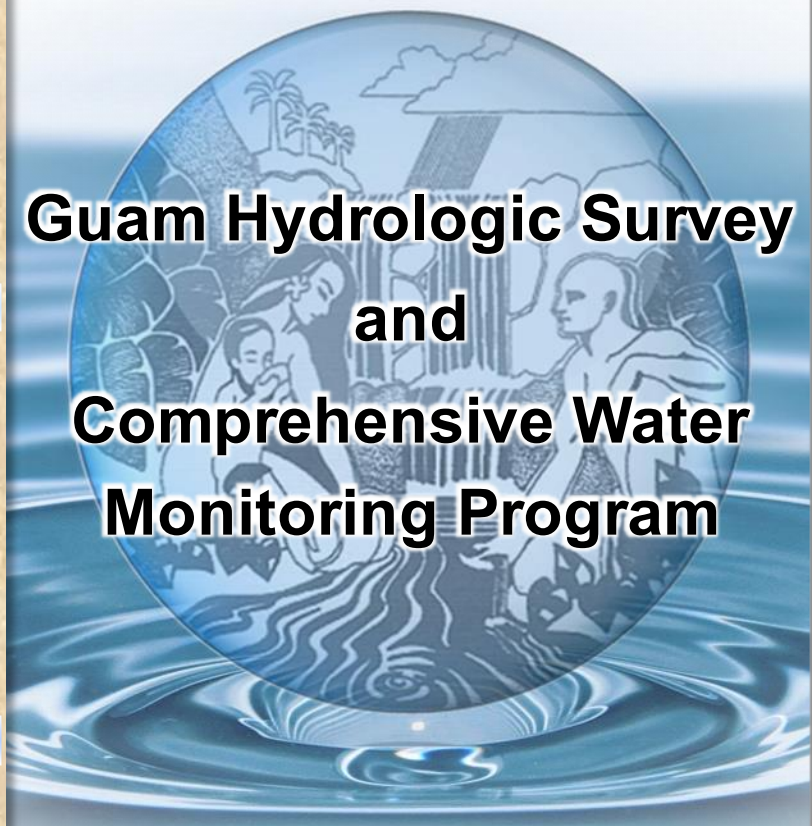

Guam Hydrologic Survey and Comprehensive Water Monitoring Program

FY 2024 Annual Report

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

October 2024

Intentional page

Guam Hydrologic Survey
and
Comprehensive Water Monitoring Program

FY 2024
Annual Report

Dr. Nathan C. Habana
WERI GHS Program Advisor

Dannika Kate U. Valerio
WERI GHS Information Management

Dr. Yuming Wen
WERI Interim Director

October 2024

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

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Introduction

This annual report covers three main sections. The first section is about the Guam public laws Guam Hydrologic Survey (GHS, P.L. 24-247) and Comprehensive Water Monitoring Program (CWMP, P.L. 24-161). This section includes the WERI organization of tasks, responsibilities, data flow, and research assistants. The next section covers GHS hydrologic information management, research focus, and education/training and outreach activities. The last is the CWMP report, focusing on the expansion of observation sites, data collection and submission, and support.

Guam Public Laws 24-247 and 24-161

In 1998, the 24th Guam Legislature enacted Public Laws 24-247 and 24-161 as the Guam Hydrologic Survey (GHS) and the Comprehensive Water Monitoring Program (CWMP), respectively. These two laws were ratified in response to an El Niño event in 1998, resulting in a prolonged drought that advised water rationing practices. CWMP addresses the need for continued collection of hydrologic data while GHS focuses on evaluation of hydrological data, analyses to assess the status of Guam's water resources, and research into water resources problems. WERI is charged with administering the annual legislative appropriations necessary to facilitate, direct, and implement the program's primary objectives. Both programs are now integral to the WERI water resources research, information dissemination, education, and training mission.

The foresight of the Guam Legislature in creating these two vital programs deserves special mention. Through their efforts and continued support, WERI advances in consolidating and interpreting several essential water resource information, constructing hydrologic information for Guam, and revitalizing the USGS water resource monitoring program. Our understanding of the complex physical, chemical, and biological processes that influence Guam's water resources has broadened, and the increase in graduate student research opportunities provided by the programs contributed to the number of highly trained water resource professionals in the island's workforce.

Guam Hydrologic Survey Program (GHS)

The purpose of GHS is to consolidate all of Guam's available hydrological data gathered 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 students, and the publication and distribution of educational posters, maps, and fact sheets. In addition, GHS also funds research assistants and associates who engage in CWMP activities, including fieldwork with USGS' observation well data collection, and phreatic groundwater and hydrologic data analyses.

For twenty-six years, WERI has continued to operate and administer the GHS Program. The GHS and CWMP Annual Reports are now available online on the GHS website:

https://guamhydrologicsurvey.uog.edu

WERI serves numerous island agency partners through the GHS Program, attending legislative hearings, providing research findings, sharing hydrologic and geologic maps, and advising on water resource concerns. Through the GHS Program, reliable research-based information can be achieved. Therefore, the Guam Legislature, Guam Environmental Protection Agency (GEPA), Guam Waterworks Authority (GWA), NAVFAC Marianas, and the Groundwater Resources Development Group (GWRDG) are more confident in determining management plans, actions, and regulations involving our water resources. WERI shared water research findings and advised agencies on wastewater issues, aquifer capacity, hydrogeologic assessments, surface hydrology, saltwater intrusion, and the new online data visualization products.

