



Guam Hydrologic Survey Program

Hydrologic Data Collection on Guam: FY1998 Report

BY

JOHN W. JENSON

AND

JOHN M.U. JOCSON, Eds.



WERI

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

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Introduction

This is the first annual report from the Water and Environmental Research Institute's (WERI) Guam Hydrologic Survey (GHS) program on the status of hydrologic data collection on Guam. Its purpose is to provide a concise reference to enable people to quickly locate hydrologic data on Guam. It is intended to support not only scientists and engineers, but policy-makers, planners, regulators, educators, and interested citizens. Besides being published as a WERI technical report, this report can be accessed from the Guam Hydrologic Survey web page < <http://uog2.uog.edu/weri/ghs/> >. Comments and suggestions should be directed to the Guam Hydrologic Survey, WERI, University of Guam, or via e-mail to GHS@uog.edu.

The Guam Hydrologic Survey program was initially established in September 1997 by the FY1998-99 Budget Authorization Act, Public Law 24-59, which mandated WERI to "collect, organize, and evaluate data being collected by the government of Guam and federal agencies regarding the availability and quality of fresh water on Guam, and maintain a centralized data base of key hydrologic information." The GHS was charged to "provide the Governor of Guam, the Guam Environmental Protection Agency, the Guam Waterworks Authority, the Guam Legislature and general public timely evaluation and recommendations regarding trends in overall water use and quality."

Work began in October 1997, when WERI research assistants began visiting data collection activities and archives. Included among the chapter authors of this report are WERI research assistants sponsored by the GHS program (Quenga, Taborosi, and Vann) and graduate students who participated in the UOG Environmental Science Seminar (EV691) during Spring Semester, 1998 (Moran and Wexel).

In April 1998, Public Law 24-161, Drought Management and Comprehensive Water Conservation Plan, mandated that WERI "administer a Comprehensive Monitoring Program regarding data collection on salt water intrusion, water lens thickness in the northern part of Guam, stream-flow data in the southern part of Guam, and related matters." Funding was provided for "the immediate reinstatement and administration of the Comprehensive Monitoring Program with the United States Geological Survey...." The Comprehensive Monitoring Program mandated by PL 24-161 is being administered as a joint WERI/USGS data collection program (with 50 percent matching federal funds), in which USGS field workers and WERI faculty, staff, and students cooperate on the collection and analysis of data. To support the joint effort, USGS will re-open its Guam Field Office on the University of Guam campus in early 1999. Field work began in September 1998, and will continue through FY1999 to rehabilitate or install rain gages and pan evaporation stations across the island, rehabilitate or install stream gages and sediment samplers in southern Guam, and maintain the tidal gage at the Hagåtña boat basin. Simultaneous work is ongoing to maintain or rehabilitate existing groundwater observation wells on northern Guam to monitor groundwater levels and the vertical distribution of chloride in the fresh water lens. The appendix outlines plans for the rehabilitation of the WERI/USGS data collection program during FY1998-99.

In August 1998, the Guam Hydrologic Survey program was permanently established by Public Law 24-247, which charged it with consolidating and analyzing hydrologic data on Guam, conducting research into selected water problems, and producing regular reports on water use, trends, and key concerns regarding Guam's water resources. With the WERI/USGS data collection program now underway, and the Guam Hydrologic Survey program permanently in place, the leaders and citizens of Guam have an important and inexpensive source of scientific data and expert advice by which to manage Guam's single more valuable natural resource.

Contents

Chapter 1: Meteorological Data <i>by Peter-Paul G. Dumaliang, Charles P. Gward, and Danko S. Taboroši</i>	Page 5
Chapter 2: Surface Water Data <i>by David Vann and Curt Wexel</i>	Page 11
Chapter 3: Groundwater Data <i>by Mauryn E. Quenga and John W. Jenson</i>	Page 17
Chapter 4: Tidal Data <i>by David Moran & John M. U. Jocson</i>	Page 30
Chapter 5: Geological Data <i>by Danko S. Taboroši, John W. Jenson, and H. Galt Siegrist</i>	Page 34
Chapter 6: Distribution System Data <i>by David Vann</i>	Page 38
Appendix: Current Physical Condition and Rehabilitation Plans for WERI/USGS-administered Observation Sites	Page 40
Acknowledgments	Page 46

Figures and Tables

Figure 1.1	Rainfall data collection stations	Page 8
Figure 2.1	Stream gaging stations on Southern Guam	Page 13
Figure 2.2	USGS stream gage periods of record	Page 14
Figure 3.1	Observation wells and sites	Page 19
Figure 3.2a	Northern Guam production wells	Page 22
Figure 3.2b	Southern Guam production wells	Page 29
Figure 4.1	Tidal gage locations	Page 31
Table 1.1	Meteorological data collection agencies, archives, points of contact	Page 5
Table 1.2	NWS and NWS-cooperative rain gages	Page 7
Table 2.1a	Points of contact for streamflow data collection	Page 11
Table 2.1b	Points of contact for surface water production and quality	Page 11
Table 2.2	Production metering status for surface sources	Page 15
Table 2.3	Surface water quality tests and collection frequency	Page 16
Table 3.1	Points of contact for groundwater data	Page 17
Table 3.2a	GWA wells by sub-basin	Page 23
Table 3.2b	Northern Guam well owners and points of contact	Page 24
Table 3.2c	Southern Guam well owners and points of contact	Page 26
Table 3.3	Wellhead chloride sampling for production wells	Page 27
Table 5.1	Geology points of contact: Guam Hydrologic Survey, WERI	Page 34
Table 5.2	Drilling data points of contact	Page 35

Chapter 1

Meteorological Data

by Peter-Paul G. Dumaliang, Charles P. Guard, & Danko S. Taboroši

This chapter discusses meteorological data collection on Guam. Current points of contact for the agencies and activities that collect or archive meteorological data are summarized in Table 1.1.

Table 1.1.
Meteorological data collection agencies, archives, and points of contact

Agency	Point of Contact	Contact
USGS	Barry R. Hill, Asst. District Chief, Hawaii, USGS	Phone: (808) 522-8290 E-mail: brhill@usgs.gov
NWS	Dave Meek, Data Manager, NWS	(671) 472-7397
Military:		
Navy	AGAN Keith Holder	(671) 349-5314 holder@nrmocw.navy.mil
Air Force	Sgt. Ronald Bridges	(671) 366-5230 bridgesr@andersen.af.mil
Private Sector	Jane Jameson Williams Clay Carlson Kuentos Communications Inc.	WERI WERI Phone: (671) 477-9109 Fax: (671) 477-4218 info@kuentos.guam.net
UOG:		
WERI	Charles Guard, Research Associate	(671) 735-2695 cguard@uog.edu
CAIS	Prem Singh, Professor	(671) 735-2000
JTWC	Edward Fukada, Technical Advisor	(671) 349-5286/7
PEAC	Ray Tanabe, Pacific ENSO Update	(808) 956-2324

Abbreviations: USGS-United States Geological Survey, NWS-National Weather Service, UOG-University of Guam, WERI-Water and Environmental Research Institute of the Western Pacific, CAIS-College of Agriculture and Life Sciences, JTWC-Joint Typhoon Warning Center, PEAC-Pacific ENSO Applications Center

DATA COLLECTION AND POINTS OF CONTACT

Several different agencies collect meteorological data on Guam. Data collected range from local rainfall, wind, and temperature to regional rainfall and typhoon-related data. The primary collectors of local weather data are the US Geological Survey, National Weather

Service, US Air Force, and US Navy. The locations and methods of collection vary. Data collection stations are shown in Figure 1.1. Data collection activities are described below.

U.S. Geological Survey (USGS)

From 1954 to the present, the USGS has recorded local rainfall at various times from a total of 16 sites. As of September 1998, the USGS operated six rain gages on Guam (Figure 1.1). Three of these — the Fena Pump House, Almagosa, and Windward Hills gages — are operated for the US Navy. Gages at Mt. Chachao, Dededo, and Umatac are operated for the Water and Environmental Research Institute (WERI) under the WERI/USGS data collection program. All of the USGS gages are float-reservoir type gages. Data are recorded by electronic data loggers at 30-minute intervals. Personnel from the Saipan field office visit Guam at the beginning of each month to download data from the data loggers at the Navy sites. WERI/USGS sites will be serviced quarterly by personnel from the Hawaii office until early 1999, when the USGS expects to have a permanent Guam field office in place on the University of Guam campus. Once the field office is in place, servicing of the WERI/USGS sites will be ongoing.

National Weather Service (NWS)

The National Weather Service Office (NWSO) currently maintains 13 rain gages on the island, of which seven are automatic and six are manual (Figure 1.1 and Table 1.2). Data from the three Fisher & Porter (named for the manufacturer of the gages) automatic rain gages at Dededo, Mangilao and Tiyan are sent monthly to the Pacific Region NWS headquarters in Honolulu, Hawaii. Data collected by the NWS's four HANDAR (also named for the manufacturer of the gages) sites are not routinely archived, and only near real-time data can be obtained from NWS (on request). The six manual stations are cooperative sites, i.e., the gages are maintained by NWS but operated by cooperating agencies (Table 1.2). These are mostly manually measured 8-inch rain cans. Rainfall data archived by the NWS are stored in the National Climate Data Center (NCDC) database and in local unpublished paper spreadsheets.

The NWS collects and archives selected satellite data for the region. The Doppler radar in Mangilao, owned and operated by the U.S. Air Force, collects cloud reflectivity and Doppler velocity data. Primary data are processed to calculate secondary data, such as accumulated rainfall. Data for Guam can be accessed through the GHS web page at <<http://uog2.uog.edu/weri/ghs>>.

Military

The US Air Force collects meteorological data at Andersen Air Force Base including rainfall variability, wind, temperature, dew point, pressure, and cloud cover (Figure 1.1). Data are collected in hourly increments and archived in the NCDC database (OK). The US Navy collects rainfall data at Nimitz Hill and at the Naval Magazine (Figure 1.1). These data are collected either manually or automatically at these sites, and are stored electronically in spreadsheets.

University of Guam

The University of Guam has four data collections sites: one each in Talofofo, Andersen Air Force Base, Inarajan and Yigo (Figure 1.1). The Talofofo and the Andersen AFB sites are maintained by WERI. The Talofofo site contains a tipping-bucket rain gage and data logger, which collects and records rainfall data at one-minute intervals. Data collection at this site started on September 1, 1986. The Andersen AFB site has two side-by-side tipping-bucket rain gages and a datalogger that collects data at 0.01-inch intervals. Data collection at this site started June 1, 1998. The Inarajan and Yigo sites are maintained by the College of

Table 1.2
NWS and NWS-cooperative rain gages

<u>Location</u>	<u>Type of Station</u>	<u>Database</u>
<i>Automatic Tipping-Bucket Rain Gage Sites</i>		
Agat Fire Station	Cooperative	NCDC; NWSO Guam
Commercial Port	NWS HANDAR	Not archived; can be downloaded
Fena Lake (Naval Mag.)	NWS* (rain gage only)	Pacific Reg. HQ NWS Honolulu
Mangilao (Univ. of Guam)	NWS HANDAR	Not archived; can be downloaded
Merizo (Mayor's Office)	NWS HANDAR	Not archived; can be downloaded
NASA Dan Dan (State Dept.)	NWS HANDAR*	Pacific Reg. HQ NWS Honolulu
Piti Fire Station	Cooperative*	Pacific Reg. HQ NWS Honolulu
<i>Manual 8-inch Can Sites</i>		
WSFO Tiyan	NWS Official	NCDC; NWSO Guam
Dededo-GWWA	Cooperative	NCDC; NWSO Guam
Inarajan Agricultural Station	Cooperative	NCDC; NWSO Guam
Mangilao-Dept. of Agriculture	Cooperative	NCDC; NWSO Guam
Umatac-GWA	Cooperative	NWSO Guam
Yigo Animal Shelter	Cooperative	NCDC; NWSO Guam

* - Fischer & Porter Type Tipping-Bucket Rain Gage

Abbreviations: NCDC = National Climate Data Center, NWS = National Weather Service, NWSO = National Weather Service Office

Note: Tafolofa Golf Course cooperative site was destroyed in Typhoon Paka, December 1997, and has not been reactivated.

Agriculture and Life Sciences (CAIS). The Inarajan site, located at the Inarajan Agricultural Experiment Station, has been operating since 1984. Both sites are equipped with tipping-bucket rain gages, with data loggers that collect and record hourly rainfall. In addition, both sites collect data on the temperature, humidity, solar flux, wind speed and direction.

Private

Three private data collection stations are currently maintained (Figure 1.1). Data collected and recorded are mainly monthly rainfall data. Most are currently recorded in electronic spreadsheets. Ms. Jane Jameson-Williams maintains a site on Nimitz Hill. Mr. Clay Carlson maintains rain gages in Bile Bay, Merizo and Tinaga, Inarajan. They have generously provided data for several recent studies, most recently a soil erosion study (Dumaliang, 1998). Kuentos Communications Inc., a commercial communications company, maintains an automatic weather station in Maite.

