Guam Hydrologic Survey (GHS)

&

Comprehensive Water Monitoring Program (CWMP)

FY 2013 Annual Report

WERI

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

November 2013

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

FY 2013
ANNUAL REPORT

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Director

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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 24th 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, both on Guam and throughout the region.

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 AND FY'12 OBJECTIVES

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'13. 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'13.

PROGRAM OUTCOMES FOR FY'13

GUAM HYDROLOGIC SURVEY (GHS)

In FY'13, 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.

Graduate students in WERI CA-GIS Laboratory

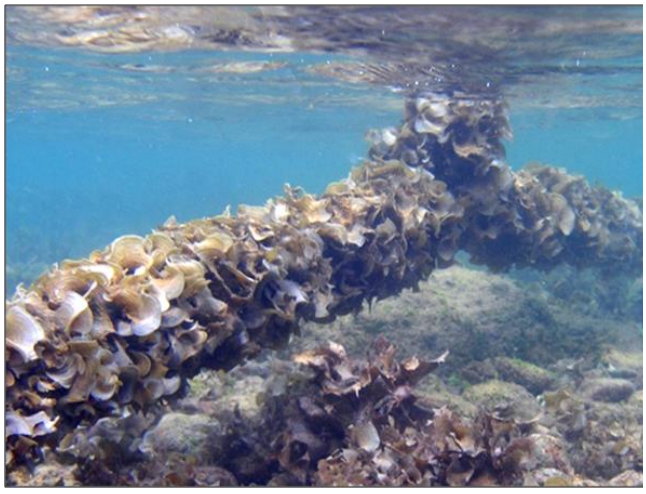
GHS provides limited stipends and tuition fees for research by graduate students working on their MS degree in Environmental Science and partial summer salaries to WERI faculty advising those students. It also pays for undergraduate field and lab assistants working on water resources projects on Guam, and the salary of one full-time Staff Hydrologist charged with operating WERI's complex and sophisticated computer analysis and GIS facility.

GHS Sponsored Research Projects Completed in FY'13:

With anthropogenically induced global warming now at the forefront of climate change research, WERI has focused on Guam's caves and corals to unlock climatic secrets of the past for this part of the world. Three such studies sponsored wholly, or in part by GHS funding are described below.

1. ***PCB Biomonitoring Strategy Development for Guam's Coastal Waters***

   PCBs are primarily land-based contaminants that are transported into coastal waters via polluted rivers and streams, contaminated groundwater, urban runoff, seepage from landfills and wastewater discharges. PCB contaminated coastal sites on Guam have so far been identified at Apra Harbor, Orote Point and Cocos Island. In all three cases the PCB contamination has been linked to past military activities. In view of the military's long-term presence on Guam, it is reasonable to assume that other as yet undiscovered PCB

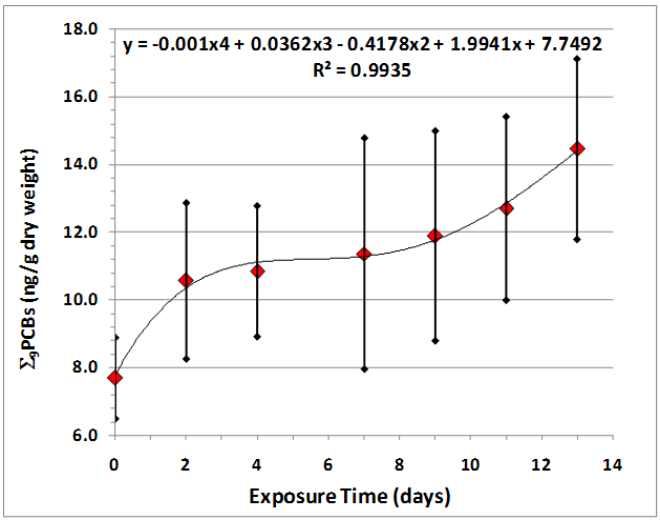


Young *P. boryana* recruits growing on newly commissioned polypropylene rope.

contaminated coastal sites exist elsewhere around the island.

The study reported here examined the utility of the common brown seaweed, *Padina boryana*, for identifying and monitoring PCB contaminated waters around the coast of Guam. Culturing techniques were explored and eventually led to the development of simple, convenient and cost-effective way of transplanting the seaweed into coastal areas where it does not normally occur. By this means, PCB uptake in *P. boryana* was subsequently studied in specimens relocated from a relatively clean environment into contaminated waters off the western side of central Guam.

Surprisingly, a biphasic uptake mechanism was identified that involved both adsorption and absorption processes. The former process achieved steady-state conditions within 2-3 days while the latter took considerably longer (>5 months) to reach equilibrium. This unique dual time-integrating system therefore allows *P. boryana* to be used for the rapid assessment of coastal sites for PCB contamination, as well for monitoring temporal changes over longer time frames. Moreover, the fact that *P. boryana* completes its entire life cycle in less than one year, makes it an attractive candidate for identifying areas currently receiving discharges of PCB contaminated freshwater as opposed to those that were historically impacted but are no longer so. Other potential useful indicators of PCB contamination with longer time-integration capacities and higher affinities for these recalcitrant contaminants are currently being examined.