WERI provided GHS outreach to the Northern Guam Soil and Water Conservation District, GWA, the Legislature, Guam DOE, visiting universities, and the private sector with the Virtual Tour into the Northern Guam Lens Aquifer. Post social distancing protocols, in 2024 the GHS Program, with the services of Global Learning and Engagement (GLE UOG), WERI resumed the Northern Guam Lens Aquifer Virtual and Site Tour.

WERI continues to expand GHS interagency support through its online web products. Since developing the GHS website in 2016, WERI has been managing and producing new hydrologic reports, presentations, maps, and databases. WERI continues to develop new online data visualization products—a new means of sharing hydrologic data through interactive maps and graphs, such as WERI Web MApps and MAppFx.

Comprehensive Water Monitoring Program (CWMP)

The CWMP is the core of essential water information, through approved measurements and analytic methods, the basis of hydrologic research interpretations. The CWMP was created to gather data on saltwater intrusion and water lens profiles in Guam's sole source aquifer in the northern part of the island. Stream flow data and other parameters associated with surface waters are collected in the south. Moreover, the program collects rainfall data for hydrologic, meteorologic, and climatologic studies. These are essential for determining sustainability assessments and water supply capacities.

The CWMP rehabilitated data collection assets that fell into disrepair. CWMP allowed WERI to obtain services from USGS Pacific Island Water Science Center (PIWSC) to collect, organize, and manage hydrologic data from stream gages, rain gages, and observation wells. Government of Guam and USGS PIWSC funds the CWMP, restores the Federal/State Territory cost-sharing for continued hydrologic monitoring.

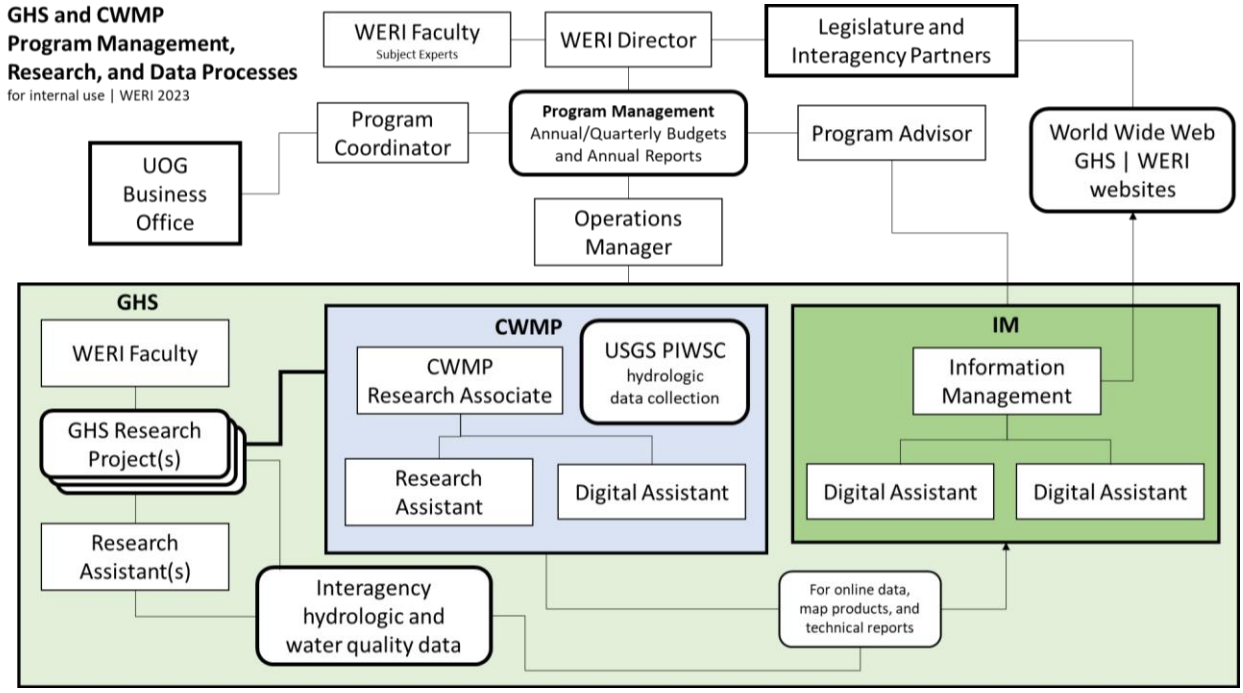
USGS PIWSC methods ensure that data are frequently and reliably collected, analyzed, and made widely available. Most data from USGS gages are readily accessible online. PIWSC collected hydrologic information for Guam are consolidated, quality is marked with provisional and approved, and made available online:

http://hi.water.usgs.gov

CWMP data is analyzed and interpreted. GHS employs research assistants and research associates to organize, analyze, and interpret CWMP data. CWMP is essential to GHS projects that processes and analyzes and interprets the collected data.

