential prerequisite for building accurate and reliable groundwater models, which is one of the goals of the groundwater availability study.

WERI anticipates publishing the latest revision of the basement map in early 2013 along with technical reports that will describe the supporting data and database, explain how the data were interpreted in developing the latest revision of map, and highlight its strengths and limitations. The new map will actually consist of a set of maps, which will show the basement topography in relation to aquifer geology, surface topography, and the locations of drinking water production wells and aquifer observation and monitoring wells. These maps will be available to other geologists and



Outcrop of weathered basalt on the summit of Mt Alutom, which gives its name to the entire unit of basement rock beneath the limestone plateau of northern Guam.

engineers in the public and private sectors, for which they will enhance the success and thereby reduce the cost of ongoing aquifer development. They will also be essential tools to environmental scientists, regulators, and policy-makers seeking to develop appropriate regulations for aquifer protection and sustainable management.



Revised contour map of the volcanic basement underlying the limestone plateau in northern Guam.

2. PCB Biomonitoring Strategy Development for Guam's Coastal Waters, Part II PCBs are a ubiquitous group of contaminants that were once widely used in industry. Considered by USEPA to be probable carcinogens, they accumulate within food chains, and are recognized endocrine disruptors. PCBs from land-based sources are transported into coastal waters via polluted rivers and streams, contaminated groundwater, urban runoff, seepage from landfills and wastewater discharges. Contaminated coastal sites on Guam exist at Apra Harbor, Orote Point and Cocos Island. The PCB status of other nearshore waters around the island is largely unknown. Previously we examined the brown seaweed, *Padina boryana*, as a biomonitor for PCBs in Guam's coastal waters. Culturing techniques were explored and a simple, convenient and cost-effective way of transplanting the seaweed into coastal areas where it does not normally occur was developed (see FY 2013 Status Report). The work outlined here extends the scope of this research and examines the biomonitoring potential of another common and widespread resident of Guam's nearshore waters, namely the soft coral, *Sinularia polydactyla*.



Sinularia polydactyla soft coral colony

### Earlier WERI studies showed S. polydactyla

accumulate PCBs to levels several orders of magnitude above ambient. However, the influence of intrinsic and extrinsic variables upon the organism's ability to do this was unknown. Within- and between-colony variations in PCB levels were thus examined in field representatives to determine the most appropriate part of coral colonies for retrieving multiple samples over multiple years. The variable effects of growth, age, sex, season and position in the water column were also examined. All uptake and depuration kinetic studies



PCB uptake& loss in *S. polydactyla* transplanted between clean and contaminated waters

made use of wild populations of *S. polydactyla* translocated and relocated between relatively clean and contaminated coastal environments of Guam. Specimens were thus exposed to PCBs in their natural setting.

Spawning was found to impact PCB concentrations. Due to rapid physiological changes, within-colony differences were significant. Increases in lipid content in reproductively active portions of the colony were not matched by increases in PCBs. During spawning, the new lipids were offloaded while PCBs were not. Postspawn, within-colony differences abated. Gender and water column position were not significant factors. Most importantly, there was little variation among colonies. Analysis by lipid weight eliminated differences between age/size groups. Overall, the comparison studies revealed that *S. polydactyla* is well suited for biomonitoring outside of the spawning season.

3. Development of a Hydrologic Map Series for the Northern Guam Lens Aquifer

The Northern Guam Lens Aquifer is Guam's primary source of water, and if managed properly will continue to supply the island's daily water needs for generations to come. It is also a very complex hydrogeologic system. No simple technique or approach can characterize this aquifer. Rather, a multi-layer analysis is required to describe, model, and manage the groundwater system. The development of a series of hydrogeologic maps that captures each of the components—while also providing a means for showing their interrelationships—is of basic and utmost importance for successful exploration, development, and management of the aquifer.

The creation of an up-to-date map of the basement topography (also described in the section, The Northern Guam Lens Aquifer Database) has provided the first step toward an integrated, multi-layered hydrologic map. The new map includes not only updates of the boundaries of the aquifer's six groundwater basins, but also provides for more accurate and detailed demarcation within each basin of its three groundwater zones: basal, para-basal, and supra-basal. This year's update incorporates new insights gained from the 2010 Exploratory Drilling Program funded by *Naval Facilities Engineering Command Pacific* (AECOM Technical Services Inc., 2011), and the 2013 *Guam Groundwater Availability Study* (Gingerich, 2013; Gingerich and Jenson, 2010).

The new map specifically shows no-pumping simulation from the modeling study to estimate the water-table, hydraulic gradients, flow lines, and basin boundaries. The modeled lens geometry shows the estimated location of boundaries of the para-basal zone. Drill-logs and contours of supra-basal waters (ICF Technology, 1995) were also incorporated in the map. Occurrence of surface streams over the Hagåtña Basin and adjacent terrain were also included. Semi-transparent surface hill-shading provide a surface elevation perspective of the limestone plateau. Other hydrologic features that will be added to the current map or included in complementary maps in the series, include hydraulic conductivities, geologic features, soils, porosities, pumping effects, groundwater locality of sustainable limit supply, land cover, and rainfall distribution.



The first complementary map, which will be published during the coming year, is a map of the sinkholes on the aquifer surface, which constitute its drainage system. Spatial analysis of LiDAR-based digital elevation model allows a precise determination of closed contour depressions on the limestone plateau.



Mapping these depressions and their relationships to other hydrologic and geologic features will be a major contribution to determining the distribution of recharge between fast vertical conduit flow channels and slow percolation through the bedrock. This is important to the refinement for accurately modeling aquifer recharge and potential contaminant entry and flow paths.