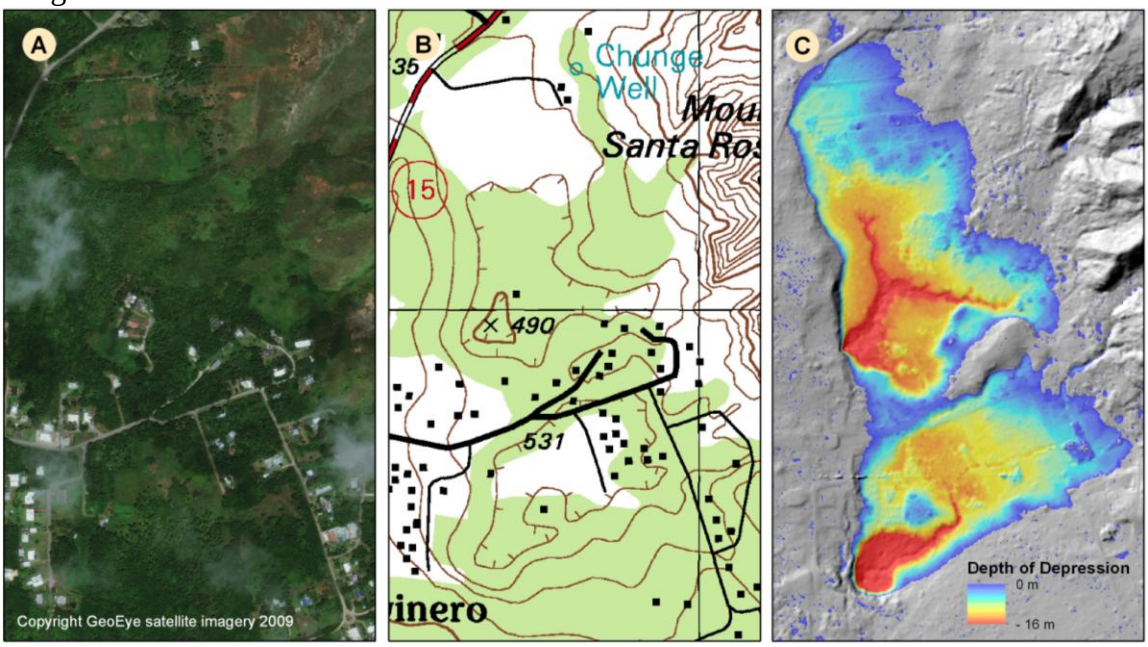


PCB uptake in *P. boryana* transplanted from a clean environment to contaminated waters adjacent to the Orote Landfill. Error bars are 95% confidence limits.

2. *Sinkhole Delineation*

Coral Sinkholes are prominent, and often dominant, landforms in nearly all karst environments. In Guam, they are exceedingly common in all karst areas, especially the northern Guam plateau. Sinkholes are internally drained, closed contour depressions that receive surface runoff and also draw in subsurface water from the soil and epikarst into preferential pathways that conduct the water downward to the water table. As such, sinkholes are vital to the recharge and water quality of the Northern Guam Lens Aquifer, the source of over 80 percent of the island's potable water. Besides their important hydrologic role, sinkholes are also geomorphologically significant because they pose serious challenges to urban development. They pose threats of collapse and flooding, the latter being especially likely if sinkholes are filled, or their drainage capacity is challenged by partial blockage of water pathways or excessive input of stormwater from nearby paved areas. For these reasons, the exact locations, geometric, geomorphic, and hydrologic parameters of sinkholes and

other possibly non-karst, but nevertheless significant depressions represent vital information to anyone involved in resource management, development, environmental research, and range of other activities in Guam. Unfortunately, the sinkholes on Guam have not been adequately mapped using a geographic information system (GIS). The only existing layer depicting sinkholes and other closed depressions was derived from USGS contour lines by WERI, circa 2000. This layer, however, shows only the location of depressions and their basic contour lines, with no additional information. Since that time, much better data sources have become available and we now have the ability to produce better, more accurate, and more informative geospatial layers for GIS. Especially the new high-resolution digital elevation model derived from 2007 LiDAR data can be used in a GIS to create extremely detailed and precise coverage of sinks and depressions that can then be accessed and modeled using a GIS.

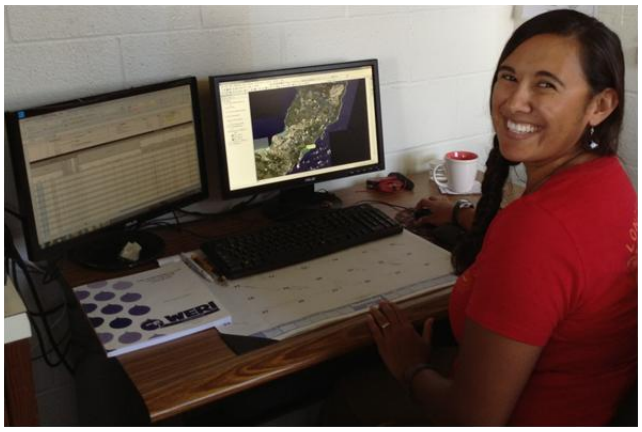


Alluvium-filled sink at the foot of Mount Santa Rosa; a) satellite imagery, b) USGS Topo Map, and c) LiDAR-derived hillshade with depth of sink modeled with a geographic information system.

Currently, WERI is working on a GHS-funded project to create an entirely new dataset that will portray the distribution and characterize sinkholes in Guam with unprecedented detail. In addition to locations of sinkholes, the data will include drainage area, depth, volumes, profiles, 3D-representation, and additional parameters derived from 2007 LiDAR data. An informative reference map depicting the delineated features will also be designed. The data set will be easily accessible and readily available to all entities involved in hydrologic modeling, groundwater quality, urban development on Guam, and essentially any interested party through direct and web-based dissemination. Such high-resolution, up-to-date, readily accessible geospatial information will be a vital resource to researchers, managers, technical staff, and others.

3. ***Northern Guam Lens Aquifer Database***

The Northern Guam Lens Aquifer supplies 80% of the island's drinking water. Anticipated growth in demand, including a possible surge to support expansion of military activities during the coming decade has elicited interest and support from both the federal and local governments for acquiring tools to support timely development and sustainable management of the aquifer. This report describes the content and organization of the *Northern Guam Lens Aquifer Database*, a comprehensive centralized database containing information on custodianship, function, operational status, and the geographical, hydrological, engineering, and geological attributes of each well installed in northern Guam for which records could be found. The database is integrated with current ArcGIS® geospatial information visualization tools. Developed in support of the 2010-2013 *Guam Groundwater Availability Study* led by the USGS's Pacific Islands Water Science Center, with funding by the US Marine Corps, and in conjunction with the 2010 NavFacPac Exploratory Drilling Program on northern Guam, its integration into WERI's Guam Hydrologic Survey Program will keep it up to date and make it permanently and readily accessible to professional and scientific users. The database is also the foundational component for WERI's topographic map of the basement rock beneath the aquifer. In preparing the database, over 4,000 pages of documents were digitally saved 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® spreadsheet, which contains key engineering and hydrogeological data. To organize, classify, and relate the enormous amount of disparate data required development of a specialized taxonomic system for the database. 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, and limitations; and assumptions and choices made in interpreting and classifying data. Finally, recommendations are offered on database maintenance and updating; improvements, refinements, and expansion; supporting operational and administrative procedures; and desirable future studies.