Organization and Operations

GHS and CWMP are organized by a program management team that involves the WERI Director and a support panel of WERI Faculty subject experts, the Program Coordinator, Operations Manager, and the Program Advisor. The WERI GHS and CWMP Programs continue to improve and may also change the internal organizational structure yearly to streamline operations management, processes, and product output. The organization is also crucial for determining the program's resource requirements, project focus, and annual budget. The figure below is an internal WERI GHS and CWMP personnel and process diagram.



GHS analyzes water resource data for investigative research and the production of reports. WERI Faculty proposes GHS projects annually and supports a research assistant to conduct a GHS-related project. This opens opportunities for a research assistant to do a master's thesis through UOG's Environmental Science Program. GHS also has an Information Management team that oversees and develops both the WERI and GHS websites. The Operations Manager collects project summaries from faculty projects, CWMP projects and activities, and Information Management, and manages the organization and drafting of the GHS and CWMP Annual Reports.

GHS Research Assistants

The following are GHS funded research assistants, educational level, and project focus.

Research Team

Hazelle Ko

Environmental Science Graduate Student; BS Natural Sciences, University of Pittsburgh, Pennsylvania

Advisor: Dr. Yuming Wen

Planned thesis topic: Relationships between Changes in Withdrawal, Recharge, Sea Level, and Chloride Concentration within Nine Active Water Production Wells in the Yigo-Tumon Basin, Northern Guam Lens Aquifer: An Analysis of a 45-Year Multivariable Time Series

Risel Uludong

Will graduate in December 2024, and plan to be enrolled in the Environmental Science Graduate Program in Spring 2025.

Supervisor: Dr. Yuming Wen

He is working on a project to update the groundwater protection zone in Guam.

Research Assistant II

Mary Clare Snaer

Environmental Science Graduate Student; BS Biology, Guam

Advisor: Dr. Blaz Miklavic

Hydrologic analysis of deep observation wells, NGLA

CWMP digital and field research assistant

Jovic Aaron Caasi

MS Mathematics, Washington; BS Mathematics and Computer Science, Guam
Groundwater Modeling Systems (GMS) model developer and testing

Atasha Bautista

Undergraduate, Chemistry and Biology, Bio-Medical Track, Guam
Groundwater model preparation and application, GIS spatial, feature analysis, and organization

GHS Information Management Team

Dannika Kate U. Valerio

B.S. Computer Science and Communications, Guam
Lead GHS and WERI website organization, design, and programming, data visualization products design and programming, WERI News

Matt Wilson Zapata

B.S. Computer Science, Guam
Assists with websites design, update, and hydrologic data organization, programmer, and management

The GHS operations and administration has posted job announcements to fill a few more research assistant/associate positions in the information management (1 Digital Assistant) and CWMP (1 CWMP Research Associate and 1 Research Assistant) sections. Job announcement for Research Assistants for research (and thesis) projects are posted as well at the UOG website (HRO Online Employment Portal).

Guam Hydrologic Survey Report

The Water and Environmental Research Institute of the Western Pacific continues to operate and manage the Guam Hydrologic Survey (GHS) and Comprehensive Water Monitoring Program (CWMP). The following are data and research product report status of GHS and CWMP for Fiscal Year (FY) 2024. GHS continues with the online information management systems and operations to organize and make hydrologic and water resources information available online. Information management includes development of online interactive data visualization products, MAppFx and Web MApps. GHS also has hydrologic research components and outreach programs. Hydrologic research investigates vulnerabilities, resilience, and sustainability of water resources under known environment and climate conditions. The research also focuses on data collection, organization, analysis, and interpretation for determining sustainable practices. Then the ongoing/completed scientific research, recommendations are presented through WERI GHS outreach and educational services.

GHS Information Management

D.K.U Valerio, M.W. Zapata, and N.C. Habana

The Information Management (GHS IM) develops the GHS website, which is the worldwide interface for accessing Guam's available hydrologic information. The secure website is a UOG web domain, and the address is:

guamhydrologicsurvey.uog.edu

University of Guam's (UOG) Web Team, Office of Information Technology (OIT), manages the GHS website security and hosting. The content management system, development platform, is WordPress®. The GHS Program addresses an accountable task in public law—dissemination of Guam's pertinent hydrologic information.

WERI leads the island with an online hydrologic information system for local interagency partners and anyone's interest worldwide. The effectiveness of the website is expressed by interagency partners who mention referencing the online information. The GHS website superiorly improved program management with data and information organization, improved information access, and reduced the need for printing. The GHS IM team organizes, designs, develops, and applies computer programming to the website's interface and online data visualization.