- AECOM Technical Services Inc., 2011, Guam Water Well Testing Study to Support US Marine Corps Relocation to Guam: Naval Facilities Engineering Command, Pacific.
- Gingerich, S. B., 2013, The effects of withdrawals and drought on groundwater availability in the Northern Guam Lens Aquifer, Guam: U.S. Geological Survey Scientific Investigations Report v. 2013–5216, p. 76.
- Gingerich, S. B., and Jenson, J. W., 2010, Groundwater availability study for Guam; goals, approach, products, and schedule of activities: U.S. Geological Survey Fact Sheet 2010–3084, p. 4.
- ICF Technology, I., 1995, Final Report: Groundwater dye trace program and well cluster proposal for the landfill area, Andersen Air Force Base, Guam: Archived at University of Guam Library, Mangilao, Guam, USAF-672-B.

# 4. VADOCHARGE-N: a Vadose Flow and Nitrogen Transport Model for the Northern Guam Lens Aquifer

VADOCHARGE-N is an innovative groundwater model that simulates meteoric recharge and nitrogen fate during vadose transport in the Northern Guam Lens Aquifer (NGLA). The purpose of this study is to develop a tool to evaluate and predict nitrogen contamination of the island's limestone aquifer from septic effluent and sewer line discharge. This modeling effort

contributes to environmental engineering, science, and management of water source quality by providing a novel way to elucidate the impact of domestic sewage discharge in a complex karst aquifer system.

Development over the NGLA is a sewage contaminant ion vulnerability concern. The source of nitrogen tested in production wells may be anthropogenic. Although the deep vadose zone may provide adequate filtering of fecal coliform, sewage nitrogen species percolating with the wastewater discharge is converted by nitrification to nitrate, which is transported to the water table.



VADOCHARGE-N applies the antecedent model VADOCHARGE (Habana et al. 2013) to

Nitrate-N transport from sewer leak scenarios and non-sewer resident sources, Machanao-Finegayan domain.

describe the flow of meteoric and wastewaters, using a vertical cell series routing algorithm based on USACE SSARR, method of cascading weirs. In each cell-phase, nitrogen constituents undergo conditional chemical kinetic transformations to simulate the nitrogen cycle transformations as it percolates. The model output is organic-N, ammonia-N, nitrate-N, and wastewater volume in specified source routers, and meteoric recharge to every node-cell of a phreatic model mesh. This output was coupled to USGS' SutraGUI in Argus ONE, a finite element flow and transport model, to simulate the phreatic transport of nitrate-N. Considering that the nitrate-N in production wells are truly of an anthropogenic source, the concentrations of nitrate-N that arrive at the water table via deep vadose transport, required about 12-20 ppm in 1-2 m<sup>3</sup> of wastewater, daily, to reach the production wells at the observed concentrations.

VADOCHARGE-N's innovativeness provides five significant contributions to Guam's water and environmental research. First, it couples vadose and phreatic solute transport models, VADOCHARGE-N and SutraGUI (USGS). It may be coupled to other phreatic flow models as well. It incorporates a fast and slow meteoric transfer through karst using a modified cascading weir algorithm. This unique innovation may be applicable to other similar karst aquifers. It incorporates nitrogen transport and transformation during deep vadose percolation, which is a new contribution to a poorly understood process. It extends Guam's groundwater flow models into N-transport, which is the first of its kind for this type of aquifer. Finally, this constitutes a new tool to help local civil developments above the water source, in an effort to maintain both quantity and quality.

Habana, N.C., L.F. Heitz, A.E. Olsen and J.W. Jenson (2013). VADOCHARGE: Groundwater Recharge Model for an Uplifted Island Karst Aquifer, Guam, USA, International Journal of Environmental Engineering and Science and Technology Research Volume 1(8), 141-164.

Habana, N. C., Salvacion, J. L., Jenson, J. W. and J. D. Rouse (2013) VADOCHARGE-N: a Vadose Flow and N-Transport Simulation Model for the Northern Guam Lens Aquifer, International Journal of Environmental Engineering Science and Technology Research, Volume 1(11), 268-287.

## **GHS Sponsored Research Projects Ongoing in FY'14:**

One of the priorities of the PL24-247 is maintenance and routine update of the Guam Hydrological Database and routine trend analyses of the data. In response, is the ongoing project pertaining to the management and data analyses of the Northern Guam Aquifer Database. The significance and current status of this study is outlined below.

### 1. The Northern Guam Lens Aquifer Database

The *Northern Guam Lens Aquifer* (NGLA) *Database*, WERI Technical Report 141, is the first of a set of three related technical reports that provide basic information essential for successful development and management of the NGLA. In preparing the database over 4,000 pages of documents were scanned and organized into individual electronic folders for each of the 525 wells documented so far. These include 20 exploratory wells, 115 observation/monitoring wells, 212 drinking water wells, 39 agricultural/industrial wells, and 104 stormwater management wells. Each well folder is electronically linked to its corresponding record in a Microsoft Excel<sup>®</sup> spreadsheet and webpage, which contains key engineering and hydrogeological data. To organize, classify, and relate the enormous amount of disparate data required development of a classification system for the data. The technical report is thus designed as a user's manual for the database, providing a detailed description of the indexing system, along with definitions and conventions adopted or devised; data complexities, nuances, limitations; and assumptions and choices made in interpreting and classifying data.