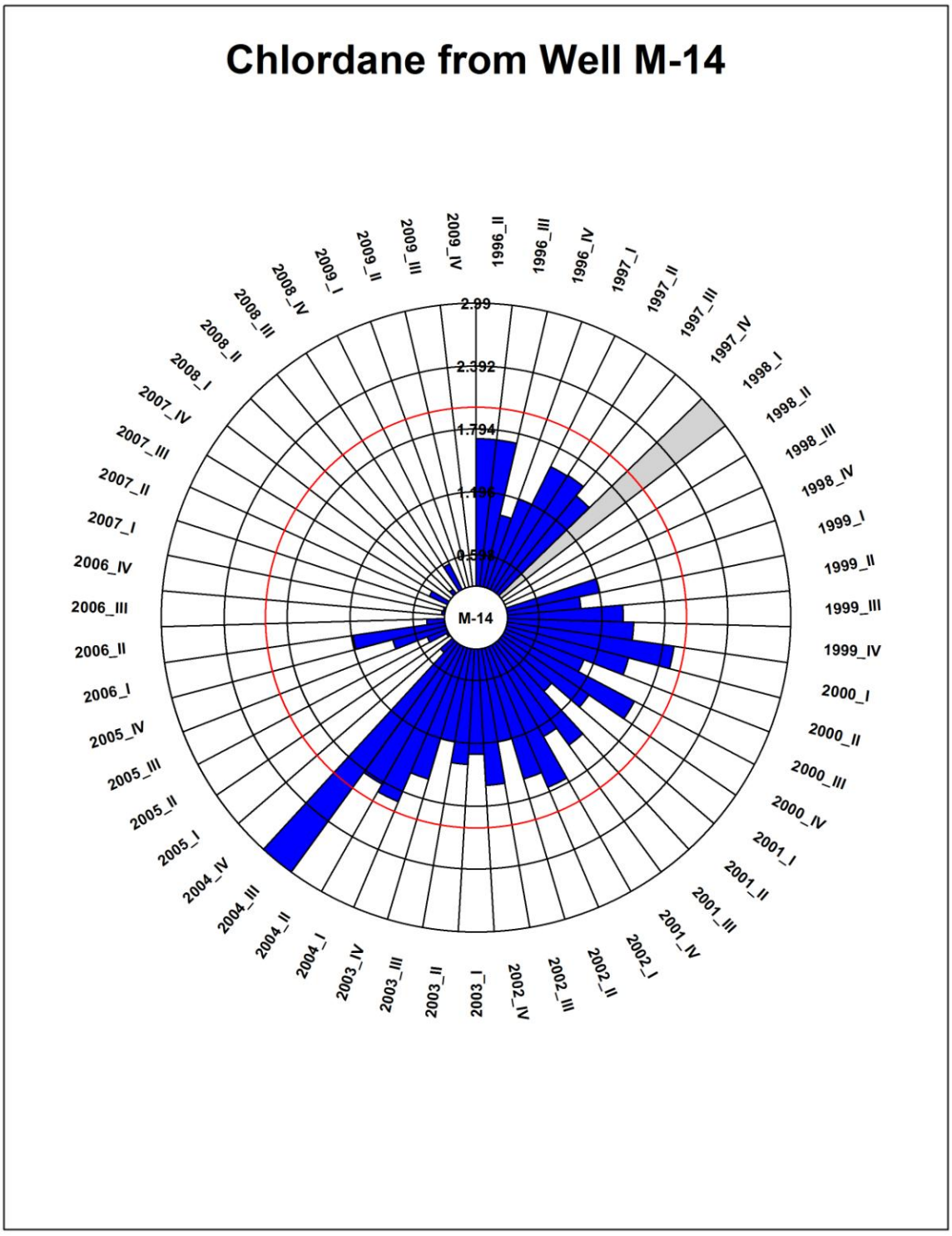
Graduate Student, Vivianna Bendixson, working on the Northern Guam Lens Aquifer database.

4. ***Development of a GIS-based model for Groundwater Quality Data Analysis on Guam***