Regional Meteorological Data Collection Activities

Typhoon-related data are currently being collected by the Joint Typhoon Warning Center JTWC at Nimitz Hill. Data are kept in both published reports and at the JTWC web site, < <http://metoc.npmocw.navy.mil/npmocw/prods/jtwc.html> >. The JTWC is scheduled to relocate from Guam to Pearl Harbor, Hawaii in January 1999. Rainfall data for Micronesia



Fig. 1.1. Rainfall Data Collection Stations

and American Samoa are reported by the Pacific ENSO (El Niño — Southern Oscillation) Application Center (co-located at the University of Guam and the University of Hawaii) in their Pacific ENSO newsletter. Data can be accessed from their web site at < <http://naulu.soest.hawaii.edu/>>. WERI meteorologists also collect typhoon- and ENSO-related satellite data. WERI inaugurated a real-time meteorological satellite imagery processing and display system in August 1998.

Data Archives

Meteorological data for Guam and the western Pacific region are archived in various locations and are accessible through different media. USGS published a rainfall data report for 1989 in Volume 2 of *Water Resources Data - Hawaii and Other Pacific Areas*. Copies of this report are held at GEPA, WERI, and at the UOG RFK Memorial Library. Reports can also be purchased from the US Department of Commerce (NTIS, 5285 Port Royal Road, Springfield, VA 22161). USGS data for the entire record can be obtained from the USGS district office in Honolulu. At the NWS office, archived data include temperature, wind speed and direction, atmospheric pressure, relative humidity, dew point, visibility, heat index, sky conditions, sunrise and sunset, cooling degree days, occurrence of thunderstorms and percent possible sunshine. These data are updated regularly and reported on the NWSO Guam web page < <http://www.nws.noaa.gov/proguam>>. They are also available in the *Climatological Data Summaries* published by the NCDC in Asheville, NC. Historical data are also available on a commercial CD-ROM database, *Climatedata*, prepared by Hydrosphere®. WERI maintains a subscription to *Climatedata* but there is typically about a one-year delay between data collection and publication in the CD-ROM database. Table 1.1 summarizes the points of contact for agencies that collect and archive data.

Recommendations

There are some serious coverage gaps in the current meteorological instrumentation of Guam, but installation of additional sites during FY1999 under the WERI/USGS data collection program (Appendix) will eliminate some of the most important ones. With the closing of the WSMO station in northern Guam in 1995, we lost our only rain gage in the northwestern corner of the island. This area is underlain by an important part of the northern Guam aquifer, with a substantial portion of the estimated reserve. Loss of the rain gage in this area leaves us with no means of directly measuring the precipitation that recharges this part of the aquifer. We also lack instrumentation at the higher elevations in northern Guam, particularly Mt. Santa Rosa and Barrigada Hill, which also influence recharge to the aquifer. Plans for the WERI/USGS data collection program during FY1999 call for installation of one new rain gage on northern Guam. WERI and the USGS are working together now to determine the priority for coverage in northern Guam and identify a suitable site for the new rain gage.

For southern Guam, WERI/USGS data collection plans for FY1999 call for installation of a new rain gage at Mount Jumulong Manglo. This will provide a high-elevation rain gage for southern Guam, which is particularly important since high-elevation rainfall can be an especially important component of the total rainfall captured by surface watersheds. Other areas lacking coverage on southern Guam include the Orote Peninsula and Cocos Island. (The former USGS-operated station at Cocos Island was taken out of service in 1966.)

An especially serious loss with the closing of the WSMO station in northeastern Guam in 1995 was the loss of the only pan evaporation station on the entire island. Lack of pan evaporation data leaves us with no means of estimating the portion of precipitation that is lost due to plant transpiration and surface evaporation. It thus limits the accuracy of aquifer recharge estimates and leaves us without local data for estimating evaporation from

surface reservoirs — a crucial parameter for managing surface water supplies, predicting the impact of droughts, and designing future surface water reservoirs. Plans for the WERI/USGS data collection program provide for installation of a new pan evaporation station for northern Guam as soon as access to a suitable site is obtained. On southern Guam, a second pan evaporation station is proposed for installation at the Fena Water Treatment Plant. Eventually, a more comprehensive network of pan evaporation sites should be established across the island and at different elevations to evaluate the dependence of pan evaporation on location and elevation.

Finally, there is a serious need on Guam for meteorological instruments designed to operate in high-wind conditions. Many rain gages and anemometers were damaged or destroyed during the passage of Typhoon Omar (August 1992) and Super Typhoon Paka (December 1997). Until more adequate spatial coverage with wind-resistant devices is realized, rainfall distribution and wind estimates during typhoons will be sparse, inconsistent, and difficult to quantify.

References

Dumaliang, P.P.G. (1998) "The Determination of Rainfall Erosivity and Soil Erodibility for Southern Guam by Accounting for the Variability of Rainfall," Master's Thesis

Chapter 2

Surface Water Data

by David Vann and Curt Wexel

This chapter discusses surface water data collection activities for streamflow, production, and water quality. Current points of contact for the agencies and activities that collect or archive surface water data are summarized in Table 2.1.

Table 2.1a. Points of contact for streamflow data collection

USGS Hawaii Office	Barry Hill Asst. District Chief	Phone: (808) 522-8290 E-mail: brhill@usgs.gov
	Jill Torikai Hydrologist	(808) 522-8290 jtorikai@usgs.gov
USGS Saipan Office	Rob Carruth Field Hydrologist	(670) 322-2060 rlcarr@usgs.gov
	Bruce Hill Hydrologic Technician	(670) 322-2060 bahill@usgs.gov

Table 2.1b. Points of contact for surface water production and quality

	Surface Water	Water Quality
US Navy PWC	Tom Ryczek Director Utilities & Wastewater (671) 339-5200	US Navy PWC Fena Laboratory Director (671) 339-3157
GWA	Joaquin San Nicolas Water Division Manager (671) 475-1658	Carmen Sian-Denton Laboratory Director (671) 632-9697
GEPA	Marilou Yamaraka WRMP Director (671) 475-1657	Vance Eflin Chief of Surveillance (671) 475-1657

STREAM-FLOW DATA

Data Collection

Over the past 45 years, the USGS has collected stream data at 20 different stations on Guam (Figures 2.1 and 2.2). They currently operate nine stream gages. Six are stream-flow gages (at which data are recorded automatically at 15-minute intervals), one is a stage-only gage (which records water level only, but does not calculate flow), and two are cresting-weir gages (which record only the maximum flow stage, i.e., flood levels). One of the

stream-flow gages is maintained on the Ylig River under the USGS's nationwide Collection of Basic Records program. The others are currently operated for the US Navy and US Army Corps of Engineers.

For the Navy, USGS operates stream-flow gages on the Almagosa River, Imong River, Malaup River, and Tolaeyuus River. They also maintain a stage-only gage (lake-level recorder) at the Navy's Fena Dam spillway. (Prior to 1973, flow data were calculated from this gage, but since 1973 only water level data have been reported.) For the Corps of Engineers, USGS operates a stream-flow gage on the Ugum River, and cresting-weir gages at the Namu River and Asan River.

Plans for the Water and Environmental Research Institute (WERI)/USGS data collection program call for reactivation of the Pago River, Geus River and Inarajan River gages (Appendix). Plans also call for the installation of new stream gages on the Atantano and La Sa Fua Rivers. Stream gages on the Ylig, Ugum, and La Sa Fua Rivers will be equipped with sediment samplers. These will provide the first sediment measurements by the USGS on Guam since the early 1980s. (Previous sediment samplers were operated on the Ylig, Ugum, and Talofofo Rivers in the early 1970s and 1980s.)

At the sites operated for the Navy, data are downloaded monthly by personnel from the USGS Saipan field office. At the other sites, data have been downloaded quarterly by personnel from the Hawaii office. Re-opening of the USGS Guam Field Office, anticipated for early 1999, will allow ongoing servicing of the all USGS sites on Guam.

Data Archives

USGS published daily mean stream-flow plus statistical summary information for water years 1961 through 1976 in *Water Resources Data - Hawaii and Other Pacific Areas*. Data from 1977 through 1989 were published in Volume 2 of *Water Resources Data - Hawaii and Other Pacific Areas*. Copies of some reports are held at GEPA (1982-1984 and 1986-1989 reports), WERI (1979 and 1982-1989 reports), and at the USCG RIFK Memorial Library (1989 report). The reports can be purchased from the US Department of Commerce at NTIS, 5285 Port Royal Road, Springfield, VA 22161.

USGS data can be obtained from the USGS district office in Honolulu. Historical data are also available on the commercial CD-ROM database, *Hydrodata*, prepared by Hydrosphere®. WERI maintains a subscription to *Hydrodata*, but there is typically about a one-year delay between data collection and publication in the CD-ROM database.

Observations and Recommendations

Although Guam has no immediate plans for development of additional surface water production facilities, surface water resources in southern Guam constitute an important remaining reserve. Engineering development of stream sources in the south depends on having adequate data on stream hydrology. Implementation of the WERI/USGS data collection program will provide important data to support future development. To help focus data collection and analysis on the sites where development will eventually take place, however, steps should be taken now to identify prospective sites for future development.

SURFACE WATER PRODUCTION DATA

Data Collection

The US Navy produces drinking water from Fena Reservoir, the Almagosa Springs (Chepek and Dobo Springs) and Bona Spring. Water from all of these sources is processed through the Fena Water Treatment Plant. The US Navy Public Works Center (PWC) records daily water production at each of these sources and the Fena Water Treatment Plant.

Surface sources used by the Guam Waterworks Authority include an impoundment on the Ugum River, and diversions from Asan Spring and Santa Rita Spring. GWA meters

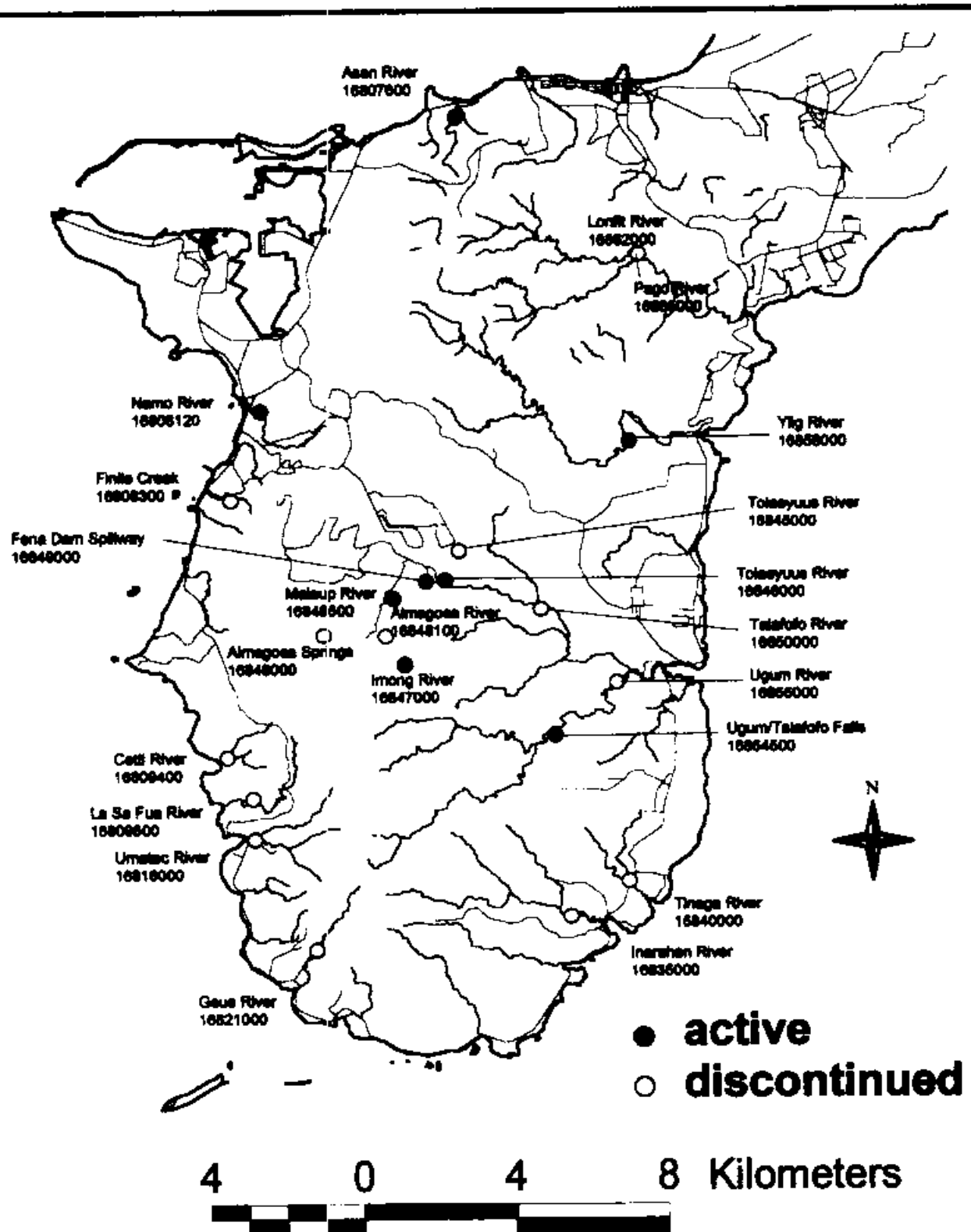
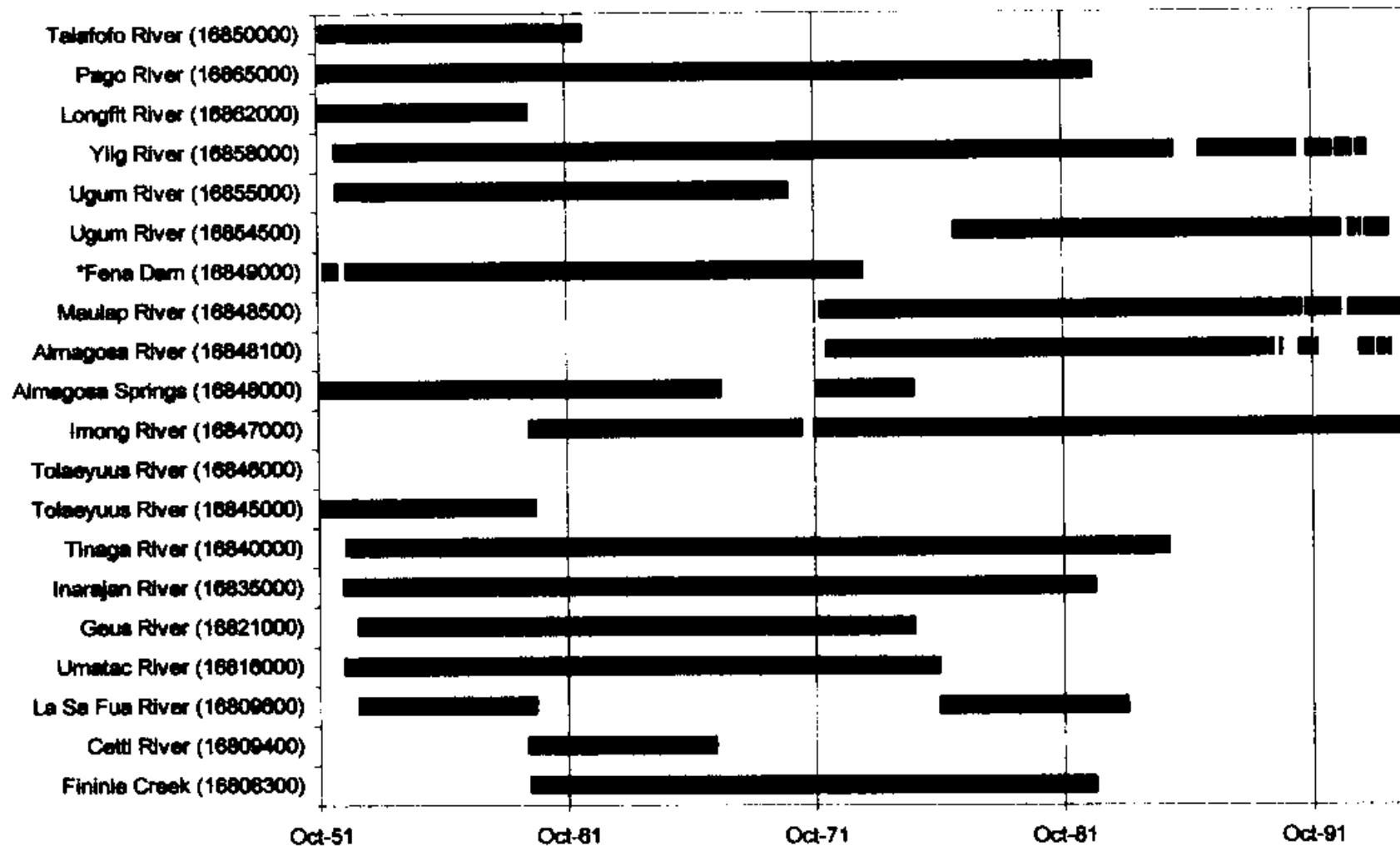


