Guam Hydrologic Survey (GHS)

&

Comprehensive Water Monitoring Program (CWMP)

FY 2008

Status Report

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

October 2008

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

FY 2008
STATUS REPORT

Prepared by

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Director

October 2008

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'08 OBJECTIVES

The FY'08 appropriations for the GHS and CWMP programs were $204,200 and $173,948 respectively, and represent the full amount as written into each public law. Local budgetary constraints saw a 6% reduction in funding support for both programs in FY'09, i.e., $192, 307 and $163,817 GHS and CWMP respectively. The information presented herein summarizes all GHS and CWMP program objectives and related activities undertaken in FY'07.

PROGRAM OBJECTIVES AND OUTCOMES FOR FY'08

GUAM HYDROLOGIC SURVEY (GHS)

In FY'08, 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.

Students in New Computer Analysis and GIS Laboratory

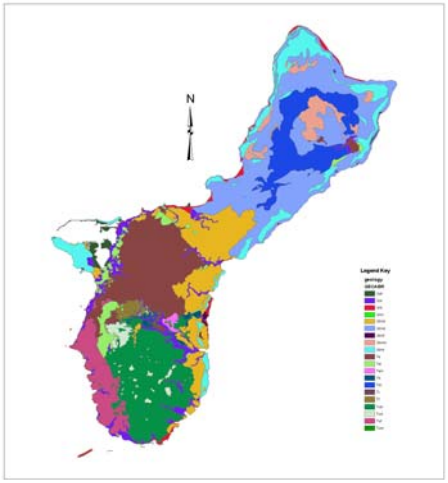
GHS provides limited stipends, tuition, and fees for research by graduate students working on their MS degree in Environmental Science, several UOG undergraduate field and lab assistants, and partial summer salaries to WERI faculty advising those students. GHS funds the salary of one full-time research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

Research Projects Completed in FY'08:

Three highly significant projects were completed in FY'08: 1) the final printing of the geologic map of Guam; 2) the development of a unified model for contaminant transport within the saturated zone of the northern Guam lens aquifer (Phase II), and 3) the role of soil moisture in determining the evapotranspiration and aquifer recharge in northern Guam. A summary report for each project is given below together with FY'08 costs.

1. *Printing the Geologic Map of Guam* ($6, 537)

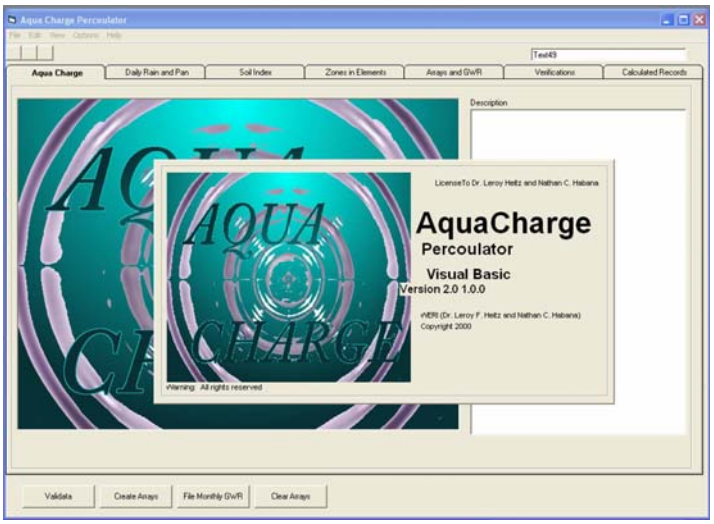
This recently completed study has yielded an updated geologic map of Guam incorporating all of the revisions of the past 40 years as well as some new data on selected questions. The map has been published at two scales: a single 15-minute quadrangle map (1:50,000) that is available in flat (34 x 45") or folded (6.75 x 9") form from WERI, and seven 7.5-minute (1:24,000) quadrangles. All of these maps are posted on the WERI website (http://weriguam.org). The revised maps include corrections and updates to the volcanic and limestone stratigraphy. The 7.5 minute quadrangles show geologic features at a level of detail heretofore unavailable to users geological information on Guam.



Geological Map of Guam

2. *The Role of Soil Moisture in Determining the Evapotranspiration and Aquifer Recharge in Northern Guam* ($26,108)

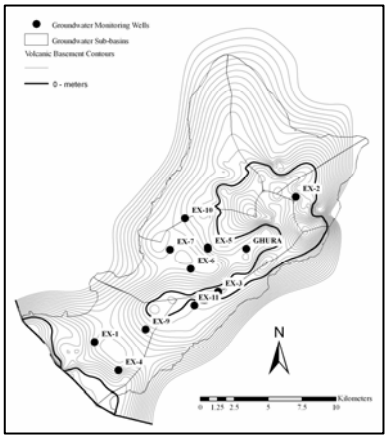
The long-term growth and development predicted for Guam will inevitably have an impact on the islands fresh water resources. Such impacts may include over pumping and deteriorating water quality through salt water intrusion. Knowing recharge rates to the northern Guam lens aquifer (NGLA) can prevent 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 current study determined how soil moisture properties affect evapotranspiration (ET) and ultimately recharge rates. The resulting spatially distributed recharge values were applied to a finite element ground water model. A computer program called Aqua Charge was developed 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.