**NGLA Trilogy** 

The database is also the primary data source for WERI's topographic map of the basement rock beneath the aquifer, which is described in the second report in the series, Technical Report 142, *Topography of the Basement Rock beneath the Northern Guam Lens Aquifer and Its Implications for Groundwater Exploration and Development*. Creation of the map employed the latest data screening and spatial analysis techniques to evaluate 697 records, from which 173 control points were applied to the map. The new map updates the boundaries of the aquifer's six groundwater basins and provides for more accurate demarcation within each basin of its *basal zone*, where freshwater is underlain by saltwater, *para-basal zone*, where freshwater is underlain by basement rock below sea level, and *supra-basal zone*, where conduits and discontinuous patches of freshwater are underlain by basement rock above sea level. The new map also incorporates new insights regarding groundwater occurrence gained from the broad-ranging 2010 Exploratory Drilling Program funded by *Naval Facilities Engineering Command Pacific*. The report concludes with recommendations regarding groundwater exploration, aquifer development, and maintenance and improvement of the basement map

The third in the series, Technical Report 143, Analysis of Salinity in the Northern Guam Lens Aquifer, examined records from 118 production wells operated by Guam Waterworks Authority (GWA); 25 production wells owned and operated by the Naval Facilities Engineering Command Marianas (NAVFACMAR); 11 freshwater production wells under private ownership; 9 test borings and 2 monitoring wells recently installed in 2010 by NAVFACMAR; and 12 monitoring wells maintained and serviced by the University of Guam's Water & Environmental Research Institute of the Western Pacific (WERI) in collaboration with the U.S. Geological Survey (USGS). The study builds on the 2003 study by McDonald and Jenson, Technical Report 98, Chloride History and Trends of Water Production Wells in the Northern Guam Lens Aquifer, covering the 12 years from 1999 through 2010, and including records from Air Force and private freshwater production wells. It thus comprises the most comprehensive historical evaluation to date of the occurrence and factors contributing to changes in groundwater salinity in the Northern Guam Lens Aquifer. Spatial patterns and temporal trends observed in production and monitoring wells are compared with records of rainfall, sea level, and the Southern Oscillation Index, as well historical pumping rates.

The National Institutes for Water Resources (NIWR) honored the project in a 2013 with its annual National Impact Award, as the outstanding NIWR project of the year contributing to effective management of the nation's water supply. The data collected for it are now incorporated into the NGLA database. All three of these products (database, basement map, and salinity study) will soon be available online to authorized users. This works supports and complements the groundwater model study led by USGS in collaboration with WERI. The set of reports provides information essential for successful exploration, development, and sustainable management of Guam's groundwater.

## SUMMARY OF FY'14 EXPENDITURES FOR GUAM HYDROLOGIC SURVEY APPROPRIATION

Below is a composite summary of all expenditures lodged against the GHS account during FY'14. As in past years, budgetary shortfalls arising out of austerity measures implemented by the Guam Legislature have so far been covered by carryover funds from GHS allotments received in previous years. As these reserves are limited they cannot be expected to sustain the program at its current high rate of activity for too much longer. This notwithstanding, we gratefully acknowledge the Guam Legislature for their continued interest in and support of the GHS program and all associated water resources related research, education and training activities carried out at WERI.

Cate	egory	Expenditure			
1.	Salaries and Wages:	\$75,655.98			
2.	Fringe Benefits:	\$24,415.34			
3.	Tuition Fees	\$0.00			
4.	Supplies:	\$5,963.03			
5.	Computer Hardware/Software:	\$2,775.00			
6.	Equipment:	\$5,367.55			
7.	Projects/Consultant Fees:	\$9,262.50			
8.	Postage/Long Distance Phone:	\$436.34			
9.	Printing:	\$1,959.00			
10.	Utilities/Subscription/Dues:	\$208.00			
11.	Administrative Fees*:	\$18,269.40			
Tot	al FY'14 Expenditures:	\$144,312.14			
Tota	al FY'14 GHS Allotment Rec'd as of 10/14:	\$138,538.40			
Bala	ance:	-\$5,773.74			
Tota	al Approved GHS Budget Allotment for FY'14:	\$182,694.00			

Guam Hydrologic Survey Expenditure Summary for FY'14\_\_\_\_\_

Category	Expenditure		
1. Projects/Consultant Fees:	\$144,580.00		
2. Administrative Fees*:	\$15,562.60		
Total FY'14 Expenditures:	\$144,580.00		
Total FY'14 GHS-CM Allotment Rec'd:	\$118,008.80		
Balance:	-\$26,571.20		

GHS Comprehensive Monitoring Expenditure Summary for FY'14

Total Approved GS-CM Budget Allotment for FY'14: \$155,626.00

\* University of Guam cost sharing administrative fee of 10% levied against all special appropriations received from the Guam Legislature.

## COMPREHENSIVE WATER MONITORING PROGRAM (CWMP)

The United States Geological Survey (USGS) has monitored our island's water resources since 1951. Unfortunately, during the 1990s they were forced to downsize this program because matching support from the Government of Guam was discontinued. This resulted in the abandonment of all deep monitoring wells needed to monitor saltwater intrusion in the north, and most of the stream gages in the south by the mid-1990s. In 1995, the USGS closed its field office at Naval Station, but continued to run a limited monitoring program (out of its Saipan and Honolulu offices).

In August, 1998 the CWMP was made a permanent part of WERI's program when Governor Gutierrez signed PL 24-247. This resulted in the refurbishment of the deep monitoring wells and a renewed program of water resource monitoring on Guam. The intent of PL 24-161 was to restore, and then to expand, as needed, the discontinued monitoring program in order to help Guam manage and safeguard all of its freshwater resources, now and in the future. Under PL 24-161, WERI/UOG and the USGS entered into a memorandum of understanding to administer and fund this program on a 50/50 cost-sharing basis. The CWMP is a permanent investment in Guam's future.

A well-designed long-term CWMP can save communities millions of dollars, and even human lives, by providing critical information for water-supply, culvert and bridge design, delineating flood-hazard areas, and tracking effects of climate change. The USGS started a water-resource monitoring program in Guam in 1951 with installation of stream gages at Pago, Lonfit, and Tolaeyuus and a rain gage near Fena dam. At the same time, measurements of discharge from

Almagosa Springs and water levels in Fena Reservoir started. Since 1951 about 22 continuous streamflow, 8 rain, and 16 groundwater monitoring stations have been operated, providing reliable information on the water resources and hydrologic hazards of Guam.

Currently, USGS monitoring on Guam consists of 6 continuous-recording streamflow gages, 8 continuousrecording groundwater wells, 7 groundwater wells where the thickness of the freshwater lens is measured, and 8 continuous-recording rain gages. From a broad perspective, the program provides long-term information on the hydrologic cycle of Guam so that its water resources can be understood and sustainably managed. The bulk of the monitoring stations on Guam are funded as part of a Joint Funding Agreement between the USGS and WERI.