Figure 2.1. Stream gaging stations on Southern Guam

Figure 2.2. USGS stream flow gaging periods of record.



*Stage-only data from 1973-present

net production from the Ugum Water Treatment Plant but does not meter raw water drawn from the Ugum River. Water drawn from Asan Springs is metered at the intake. GWA data telemetry from the Santa Rita Spring meter is currently not operational. Previous GWA production data recorders at Malojloj (Pigua Dam) and Umatac (Sapua Spring and Lae Lae River) have been deactivated. Metering status is summarized for each source in Table 2.2.

Table 2.2. Production metering status for surface sources

Source	Frequency	Production Meter	Metering description
Fena WTP (Navy)	Daily	Sparling Meter Venturi Meter	Multiple sub-meters for raw water and combined sources
Ugum River (GWA)	Daily	None	Estimates based on finished water production meter
Asan Spring (GWA)	Monthly		Estimates based on intake meter
Santa Rita Spring (GWA)	None	None	Meter out of service

Data Archives

The Navy Public Works Center (PWC) archives daily production flow in spreadsheet files, summarized monthly. GWA keeps daily production estimates at the Ugum treatment plant. Under current environmental regulations, producers are required to provide GEPA with an annual report of water production. Beginning in FY1999, the Guam Hydrologic Survey Program at WERI will maintain, in the Guam Water Resources Data Library, annual summary production statistics compiled from the GEPA consolidated data base. Data in the Guam Water Resources Data Library can be accessed via the WERI/GHS web site < <http://uog2.uog.edu/weri/ghs/> >.

Observations and Recommendation

Metering for the Ugum River production plant and telemetry at the Santa Rita Springs should be re-established.

WATER QUALITY

Data Collection Activity

Water quality tests performed at surface water production sites are summarized in Table 2.3. Testing for the Fena water treatment plant (WTP), Almagosa and Bona Spring is performed by the Navy PWC Fena Laboratory. Testing for the Ugum WTP, Asan Spring and Santa Rita Spring is performed by the GWA laboratory.

Data Archive

Records of water quality testing performed by the GWA and Navy laboratories are retained at their laboratories. Summary reports on potable water are forwarded to GEPA, as required. Intermittent periods of record containing this information between December 1975 and June 1995 can be accessed on the USEPA STORET database.

Table 2.3. Surface water quality tests and collection frequency

Source Water Tests	Fena WTP Raw Pit* (Navy)	Ugum WTP (GWA)	Almagosa & Bona Springs (Navy)	Asan & Santa Rita Spring (GWA)
Bacteria:				
Plate Count (HPC)	Monthly	None	Monthly	None
Total Coliform	Daily	10 per mo.	Monthly	None
Fecal Coliform	Monthly	10 per mo.	Monthly	None
Turbidity, pH, Conductivity, Calcium Hardness, Alkalinity, Total Coliform	Daily	10 per mo.	None	None
Temperature, Apparent Color, Odor, Carbon Dioxide	Daily	None	None	None
Total Hardness, Chlorides	Monthly	Monthly	None	None
Sulfate, Iron, Manganese, Silica, Aluminum, Dissolved Oxygen	Monthly	None	None	None
Semi-Volatile, Volatile, and Synthetic Organic Compounds	Quarterly or as required	Quarterly or as required	Quarterly or as required	Quarterly or as required

* Spring water is mixed with Fena Lake water in the pit whenever spring water is turbid

Observations and Recommendations

Both the GWA and Navy laboratories generate data to meet USEPA standards. Data archived by GEPA, however, have not been systematically inserted into the USEPA STORET database since 1990, and can therefore be accessed only from the original hard copy records at GEPA. Detailed and comprehensive studies of water quality data will be greatly facilitated when all the historical data have been entered and new data are systematically maintained in the STORET database.

Chapter 3

Groundwater Data

by Maurya E. Quenga and John W. Jensen

This chapter discusses groundwater data collection activities for water table elevation, groundwater production, and chloride along with other water quality parameters. Current points of contact for the agencies and activities that collect or archive groundwater data are summarized in Table 3.1.

Table 3.1. Points of contact for groundwater data (in alphabetical order by agency/activity)			
Agency/Entity	Data Type	Contact Person / ##	Address / Numbers
Andersen AFB	Groundwater quality	Joan Poland, Installation Remediation Prog. Mngr. Phone: (671) 366-2556 Fax: (671) 366-5088 polandj@andersen.af.mil	Installation Restoration Program 36th CES/CEVR Unit 14007 Andersen AFB APO AF 96343-4007
GEPA	Water-table levels Well production Groundwater quality	Marilou Yamanaka, WRMP Director Phone: (671) 475-1658 Fax: (671) 477-9402	P.O. Box 22439 GME, Guam 96921
GWA	Well Production	Subero Calera, Planner Phone: (671) 647-7893 Fax: (671) 649-0158	P.O. Box 3010 Hagåtña, GU 96939
	Groundwater quality	Carmen Sian-Denton, Laboratory Administrator Phone: (671) 632-9697 Fax: (671) 637-2592	
Navy Public Works Center	Groundwater quality	Tony Roberson, Environmental Services Dept. Supervisor Phone: (671) 339-4100 Fax: (671) 333-2035 robersot@pwc.guam.navy.mil	Code 900 PSC 455 Box 195 FPO AP 96540-2937
USGS	Water table levels Chloride profiles	Barry Hill, Asst. District Chief Phone: (808) 522-8290 Fax: (808) 522-8298 brhill@usgs.gov	Water Resources Div. 677 Ala Moana Blvd Suite 415 Honolulu, HI 96813
WERI	Water table levels Well production Groundwater quality	John Jocson, GHS Staff Hydrologist Telephone: (671) 735-2685 Fax: (671) 734-8890 jjocson@uog9.uog.edu	University of Guam UOG Station Mangilao, Guam 96923

WATER TABLE ELEVATION DATA

Data Collection

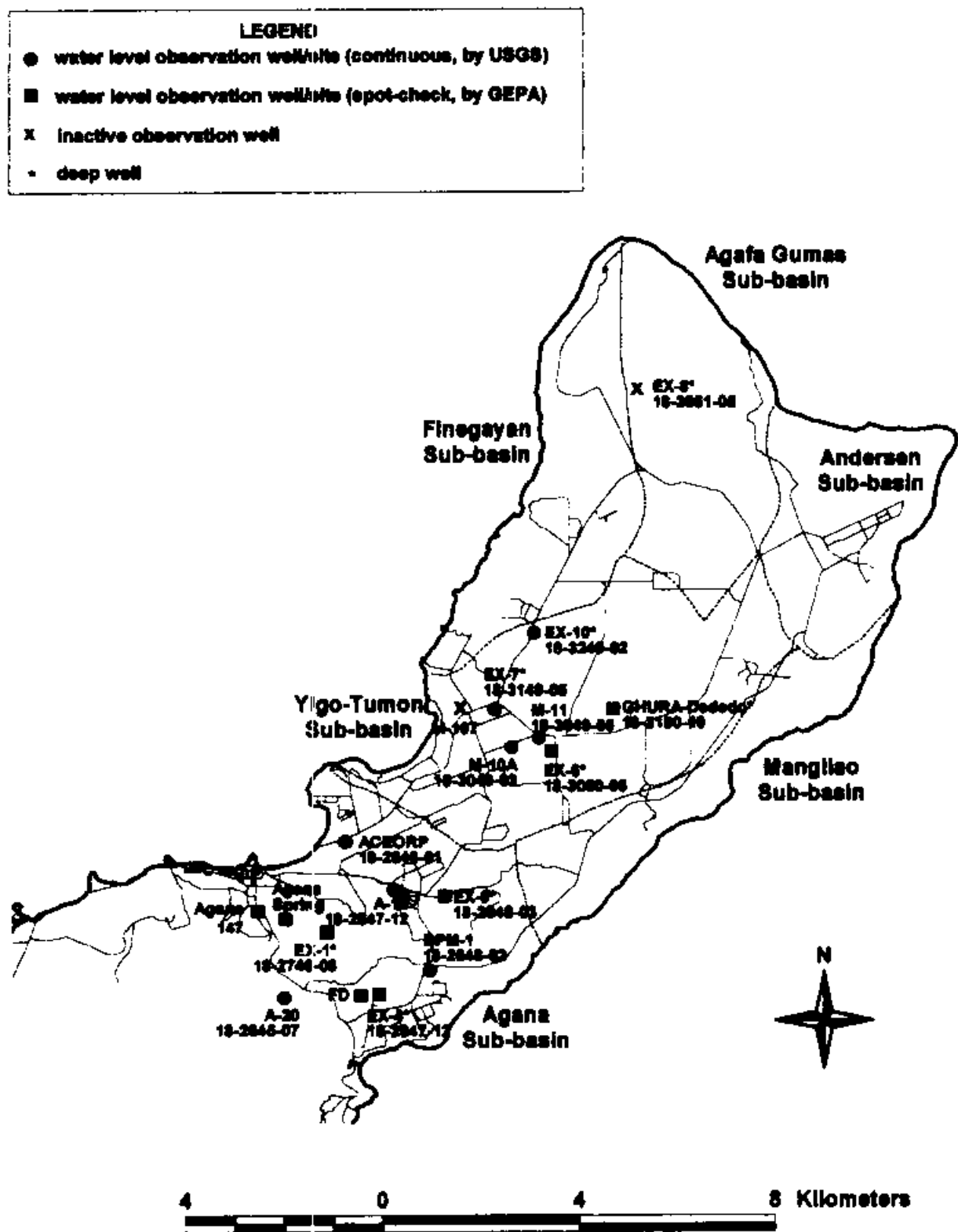
The USGS currently collects water level data from eight sites in northern Guam (Figure 3.1) as part of the Water and Environmental Research Institute (WERI)/USGS data collection program. Three of these are in the Yigo-Tumon Sub-basin: EX-7 (at the intersection of Route 3 and Marine Drive), M-10A (by Harmon Loop Elementary School), and M-11 (in the Dededo flea market). Four are in the Hagåtña Sub-basin: A-16 (in front of Carbullido Elementary School in Barrigada), A-20 (in front of the Ordot Elementary School), BPM-1 (near the Mangilao Catholic Church of Santa Teresita), and ACEORP tunnel (in Tamuning, behind the Taco Bell by the ITC Building). The last of the eight is EX-10 (near South Finegayan Navy housing). [Note: On existing maps based on the Northern Guam Lens Study (Barrett, Harris & Associates, Inc., 1982,) this well falls on the Finegayan side of the hydrologic boundary designated between the Finegayan and Yigo-Tumon Sub-Basins. Placement of these boundaries is under study and subject to revision.] Each site is instrumented to record water table elevations at 30-minute intervals. During FY1998, these sites were serviced quarterly by personnel from the Hawaii office. Quarterly servicing will continue until early 1999, when the USGS expects to have a permanent Guam field office in place on the University of Guam campus. When the field office is open, servicing of the wells will be ongoing.

