Guam Hydrologic Survey (GHS)

&

Comprehensive Water Monitoring Program (CWMP)

FY 2009 Status Report

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

November 2009

GUAM HYDROLOGIC SURVEY (GHS) AND COMPREHENSIVE WATER MONITORING PROGRAM (CMP)

FY 2009
STATUS 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'09 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, 307 and $163,817 for GHS and CWMP respectively. These shortfalls continue through FY'10. The information presented herein summarizes all GHS and CWMP program objectives and related activities undertaken in FY'09.

PROGRAM OBJECTIVES AND OUTCOMES FOR FY'08

GUAM HYDROLOGIC SURVEY (GHS)

In FY'09, GHS provided funding to maintain and upgrade the state-of-the-art computer analysis and Geographic Information System (GIS) laboratory housed in WERI. 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.

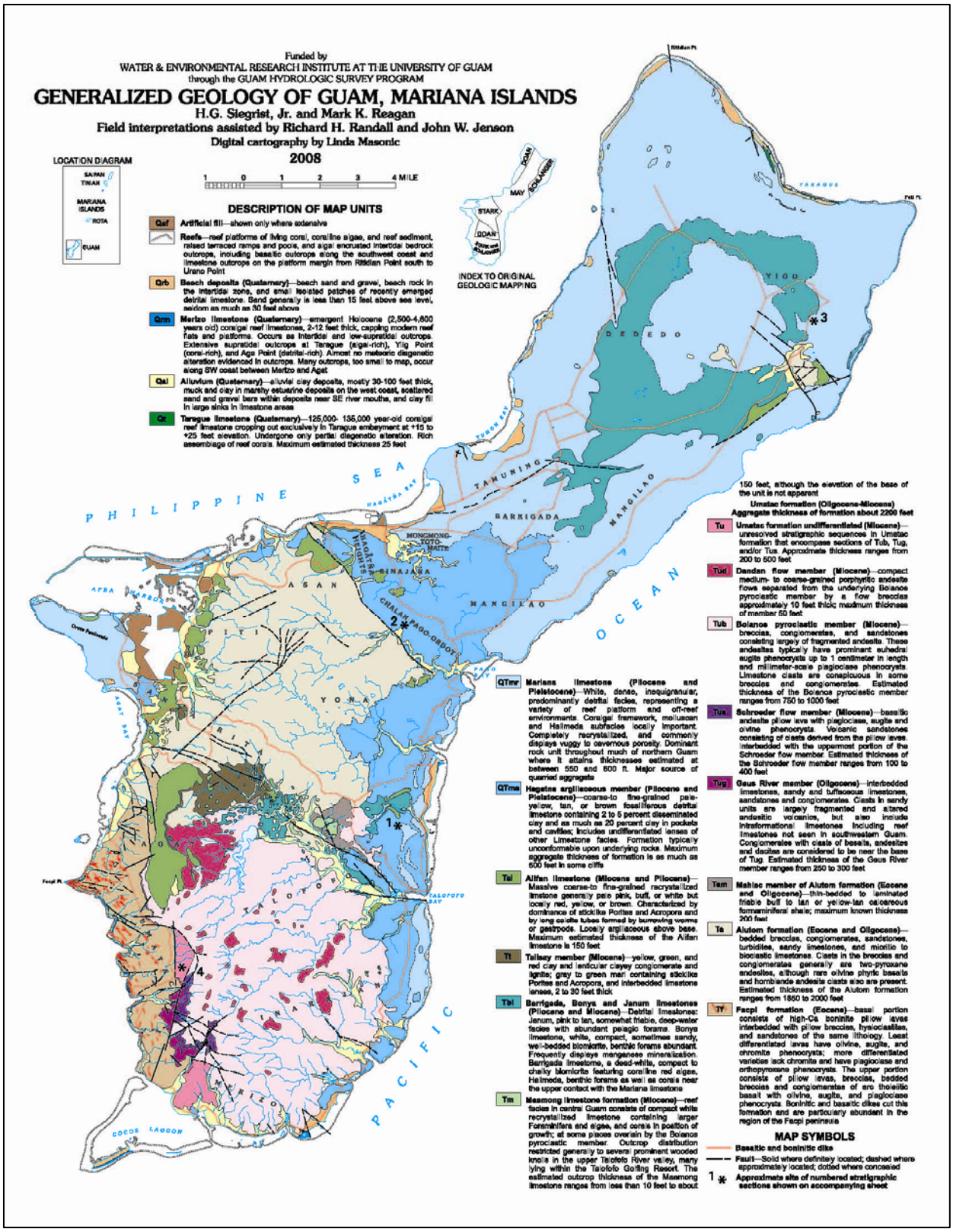
Graduate Students in WERI GIS Laboratory