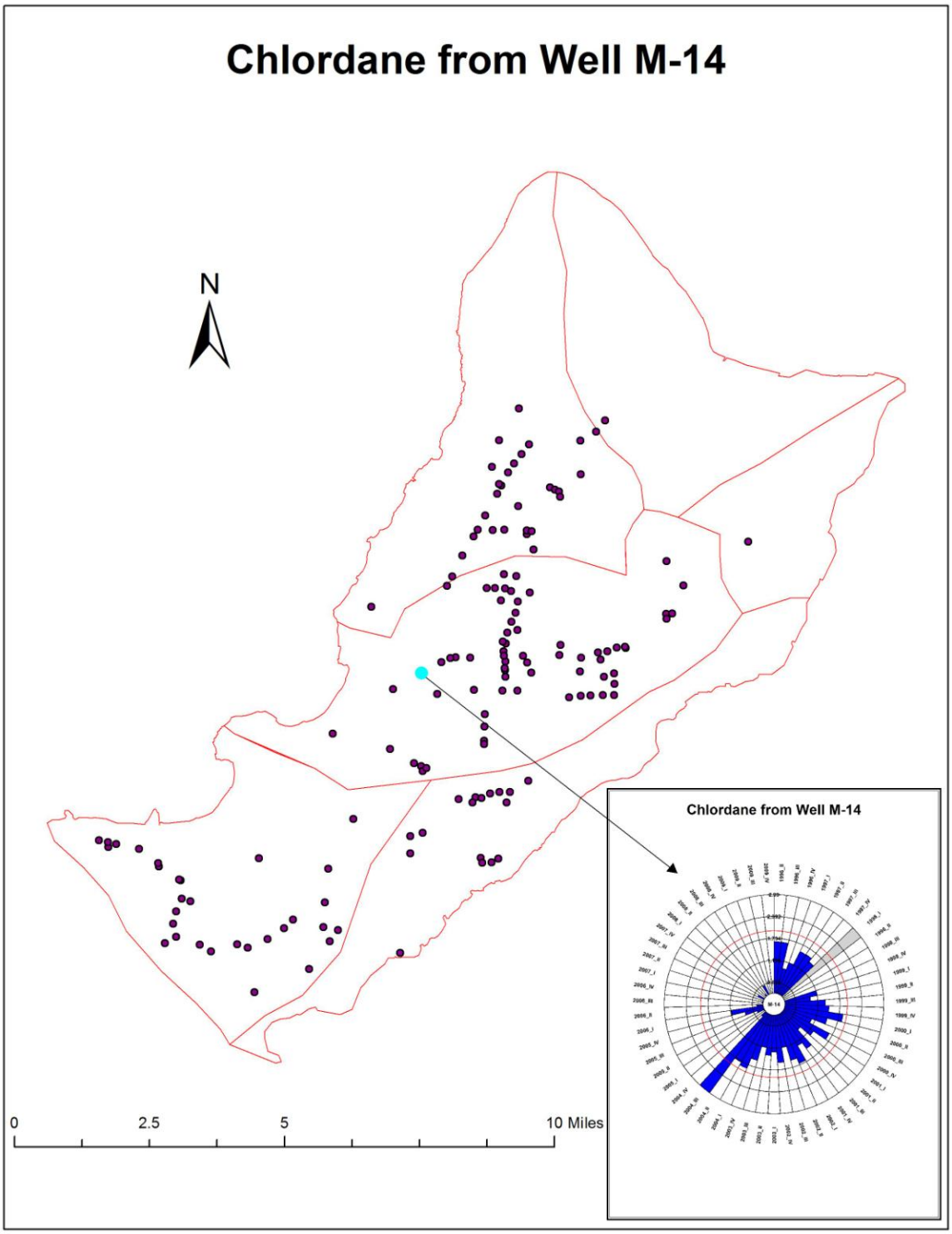
Guam Waterworks Authority (GWA) are the custodians of Guam's public water supply and are responsible for ensuring that it meets all appropriate standards as mandated under the Safe Drinking Water Act. To this end, GWA regularly evaluates the physical, chemical and biological integrity of the island's drinking water in accordance with US EPA requirements. While the agency has collected a considerable amount of monitoring data over the years,

only values that approach or exceed the water quality standards are paid any attention. The remainder, which account for well over 99% of all monitoring data collected thus far, falls well below critical thresholds of concern and is of little immediate interest. As a consequence, these data are simply stored on file for reference purposes only when they could and should be used to identify subtle changes in contaminant abundances and distributions within the aquifer.

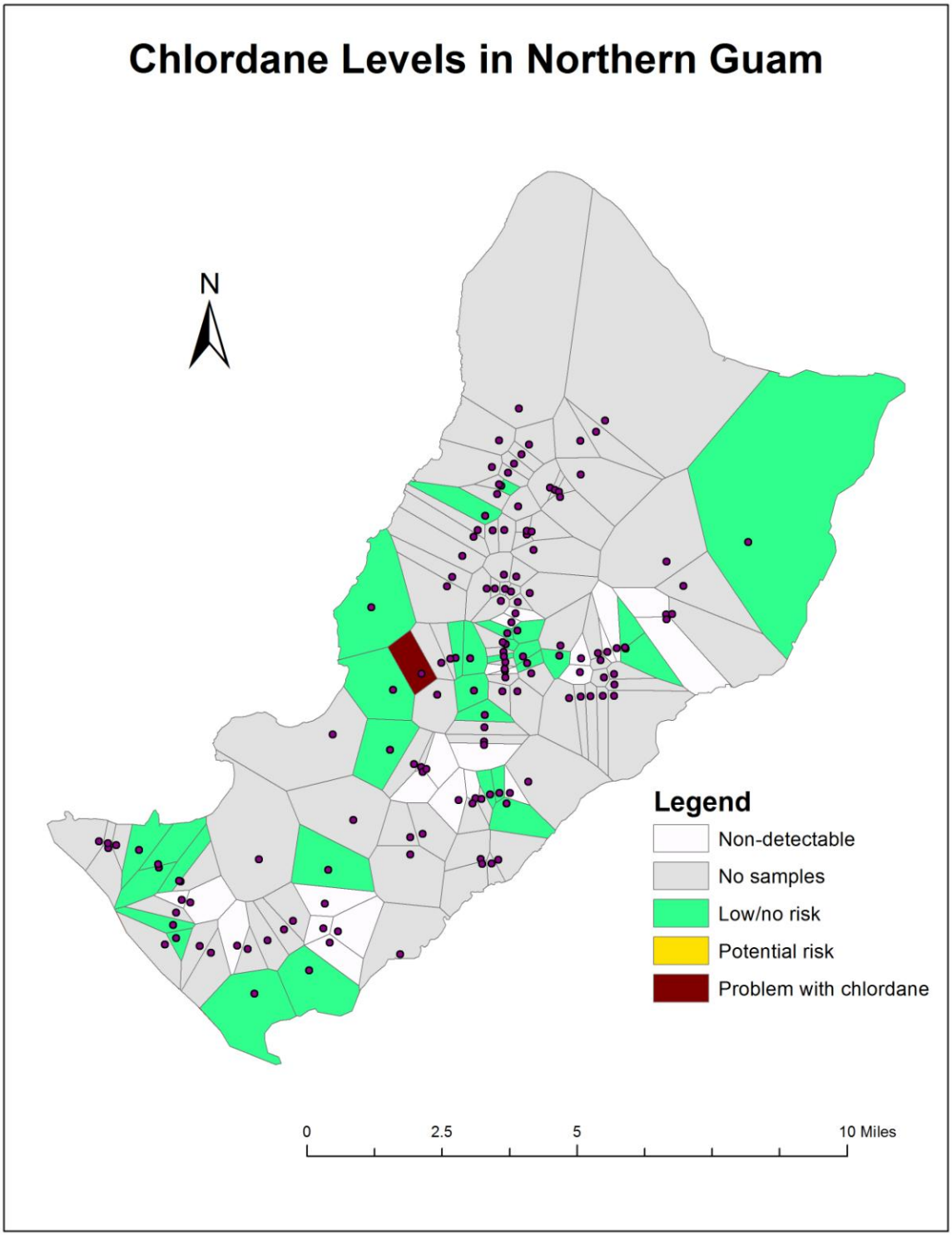
This project aims to create a GIS-based model, which can be utilized to demonstrate distribution patterns of concentrations or occurrences of contaminants in all GWA wells. Rapid visualization of contaminant changes within and between wells over space and time can be achieved. Previous GHS projects have been focused on point-based and polygon-based (Thiessen polygons) visualization and analysis of contaminants such as tetrachloroethylene (PCE*)* and trichloroethylene (TCE). Their distributions have been analyzed by Thiessen Polygons and spatial analysis. This project focuses on contamination levels of chlordane in the groundwater sampled from drinking wells in the northern Guam aquifer. The methods used in the study will be useful for identifying and predicting subtle long-term changes in contaminant levels within the aquifer. A GIS-based model will be established to deal with chlordane contamination for a single well for all or selected sampling time periods or all wells in a specific sampling time. The model can provide GWA with a robust tool for locating problem wells and implementing appropriate adaptive management strategies for mitigating contaminants of primary concern about some wells with water quality deficiency. Some preliminary results from the model are listed in the following figures.