GEPA's Water Resources Management Program (WRMP) began collecting monthly single-measurement water-level measurements at the Hagåtña Springs station (in the Hagåtña Sub-basin) in January 1976. Since then, the WRMP added seven observation wells (Figure 3.1) to its water-level measurement program. Of the seven observation wells, two are in the Yigo-Tumon Sub-basin: EX-6 (along Macheche Road in Mogfog, Dededo) and GILURA-Dededo (at the Guam International Country Club). Five are in the Hagåtña Sub-basin: Hagåtña 147 (near the Hagåtña McDonald's), EX-1 (Chochogo, near San Miguel Elementary School), EX-4 (in Mangilao, near Father Duenas Memorial School), EX-9 (in Barrigada, near P.C. Lujan Elementary School), and the FD well (behind Father Duenas High School). Two additional observation wells — at which monthly single-measurement water levels were previously taken by GEPA-H-107 (along the road to Two Lovers' Point in the Harmon Annex) in the Yigo-Tumon Sub-basin, and EX-8 (in Northwest Field on Andersen AFB) in the Agaña-Gumua Sub-basin — are completely out of service due to blocking or cave-ins.

Data Archive

USGS published annual reports of daily mean water levels plus statistical summary information from 1972 to 1976 in *Water Resources Data — Hawaii and Other Pacific Areas*. Data from water years 1977 through 1989 are in Volume 2 of *Water Resources Data — Hawaii and Other Pacific Areas*. Copies of some reports are held at GEPA (1982-1984 and 1986-1989 reports), WERI (1979 and 1982-1989 reports), and at the UOG RFK Memorial Library (1989 report). Reports can be purchased from the US Department of Commerce at: NTIS, 5285 Port Royal Road, Springfield, VA 22161.

The USGS also documented both GEPA and USGS groundwater data in annual reports entitled *Guam Water Data Management System Annual Reports*, from 1980 to FY1996. (The FY1997 report is in preparation.) Guam groundwater data are not yet available on the USGS web site, but GEPA and WERI have hard copies of *Guam Water Data Management System Annual Reports*. Historical data (from the 1970s through 1997) are available on *Hydrodata*, prepared by Hydrosphere®. WERI maintains a subscription to *Hydrodata*, but there is about a one-year delay between data collection and publication in the database.



Recommendations

Plans for the implementation of the WERI/USGS data collection program call for maintaining continuous water-level recording at A-16, A-20, ACEORP Tunnel, BPM-1, EX-7, EX-10, M-10A, and M-11. To adequately characterize water levels throughout the aquifer, however, each sub-basin should contain one or more observation wells. The location for any one well should be based on development plans for the sub-basin and the prospect that the well might reveal either important hydrologic characteristics of the aquifer or effects of human activities (such as pumping or storm-water diversion) in the sub-basin. At a minimum, each observation well should be equipped with an automatic data recorder capable of tracking water levels at intervals sufficiently small to identify the responses of the water level to tidal variation (i.e., 15-30 minutes), seasonal changes in precipitation, and storm water infiltration. Monthly single-measurement water level data are of no value for assessing trends in water levels since the sampling interval is too large to reveal the contribution of short-term variables such as tidal variation or recent storms.

Lack of coverage of the Finegayan Sub-basin — which contains no observation wells at internal locations — is the most serious current shortfall in water-level data collection capability, especially since the Finegayan Sub-basin is already well developed and undergoing development, and may yet possess significant reserve. Priority should be given to installation of at least an additional well or two in the central and northern portions of the sub-basin, where production wells are concentrated. Ideally, at least one observation well should be placed in a para-basal location (where the base of the fresh water lens is in contact with the volcanic basement rock), and one in a basal location (where the fresh water lens is underlain salt water permeating the limestone).

In the Yigo-Tumon Sub-basin, the largest producer of the six sub-basins, the USGS currently collects continuous water-level data at four observation wells (EX-7, EX-10, M-10A, and M-11) and GEPA collects monthly single-measurement water levels at two observation wells (EX-6 and GIURA-Dededo). Spatial distribution of these data collection sites is probably inadequate for the long-term management of this most important sub-basin, however. Current observation wells are concentrated near the southern end of Dededo. There are no observation wells at the head of the Yigo Trough, nor along its axis between Dededo and Yigo. Since these are areas known to possess substantial concentrations of groundwater, and probably a significant portion of the remaining reserve, plans should be made to install at least one observation well in each of in these areas and to cover both para-basal and basal zones.

After the Yigo-Tumon Sub-basin, the Hagåtña Sub-basin contains the second largest number of production wells. Spatial coverage in the Hagåtña Sub-basin — in which USGS collects continuous water-level data at four observation wells (A-16, A-20, ACEORP Tunnel, and BPM-1) and GEPA collects monthly single-measurement water levels at six sites (Hagåtña Spring, Hagåtña 147, EX-1, EX-4, EX-9, and FD) — is the best of the six sub-basins, although there is no continuous observation in the west-central portion of the sub-basin. In this area, data collection could probably best be improved by installing continuous data recording equipment at Hagåtña-147 or EX-1. It is important to maintain existing coverage in this sub-basin since it is heavily developed and some production wells appear to have begun to exhibit higher and increasing chloride concentrations. Additional observation wells might eventually be installed as areas of special concern are identified. Because the aquifer in the Hagåtña Sub-basin is dominated by the less permeable Argillaceous Member of the Mariana Limestone, it exhibits classic karst features (such as blind valleys and disappearing streams) that make generalizations regarding the hydrology of the aquifer extremely uncertain. Locations for additional observation wells in this sub-basin should be based on needs to characterize specific anomalies or important local variations in aquifer behavior, as they are identified.

Development in the Mangilao Sub-basin is generally a higher risk than in the others because of its limited reserve and the difficulty of locating productive well sites. Presently, there are only seven potable water production wells in this elongate sub-basin, all located near its southern end (Figure 3.2a). If these wells are to be kept in production, a co-located observation well would be useful for managing these wells and assessing the response of the local groundwater body to seasonal changes and storm water infiltration.

The Agafa Gumas and Andersen Sub-basins are also without active observation wells, but both are virtually undeveloped since they are overlain mostly by federal property. Basic hydrologic data are important for evaluating development potential and establishing baseline characteristics to support management when they are eventually developed. Rehabilitation of EX-8 in the Northwest Field area of Andersen AFB would provide a good starting point for gathering baseline data in the Agafa Gumas Sub-basin. On Andersen AFB there are numerous observation wells installed by the US Department of Defense Installation Restoration Program to monitor for chemical contaminants. One or more of these might eventually be equipped to collect continuous water level data if plans are made to install water production wells in the interior of the sub-basin.

Groundwater Production Data

Data Collection and Points of Contact

Under current environmental regulations, the groundwater production of Guam's 172 permitted production wells (Tables 3.2a, b, and c) is monitored by well owners and reported to GEPA. Guam Waterworks Authority, with 109 wells, administers the majority of the island's production wells. GWA wells are listed by sub-basin in Table 3.2a. Contact information for GWA is provided below:

Guam Waterworks Authority	Point of contact:
P.O. Box 3010	Subero Calara
Hagåtña, Guam 96939	Water Construction Superintendent
Phone number: (671) 647-7893	
Fax number: (671) 649-0158.	

For the privately-owned wells on Guam, points of contact, numbers of wells, well IDs, and types of water use are shown in Tables 3.2b (northern Guam) and 3.2c (southern Guam). Locations for all production wells are shown in Figure 3.2a (northern Guam) and 3.2b (southern Guam).

Data Collection

Well owners must obtain a well operating permit from GEPA's Water Resources Management Program before bringing the well into production. Operating permits require well owners to report monthly production by the 10th of each month to the WRMP. An annual report for each well itemizing monthly production, alteration, repair, and rehabilitation is due to WRMP by January 15th each year. Specific information can be obtained from the WRMP Director (Table 3.1).

Data Archives

GEPA's WRMP maintains islandwide well production records. Data prior to 1980 are primarily limited to GWA, Navy, and Air Force public water supply wells and are stored on hard copy in WRMP files. Data from 1980 through FY1996 are compiled in *Guam Water Data Management System Annual Reports* by the USGS. The FY1997 report is still in prepa-

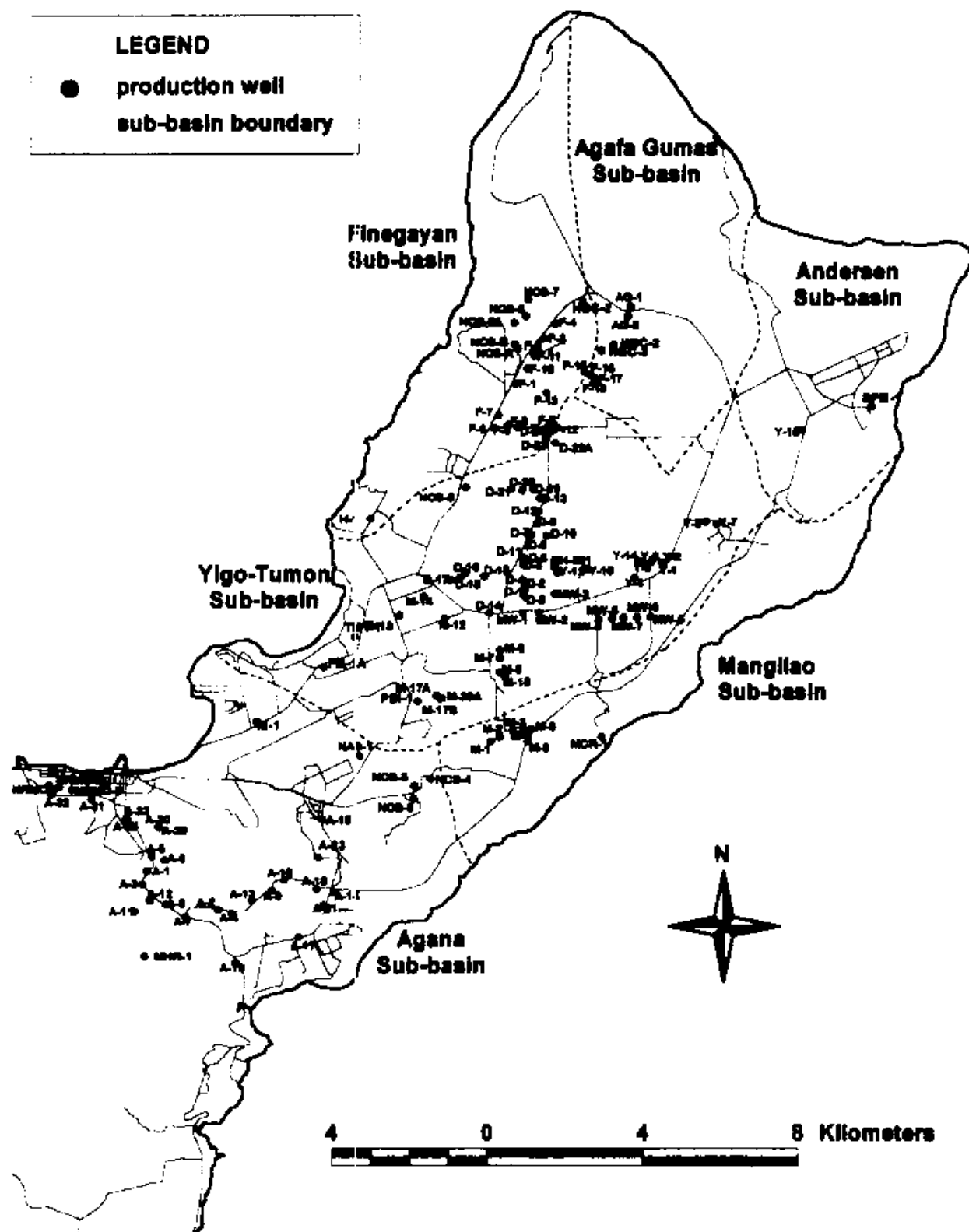


Table 3.2a. GWA wells by sub-basin

<i>Sub-Basin</i>	<i>Number of Wells</i>	<i>Well IDs</i>
Northern Guam		
Agana	28	A-1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19, 21, 23, 25, 26, 28, 29, 30, 31, 32, NAS-1
Agafa Gumas	3	AG-1, 2, HGC-2
Andersen	1	Y-15
Finegayan	21	D-22A, 23, 24 F-1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17, 18 H-1
Mangilao	8	EX-11, M-1, 2, 3, 4, 8, 9, 16B
Yigo-Tumon	44	D-1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21 EX-5A GHI-501 M-5, 6, 7, 12, 14, 15, 17A, 17B, 18, 20A* Y-1, 2, 3, 4A, 5, 6, 7, 9, 10, 12, 14
Southern Guam		
Almagosa Springs	2	AI-1, 2
Malojloj	2	MJ-1, 5
* permit for M-20A is pending		

ration. Copies of the Guam Water Data Management System reports through 1996 are available at GEPA and at WERI. Production data from 1993 through the present are maintained on ExcelTM spreadsheets and can be obtained from GEPA or WERI. Beginning in FY1999, the Guam Hydrologic Survey Program at WERI will maintain, in the Guam Water Resources Data Library, annual summary production statistics compiled from the GEPA consolidated data base. Data in the Guam Water Resources Data Library can be accessed via the WERI/GHIS web site < <http://uog2.uog.edu/weri/ghis/> >.