GHS Website Content and Navigation

The GHS website stems from a modern version of the classic webpage design, including a traditional main menu bar. The menu bar lists: REO (Research, Education and Outreach) Agendas; Sustainable Management; Groundwater | Hydrogeology; Hydrology; Climate | Weather; Wastewater | Toxicology; Library; and About GHS (see

following figure). Each menu item has a dropdown list. A photo slider of essential content links on the home page is below the menu bar, followed by information on upcoming events, the latest news, sustainable management, annual reports, interagency partners, charters and agreements, and GHS and CWMP mission statements and goals. White papers and program reports are found in the REO Agendas and Sustainable Management tabs, respectively. The REO tab contains years

Guam Hydrologic Survey website homepage

of WERI white papers about REO. The Sustainable Management tab contains the Annual Reports, and unit organization and management of its operations. The following four tabs refer to components of the hydrologic cycle, beginning with groundwater and hydrogeology.

Each of these hydrological menus contains pertinent, recent, and significant published WERI research work with technical reports, publications, maps, data visualization products, and databases. The GHS website is often presented at the Guam Advisory Council Meetings and in the Global Learning and Engagement WERI Workshop 2024. The workshop also unveiled and demonstrated the use of WERI's new online data visualization products, which will be further discussed in the next section.

More Online Data Visualization Products

Online data visualization is now of great interest with interagency partners for its organization, an interactive and intuitive interface, and reliable reference. WERI's development of MAppFx and Web MApps has made large data organization useful,

modern, and practical. WERI GHS IM has presented MAppFx and Web MApps at conferences and meetings: University Council On Water Resources – National Institute of Water Resources (UCOWR-NIWR 2023), Guam Advisory Council Meeting (2023), National Groundwater Association (NGWA 2023), WERI-FCU Taiwan Exchange Event (2024), GLE-WERI Workshop (2024). From samples shown in advisory council meetings for the Western Pacific, stakeholders from CNMI are now sharing nitrates and chloride data to help with data management. Showcased in the 2024 AWWA Conference (Hyatt, Tumon) for CNMI BECQ, Yap is now interested in having their data converted into a MAppFx product.

In 2023, WERI developed two MAppFx products: Ugum Watershed stream flow duration curves and production well nitrates. WERI now expands and develops more online data visualization products on the GHS website. MAppFx products are also found in the link:

https://guamhydrologicsurvey.uog.edu/index.php/mappfx/

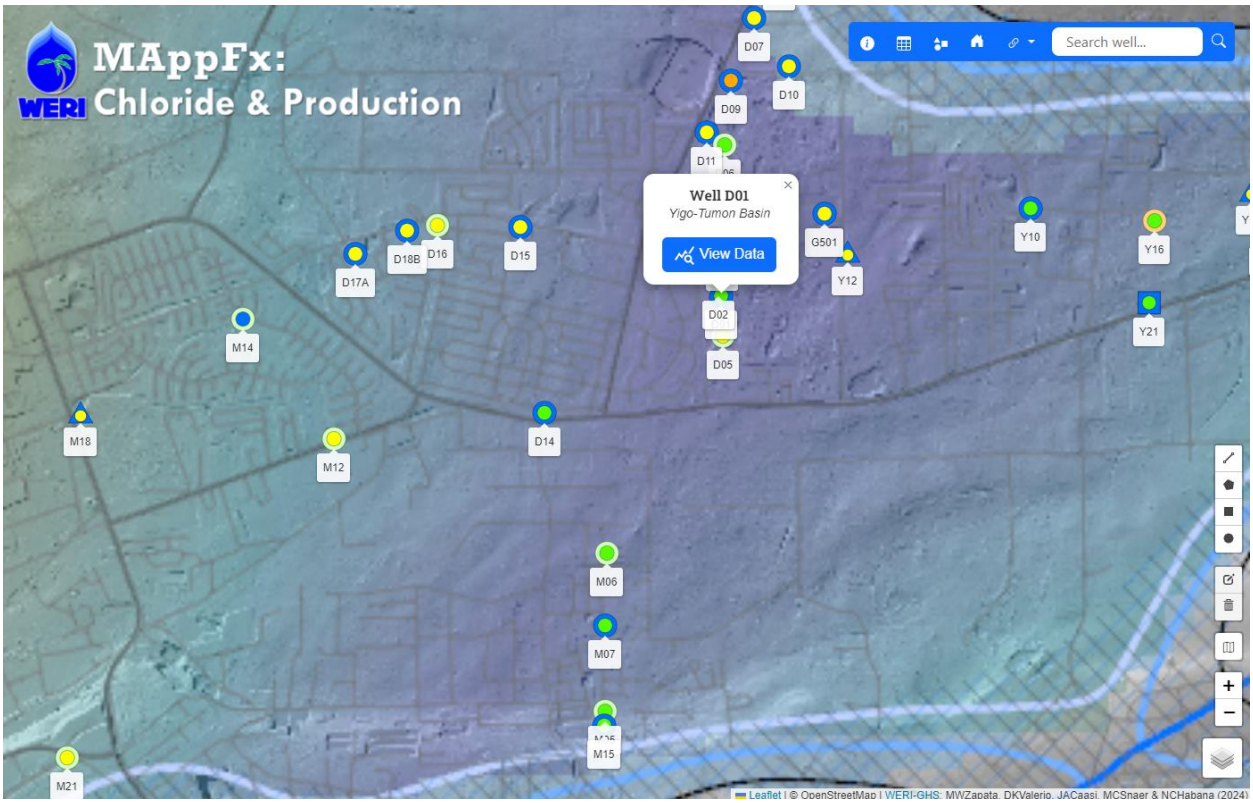
The following sections are new MAppFx and WERI Web MApp products of chloride and production, stream flow duration curves, deep observation wells, and hydrologic terrain analysis.