Blue stands for real values from samples, grey for non-detectable value (ND), i.e., less than detection level (DL), and white for no samples or no data. The red circle indicates the maximum contaminant level (MCL). MCL for detecting chlordane is 2 ug/l.



The location of the well M-14. The inlet is the information from the previous figure.

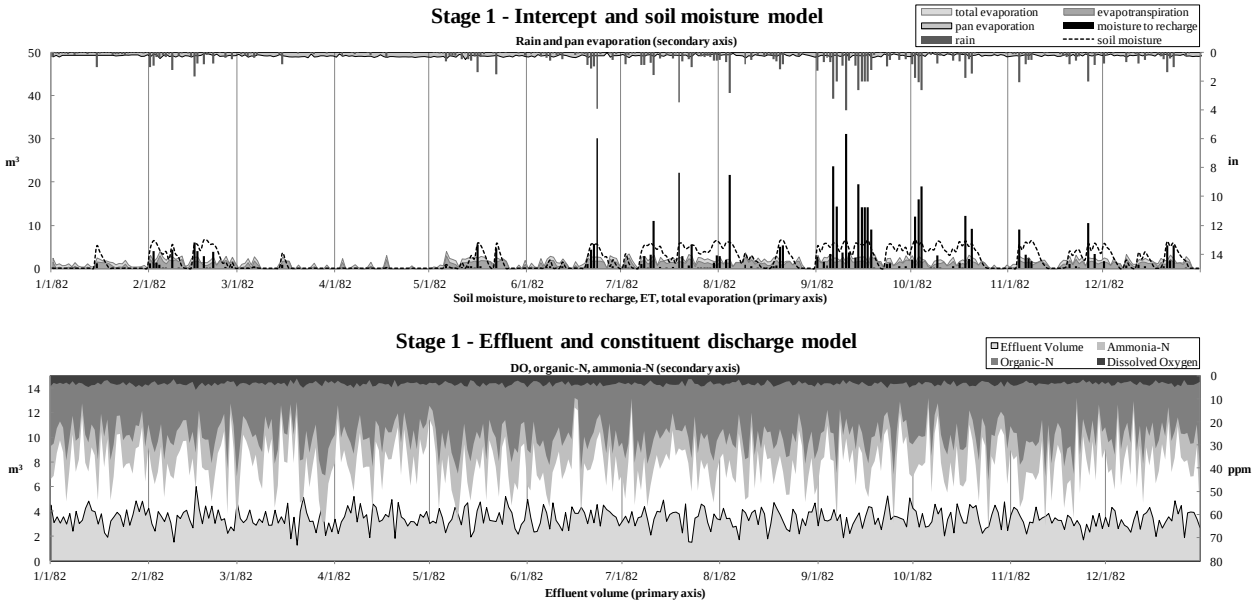


Distribution of chlordane in wells for the 3rd quarter of 2004. The map indicates that the well M-14 had a problem with chlordane contamination.

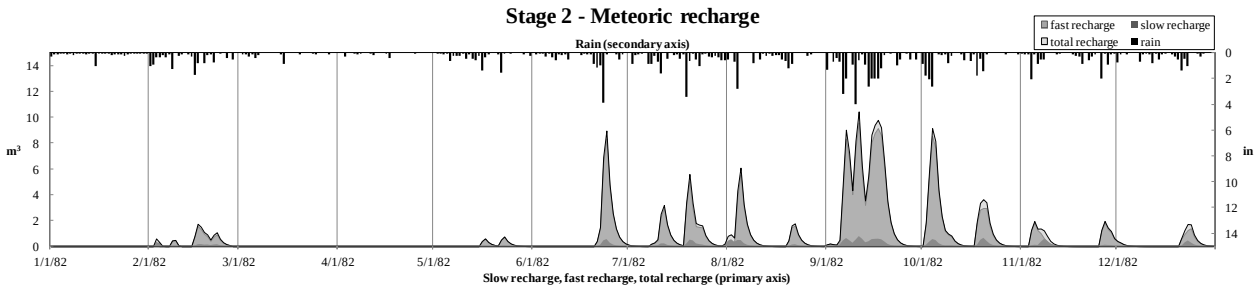
GHS Sponsored Research Projects Ongoing in FY'13:
Two ongoing research projects pertaining to the management and sustainability of the Northern Guam Lens Aquifer are currently sponsored wholly or in part by GHS and are on the brink of that yielding significant. The significance and current status of each of these studies are outlined below.

1. ***Development of Vadose Contaminant Transport Model for Northern Guam***
   Modeling the percolation of wastewater nitrogen from septic tanks and sewage spills through the deep karst vadose zone into the NGLA is a particularly complex and challenging process. WERI is tackling this problem using a modification of its recently developed VADO-CHARGE program. Originally designed to simulate the delivery of moisture through the vadose zone, this program has been modified to model the mass transport of wastewater nitrogen to the water table. The modified program is called, appropriately, the VADOCHARGE-N model.