The AquaCharge Model is Used to Assess Temporal and Spatial Evapotranspiration Variability across the Aquifer

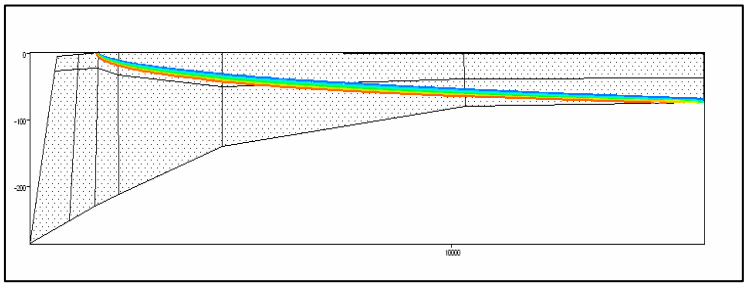
The technique fist determines the amount of rain falling on the soil surface. A water balance equation and a soil moisture curve is then used to split the portion of the moisture input that goes to recharge and the portion that remains in the soil as soil moisture. The amount for water leaving the soil through ET and the effect of soil moisture levels on the ET process is also accounted for. Each soil type has two adjustable curves that determine the percent of moisture going to aquifer recharge and ET (as a function of soil moisture). The spatial parameters of soil type, hydrologic node-shed recharge area, Euclidean allocated polygons of rainfall and pan evaporation are prepared using a Geographic Information Systems (GIS). This hydrologic modeling approach is similar to that used by the US Army Corps of Engineers Streamflow Synthesis And Reservoir Regulation (SSARR) model and has been applied to watersheds throughout the world. Various subroutines used in the SSARR model are rewritten in BASIC using Microsoft Visual Basic® and applied in the Aqua Charge model. The recharge values output from the Aqua Charge model serve as inputs to a simple finite element ground water model that can be used to compare simulated and observed recharge production responses to rainfall.

3. *Spatially Distributed Precipitation and Water Table Response of the NGLA* ($36,251)



Real-time precipitation and lens response were recorded at wells EX-6, 7 and 10 and the GHURA

The fresh water lens contained within the limestone plateau of northern Guam is the primary drinking water resource for the residents of Guam. In order to meet future water demand, while maintaining acceptable water quality, water resource managers must be provided with the most up-to-date estimates of sustainable yield available. To support the development of more reliable future estimates of sustainable yield, WERI, in collaboration with the Guam Environmental Protection Agency and US Geological Survey, undertook a thorough analysis of the response of the freshwater lens in the Northern Guam Lens Aquifer to actual events. The project drew on data collected from specially instrumented observation wells in which real-time response (as frequent as 15-minute intervals for some data) of the lens to rainfall events could be observed. Fortunately, the data included response to Tropical Storm Tingting of June 2004, which deposited the heaviest rainfall ever recorded in 24 hours on Guam. In addition, WERI modelers developed a two-dimensional SUTRA model, by which estimates could be made for responses in other parts of the lens, from which direct observations are not available. Initial results of the study, particularly the well responses, have been reported by Wuerch et al. (2007). The report of the modeling study is forthcoming.



Simulations with the USGS SUTRA model allow estimates of lens response across the aquifer.

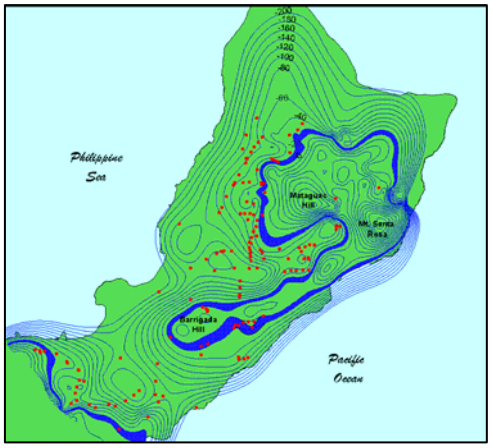
Research Projects Initiated during FY'08:

The three ongoing projects which are poised to yield significant data are: 1) stratigraphic sections of the revised geologic map of Guam; 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.