MAppFx: Production well chlorides

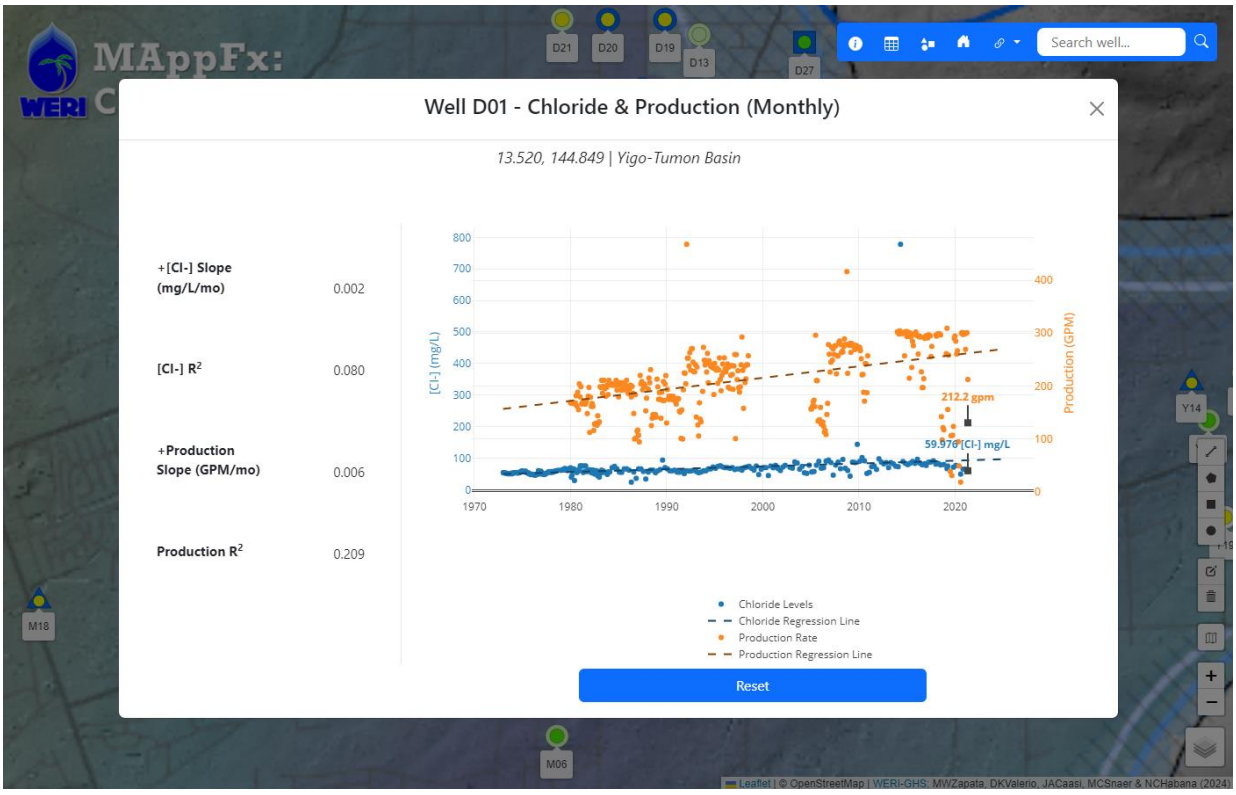
M.W. Zapata, D.K.U. Valerio, and N.C. Habana

MAppFx production well chloride concentration is one of the latest WERI data visualization products. Chloride and production rate data visualization was developed soon after the MAppFx for production well nitrate level [Valerio et al. 2023, WERI Technical Report (WTR) 180]. Chloride is another very important production well constituent like nitrate, that chloride may also limit production. GWA tests wells for chloride concentration, since high levels of chloride is often a result of saltwater intrusion. Chloride translates to salinity, a water quality aesthetics concern, often a result of drawing excessively from a freshwater lens. The management of water quality and production includes the observation of changes in chloride of utility water production. Guam uses about 100 deep vertical wells to extract more than 38 MGD of utility water from the Northern Guam Lens Aquifer (NGLA). The MAppFx Chloride web interface opens with a layer version of the Northern Guam Lens Aquifer map (Habana and Jenson 2018) and Guam Waterworks Authority (GWA) production wells.