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

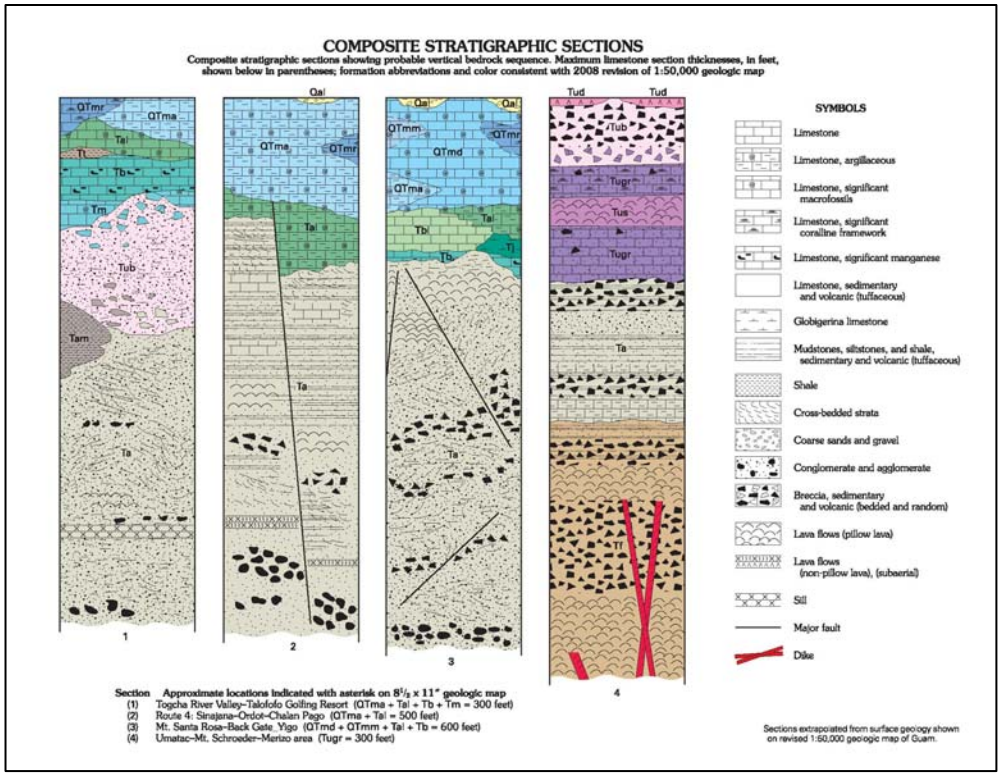
GHS Sponsored Research Projects Completed in FY'09:

Two highly significant projects were completed in FY'09: 1) the augmentation the recently completed revised geologic map of Guam with composite stratigraphic cross-sections of representative areas and a chronology of the geologic evolution of Guam and other islands in the region, and 2) the development of a soil moisture model for determining the evapotranspiration and aquifer recharge in northern Guam. A summary report for each project is given below together with FY'09 costs.

1. ***Stratigraphic Sections and chronology of the Revised Geologic Map of Guam*** **($24,000)**
   As a follow-up to the revision of the geological map of Guam (Fig. 1), we have developed composite stratigraphic cross-sections for the following four representative locations: a) Talofofo-Upper Togcha Valley, b) Route 4 from Sinajana to Chalan Pago, c) Mt. Santa Rosa-Back Gate-Yigo and d) Umatac-Mt. Schroeder-Merizo area (Fig. 2). The sections present generalized subsurface geology using colors consistent with the revised map and a standardized key to the nature of the formations. These cross-sections are important tools for future land use decisions, including the characterization of watersheds and aquifers; water well location, drilling, and construction; and instruction by earth science teachers in the geology and natural history of Guam. In addition, the map is also now augmented with a chart that shows the chronological relationships during the evolution of the major rock units of Guam and the surrounding islands (Fig. 3). This is also of significant value to professional geologists and students for studying and predicting the properties of various rock units