Data Evaluation

Data collection by private well owners generally appear to be accurate, consistent, and timely. The most recent GWA production report submitted to GEPA was for September 1997.

Groundwater Chloride Data

Data Collection

Chloride Profiles

From 1982 through 1996, USGS prepared quarterly chloride depth profiles on up to seven deep observation wells (EX-1, LX-4, EX-6, EX-7, EX-9, EX-10, and GHURA-Dededo) by measuring the chloride concentrations at selected elevations in the groundwater column. (Deep wells are defined in this document as wells of sufficient depth to penetrate the entire thickness of the fresh water lens down to 100 percent seawater.) The last of the

**Table 3.2b. Northern Guam well owners and points of contact
(alphabetical order by owner)**

Well Owner	Contact	Phone/ Fax	No. of Permitted Wells	Well Ids	Water Use
Fadian Fish Hatchery	Victor Camacho, Biologist	T: 734-3011 F: 734-7327	8 (brackish water)	FFH-1, 2, 3, 4, 5A, 6, 7, 8	Aquaculture
Foremost Foods, Inc.	Joe Collado, Chief Eng.	T: 649-9782 - 6 F: 646-9059	1	FM-1A	Industry (potable wtr.)
Hatsuko Internl. Country Club	James Taylor, Gen. Mgr.	T: 632-1268 632-0367 F: 637-4129	1	HGC-3	Irrigation
Hawaiian Rock Products	J.C. Quitugua, Adm. Mgr.	T: 734-2971 - 6 F: 789-1361/3	2	HRP-1,2	Industry
Island Equipment, Co.	Rudolfo Dilanco, Plant Manager	T: 565-2485 F: 565-4971	1	IE-1	Industry
Leo Palace Resort	Clint Huntington, Grounds/Maint. Division	T: 888-0001 ext. 1118 F: 888-0030	1	MHR-1	Irrigation
Mangilao Golf Club	Akhiro Furuta, Gen. Mgr.	T: 734-7030 F: 734-7034	4	MGC-3, 4A, 5, 6A	Irrigation
Marbo Cave Resort	Koichi Suzuki, Gen. Mgr.	T: 789-1361/3 F: 789-1496	1	MCR-1	Irrigation
Mawashima	(informally abandoned - contact GEPA for more information)		1	BCC-1	Industry
Pacific Islands Club	Sue Emde, Marine Curator	T: 646-9171 ext. 2819 F: 646-5762	1 salt water	PIC-1	Industry
Perez Brothers, Inc.	Mar Alojapan, Chief Engineer	T: 646-4945/6 F: 649-2972	1	PBI-1	Industry
U. S. Air Force	Ron Schotter, Environmental Flight	T: 366-5081 F: 366-5088	10	BPM-1, TMT-1, MW-1, 2, 3, 5, 6, 7, 8, 9 A	Public water supply
U. S. Navy	Linda Barlan, Navy PWC	T: 339-8152 F: 333-2035	13	NCS-A, B, 2, 3, 4, 5, 6, 7, 8, 9A, NRM-1, 2, 3	Public water supply

chloride profile data collection ceased at the end of 1996, when sampling equipment could no longer penetrate EX-7 and EX-9, the last two deep wells in service. Implementation of the WERI/USGS data collection program in FY1999 will rehabilitate all seven wells for chloride profiling. (Note: All wells, except for EX-1, GHURA-Dededo, and EX-4, are uncased. Most of them were taken out of service as they became blocked from spalling-off of the rock in the bore hole.)

Wellhead Sampling

The Guam Waterworks Authority (GWA) laboratory collects and analyzes source water at each of its wells once per quarter. Contact information is provided below:

Mailing Address:	Point of contact:
Guam Waterworks Authority	Carmen Sian-Denton
P.O. Box 3010	Monitoring Services Laboratory Administrator
Hagåtña, Guam 96939	
Telephone: (671) 632-9697	
Fax: (671) 637-2592	

Environmental regulations require owners of potable water wells to monitor chloride concentrations. Monitoring frequencies (Table 3.3) vary depending on water use (see Tables 3.2b and c). Non-potable water wells may also be tested if background chloride levels are high. Results are submitted to GEPA's Water Resources Management Program. GEPA confirms well owners' results by conducting annual wellhead chloride sampling of all production wells, regardless of water use and background chloride levels.

Data Archive

USGS groundwater data for Guam are not currently available on its web site, but USGS chloride profiles were annually published in *Water Resources Data - Hawaii and Other Pacific Areas*, Volume 2 from 1982 to 1989. Copies of some reports are held at GEPA (1982-1984 and 1986-1989 reports), WERI (1982-1989 reports), and at the UOG RFK Memorial Library (1989 report). The reports can be purchased from the US Department of Commerce at NTIS, 5285 Port Royal Road, Springfield, VA 22161.

USGS chloride profiling data from 1985 through 1996 and GEPA data from 1980 through FY1996 have been compiled in *Guam Water Data Management System Annual Reports* by the USGS. The 1997 report is still in preparation. The GWA Laboratory maintains quarterly chloride data on hard copy from 1973 to the present and on ExcelTM spreadsheets for FY1997. Data from 1993 through FY1997 are available on ExcelTM spreadsheets. GEPA and WERI maintain copies of the *Guam Water Data Management System Annual Reports* and spreadsheets. Limited chloride and other water quality data (from 1976 to 1996) are available on Hydrosphere[®]'s EPA Storet CID-ROM database. WERI maintains a subscription to Hydrosphere[®], but there is about a one-year delay between data collection and publication in the EPA Storet database.

Data Evaluation and Recommendations

The fundamental limit to production from island and coastal aquifers is the amount of fresh water that can be withdrawn without contaminating the production zone of the fresh water lens with salt water. Monitoring chloride concentration in the groundwater is the single most important means for assessing whether current management practices and estimated sustainable yields are appropriate. Rehabilitation of the USGS chloride profiling program (at EX-1, EX-4, EX-6, EX-7, EX-9, EX-10, and GHURA-Dededo) (Figure 3.1 and Appendix) is an important move towards adequate data collection.

**Table 3.2c. Southern Guam well owners and points of contact
(alphabetical order by well owner)**

Well Owner	Contact	Phone/ Fax	No. of Permitted Wells	Well Ids	Water Use
Cocos Island Resort	Nolan Uhls, Facilities Dir.	T: 828-8691 F: 828-2038	2 (salt water)	CIR-1, 2	Private water Private water
Country Club of the Pacific	Koichi Suzuki, Gen. Mgr.	T: 789-1361 - 3 F: 789-1496	6	CCP-1, 2, 3, 4, 5, 6	Irrigation
Island Equip- ment, Co.	Rudolfo Dilanco, Plant Manager	T: 565-2485 F: 565-2485	1	IE-2	Industry
MCI	Samuel Silva, Supervisor	T: 475-3740 F: 477-8401	1	RCA-1	Private water supply
Shell Guam, Inc.	Frederick Otte, Environ. Mgr./ Engr. Coord.	T: 477-4348 - 52 F: 477-4353	1	GOR-1	Industry
Talofofo Golf Resort	Ikuo Kuniyoshi, Golf Course Sup.	T: 789-5555 F: 789-3333	6	TGR/E-1, 2, 3, 4, 5, 6	Irrigation
Windward Hills C. C., Inc.	Frank Cruz, Grounds/ Maint. Div.	T: 789-1612 F: 789-9422	1	TGC-1	Irrigation

It is important to note, however, that even after all seven of the wells are brought back on line, chloride profiles will still be obtained only in the Hagåtña and Yigo-Tumon Sub-basins (and, at EX-10, along the boundary between the Yigo-Tumon and Finegayan Sub-Basins). The Finegayan Sub-Basin should be given high priority for the installation of additional observation wells for chloride profiles. The Mangilao well cluster should also be given high priority if the production wells in that sub-basin are to be kept in production. Before development proceeds in the Agafa Gumas and Andersen Sub-basins, chloride profiling should be initiated in at least one well located in the approximate center of the area from which production is anticipated. Rehabilitation of EX-8 (currently inactive) for chloride profiling and water level measurement would an important step for characterizing the freshwater lens in the Agafa Gumas sub-basin. This should be given priority following rehabilitation of the seven wells currently planned under the WERI/USGS data collection program.

It should also be noted that even with the implementation of the WERI/USGS data collection program, current plans provide for only quarterly collection of chloride profile data. It would be useful to eventually equip some wells with electronic instruments capable of collecting continuous chloride profile data. GEPA is currently pursuing plans to obtain such equipment. Installation of continuous recorders at selected observation wells will enable hydrologists to observe responses to storms, droughts, and nearby human activities (such as storm water diversion). Periodic profiling of the wells under the WERI/USGS data collection program will provide data for keeping electronic instruments cali-

**Table 3.3. Wellhead chloride sampling for production wells
(alphabetically by owner)**

Well Owner	Number of Permitted Production Wells	Chloride Monitoring Frequency
Cocos Island Resort	2 (salt water)	N/A
Country Club of the Pacific	6	Quarterly
Fadian Fish Hatchery	8 (brackish water)	Annually
Foremost Foods, Inc.	1	Annually
Guam Waterworks Authority	109	Quarterly
Hatsuho International C.C.	1	Annually
Hawaiian Rock Products	2	Annually
Island Equipment, Co.	2	Annually
Leo Palace Resort	1	Annually
Mangilao Golf Club	4	Monthly
Marbo Cave Resort	1	Annually
Mawashima	1	N/A
MCI	1	Annually
Pacific Islands Club	1 (salt water)	N/A
Perez Brothers, Inc.	1	Quarterly
Shell Guam, Inc.	1	Annually
Talofofo Golf Resort	6	Annually
U. S. Air Force	10	Annually
U. S. Navy	13	Annually
Windward Hills Country Club	1	Annually

brated. These two programs, once implemented, could be operated concurrently and would provide very useful complementary data.

Wellhead chloride sampling of production wells is useful and should be continued. It is important to note, however, that wellhead sampling gives no information on the thickness of the lens; the chloride concentration at the well head is a function of the relative location of the well screens within the lens, as well as the lens thickness. Comparisons of differences in chloride data from well to well must therefore take into account differences in well screen depths and local lens geometry. Temporal trends at a given well, however, can provide useful information for identifying changes in fresh water lens conditions.

In addition to the ongoing collection of chloride data, a useful and inexpensive addition to the data collection program would be to evaluate the pre-development chloride profile to the depth of the well in each new production well. Although in most cases well depths do not penetrate the entire thickness of the lens, information of the vertical gradient of the chloride concentration might be useful in characterizing the lens and diagnosing possible future problems.

Other Water Quality Parameters

Observation Wells

In addition to chloride, the USGS also constructed profiles based on specific conductance from 1980 to 1996. These data can be found in the reports described in the "Data Archive" section of this chapter.

Production Wells

GEPA requires sampling for certain water quality parameters before well operators are issued operating permits. These tests must be repeated every five years, when the well operating permit is renewed. Testing parameters depend on the intended use of the well. Wells used as potable water sources must be tested for all Primary Safe Drinking Water parameters while wells intended for non-potable use have less extensive sampling requirements. In addition, certain well owners are required to periodically test for pesticides and fertilizers (in both ground and surface water). GEPA's Water Resources Management Program can be contacted for detailed information (Table 3.1).

Underground Injection Control (UIC) Wells

GEPA requires UIC well owners to periodically sample injection wells, in which storm water runoff is allowed to drain through a borehole. The WRMP Director can be contacted for more information (see Table 3.1).

Military Groundwater Monitoring

Since 1983 the Andersen Air Force Base Installation Restoration Program (IRP) has investigated possible groundwater contamination as a result of Air Force activities. IRP documents are available at the Nieves M. Flores Memorial Library in Hagåtña and UOG's RFK Memorial Library. For more information the Remedial Project Manager can be contacted at the addresses and numbers listed in Table 3.1.