Locations of USGS monitoring stations on Guam

## Stream Gages for Water Availability and Flood Planning in Southern Guam

Most freshwater used in southern Guam comes either from streamflow or wells that withdraw water from near the banks of streams. Data from USGS stream gages provide information needed by managers and engineers to properly manage the long-term sustainability of these water resources. Statistical analysis of long-term streamflow data are needed so the effects of abnormally wet or dry years can be understood and planned for. For example, USGS gages provide information that can be used to assess and manage the sustainability of surface water from the GWA Ugum Treatment Plant. Other gages, funded in cooperation with the U.S. Navy, are used to manage withdrawals from Fena Reservoir.

Long-term streamflow information is needed for flood planning. This information is used to delineate flood zones, estimate the magnitude of floods and frequency with which they could be expected to occur, and design



Geus River during low flow versus high flow conditions.

bridges and culverts. For example, information from 11 stream gages and 3 other sites was used to assess the flood peak magnitude and recurrence interval following Typhoon Chata'an in 2002. FEMA uses information from USGS stream gages to determine the level of financial aid from FEMA after storms. Currently, the WERI-USGS CWMP funds the operation of 3 stream gages at key locations in southern Guam.

## Well Monitoring of the Northern Guam Lens Aquifer



A WERI research assistant and in northern Guam.

Monitoring wells operated as part of the USGS-WERI CWMP provide information to assess the health and sustainability of the Northern Guam Lens Aquifer. This aquifer is the most important source of freshwater on the island. Currently, the program includes 8 wells where water level is continuously measured and 7 wells where the thickness of the freshwater lens is measured biannually. Collectively, this information allows scientists at WERI, GEPA, GWA, and USGS to understand the flow of water through the aquifer and refine sustainability estimates of

this resource. This information is used to understand how USGS hydrogeologist collecting data current levels of pumpage are affecting the aquifer and how from a groundwater monitoring well future changes in climate and groundwater production may affect the sustainability of groundwater resources. Coupled

with detailed geologic mapping and modern hydrologic tools such as groundwater flow models, information from this long-term program will be invaluable as additional water is needed to support increasing economic development on Guam.

## Rainfall Data to Estimate Water Supply Recharge and Flood-Water Distribution

The USGS currently operates 8 rain gages on Guam, 6 of which are funded by the WERI-USGS CWMP. Rainfall data are fundamental to understanding the water supply and threats from flooding. Information from these gages is used to evaluate the extent of drought during El Nino events and the severity of flooding during typhoons. Information from rain gages is also essential in determining how much freshwater infiltrates past the ground surface to reach the water table. This water, known as recharge, is the source of freshwater in the Northern Guam Lens Aquifer and only by measuring rainfall can its abundance be accurately estimated.

## What does it cost to operate a stream flow and other gages?

In fiscal year 2015, the cost to operate a continuous-record streamflow gage will be \$21,683. This includes all operation and maintenance, site visits, field data collection, data analysis, and computation of the flow record. Gage operations are frequently reviewed and upgraded as improvements become available. Other gages, such as rainfall (\$10,413) and groundwater (\$6,919), require less funding. With over 100 years of experience, USGS procedures ensure that data are reliably collected, analyzed, and publicly available

## How can one get USGS water resource information?

Most data from USGS gages are readily available on the internet. As part of CWMP between WERI and the USGS, historic data and other hydrologic information for Guam are consolidated and made publicly available at: http://hi.water.usgs.gov.

## New deep monitor wells and expanded monitoring for the Northern Guam Lens Aquifer

Accurate and detailed data on aquifer hydrology and geology is the foundation for sustainable management of groundwater resources; especially on the island of Guam where fresh groundwater is limited and vulnerable to saltwater intrusion. Given the anticipated expansion of groundwater production from the Northern Guam Lens Aquifer during the coming decades, expansion of the existing hydrologic data collection network needs to begin in FY 2013. Baseline data are critically needed in areas targeted for development. These data will enable managers to evaluate and consider seasonal and long-term changes in rainfall, groundwater levels, and salinity in relation to sustainable groundwater production from the Northern Guam Lens Aquifer. The successful application of modern management tools, especially numerical groundwater models such as the one currently under development in cooperation with the U.S. Marine Corps, is crucially dependent on reliable aquifer-wide data on the responses of the freshwater lens to changes in the amounts and distribution of recharge and production. Proposed intensive development creates a need for additional data that the existing network cannot provide. Approximate locations where eight new deep monitor wells are needed are identified on the map below. The precise location of each new well will be constrained by landowner access, land use, and local hydrogeological factors. The cost of design and construction for each new deep monitor well is estimated to be \$100,000. The prioritization and cost share agreement for well installation and monitoring will require inter-agency cooperation as defined in the Memorandum of Understanding between the Guam Waterworks Authority and the U.S. Navy dated July 16, 2011.