Generalized Geology of Guam, Mariana Islands, Showing Locations of Stratigraphic Sections (1-4) Depicted in Figure 2 below



Stratigraphic Cross-sections for the Four Representative Locations Shown in Figure 1 Above

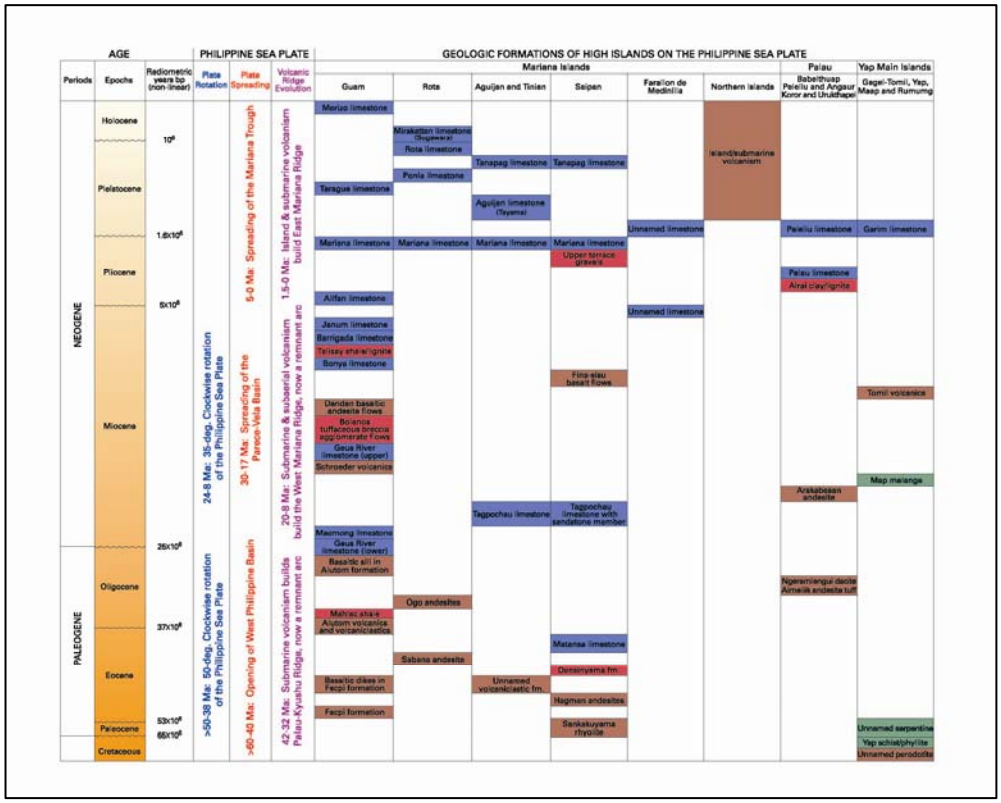
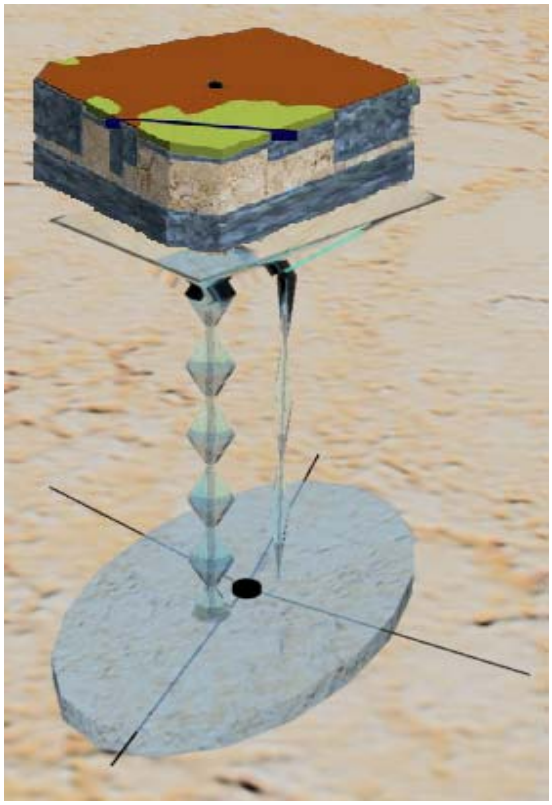