The Navy also conducts groundwater contamination investigations as part of the Base Realignment and Closure (BRAC) program and other projects. The Navy Public Works Center (PWC) Environmental Services Supervisor can be contacted for more information at the addresses and numbers listed in Table 3.1.

References

Barrett, Harris & Associates, Inc., 1982, Northern Guam Lens Study.

LEGEND

- production well

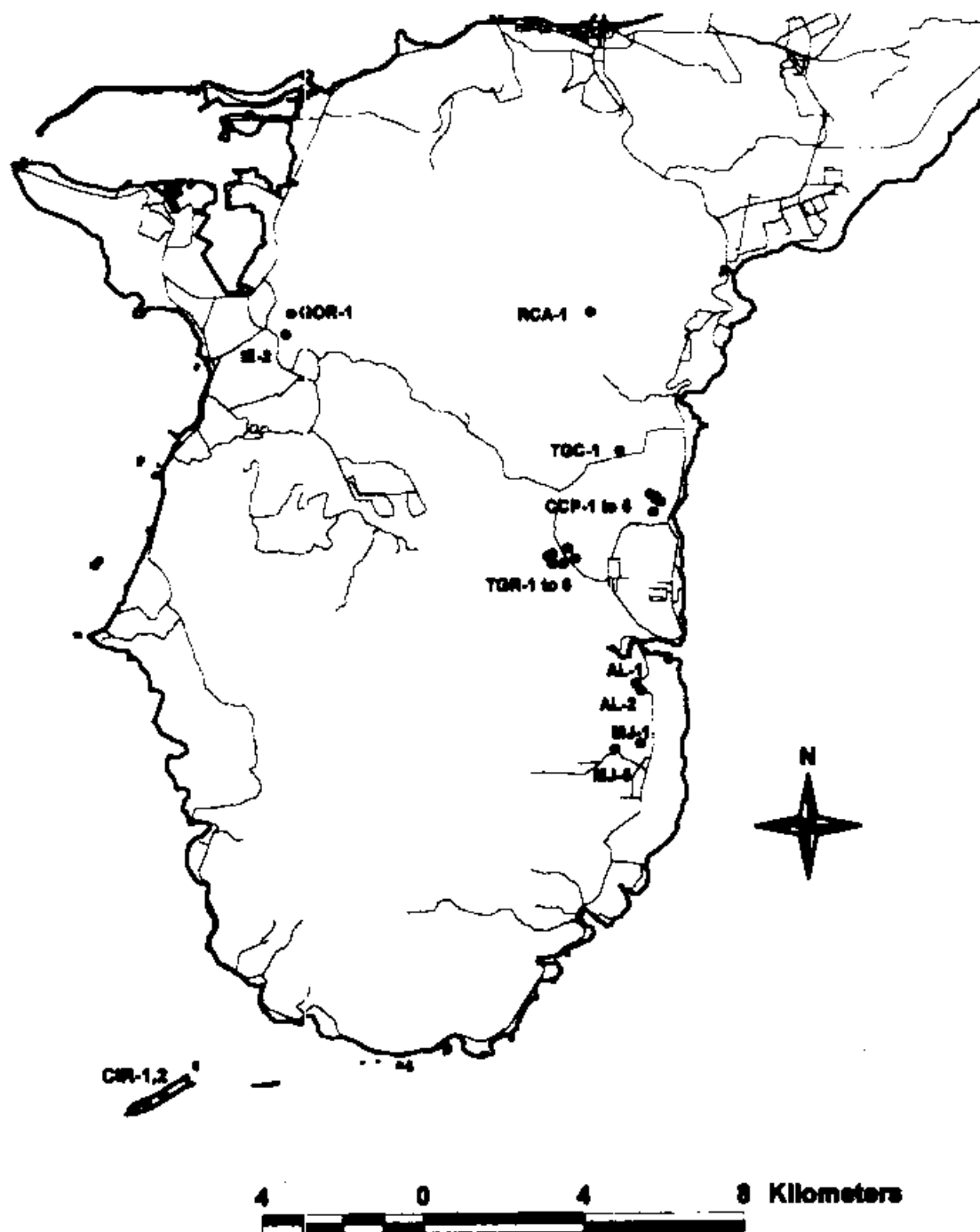


Figure 3.2b. Southern Guam production wells.

Chapter 4

Tide and Coastal Zone Data

by David Moran and John M.U. Joeson

This chapter discusses tidal data collection activities and provides points of contact for current work on the impact of fresh water discharge on coastal water quality.

Tidal Data

DATA COLLECTION AND POINTS OF CONTACT

US Geological Survey

Under the Water and Environmental Research Institute (WERI)/USGS data collection program, the United States Geological Survey (USGS) operates a tidal gage at the top of the ramp to the commercial boats in the Hagåtña Boat Basin (Fig. 4.1). Water level is recorded every 15 minutes by a digital recorder. USGS personnel from the Honolulu office visit Guam quarterly to download the data. With the re-opening of the USGS Guam Field Office during FY1999, servicing of the gage will be ongoing.

USGS Data Archive

USGS has published daily mean tidal levels plus statistical summary information for the Hagåtña tide gage since April 1983. Tidal information from 1986 through water year 1989 is published in Volume 2 of *Water Resources Data – Hawaii and Other Pacific Areas*. Copies of some reports are held at GEPA (1982-1984 and 1986-1989 reports), WERI (1979 and 1982-1989 reports), and at the UOG RFK Memorial Library (1989 report). The reports can be purchased from the US Department of Commerce at NTIS, 5285 Port Royal Road, Springfield, VA 22161.

USGS also documented tidal data in printed reports, *Guam Water Data Management System Annual Reports*, from 1980 to 1996 (The report for 1997 is in preparation). Hard copies of these reports are held at GEPA and WERI. USGS data can be obtained from the USGS district office in Honolulu. Historical data are also available on a commercial CD-ROM database, *Hydrodata*, prepared by Hydrophere®. WERI maintains a subscription to *Hydrodata*. There is typically about a one-year delay between data collection and publication in the CD-ROM database.

National Oceanographic Atmospheric Administration (NOAA)

The NOAA station is located at the western entrance to Sumay Cove Marina in outer Apra Harbor (Fig. 4.1). It normally contains an acoustic gage, a back-up analog bubbler gage with a chart recorder, and a tsunami device. Up until the passage of Typhoon Paka on December 16-17, 1997, tide levels were measured at six-minute intervals, with the data sent via satellite telemetry to NOAA Data Collection Center in Seattle. Typhoon Paka put the gage station out of service, however. Plans are underway to rebuild the station but actual construction will be dependent on the availability of funds, which are not expected to be available until the next fiscal year. Point of contact for the station is:

Mr. Mickey Mcss
NOAA Ocean Systems Pac. Reg. Office
7600 Sand Way NE Seattle, WA 98115-0700
Phone: (206) 526-6360

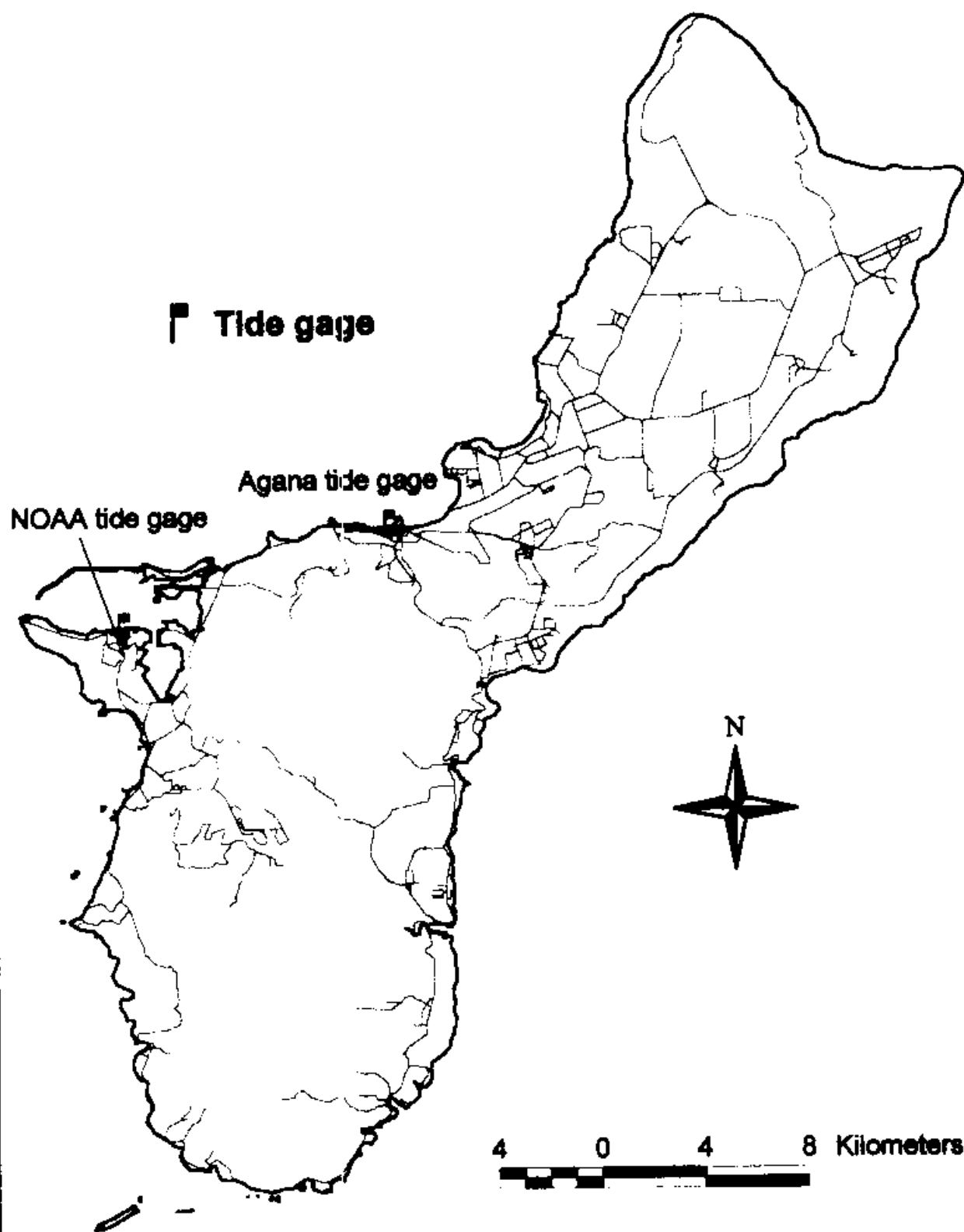


Fig. 4.1 Tide gage locations

NOAA Data Archive

NOAA data can be obtained through the National Ocean Service web site < <http://www.opsd.nos.noaa.gov> > or through the University of Hawaii web site at < <http://uhslc.soest.hawaii.edu> >.

Evaluation and recommendations

The USGS tide gage station is a reliable site, but it is currently the island's only operating tidal data collection site. Until the NOAA station is restored there will be no backup for failure of the Hagåtña gage. Installation of a second station by USGS would provide backup to the existing gage. It should also be noted that the island has no gage on the Pacific Ocean side of the island; there is therefore no means of evaluating tidal differences between the two sides of the island.

Coastal Water Quality

DATA COLLECTION AND POINTS OF CONTACT

Guam Environmental Protection Agency (GEPA)

GEPA currently collects coastal water quality data at selected river mouths and beaches. Water samples are tested in the GEPA laboratory. Point of contact is

Mr. Vance Eflin, Chief of Surveillance
P.O. Box 22439, GMF
Barrigada, GU 96921
Phone: (671) 475-1665
Fax: (671) 477-9402

Archive

Until 1990, GEPA sent its data to the USEPA STORET archival system. Since 1990, however, data have not been systematically sent to the STORET database. Data from 1990 to present are kept in hard copy at GEPA and are currently being transferred into ExcelTM spreadsheet files.

Evaluation and recommendations

Since contaminants from fresh water discharging at the coast can affect the quality of near-shore waters which support recreation and food collection, the quality of the fresh water entering the coastal zone is an essential piece of information for evaluating the impact of development and human activities on the coastal zone and for determining what sort of remedial steps might be needed. Although coastal waters near river mouths are sampled regularly, groundwater discharging at the coast is not being systematically sampled. Groundwater discharging from the lens can entrain contaminants from the surface, including sewage from leaking lines or septic tanks, agricultural chemicals and fertilizers. Testing coastal springs for plant nutrients, particularly nitrates and phosphates, as well as for selected pesticides and other potential contaminants, can provide a means of determining whether contaminants are being released in the groundwater sub-basin. It is particularly important to obtain baseline data against which to evaluate the affects of ongoing development and pollution from human activities.

As part of a series of studies on nutrient flux into the bay, Dr. Ernest Matson, University of Guam, collected bi-weekly groundwater samples in Tumon Bay from 1986 until 1996. Currently, there is no ongoing sampling of coastal spring discharge into Tumon Bay or anywhere else along the coast. A program of regular sampling of groundwater coastal

discharge should be instituted immediately. This program would provide baseline data from which to determine trends in selected nutrient (e.g., nitrate and phosphate) species that could affect coastal water quality, as well as occurrence of selected chemical or biological indicators of storm water and sewage contamination.