Location of monitoring and production wells and rain gages in the Northern Guam Lens Aquifer

#### WERI RESEARCH PUBLICATIONS ARISING FROM GHS SPONSORED PROGRAMS

#### 2014

- Morrison, R.J., G.R.W. Denton, U. Bale Tamata and J. Grignon (2014). Anthropogenic Biogeochemical Impacts on Coral Reefs in the Pacific Islands - An Overview. Deep-Sea Research II, 6: 5-12
- Schaible, B.C. and G.R.W. Denton (2013). Utility of the Brown Alga, *Padina boryana*, as a Biomonitor of Polychlorinated Biphenyls (PCBs) in Tropical Marine Waters: A Preliminary Assessment. *WERI Technical Report*. 34 pp.
- Denton, G.R.W. (2013). Metal Deficiencies and Imbalances in Wetland Plants from a Manganese-Enriched Wetland in Southern Guam: A Possible Lytico-Bodig Connection? APASEEM General Meeting, November 20-21, 2013, American Memorial Park Auditorium, Saipan.
- Denton, G.R.W. and C.M. Denton (2014). Regulatory Framework and Monitoring Strategies Adopted by GWA for the Sustainable Production of Safe Drinking Water from the Northern Guam Lens Aquifer. *Regional Islands Sustainability Conference*, Hyatt Regency, Tumon, Guam, April 15-16 2014.
- Denton, G.R.W. and J.W. Jenson (2014). Wind, Weather Watersheds and Water Quality: WERI Regional Research. Annual UOG Faculty Development Day, Hyatt Regency, Tumon, Guam February 21, 2014.
- Denton, G.R.W. and S. Namazi (2014). Indoor Radon Levels and Lung Cancer on Guam, 35<sup>th</sup> Annual Research Conference, University of Guam, March 11, 2014.
- Taboroši, D., Jenson, J. and Stafford, K.W. (2014). "Artefatos militares e uso de cavernas durante a Segunda Guerra Mundial nas Ilhas Marianas, Pacífico Oeste (World War II artifacts and wartime use of caves in the Mariana Islands, Western Pacific)." *Caderno de Geografia* 24(42): 218-231.
- Stafford, K.W., Taboroši, D. and Jenson, J.W. (2013). Caves and Karst Hydrology of the Mariana Islands. *Coastal Karst Landforms*. Lace, M.J. and Mylroie, J.E. Dordrecht, Springer. 5: 277-298.
- Bendixson, V.M. (2013). "The Northern Guam Lens Aquifer Database." WERI Technical Report No. 141: 45.
- Mccutcheon, A., Raymundo, L., Prouty, N., Jenson, J., Lander, M. and Randall, R. (2014). Coral Growth Calibration of the Sr/Ca Proxy for SST Reconstruction in Guam. *17th Biennial Ocean Sciences Meeting*. Honolulu, Association for the Sciences of Limnology and Oceanography (ASLO), The Oceanography Society (TOS), and the American Geophysical Union (AGU).

Moore, M., Hardt, B., Banner, J. and Jenson, J. (2013). Program & Abstracts: Evaluation of

speleothem oxygen isotope fractionation from a tropical cave on the island of Guam. *Fall Meeting, American Geophysical Union*. San Francisco: December 9-13, 2013.

- Jenson, J.W., Taboroŝi, D., Rotzoll, K., Mylroie, J.E., and Gingerich, S.B. (2013). Symposium Program and Abstracts: A hypothesis for carbonate island karst aquifer evolution from analysis of field observations in northern Guam, Mariana Islands. *International Symposium on Hierarchial Flow Systems*. Mádl-Szőnyi, J., Erőss, A., Mindszenenty, A. and Tóth, A.
- Mccann, S., Mylroie, J.E., Jenson, J.W. and Lander, M.A. (2013). Meteorological Conditions Affecting Speleothem Paleoclimate Record in a Tropical Cave, Guam, Mariana Islands. *National Speleological Society Convention*. Shippensburg University, PA.
- Habana, N.C., Salvacion, J.L., Jenson, J.W., Rouse, J.D. "VADOCHARGE-N: a Vadose Flow and N-Transport Simulation Model for the Northern Guam Lens Aquifer." *International Journal of Environmental Engineering Science and Technology Research*. November 2013, Vol. 1, No. 11, 268-287; ISSN: 2326-3113.
- GIS-based screening for cumulative and secondary impacts from development projects in northern Guam. WERI Technical Report No. 146, December 2013.

#### 2013

- Taborosi, D., Jenson, J.W., and Mylroie, J.E., 2013, Field observations of coastal discharge from an uplifted carbonate island aquifer, northern Guam, Mariana Islands: A descriptive geomorphic and hydrogeologic perspective, Journal of Coastal Research, v. 29, no. 4, p. 926-943.
- Bell, Tomoko, John W. Jenson, Mark A. Lander, Richard H. Randall, Judson W. Partin, Benjamin F. Hardt, and Jay L. Banner, 2011, Coral and Speleothem in situ Monitoring and Geochemical Analysis: Guam, Mariana Islands, USA, WERI Technical Report No. 136: Mangilao, Water & Environmental Research Institute of the Western Pacific, University of Guam, Mangilao, Guam, 70 p.
- Habana, N.C., Salvacion, J.L., Jenson, J.W., and J.D. Rouse, in review. VADOCHARGE-N: a Vadose Flow and N-Transport Simulation Model for the Northern Guam Lens Aquifer. 2013 International Conference on Sustainable Environmental Technologies, Mapúa Institute of Technology, Intramuros, Manila, Philippines.
- Schaible, B.C. and G.R.W. Denton (2013). Utility of the Brown Alga, *Padina boryana*, as a Biomonitor for Polychlorinated Biphenyls (PCBs) in Tropical Marine Waters: A Preliminary Assessment. WERI Technical Report. 34 pp.
- Simard, C.A., Jenson, J.W., Lander, M.A., 2013, in review. Analysis of Salinity in the Northern Guam Lens Aquifer. In: Savarese, M., Glumac, B. (Eds.), 16th Symposium on the Geology of the Bahamas and Similar Regions, Gerace Research Center, San Salvador Island, Bahamas.

Sh. Khosrowpanah, 2013. "Watershed Management: Ugum and Piti-Asan Watersheds", Presented at 27<sup>th</sup> Pacific Islands Environment Conference, Guam, June 26-28, 2013.