The JSON, JavaScript Object Notation (data form file), for this online application was configured for plotting chloride and production data over time (date). An Excel file is used to organize GWA data, and the Excel program generates the JSON file. This makes ease of managing chloride and production data that can be updated quarterly and serves as a state of the aquifer component. This data visualization product is coded to provide a summary interface of production weighted average chloride and total production for each aquifer basin in the NGLA. The well points on the interactive map utilize symbology based on the latest data chloride concentration (mg/L or ppm) and production rate (GPM). Side panel widgets are available as well for symbology and summary. The symbology panel is interactive that one can select to activate wells based on concentration and production rate. The summary panel is the annual production well rate (MGD) and production weighted average chloride concentration for each of the 6



MAppFx: Production well chloride



Production Well D01, interactive graph chloride and production history

aquifer basins in the NGLA. Selecting each aquifer basin in this panel expands to a last 10 years of annual summaries showing total production and weighted average chloride. Upon selecting a well point on the interactive map, an interactive double axis chart appears showing the historical positive concentration, production, and their respective trend line. This MAppFx product was presented in September 2024 to the American Water Works Association, Hawaii Western Pacific Sub Section, and training for use was conducted at the Guam Hydrologic Survey WERI Workshop to interagency partners. The next task is to try to include the military wells. The technical report is underway.

MAppFx: Southern Guam Flow Duration Curves

D.K.U. Valerio, N.C. Habana, L.F. Heitz

Southern Guam's watershed and stream may have potential for energy and/or water supply development. A useful information for determining such potential is streamflow variability and flow duration analysis. Flow variability and flow duration curves were quantified directly from gaged sites and ungaged reaches, using inferential techniques (Heitz et al. 2016 and 2017, WTR 154 and 164, respectively). This project expands the *MAppFx: Ugum Flow Duration* Curves (Habana et al. 2023, WTR 181), into the entire southern Guam (14 watersheds and 19 stream gages).

MAppFx: Southern Guam Flow Duration Curves

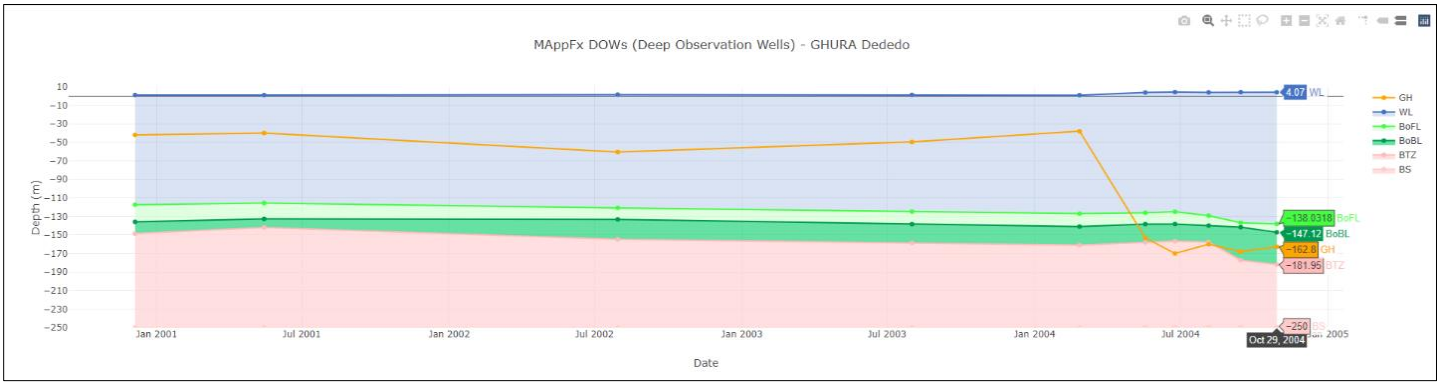
To obtain proper watershed and stream topology, the technique required modifying the GeoJSON file, expanding its data nesting configuration. All of the assessed gaged streams in southern Guam are now available online.

The use of the interactive web map and graph interface was demonstrated in the Guam Hydrologic Survey WERI Workshop in September 2024. More than 40 interagency employees learned about the use and access of MAppFx products in the WERI Workshop 2024. The technical report is underway.

MAppFx: Deep Observation Wells

M.W. Zapata, M.C. Snaer, D.K.U. Valerio, and N.C. Habana

Deep observation wells (DOWs) are phreatic access ports for conducting salinity profiles in the NGLA. A DOW is a vertically positioned tubular structure that extends down a borehole with perforation below the saturated zone, penetrating the freshwater lens, extending into the saltwater zone. This allows for a depth and conductivity analysis that translates into a salinity profile. The salinity profile sampling is done at least twice a year. This operation is a WERI-USGS data collection, CWMP. Dougher et al. (2019, WTR 168) developed the first historic graphing of salinity profiles for three DOWs in the Tomhom Aquifer, NGLA. The report defines the phreatic zone of freshwater, transition zone, and saltwater. Dougher's research revealed the capacity and durability of the aquifer that went through a major recharge event from typhoons, followed by a 6-year drought. WERI GHS IM has started developing the historic graph of phreatic zone for the DOWs as a component of the MAppFx web app. The project will continue and plans to finish the product in 2025. This product will have 8 DOW historic profiles that begin in 2001. Soon after will include the newly installed DOWs of both GWA and Military. The challenge so far is the multi-data input and developing an Excel to JSON database conversion program that will be easy to manage and update as new data is received. DOW salinity profiles alone are difficult to analyze and present in such a way that could be well understood. Historic salinity profiles provide a better and valuable insight for determining the status of the aquifer, showing changes in freshwater lens thickness in response to drought and ample recharge. MAppFx will make this easier to visualize and support with the management of the island's major water resource.