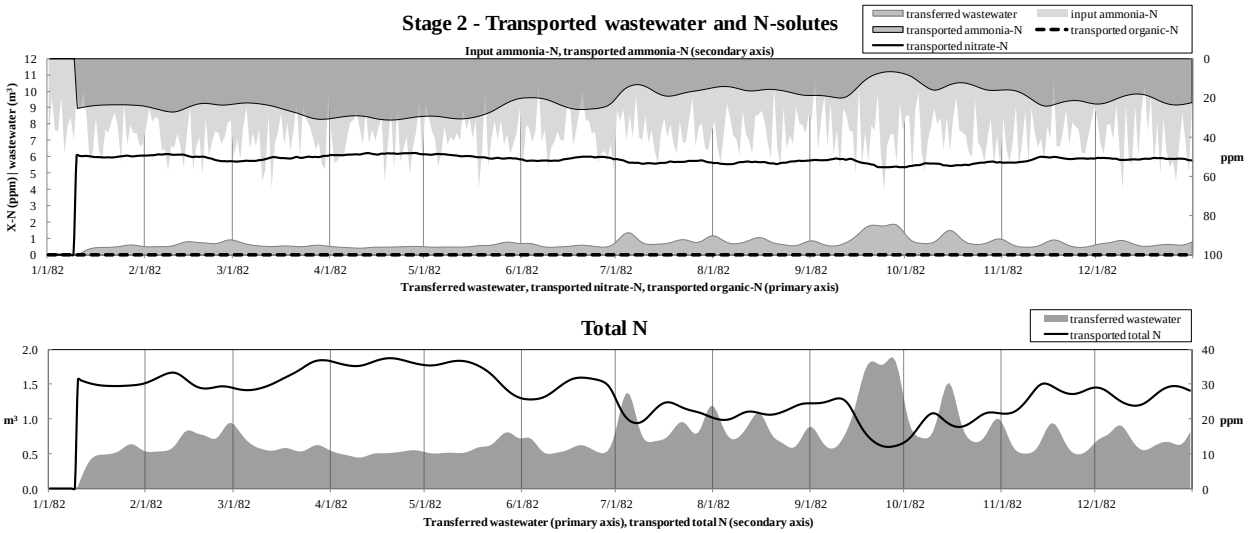
   This two stage program utilizes vertically aligned cell storages connected in a series and is programmed into a numeric algorithm. As wastewater nitrogen mass passes through each cell series of a designated effluent source, sorption and chemical kinetics for nitrification and denitrification are applied to account the chemical transformations in its life cycle. Below are extracted results of a particular node cell of the model for Stage 1 and Stage 2. Stage 1 is a daily meteoric moisture accounting model in the interception and soil zones, and the effluent volume and Kjeldahl N discharge model. Stage 2 is the transfer and transport of meteoric recharge, wastewater, and fate of N constituents.



Stage-1, sample of soil moisture and discharge model results.

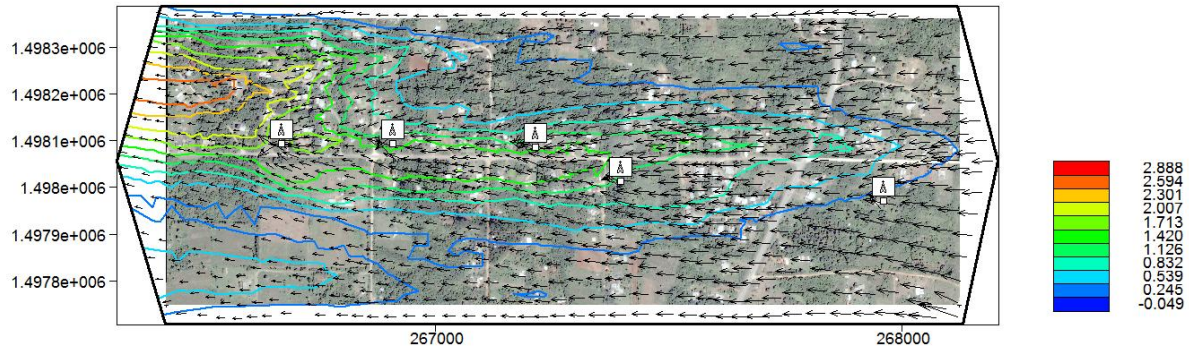


Stage 2, meteoric recharge hydrograph of a selected node-shed.



Top chart shows vadose transfer of wastewater and transport of nitrate-N, organic-N, and ammonia-N.