Chapter 5

Geologic Data

by Danko S. Taboroši, John W. Jenson, John M.U. Jocson and H. Galt Siegrist

This chapter summarizes the historical information regarding the basic geology and hydrogeology of Guam, the current geological research, and data held or being compiled by Water and Environmental Research Institute (WERI).

DATA COLLECTION AND POINTS OF CONTACT

Surface Geology

The first comprehensive geologic studies of Guam were done by the United States Geologic Survey (USGS) during the two decades following World War II. A preliminary report by Cloud (1951) was followed by a series of USGS Professional Papers in the early 1960s, most notably the report by Tracey, Schlanger, Stark, Doan, and May, (1964) on the general geology of Guam, which included a 1:50,000-scale map of the surface geology of the island. (Other reports in the series were Emery, 1963; Stark and Tracey, 1963; Schlanger, 1964; Cole, 1963; Carroll and Hathaway 1963; Stensland, 1963; Johnson, 1964; Ward, Hofford and Davis, 1965; and Todd, 1966). Ward and Brookhart (1962) published an earlier report on the Military Geology of Guam which included a water resources supplement.

The first comprehensive hydrologic study was published by Ward et al. in 1963. The next was in 1976 by Mink. In 1980, the Guam EPA administered the most exhaustive study of the aquifer to date, known locally as the Northern Guam Lens Study (NGLS). The chief contractor for the study was Barrett, Harris, and Assoc., who published the study report in 1982. Local contributions to the NGLS by WERI included a hydrogeologic analysis by Ayers (1981) and a preliminary study of aquifer discharge by Zolan (1982). In 1992, Barrett Consulting Group prepared a revision of the 1982 study for Guam EPA, but the report was not published nor widely circulated. WERI has a copy in the Water Resources Data Library. A comprehensive bibliography of geologic and hydrogeologic studies of Guam has been compiled by Siegrist (1992). (The bibliography is available on the WERI-GHS web site < <http://uog2.uog.edu/weri/microbib/index.htm> >).

Since 1994, WERI has been compiling an unpublished map of sinkhole distribution on northern Guam. Recently, Lewis and Siegrist (1994-1995, unpublished data at WERI) mapped fracture orientations in southern Guam. WERI points of contact are summarized in Table 5.1.

Table 5.1. Geology points of contact: Guam Hydrologic Survey program, WERI

Individual	Phone number	E-mail address
Dr. H. Galt Siegrist, Jr.	(671) 735-2685	hsiegris@uog.edu
Dr. John Jenson	(671) 735-2685	jjenson@uog.edu
Mr. John Jocson	(671) 735-2693	jjocson@uog.edu
Mr. Danko Taboroši	(671) 735-2146	dankot@campus.univguam.edu.gu

Basement geology

The first map of the basement topography prepared from comprehensive geophysical data was published as part of the 1982 NGLS. This map was slightly revised in 1992 by the Barrett Consulting Group, using the time domain electromagnetic technique (TDEM). Ongoing drilling by GWA and by consultants to the military Installation Restoration Programs has demonstrated that these maps must be used with circumspection and should be systematically updated on the basis of the most complete and recent information, especially drilling log data.

Beginning in January 1998, under the GHS program, WERI began consolidating data on basement topography, including historical drilling logs obtained from Guam Waterworks Authority, Guam EPA, local engineering consulting firms, and local drilling companies. WERI now maintains copies of these data in the Guam Hydrologic Survey Data Library. Current points of contact for drilling data are summarized in Table 5.2. Work is underway by the GHS at WERI to revise the basement map using this newly consolidated information.

Table 5.2 Drilling data points of contact

Company/ Agency	Individual responsible	Phone number
Earth Tech	Todd Webster	(671) 647-6083
Pacific Drilling, Inc.	Danny Mafnas	(671) 646-6371
Marianas Drilling, Inc.	Dar Ramos	(671) 646-7710
JTTL Enterprises	John Lund	(671) 653-1897
Guam EPA	Marilou Yamanaka	(671) 475-1636

NEW DATA COLLECTION EFFORTS

Surface geology

In July 1998, WERI began a two-year field study, sponsored by the USGS Water Resources Research Institute Program, to characterize the karst features of the Northern Guam Lens Aquifer. This includes a comprehensive inventory of sinkholes, coastal springs and seeps, and cave systems, as well as the structural and stratigraphic features that influence or control the development of the karst.

Bedrock and basement geology

GEPA permitting regulations require drillers to maintain drilling logs and to collect rock samples during the drilling, according to their permit agreements. Under the GHS program, WERI is consolidating this information, to include archiving drilling cuttings. Public Law 24-247 (August 1998) requires permit applicants to notify WERI prior to drilling so that a WERI geologist can supervise on-site data collection.

Data Archive

We are confident that most of the hydrologically significant reports and drilling logs that remain on the island have been located and archived in the GHS Data Library at WERI. Currently, the data have to be accessed physically at the locations where they are stored.

WERI plans to make some of the data available on-line beginning October 1998. Access will be possible through our web page at < <http://uog2.uog.edu/weri/ghs> >.

DATA EVALUATION AND RECOMMENDATIONS

Surface Geology

The 1:50,000 scale map of Guam by Tracey et al (1964) is still the only comprehensive geologic map of Guam. Although the map is of high quality for its scale, subsequent work (e.g., Randall and Seegrist, 1996; Reagan and Meijer, 1983) has shown that some parts are incomplete and that revisions are needed. More important, the 1:50,000 scale of the map is inadequate to support the current and growing need for greater precision and finer resolution of the geologic features of Guam. The rapid economic growth of the island, with the accompanying needs for installation of more new infrastructure, site evaluations for development projects, and settlement of land use questions makes it imperative that selected portions of the island soon be remapped at 1:24,000 or larger scale. Currently, there are no plans or funding for such mapping.

Basement geology

The kind, amount, and quality of hydrogeologic data collected varies widely because of the previous lack of a standard for on-site data collection. Drilling log data, however, are of central importance for accurately predicting the location of productive zones of groundwater and understanding the behavior of production wells. Implementation of the requirement under Public Law 24-247 to notify WERI prior to drilling and to have a WERI geologist supervise drilling data collection will ensure that scientific standards are met, data (including cutting samples) are properly archived, and that new knowledge gained is retained and exploited to update and revise existing maps and analyses.

In addition to collecting and keeping data from drilling associated with public and private water development projects, the island's water resource managers would be well served by a comprehensive update of island bedrock (aquifer) and basement geology based on new seismic data and selected corings from key locations on the island. Improved accuracy and resolution of the basement map will allow us to more efficiently utilize the groundwater resource by being able to precisely locate areas of water accumulation and to make more accurate assessments of sustainable yield. There are currently no plans or funding for systematic study of the bedrock or revision of the basement topography, however.

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Mink, J. (1976) Groundwater Resources of Guam: Occurrence and Development. University of Guam, Water Energy Research Institute of the Western Pacific. Tech Report No. 1 Sept.

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Schlanger S.O. (1964) Petrology of the limestones of Guam with a section on petrography of the insoluble residues by J. C. Hathaway and D. Carroll. U.S. Geol. Survey Prof. Paper 403-D: 52 p. & 21 pls.

Siegrist (1992) Selected bibliography of 20th century geoscience and related scientific literature of Micronesia, part I: Mariana island arc. Micronesian Area Research Center, University of Guam.

Stark, J. T. and J. I. Tracey, Jr. (1963) Petrology of the volcanic rocks on Guam. U.S. Geol. Survey Prof. Paper 403-C: 32 p.

Stensland C. S. (1963) Description of soil profiles. In: D. Carroll and J. C. Hathaway, Mineralogy of selected soils from Guam. U.S. Geol. Survey Prof. Paper 403-F: 43-49

Todd R. (1966) Smaller foraminifera from Guam. U.S. Geol. Survey Prof. Paper 403-I: 41p

Tracey, J. I., Jr., Schlanger, S. O., Stark, J. T., Doan, D. B., and May, H. G. (1964) General Geology of Guam. U.S. Geol. Survey Prof. Paper 403-A.

Ward, P. E., and Brookhart, J. W. (1962) Military geology of Guam. Water resources supplement. U.S. Army: Chief Eng., Intellig. Div., Headq. U.S. Army Pacific, Tokyo.

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Zolan, W. J. (1982) A Preliminary Study of Natural Aquifer Discharge on Guam. University of Guam, Water Energy Research Institute of the Western Pacific. Tech Report No. 34 Aug

Chapter 6

Distribution System Data

by David Vann

Guam Waterworks Authority, US Navy Public Works Center (PWC), and the US Air Force 36th Civil Engineering Squadron are the three principle agencies responsible for the production and distribution of potable water on the island of Guam. Each maintains a division responsible for mapping and archiving water distribution data. GWA currently has a contract with Earth Tech (formerly W.B. Flores Engineers) for distribution system modifications. Earth Tech maintains its own data archive for GWA's distribution system.

Between January and June 1998 the Guam Hydrologic Survey visited with each organization to establish a point of contact and obtain copies of maps and files describing distribution systems. Agencies, points of contact, and observations are listed below.

Data Archives and Points of Contact

GOVGUAM

Guam Water Authority (GWA)
Map Utilities
PO Box 3010
Hagåtña, Guam 96910

Point of contact:
Quirino Bas Bas
Chief Engineer
Ph: 649-7880

Data format and archiving

Maps are kept in hard copy only. GWA relies mainly on a 1997 1:400 scale map set, "Existing Islandwide Water Facilities System Maps," prepared by Barrett, Harris, and Associates, Inc. in association with Arizala, Costiniano, Villereal, and Associates. Drawings of any additions to the system are in blueprint form ("as-builts"). As-builts are provided to GWA by the contractors with each distribution system modification, and are archived at Map Utilities.

Data evaluation

Evaluation of the accuracy and completeness of the current distribution maps will require an exhaustive long-term field investigation by GWA. The GHS recommends digitization of the existing maps be accomplished as quickly as possible and that steps be taken to ensure maps are subsequently kept current. GHS can keep copies of the maps and plans in the GHS Data Library at Water and Environmental Research Institute (WERI), but comprehensive revision and archiving of the source documents can only be done by the organization responsible for installation, maintenance, repair, and modification of the distribution system.

PRIVATE SECTOR

Earth Tech
790 S. Marine Drive Suite 2
Tamuning, Guam 96931
Mailing Address: PO Box 12346
Tamuning, Guam 96931

Point of contact:
Todd Webster
Chief Engineer
Ph: 647-6083
Fax: 647-6086

Data format and archiving

Maps and drawings are in multiple formats. Earth Tech maintains ad-ons to the GWA system in AutoCAD files. Hard copies of the main GWA distribution system are kept as standard maps in a 1:400 scale (Barrett, 1977).

Data Evaluation

Base maps and digital files of the distribution system are updated regularly. All digital files are in a common format.

US NAVY

US Navy Public Works Center
PSC 455, Box 195
FPO, AP 96540-2937

Point of contact:
Director of Engineering Fena Reservoir and Lab
Ph: 339-7181 or 339-3220
Fax: 333-2035

Data format and archiving

Maps of the US Navy distribution system are stored in multiple formats. Hard copy maps are available in varying scale and are kept at both PWC-Piti and PWC-Sumay. AutoCAD drawings on CD are maintained at the Piti-PWC in 1:200 scale. Unrestricted maps and files may be obtained with a written request. Transfer of this information is limited to federal and local agencies and professionals in the private sector.

Data evaluation

Large-scale studies of the Navy water distribution system are done on a contractual basis, roughly at five-year intervals. The quality of the data is excellent. With each new study, data files are upgraded to reflect changes. Modifications to the system done in the interim are added to the existing AutoCAD files. All digital files are in a common format.

USAF

AAFB Environmental Division
36 CES/CEV
Unit 14007

Point of contact:
MSGT David Martin
Utilities Superintendent
Ph: 366-4305

Data format and archiving

Maps of the USAF water distribution system are archived in multiple formats. Hard copy maps in varying scale and AutoCAD drawings are available at the 36th Civil Engineering Office. The transfer of this information is limited to federal and local agencies and professionals in the private sector.

Data evaluation

Physical evaluation and modification of the distribution system is performed internally by USAF engineers. As the system is upgraded, data files are revised to reflect changes to the existing system. Digital maps are maintained in an AutoCAD format.

RECOMMENDATIONS

Current data collection efforts by the federal government and the private sector are of high quality, but more important, are in a common format. The GHS recommends GWA data to be standardized into the same format. This will greatly facilitate engineering analysis.

Appendix

Current Physical Condition and Rehabilitation Plans for WERI/USGS-administered Observation Sites

(as of September 15, 1998)

Meteorological Stations

RAIN GAGES

Northern Guam rain gage

A new gage is to be added to cover one of the areas in northern Guam where coverage is currently insufficient. Location is still to be determined. Candidate sites are the radar station on top of Mt. Santa Rosa and Northwest Field on Andersen AFB. The existing gage in Dededo will be maintained.

Southern Guam rain gages

A new rain gage station will be installed at Mt. Jumullong Manglo. Existing gages at Mt. Chachao and Umatac will be maintained.