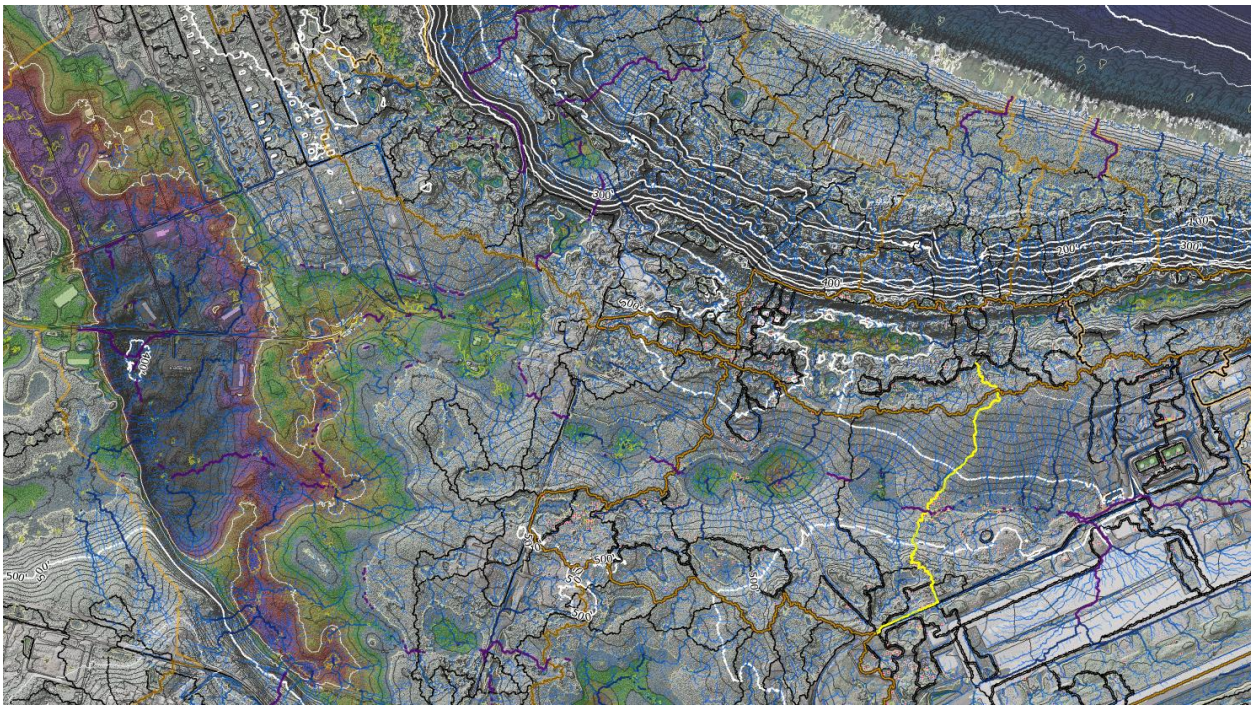
Development of the interactive graph for the MAppFx: Deep observation well project

Web MApps: Surface Hydrology of Northern Guam, Phase II

N.C. Habana, L.F. Heitz, and D.K.U. Valerio

High resolution topological mapping of surface hydrologic boundaries and waterflow is a fundamental necessity for determining resources protection strategies. The surface hydrology and activities above the NGLA may affect the groundwater. A major concern is contaminant transport via stormwater runoff, solute transport, and recharge. Another is terrain reconfiguration from development that may change the natural waterflow and aquifer infiltration. The surface hydrology was determined in finer detail through hydrogeologic assessments of sinkholes for the development of large facilities (GEPA Regulation, Title 22, Chapter 10). Terrain and hydrologic analysis of high-resolution digital elevation over the limestone plateau revealed a plateau basin of tributary watersheds and runoff paths that may transport to a focal watershed. The focal watershed is the lowest point of a plateau basin containing an analytic fill area (surface depression) that is likely and often a large sinkhole. The runoff paths were useful for field trek, in several cases had led to finding solution pipes along the way towards the focal depression in a plateau basin.