#### 2012

- Jenson, J., Roff, D., Bendixson, V., Hylton, T., Simard, C. (2012). New Insights and Questions from Exploratory Drilling in the Northern Guam Lens Aquifer, 16<sup>th</sup> Symposium of the Geolgy of the Bahamas and other Carbonate Regions, Gerace Research Center, San Salvador Island, Bahamas.
- Luo, Q.C., Khosrowpanah, S. (2012). Continuing Calibration and Application of Luom in the Southern Guam Watersheds Not Covered in the Preceding Project, *Water and Environmental Research Institute (WERI) Technical Report*, No. 131, 68 pp.
- Miklavič, B., Mylroie, J.E., Jenson, J.W., Randall, R.H., Banner, J.L., Partin, J.W. (2012).
   Evidence of the Sea-level Change Since MIS 5e on Guam, *Tropical West Pacific, NSF* Workshop: Sea Level Changes Into MIS 5: From Observations to Predictions, April 10-14, 2012, Palma de Mallorca, Mallorca, Spain.
- Miklavič, B., Mylroie, J.E., Jenson, J.W., Randall, R.H., Zabukovec Logar, N., Taboroši, D. (2012). Denudation of Eogenetic Limestone During the Last Glacial Cycle in a Tropical Environment. 20<sup>th</sup> International Karstological School "Classical Karst", Karst forms and Processes; 18th to 23rd June, 2012; Karst Research Institute, Postojna, Slovenia.
- Partin, J.W., Jenson, J.W., Banner, J.L., Quinn, T.M., Taylor, F.W., Sinclair, D., Hardt, B. Lander, M.A., Bell, T., Miklavič, B., Jocson, J.M.U., and Taboroši, T. (2012).
  Relationship between Modern Rainfall Variability, Cave Dripwater and Stalagmite *Geochemistry in Guam, USA: Geochemisty, Geophysics, Geosystems*, 13 (3): 1-17.
- Sinclair, D., Banner, J.L., Taylor, F.W., Partin, J.W., Jenson, J.W., Mylroie, J.E., Goddard, E., Quinn, T.M., Jocson, J.M.J., and Miklavič, B. (2012). Magnesium and Strontium Systematics in Tropical Speleothems from the Western Pacific: *Chemical Geology*, v 294-295: 1-17
- Simard, C.A. (2012). Analysis of Salinity in the Northern Guam Lens Aquifer, MS Thesis, University of Guam, Mangilao, Guam, 84 pp.
- Simard, C., Jenson, J.W., Lander, M.A. (2012). Salinity Trends in the Northern Guam Lens Aquifer, 16<sup>th</sup> Symposium of the Geolgy of the Bahamas and other Carbonate Regions, Gerace Research Center, San Salvador Island, Bahamas.

#### 2011

Bell, T., Endo, T., Jenson, J.W., Bell, R., and Lander, M.A. (2011). Pneumatic Underwater Drill for Extracting Coral Cores, *Water and Environmental Research Institute (WERI) Technical Report*, No. 135: 18 pp.

- Bell, T., Jenson, J.W., Lander, M.A., Randall, R.H., Partin, J.W., Hardt, B.F., and Banner, J.L. (2011). Coral and Speleothem *in situ* Monitoring and Geochemical Analysis: Guam, Mariana Islands, USA, *Water and Environmental Research Institute (WERI) Technical Report*, No. 136: 70 pp.
- Denton, G.R.W. and Sian-Denton, C.M. (2011). A Retrospective Analysis of Water Quality Data for Chemicals of Concern in Guam's Groundwater: Emerging Trends and Future Concerns, Abstract, 14-16 November, Water Resources Research Center, University of Hawaii at Manoa, National Institutes for Water Resources, Honolulu, HI.
- Jenson, J.W., Lander, M.A., Randall, R.H. (2011). Vadose Flow in the Northern Guam Lens Aquifer, Water Resources Sustainability Issues on Tropical Islands, Abstract, 14-16 November, Water Resources Research Center, University of Hawaii at Manoa, National Institutes for Water Resources, Honolulu, HI.
- Kottermair, M., Golabi, M., Khosrowpanah S. and Wen, Y. (2011). Spatio-temporal Dynamics of Badlands in Southern Guam: A Case Study of Selected Sites, *Water and Environmental Research Institute (WERI) Technical Report*, No. 133, 90pp.
- Partin, J.W., Jenson, J.W., Banner, J.L., Quinn, T.M., Taylor, F.W., Sinclair, D., Lander, M.A., Bell, T., Miklavič, B., Jocson, J.M.U., Hardt, B., and Taboroši, D. (2011). Relationship between Rainfall Variability, Cave Dripwater and Stalagmite Geochemistry in Guam, USA: *Earth and Planetary Science Letters* (in press).
- Sinclair, D., Banner, J.L., Taylor, F.W., Partin, J.W., Jenson, J.W., Mylroie, J.E., Goddard, E., Quinn, T.M., Jocson, J.M.U., and Miklavič, B. (2011). Magnesium and Strontium Systematics in Tropical Speleothems from the Western Pacific: *Chemical Geology* (in press)
- Sinclair, D., Banner, J.L., Taylor, F.W., Partin, J.W., Jenson, J.W., Mylroie, J.E., Goddard, E., Quinn, T.M., and Jocson, J.M.U. (2011). Magnesium and Strontium Systematics in West Pacific Speleothems *Quatenary Science Reviews* (in press).
- Wen, Y. (2011). Impacts of Human Activities on Groundwater Quality in Guam, Mariana Islands, International Journal of Environmental, Cultural, Economic and Social Sustainability, 7 (5): 243-256.
- Wen, Y., Khosrowpanah, S., and Heitz, L. (2011). Land Cover Change of Watersheds in Southern Guam from 1973 to 2001, *Environmental Monitoring and Assessment*, 179 (1-4): 521–529 (DOI 10.1007/s10661-010-1760-5).
- Wen, Y. (2011). Application of Multi-temporal and Multi-source Data for Land Cover Change Detection in Guam, USA, *Proceedings of the 19<sup>th</sup> International Conference on GeoInformatics*, June 24-26, 2011, Shanghai, China, published in IEEE Xplore in August, 2011 (DOI: 10.1109/GeoInformatics.2011.5981058, and Print ISBN:978-1-61284-849-5).