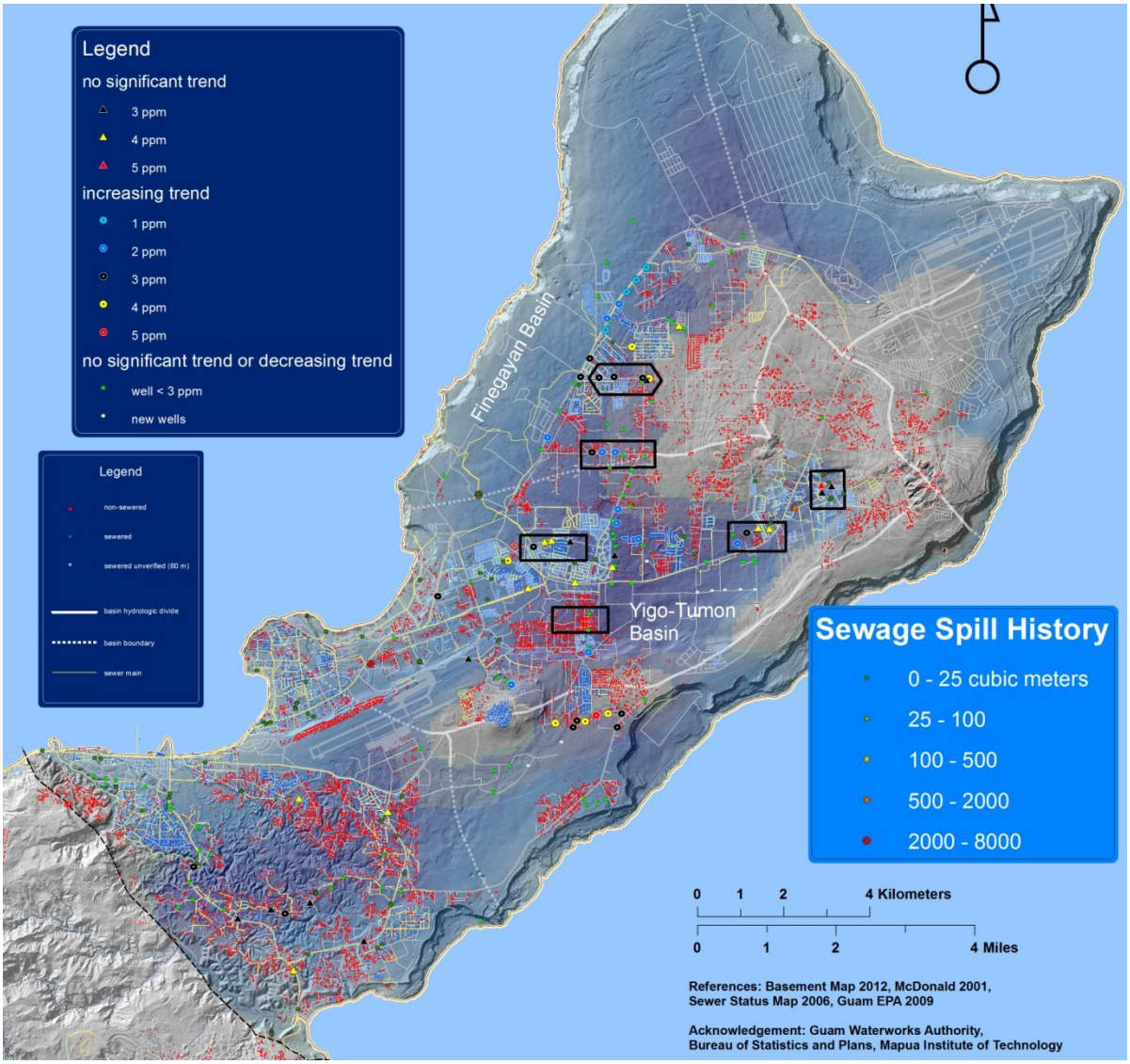
The vadose model may be calibrated using USGS's SUTRA. The figure below displays the simulation of groundwater solute transport plume, through the well series in Swamp Road Dededo, influenced by domestic discharge from non-sewered sources. This modeled plume provides estimates of possible transferred and transported rates of wastewater and N constituents, used to adjust the vadose model parameters.



Solute transport model, in preparation for history matching and coupling to phreatic model.

Several sites of concern were mapped, which includes building sewer status, nitrate trend analysis, and sewage spill history. VADOCHARGE has been specifically designed and

programmed to provide a subsurface modeling insight for evaluating the extent of current civil development sewage discharge impact into the aquifer, and useful for future visualizing impact of future developments as well.

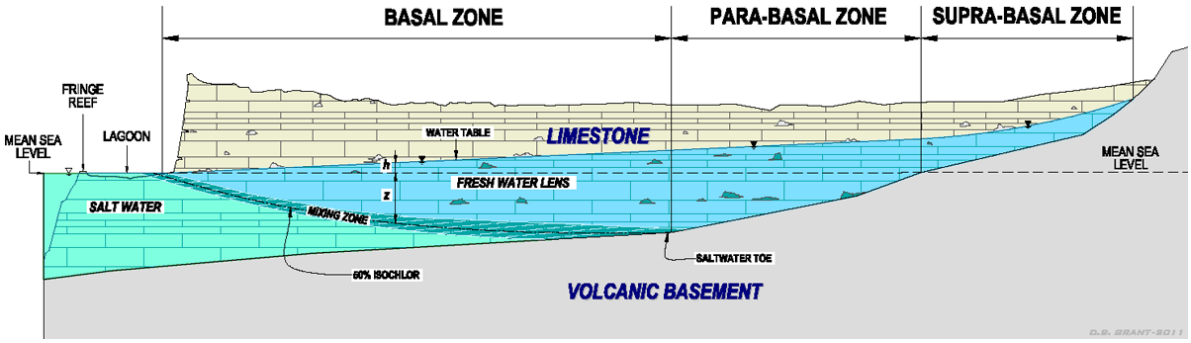


Sites of groundwater contamination concern are mapped in our latest renderings of the NGLA.

2. *Basement Map of the Northern Guam Lens Aquifer*

Sinking new NGLA wells

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 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 24th 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.

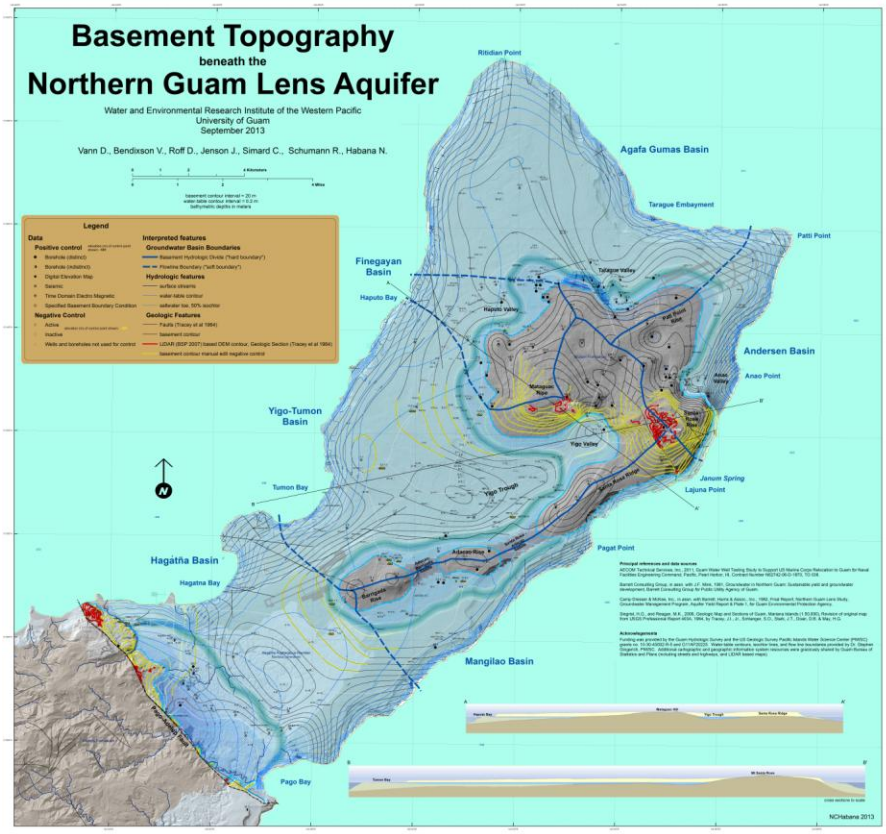
Most recently, the exploratory drilling program undertaken by the US Navy in 2010 in support of the anticipated military build-up provided additional new control on the elevation of the basement in crucial locations. Moreover, the new Guam Groundwater Availability

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.