Figure 3: Evolutionary Chronology of the Major Rock Units of Guam and the Surrounding Islands

GHS Sponsored Research Projects Active in FY'09:
Three GHS sponsored research projects are ongoing and poised to yield significant data are: 1) vadose flow synthesis for the northern Guam lens aquifer, and 2) spatio-temporal analysis of groundwater quality on Guam, and 3) reconstructing the climate history of Guam. The significance and current status of each of these studies are outlined below.

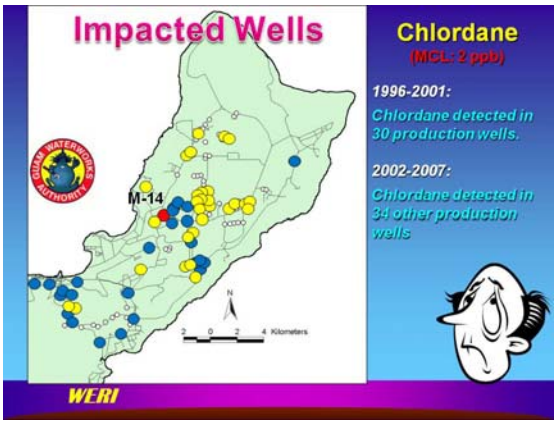
1. ***Vadose Flow Synthesis for the Northern Guam Lens Aquifer*** **($27,382)**
   The long-term growth and development predicted for Guam will inevitably have an impact on the islands fresh water resources. Such impacts may include over pumping and deteriorating water quality through salt water intrusion. Knowing recharge rates to the northern Guam lens aquifer (NGLA) can prevent this from happening. Recharge estimates the NGLA first began in the late 1940s and have become more sophisticated in their approach over the years, particularly since the advent of super computers.

   The 'AquaCharge' Vadose Flow Synthesis Conceptual Model

   A study completed this year by WERI graduate student, Mr. Nathan Habana, applied empirically derived spatially distributed recharge values to a finite element ground water model. Mr. Habana developed a computer program called AquaCharge to bring together the spatially distributed properties of the aquifer and the recharge model with the time variable inputs of rainfall and pan evaporation. The spatially varied data was developed using ESRI ArcGIS® techniques. Mr. Habana's thesis, entitled *Vadose Flow Synthesis for the Northern Guam Lens Aquifer,* describes how he used a sophisticated two-stage, conceptual model that combined the soil moisture model and modified routing technique to synthesize the lagged and attenuated arrival time of fast and slow flows to the lens. The model is a major advancement on previous finite-element method groundwater models that used crude recharge estimates, and will provide and important tool for sustainable management of Guam's major aquifer.

2. ***Spatio-Temporal Analysis of Groundwater Quality on Guam*** **($7,206)**



Visualization of Contaminant Profiles in Guam's Water Production Wells

Since 1996, GWA has regularly monitored Guam's groundwater resources for all contaminants listed under the Safe Drinking Water Act. A substantial bank of data now exists from which certain space- and time-dependant trends are emerging. The objectives of this project is to convert data to GIS format and explore various ways of presenting the information so that spatial and time series trends can be easily visualized. GIS, GPS and geospatial statistics are being used to complete this work. Well locations and sub-basin information along with water quality data from 1996 to 2007 are available from the GWA database. GIS mediated spatio-temporal analysis of this nature is an important means of identifying vulnerable well clusters within the aquifer and predicting long- and short-term changes in well water quality data.