#### 2010

- Denton, G.R.W. and Sian-Denton C.M. Groundwater Monitoring on Guam (2010): Management Responses to Recent Water Quality Violations, *Journal of Groundwater Monitoring and Remediation* Spring 2010: 127-133.
- Hoffman, S.M., J.W. Jenson, G.R.W. Denton, D.C. Moran and L.L. Vacher (2010). Background Fluorescence in Guam's Coastal Waters. *Proceedings American Water Resources Association (AWRA) 2010 International Specialty Conference & 8th Caribbean Islands Water Resources Congress on Tropical Hydrology and Sustainable Water Resources in a Changing Climate*, August 30 - September 1, 2010, San Juan, Puerto Rico. American Water Resources Association.
- Khosrowpanah, S., Y. Wen, and M. Kottermair (2010). Spatial Distribution of Badlands in the Ugum Watershed: Characterization and Temporal Analysis. *Water and Environmental Research Institute (WERI) Technical Report*, No. 126: 29 pp
- Luo, Q.C. and S. Khosrowpanah (2010). Developing the LUOM in Southern Guam Watersheds. *Proceedings of 4th International Workshop on Catchment-Scale Hydrological Modeling and Data Assimilation*, Lhasa, China, 21-23 July 2010.
- Luo, Q.C., and S. Khosrowpanah (2010). Calibration and Application of LUOM in Southern Guam Watersheds With and Without Flow Data, *Water and Environmental Research Institute (WERI) Technical Report*, No. 128: 87.
- Miklavič, B., Mylroie, J.E., Jenson, J.W., Randall, R.H., Banner, J.L., and Partin, J.W. (2010). Interglacial Limestone and its Geomorphic Features on Guam: Implications for Relative Sea Level Changend Flank Margin Cave Formation. <u>In</u>: Gamble, D.W., ed., 15th Symposium of the Geolgy of the Bahamas and other Carbonate Regions: Gerace Research Center, San Salvador Island, Bahamas (in press).
- Wen, Y. (2011). Land Cover Change of Coastal Watersheds in Southern Guam from 1973 to 2001, *Environmental Monitoring and Assessment* (in press).

#### 2009

- Habana, N., L.F. Heitz, A.E. Olsen and J.W Jenson (2009). Vadose Flow Synthesis for the Northern Guam Lens Aquifer. Water and Environmental Research Institute (WERI) Technical Report, No. 127: 223 pp.
- Luo, Q. C. and S. Khosrowpanah (2009). Developing the LUOM in southern Guam watersheds without flow data, *Proceedings of AWRA 2009 Annual Water Resources Conference*, Seattle, Washington, November 9-12, 2009.
- Lander, M.A. and Jenson, J.W. The Post-1997 El Niño Sea-Level Highstand in Micronesia: A Bona Fide Climatic "Hockey Stick" (in prep).

Sinclair, D.J., Taylor, F.W., Banner, J.L., Jenson, J.W., Mylroie, J.E., Goddard, E. and Quinn, T.M. (2009). Speleothem Evidence for Global Changes in Atmospheric Circulation During the Early-Mid Holocene, *Quaternary Science Reviews*. (in review).

#### 2008

Denton, G.R.W. and R.J. Morrison (2008). Impact of a Rudimentary Landfill on the Trace Metal Status of Pago Bay, Guam. *Marine Pollution Bulletin*, 58: 150-162

#### 2007

- Denton, G.R.W., M.C. Olsen and Y. Wen (2007). Solid Waste Disposal on Guam: Impact of an Unsanitary Landfill on the Heavy Metal Status of Adjacent Community Representatives. <u>In:</u> Wang, Y. et al. (Eds.). *Progress in Environmental Science and Technology*, vol 1. Science Press, Beijing, pp1169-1176.
- Hoffman, S.M., J.W. Jenson, D. Moran, G.R.W Denton, H.R. Wood and L. Vacher (2007). A Qualitative Baseline Study of Background Fluorescence in Guam's Groundwater. *Water and Environmental Research Institute (WERI) Technical Report* 57 pp.
- Khosrowpanah, S., L.F. Heitz, Y. Wen and M. Park (2007). Developing a GIS-Based Soil Erosion Potential Model of the Ugum Watershed. *Water and Environmental Research Institute (WERI) Technical Report* No. 117. 98 pp.
- Wuerch, H.V., B.C. Cruz, A.E. Olsen (2007). Analysis of the Dynamic Responses of the Northern Guam Lens Aquifer to Sea Level Change and Recharge. Water and Environmental Research Institute (WERI) Technical Report No. 118, 47 pp.

#### 2006

- Denton, G.R.W., W.C. Kelly III, H.R. Wood and Y. Wen (2006). Impact of Metal Enriched leachate from Ordot Dump on the Heavy Metal Status of Biotic and Abiotic Components in Pago Bay. Water and Environmental Research Institute (WERI) Technical Report No. 113, 63 pp.
- Taboroši, D., J.W. Jenson J.E. Mylroie (2006). Karst features of Guam, Mariana Island, *Micronesica*, 38: 17-46

#### 2005

Khosrowpanah, S. and J. Jocson (2005). Environmental Assessment for Non-Point Sources of Pollution for Ugum Watershed. *Water and Environmental Research Institute (WERI) Technical Report* No. 109, 53 pp.

#### 2004

Jenson, J.W., T.M. Keel, J.E. Mylroie, J.R. Mylroie, K.W. Stafford, D. Taboroši, and C. Wexel (2004). Karst of the Mariana Islands: The Interaction of Tectonics, Glacio-eustasy and Fresh-water/Sea-water mixing in Island Carbonates. GSA Special Paper 404. *Proceedings of the Geological Society of America*, pp. 129-138.