2. *Stratigraphic Sections of the Revised Geologic Map of Guam* ($12,000)

As a follow up on the revision of the geological map of Guam, we are developing composite stratigraphic 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. The sections will present generalized subsurface geology using colors consistent with the revised map and a standardized key to the nature of the formations. They sections will greatly facilitate future land use decisions, including drilling and construction and the characterization of watersheds and aquifers on the island, as well as instruction by earth science teachers in the geology and natural history of Guam.

3. *Spatio-Temporal Analysis of Groundwater Quality on Guam* ($28,194)



GWA Monitors Guam's Groundwater Quarterly

This project will help identify characteristics of aquifer, and relationship of groundwater quality and sub-basins in the northern Guam._Since 1996, GWA has monitored Guam's surface waters and groundwater resources on a quarterly basis 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 now 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 will be used to complete the project. Well locations, and sub-basin information along with water quality data from 1996 to 2006, will be available. Water quality data will be linked to well locations. Levels of organic and inorganic chemicals and bacteria from water quality data will be analyzed spatially and temporally to determine which wells have water quality deficiencies. Groundwater quality may be predicted using the spatio-temporal water quality data.

2. *Reconstructing the Climate History of Guam* ($51,060)

WERI Researchers Examine Limestone Formations in Guam Cave

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.

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 hydrologic data collection network 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 hydrologic data 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 stream flow, 8 rain, and 16 ground-water 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 stream-flow gages, 9 continuous-recording ground-water wells, 7 ground-water wells where the thickness of the freshwater lens is measured, and 7 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 hydrologic data network on Guam is part of a cooperative data program that is funded by the USGS and WERI.

Locations of USGS monitoring stations on

Stream Gages for Water Availability and Flood Planning in Southern Guam

Most fresh water used in southern Guam comes either from stream flow 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 stream flow 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 US Navy, are used to manage withdrawals from Fena Reservoir.

Long-term stream-flow 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 Chata'an in 2002. FEMA uses information from USGS stream gages to determine the level of financial aide from FEMA after storms. Currently, the WERI-USGS Cooperative Data Program 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 Cooperative Data Program provide information to assess the health and sustainability of the Northern Guam Lens Aquifer. This aquifer is the most important source of fresh water on the island. The current data program includes 9 wells where water level is continuously measured and 7 wells where the thickness of the freshwater lens is measured. Collectively, this information allows scientists at WERI, GEPA, GWA, and USGS to understand the flow of water through the aquifer and refine 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 ground water production may affect the sustainability of ground water resources. Coupled with detailed geologic mapping and modern hydrologic tools such as ground water 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 7 rain gages on Guam, 5 of which are funded by the WERI-USGS Cooperative Data Program. 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 fresh water infiltrates past from the surface to reach the water table. This water, known as recharge, is the source of fresh water 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 with the design and implement mitigation strategies.

Coral reefs on Guam are thought to be damaged by sediment carried in runoff from watersheds. Managers are trying 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 erosion and sedimentation in coastal waters and onto coral reefs, thereby increasing compliance with the Clean Water Act. Streams may also become less destructive if sediment load is reduced. As part of the WERI-USGS Cooperative Data Program, 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 2009, the cost to operate a continuous-record streamflow gage will be $21,660. 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 $24,300. Other gages, such as rainfall ($10,400) and groundwater ($6,500), 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 a cooperative project between WERI and the USGS, historic data and other hydrologic information for Guam are consolidated at http://hi.water.usgs.gov/guam/guam_tab.htm.

GHS PUBLICATIONS AND ASSOCIATED DOCUMENTS

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Government of Guam
Fiscal Year 2010 Budget
Program Fiscal Summary

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

Budget Account Allocation **FUND TITLE**	**Fund**	**FY2008** Actual Appropriation	**FY2008** Percent of Program	**FY2009** Authorized Appropriation	**FY2010** Current Service	**FY2010** Program Plan	**FY2010** Governor's Recommendation	**FY20011** Projected	**FY20012** Projected
General Fund Appropriation		$848,919		$964,372	$964,372	$1,095,527		$1,244,519	
Guam Hydrologic Survey (Local)		$204,200		$192,307	$204,200	$204,200		$204,200	$204,200
Guam Water Monitoring Project (Local)		$173,948		$163,817	$173,948	$173,948		$173,948	$173,948
Guam Water Monitoring Project (Federal)		$173,948		$163,817	$173,948	$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		$50,000		$50,000	$50,000	$50,000		$50,000	$50,000
Total Program Appropriations		$1,728,020		$1,843,473	$1,843,473	$1,974,628		$2,123,620	$??
FTE Positions									
Performance Indicators	**TYPE**								
Projects Initiated	WKLD	15		15	15	16		16	16
Projects completed	WKLD	10		11	11	12		12	12
Technical Reports	WKLD	9		5	5	5		5	5
Journal Articles/Conference Proceedings.	WKLD	12		10	10	10		10	10
Workshops/Conference Presentations	WKLD	8		10	10	10		10	10