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.

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 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.

SUMMARY OF FY'13 EXPENDITURES FOR GHS APPROPRIATION

Below is a composite summary of all expenditures lodged against the GHS account during FY'13. 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.

Expenditure Summary for FY'13

Category		*Expenditure*
1.	**Salaries and Wages:**	**$98,363.17**
2.	**Fringe Benefits:**	**$27,338.62**
3.	**Tuition Fees**	**$0.00**
4.	**Supplies:**	**$1,009.76**
5.	**Computer Hardware/Software:**	**$7,002.51**
6.	**Equipment:**	**$5,952.93**
7.	**Projects/Consultant Fees:**	**$51,423.80**
8.	**Postage/Long Distance Phone:**	**$951.84**
9.	**Printing:**	**$1,092.50**
10.	**Subscription/Dues:**	**$0.00**
11.	**Administrative Fees*:**	**$18,269.40**
Total FY'13 Expenditures:		**$204,404.53**
Total FY'13 GHS Allotment Rec'd:		**$198,523.00**
Balance:		**-$5,881.53**
Total Approved Budget Allotment for FY'13:		**$182,694.00**

* 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 continuous-recording 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 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 Chataʻan 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.

Flow in Pago Stream has been measured since 1951

Well Monitoring of the Northern Guam Lens Aquifer

WERI field assistant measures water levels in the Northern Guam Aquifer

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 current levels of pumpage are affecting the aquifer and how 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?

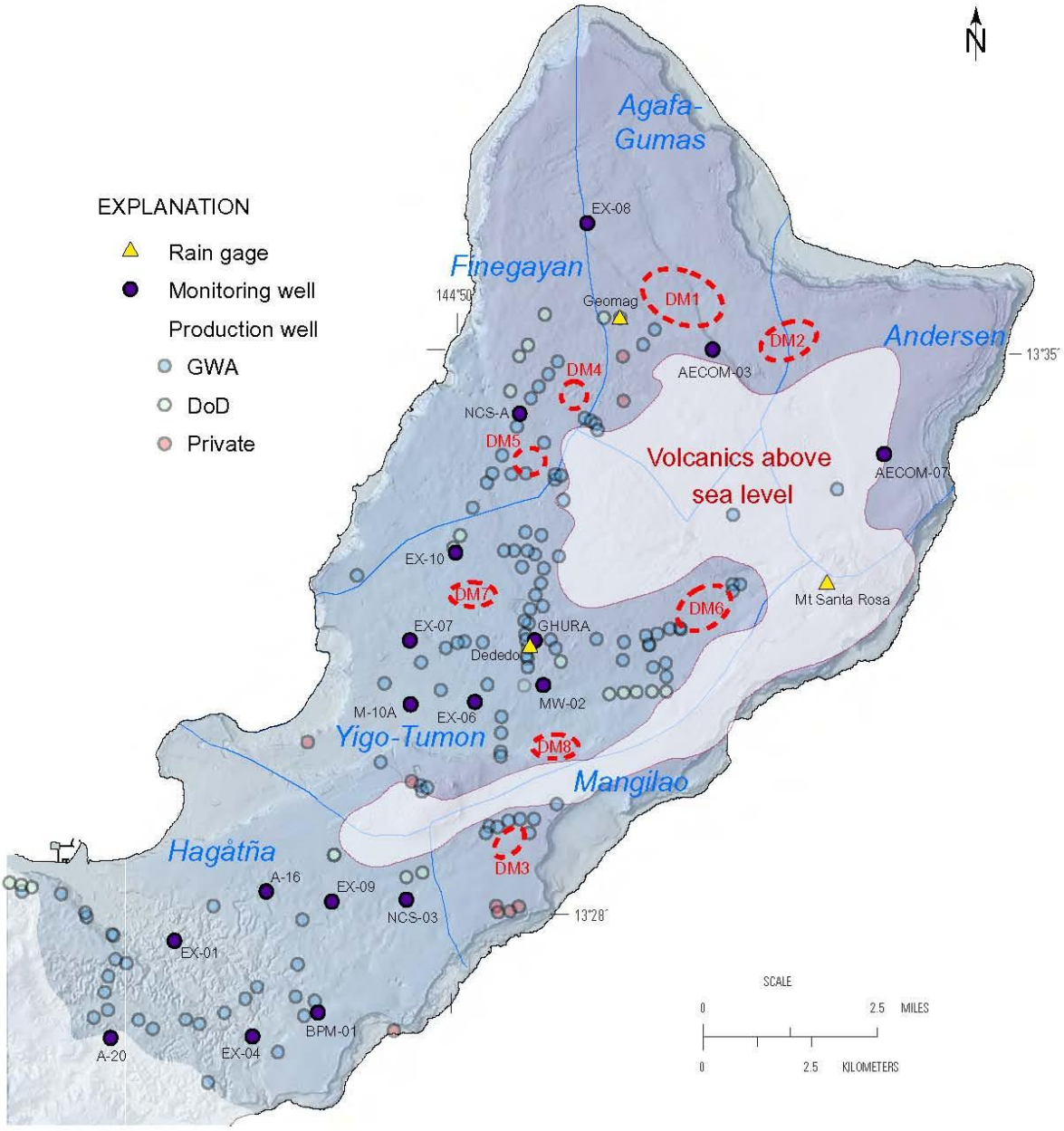
In fiscal year 2013, the cost to operate a continuous-record streamflow gage will be $23,000. This includes all operation and maintenance, site visits, field data collection, data analysis, and computation of the flow record. Gage operations are frequently reviewed and upgraded as improvements become available. Other gages, such as rainfall ($10,900) and groundwater ($7,000), 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

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(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	**Type**								
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