- Taboroši, D., J.W. Jenson and J.E. Mylroie (2004), Karst features of Guam, Mariana Island, Water and Environmental Research Institute (WERI) Technical Report No. 104, 26 pp.
- Taboroši, D., J.W. Jenson and J.E. Mylroie (2004). Karren Features in Island Karst: Guam, Mariana Islands, *Zeischrift fur Geomopholigie*, 48: 369-389.
- Moran, D. C. and J.W. Jenson (2004). Dye Trace of Groundwater Flow from Guam International Airport and Harmon Sink to Agana Bay and Tumon Bay, Guam. *Water and Environmental Research Institute (WERI) Technical Report* No. 97, 32 pp.

#### 2003

- Gamble, D. W., D. Taboroši, J.E. Mylroie, J.W. Jenson, J.L. Carew, J.M.U. Jocson, J.R. Mylroie and D.T. Vann (2003) The Use of Water Temperature to Characterize Groundwater Discharge of a Coastal Fracture on Guam, U.S.A.: *Journal of Coastal Research*, 19: 462-471.
- Quenga McDonald, M. and J.W. Jenson (2003). Chloride History and Trends of Water Production Wells in the Northern Guam Aquifer. *Water and Environmental Research Institute (WERI) Technical Report* No. 98, 64 pp.
- Taboroši, D., J.W. Jenson and J.E. Mylroie (2003). Zones of Enhanced Dissolution and Associated Cave Morphology in an Uplifted Carbonate Island Karst Aquifer, Northern Guam, Mariana Islands: *Speleogenesis and Evolution of Karst Aquifers*, 1: (4), 16 pp.

#### 2002

- Jocson, J.M.U., J.W. Jenson and D.N. Contractor (2002). Recharge and Aquifer Response: Northern Guam Lens Aquifer, Guam, Mariana Islands. *Journal of Hydrology*, 260: 231-254.
- Quenga McDonald, M. (2002). Nitrate-Nitrogen Concentrations in the Northern Guam Lens and Potential Nitrogen Sources. *Water and Environmental Research Institute (WERI) Technical Report* No. 95, 37 pp.

#### 2001

- Lander, M.A., J.W. Jenson and C. Beausoliel (2001). Responses of Well Water Levels on Northern Guam to Variations of Rainfall and Sea Level, *Water and Environmental Research Institute (WERI) Technical Report* No. 94, 36 pp.
- Mylroie, J.E., J.W. Jenson, D. Taborosi, J.M.U. Jocson, D.T. Vann and C. Wexel (2001) Karst Features of Guam. *Journal of Cave and Karst Studies*, 63: 9-22.

#### 1999

Contractor, D.N. and J.W. Jenson (1999). Simulated Effect of Vadose Infiltration on Water Levels in the Northern Guam Lens Aquifer. *Water and Environmental Research Institute* (WERI) Technical Report No. 90, 18 pp.

- Jocson, J.M.U., J.W. Jocson, and D.N. Contractor (1999). Numerical Modeling and Field Investigations of Infiltration, Recharge, and Discharge in the Northern Guam Lens Aquifer. *Water and Environmental Research Institute (WERI) Technical Report* No.88, 22 pp.
- Mylroie, J.L. and J.W. Jenson, J.M.U. Jocson and M.A. Lander (1999). Karst Geology and Hydrology of Guam: A Preliminary Report. *Water and Environmental Research Institute* (WERI) Technical Report No. 89, 32 pp.

#### 1998

Jenson, J.W. and J.M.U. Jocson (1998). Hydrologic Data Collection for Guam. *Water and Environmental Research Institute (WERI) Technical Report* No. 83, 46 pp.

(BBMR PFS-1)

#### FUNCTION: EDUCATION & CULTURE

#### AGENCY: UNIVERSITY OF GUAM

PROGRAM: WATER AND ENVIRONMENTAL RESEARCH INSTITUTE (WERI)

Budget Account Allocation		FY2012		FY2013	FY2014				
FUND TITLE	Fund	Actual Appropriation	Percent of Program	Authorized Appropriation	Current Service	Program Plan	Governor's Recommendation	FY2015 Projected	FY2016 Projected
General Fund Appropriation		\$850,036		\$922,781	\$922,781	\$995,781		\$1,068,781	\$1,141,781
Guam Hydrologic Survey (Local)		\$192,309		\$182,694	\$182,694	\$182,694		\$204,200	\$204,200
Guam Water Monitoring Project (Local)		\$163,817		\$155,626	\$155,626	\$155,626		\$173,948	\$173,648
USGS Water Institute Program (Federal)		\$277,005		\$166,575	\$166,575	\$166,575		\$166,575	\$166,575
USGS Supplemental Program (Federal)		\$24,963		\$19,976	\$19,976	0		0	0
USGS Pacific Islands Climate Center (Federal)		\$83,008		\$83,008	\$83,008	0		0	0
ENSO Application Center (Federal, National Weather Service		\$259,248		\$50,000	\$50,000	0		0	0
National Science Foundation (Federal)		\$164,335		\$164,335	\$164,335	0		0	0
GWUDI Program (Local)		\$69,219		\$69,219	\$69,219	0		0	0
GWUDI Program (Federal)		\$44,870		\$44,870	\$44,870	0		0	0
Total Program Appropriations		\$2,128,810		\$1,859,084	\$1,859,084	\$1,460,676		\$1,613,504	\$1,686,204
Performance Indicators	Туре								
Undergraduate Courses Taught	WKLD	3		1		0		0	0
Graduate Courses Taught	WKLD	8		9		0		0	0
Thesis Committees served (chaired)	WKLD	15(9)		11 (9)		0		0	0
Projects Initiated	WKLD	12		13		0		0	0
Projects completed	WKLD	12		13		0		0	0
Technical Reports	WKLD	5		11		0		0	0
Journal Articles/Conference Proceedings.	WKLD	10		9 (7)		0		0	0
Professional Presentations	WKLD	10		12		0		0	0
Workshops/Conference Presentations	WKLD	2		1		0		0	0