3. ***Reconstructing the Climate History of Guam*** **($67,788)**

Stalagmites and water samples from a cave on northern Guam are providing clues to how the climate of Guam and the surrounding region evolved over the past 22,000 years. Stalagmites were initially collected by WERI researchers in April 2005. Laboratory work on the stalagmite has been underway for the past three years by collaborators at the Jackson School of Geosciences at the University of Texas-Austin. The project builds on a previous GHS sponsored study focused on locating and mapping the limestone rock units of Guam. The initial results are consistent with results from other islands in the Pacific and suggest, among other things, that the regional climate was much drier some 5000-6000 years ago. The western Pacific Ocean plays an important, but still poorly understood role in global climate. Results of this study will not only help to understand and predict longer-term climate trends for Guam, but for the entire western Pacific region. This study is thus an ongoing long-term study, which is now being linked to similar, collaborative regional studies. In particular has supported two proposals for additional funding from the National Science Foundation (still awaiting funding decisions at this time), which will extend the same investigation to the Philippines and Borneo. As these studies continue to progress, Guam and the surrounding region will gain an increasingly reliable understanding of long-term climate cycles and weather-related events that control the hydrologic cycle and water resources of the islands in the region.

WERI Researcher Collects Drip Water Residues in Guam Cave

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.

The current monitoring program consists of 8 continuous-recording streamflow gages, 6 continuous-recording groundwater wells, 6 groundwater wells where the thickness of the freshwater lens is measured, and 5 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 5 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 6 wells where water level is continuously measured and 6 wells where the thickness of the freshwater lens is measured quarterly. 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 5 rain gages on Guam, 4 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.

Sediment Measurements for Watershed Management

Ugum River after heavy rains transports large amounts of sediment to the coast and severely impact coral reefs. Knowing the sediment sources and amounts discharged can assist managers in the design and implementation of mitigation strategies.

Coral reefs on Guam are thought to be damaged by sediment carried in runoff from watersheds. Managers are trying to understand the sources and amounts of sediment moving from watersheds to coral reefs so that this problem can be addressed. Successful watershed restoration may result in reduced soil erosion and sediment transport to coastal waters, thereby increasing compliance with the Clean Water Act. Streams may also become better habitats for native stream organisms if sediment load is reduced. As part of the WERI-USGS CWMP, two stream gages in southern Guam have been upgraded with specialized equipment that automatically collects water samples so that the amount of sediment flowing to the ocean can be measured.

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

In 2010, the cost to operate a continuous-record streamflow gage will be $22,400. 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. Determining the suspended-sediment load at a gage increases the annual cost an additional $26,880. Other gages, such as rainfall ($10,750) and groundwater ($6,720), 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.

GHS PUBLICATIONS AND ASSOCIATED DOCUMENTS

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Government of Guam
Fiscal Year 2011 Budget
Program Fiscal Summary

FUNCTION: EDUCATION & CULTURE
AGENCY: UNIVERSITY OF GUAM
PROGRAM: WATER AND ENVIRONMENTAL RESEARCH INSTITUTE (WERI)

Budget Account Allocation		FY2009		FY2010	FY2011				
FUND TITLE	**Fund**	Actual Appropriation	Percent of Program	Authorized Appropriation	Current Service	Program Plan	Governor's Recommendation	**FY20012** Projected	**FY20013** Projected
General Fund Appropriation		$891,109		$913,569	$913,569	$936,800		$957,053	$978,316
Guam Hydrologic Survey (Local)		$192,307		$192,307	$192,307	$204,200		$204,200	$204,200
Guam Water Monitoring Project (Local)		$163,817		$163,817	$163,817	$173,948		$173,948	$173,948
Guam Water Monitoring Project (Federal)		$163,817		$163,817	$163,817	$173,948		$173,948	$173,948
USGS Water Institute Program (Federal)		$277,005		$277,005	$277,005	$277,005		$277,005	$277,005
ENSO Application Center (Federal, National Weather Service		$100,000		$100,000	$100,000	$100,000		$100,000	$100,000
Total Program Appropriations		$1,788,055		$1,810,515	$1,810,515	$1,865,901		$1,886,154	$1,907,417
FTE Positions									
Performance Indicators	**TYPE**								
Projects Initiated	WKLD	16		15	15	15		15	15
Projects completed	WKLD	10		11	11	12		12	12
Technical Reports	WKLD	4		5	5	5		5	5
Journal Articles/Conference Proceedings.	WKLD	12		10	10	10		10	10
Workshops/Conference Presentations	WKLD	25		10	10	10		10	10