PAN EVAPORATION STATIONS

Northern Guam: Andersen AFB

The Air Force has given tentative permission to install an evaporation pan. License is pending.

Southern Guam: Fena water treatment plant

USGS has requested permission from the Navy to install an evaporation pan at the water treatment plant.

Surface Water Stations

STREAM GAGES

Currently there are no active stream flow gages under the WERI/USGS data collection program. The first to be activated under the WERI/USGS data collection program will be on the Pago River, in October 1998.

OUT-OF-SERVICE FACILITIES TO BE REHABILITATED

Pago River (16865000)

Repair leaking control. Clean stilling well. Replace well and shelter doors. Replace window glass, shelter floor, equipment shelf, and stairs. Replace outside and inside staff plates. Drill one new intake in well. Install float tape and recorder. Install bank-operated cable system. Landowner, CZM, USFWS, and Corps approval have been obtained, GELPA WQC (Section 401, CWA) pending.

Inarajan River (16835000)

USGS to visit site in September. This was an existing gage with concrete control and well, condition is probably similar to Pago River.

Geus River (16821000)

USGS to visit site in September. This was an existing gage with concrete control and well, condition is probably similar to Pago River.

NEW SITES

La Sa Fua River

New stream gage plus sediment-collection station construction. The gage will be a gas-feed pressure transducer system. A low concrete control will be needed across the low-water channel. The gage house will consist of aluminum, fiberglass, or CMP shelter for stage recorder and sediment sampler with concrete pad foundation on the right bank. A metal pipe, containing gas line and sampler intake tube, will connect the shelter to the stream and will be anchored with concrete. An outside staff and crest-stage gage will be installed in the gage pool, using concrete anchors with wood backings. Landowner approval still pending. Approval has been obtained from the CZM office and USFWS, but USGS has not yet submitted permit applications to Corps or GEPA.

Atantano River

Construction of a new gage, similar to La Sa Fua River, is planned but without the sediment sampler. Site has not yet been identified. Permit applications still have to be filed.

SEDIMENT GAGES

USGS will install sediment gages on three of the stream-flow gages. Two of these, Ylig and Ugum, are active stream-flow gages under different programs, for which USGS will only have to purchase and install the sediment samplers. The third is the La Sa Fua gage, at which both the stream gage and sediment gage will be new.

Groundwater Stations

WATER-LEVEL ONLY

ACEORP Tunnel (Tamuning)

- A site assessment of the tunnel has not been conducted.

A-16 (Carbullido Elementary School)

- No fence exists.
- The well is located in front of an elementary school, so work should be coordinated with the school principal.
- Access should not be a problem.
- Residences are located sufficiently far enough away that noise should not be a problem.

A-20 (Ordot Elementary School)

- The well is located within the boundaries of an elementary school, so work should be coordinated with the school principal.
- Residences are located sufficiently far enough away that noise should not be a problem.

M-10A (Harmon Loop Elementary School)

- The well is located within the boundaries of an elementary school, so work should be coordinated with the school principal.
- A housing area is located across the street from the well.

M- 11 (Dededo Flea Market)

- Fence posts are intact but the chain-link fence is missing.
- The well is located in an area used for weekend flea markets.
- Old tires and pipes have been dumped near the well.
- Access to the well and noise created by drilling should not be a problem.

BPM-1 (Mangilao Catholic Church of Santa Teresita)

- No fence exists.
- The well is located near private residences and some vegetation may have to be cleared to avoid a drill rig from blocking a road.

DEEP OBSERVATION WELLS (chloride profiles and/or water-level)

Rehabilitation work for deep wells scheduled for FY1998-99 includes the following:

1. Determine blockages in the wells.
2. Clean out blockage.
3. Case with flush-joint, threaded, schedule 80 PVC pipe, solid and screen, except well EX-4.
4. Demonstrate well is clear of any obstructions.
5. Construct a 4-foot x 4-foot x 4-inch concrete pad around well (if none exists) and place a USGS survey marker in pad.

Deep Well EX-1 (18-2746-06) Chochogo, Guam, near San Miguel School.

Wellhead status

- The borehole is covered with a concrete slab and is not padlocked.
- Access is obtained by driving through the parking lot of an elementary school so work should be coordinated with the school principal.
- No residences are located nearby.

Borehole status

- Depth 597 feet.
- Diameter of hole 8 inches.
- Casing: 6- or 8-inch steel surface casing, length unknown; 6-inch PVC to 300 feet.
- Elevation of measuring point 95.76 feet.
- Depth to water is about 90 feet.
- Deepest sampling point 550 feet below MP, Cl = 18,200 mg/l.
- Last logged 1/6/93.
- Well reported blocked about 3 to 4 feet below water table.
- Data indicate that the well was cased to 300 feet with 6-inch PVC but last sampling depth is at 550 feet, near the bottom of the well, which implies about 250 feet of uncased hole.
- Work needed: Clear blockage, clean well to 560 feet, place clean limestone gravel into well to bring depth up to 560 feet, re-case with 5-inch PVC solid and screen. Install clean limestone gravel around casing to a depth of about 300 feet.
- Casing materials required: 85 feet solid PVC casing, 475 feet of screen (in water).

Deep Well EX-4 (18-2647-12) Mangilao, Guam, near Father Duenas Memorial High School

Wellhead status

- The fence and gate are intact.
- The well is located in front of a private residence and near a road so a drill rig would have to be parked on someone's front lawn to avoid blocking the road — permission will have to be obtained from the homeowner.

Borehole status

- Depth 400 feet.
- Diameter of hole: 8 inches.
- Casing: Surface casing type and length uncertain; 6-inch PVC to 400 feet.
- Elevation of measuring point 153.71 feet.
- Depth to water about 148 feet.
- Deepest sampling point 390 feet below measuring point, Cl = 16,900 mg/l
- No reported problems, well last logged 1/31/96.
- Work needed: Sound well with 10 foot dummy pipe of 4 inch inside diameter to demonstrate well is clear of obstructions. Clean out if required.
- No casing materials required.

Deep Well EX-6 (18-3050-05) Macheche Road, Guam

Wellhead status

- No fence exists.
- The borehole cover is rusty and has holes.
- The well is located adjacent to a private residence.
- A bulldozer may be needed to clear a pathway for a drill rig in order to avoid encroaching on private property (if a bulldozer is used then steps must be taken to insure that private property is not cleared).

Borehole status

- Depth 462 feet.
- Diameter of hole: 12 inches.
- Casing: 4 feet steel surface casing (8 inch?); remainder of hole open.
- Elevation of measuring point 309.41 feet.
- Depth to water about 306 feet.
- Deepest sampling point 455 feet below measuring point, Cl = 18,000 mg/l.
- This hole contains a sampling probe lost 9/19/95.
- Work needed: Lower 6-inch dummy pipe 10 feet long to bottom of well. If well clear, place about 8-10 feet of washed limestone gravel over lost probe. If blockage is encountered clean hole with drill. Case with 6-inch PVC solid and screen. Install gravel around casing to 20 feet from surface, install 3 feet of sand and 17 feet of neat cement grout.
- Casing materials required: 300 feet solid, 152 feet screen.

Deep Well EX-7 (18-3149-05) Wettengel Exploratory Well, Wettengel Junction, Guam

Wellhead status

- The fence and gate are intact.
- The well is located next to Guam's main road, so access and noise should not be problems.

Borehole status

- Depth 698 feet.
- Diameter of hole: 8 inches.
- Casing: 10 feet of 6- or 8-inch steel surface casing; remainder of hole open.
- Elevation of measuring point 283.31 feet.
- Depth to water about 280 feet.
- Deepest sampling point 450 feet below measuring point, Cl = 19,800 mg/l.
- Last logged 2/2/96 No problems reported.
- Work needed: Lower 5- or 6-inch dummy pipe 10 feet long to bottom of well. If well clear, place washed limestone gravel in to well to bring depth to 500 feet below measuring

point. If well not clear, clean out with drilling tools to 500 feet depth below measuring point. Case well with 5 or 6-inch solid and screen PVC pipe. (Size depends on diameter of surface casing.)

- Casing materials required: 280 feet solid; 220 feet screen.

Deep Well EX-9 (18-2848-03) Barrigada, near P.C. Lujan Elementary School, Guam

Wellhead status

- The fence is broken and the gate is not locked.
- The well is located between an elementary school and a private residence, so work should be coordinated with the school principal and noise may be a problem for the residence.
- A short path to the well (about 50 ft. long) may not be wide enough for a drill rig, but the path can be widened using a bulldozer.

Borehole status

- Depth 513 feet.
- Diameter of hole: 3 inches.
- Casing - 5 feet of 6- or 8-inch surface casing.
- Elevation of measuring point 239.41 feet.
- Depth to water about 236 feet.
- Deepest sampling point 450 feet below measuring point, Cl = about 18,000 mg/l.
- Last logged 2/12/96. No problem reported.
- Work needed: Lower 5- or 6-inch dummy pipe 10 feet long to total depth. If blocked, then clean out. Case with 6- or 5-inch PVC pipe solid and screen (Size depends on diameter of surface casing.)
- Casing materials required: 235 feet solid 278 feet screen.

Deep Well EX-10 (18-3249-02) Finegayan Exploratory Well, near NAVCAMS Housing Area, Guam

Wellhead status

- The fence and gate are intact.
- The well is located adjacent to a private residence, so drilling should be conducted during the week to avoid noise pollution.
- The public road to the well is narrow and bound on one side by a fuel pipeline so if a drill rig can't fit on the road, permission has to be obtained from a property owner to cross private property.

Borehole status

- Depth 704.5 feet.
- Diameter of hole 8 inches.
- Casing - 5 feet of 6- or 8-inch steel surface casing.
- Elevation of measuring point 348.54 feet.
- Depth to water about 346 feet.
- Deepest sampling point 480 feet below measuring point, Cl = about 19,600 mg/l.
- Last logged 4/4/95. Problem noted: Very hard to get tape down to water level, some partial obstruction.
- Work needed: Lower 5- or 6-inch dummy pipe 10 feet long to total depth. If blocked then clean out to 500 feet. Back fill hole to depth of 500 feet with washed limestone gravel. Case well with 5- or 6-inch PVC pipe solid and screen (size depends on diameter of surface casing).
- Casing materials required: 340 feet solid 160 feet screen.

Deep Well GHURA-Dededo (18-3150-10) Dededo, Guam (In Dededo Well Field)

Wellhead status

- The borehole cover is rusty.
- According to Marilou Yamanaka (Guam EPA), the well was reamed and cased in 1985.
- The well is located within Guam International Country Club boundaries so access to the well needs to be coordinated with the golf course.

Borehole status

- Depth 785 feet.
- Diameter of hole: 12-inches.
- Casing: 6- or 8-inch steel surface casing, length unknown, most likely about 5 feet; remainder of hole is open.
- Elevation of measuring point 393.90 feet.
- Depth to water about 391 feet.
- Deepest sampling point about 550 feet below measuring point, CI = 19,000 mg/l.
- Last logged 1/8/90. Reported blocked, depth unknown.
- Work needed: Lower 5- or 6-inch dummy pipe 10 feet long to total depth or blockage. If blocked clean out with drill to about 560 feet. Backfill hole with to depth of 560 feet with washed limestone gravel. Case well with 5- or 6-inch PVC pipe solid and screen. Install gravel pack around casing to 20 feet of surface, install 3 feet of sand and 17 feet of neat cement grout.
- Casing materials required: 390 feet solid 170 feet screen.

Deep Well EX-8 (18-3651-05) Northwest Field Exploratory Well, Guam, in old Air Force Housing Area

- Depth 658 feet.
- Diameter of hole: 8 inches.
- Casing: 5 feet of 6 inch steel surface casing; remainder of hole open.
- Elevation measuring point 462.49.
- Depth to water about 460 feet. Deepest sampling point about 620 feet below measuring point, CI = about 19,000 mg/l.
- Last logged 10/29/85. Well reported to be collapsed, depth unknown.
- Note: well contains a sampling probe which was lost 12/10/85.
- Work needed: Clean out well with drill to depth of 630 feet depth. Fill hole with clean limestone gravel to depth of 630 feet. Case well with 5-inch steel casing, solid and screen.
- Casing materials required: 460 feet solid; 170 feet screen.
- No current plans for rehabilitation of EX-8 during FY 1999. If sufficient funds remain after other wells are rehabilitated, USGS may pursue rehabilitation of EX-8 late in FY1999.

TIDAL STATIONS

The existing tide gage at Hagåtña Boat Basin will be maintained.

Acknowledgments

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We also wish to acknowledge the current leadership of Guam, who saw and acted on the need to establish a permanent local program to collect the scientific data needed to properly manage the island's water resources, as well as the need consolidate the data into a single source, readily accessible to users. In particular, we acknowledge the foresight of the Infrastructure Committee of the Governor's VISION 2001 Task Force, which recognized these needs and identified them as specific goals of the VISION 2001 initiative. We most especially acknowledge the leadership of Senator Joanne Brown, chair of the Natural Resources Committee, 24th Guam Legislature, who authored and spearheaded Public Laws 24-161 and 24-247 to make these programs a reality. We also acknowledge the 24th Legislature for its unanimous, bipartisan support of the legislation, and the Governor of Guam for his timely implementation of the programs authorized by the legislation.