The *Surface Hydrology of the NGLA* (Habana et al. 2022, WTR 175) performed the first phase organization of the NGLA plateau hydrology. Application of GIS hydrologic spatial analysis of high resolution (LiDAR based) Digital Elevation Model was the key for delineating the plateau basins, surface depression fill area, fill area watersheds, runoff paths, and overflow runoff paths. Sixty plateau basins were discovered and were given proper names based on historic map research approved by the Kumisión I Fino CHamoru's section, Kumisión I Na'an Lugåt Guåhan. In phase II, new techniques and process algorithms were determined that reveal the internal details within a fill area,



Northern Guam Surface Hydrology, Phase II

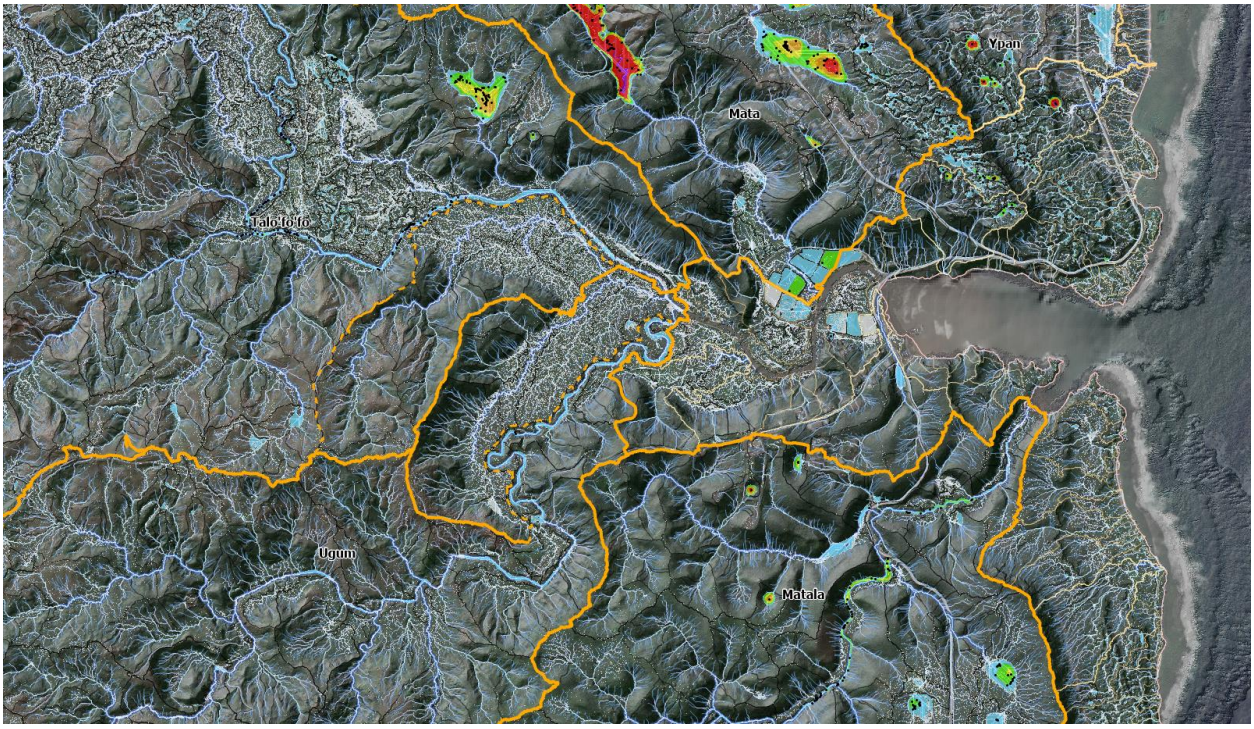
which are internal fill areas, runoff paths, and low points. These details were important in tracking flow paths in large surface depressions that may cross into several vertical holes, soil pipes, and solution pipes. Solution pipes may have caverns beneath.

The significance of surface hydrology applies to the protection of the water source in the NGLA. This map is of great significance for determining and addressing secondary and cumulative Impact, protection of sinkholes, adherence to the groundwater protection zone, development strategies, and management plans. For developing and activities over the aquifer, atop the water source, surface hydrology maps may be the chance for strategic development that could prevent or reduce contamination of the utility water source.

Web MApps: Surface Hydrology of Southern Guam

N.C. Habana, D.K.U. Valerio, L.F. Heitz

A high-resolution surface hydrologic map is invaluable for watershed planning, environmental and water resources protection, preservation, and determining strategies for sustainable development. With the success of producing a high-resolution map of the surface hydrology of northern Guam's limestone plateau (Habana et al. 2022, previous section), stake holders expressed the need to include the terrain and hydrologic spatial analysis for southern Guam. The northern Guam surface hydrology techniques were applied to southern Guam DEM and the results are astounding, resulting in a high-resolution watershed map of southern Guam. The final product will be the most comprehensive surface hydrology map ever produced. Intricate details include runoff paths, enhanced terrain texture, internal watershed features, size categorized watersheds, fill areas or surface depressions, and coastal watershed feature details.



Surface Hydrology of Southern Guam

The current task is the proper naming of watersheds through the Kumisión I Na'an Lugåt Guåhan. A large map plate and accompanying technical report is in progress as well, and once complete may be distributed to stakeholders in the Watershed Planning Committee, Bureau of Statistics and Plans, the Guam Coastal Management Program, the Guam Environmental Protection Agency, and Department of Education. Members of these programs have seen samples and have expressed great interest and are anticipating the map's completion.

The current map results are already creating excitement with interagency partners. Another phase plan for surface hydrology is to repeat the process on the new Guam DEM (2020) and will be combined north and south and turned into an extra-large map of the surface hydrology of Guam.

Guam Hydrologic Survey Research

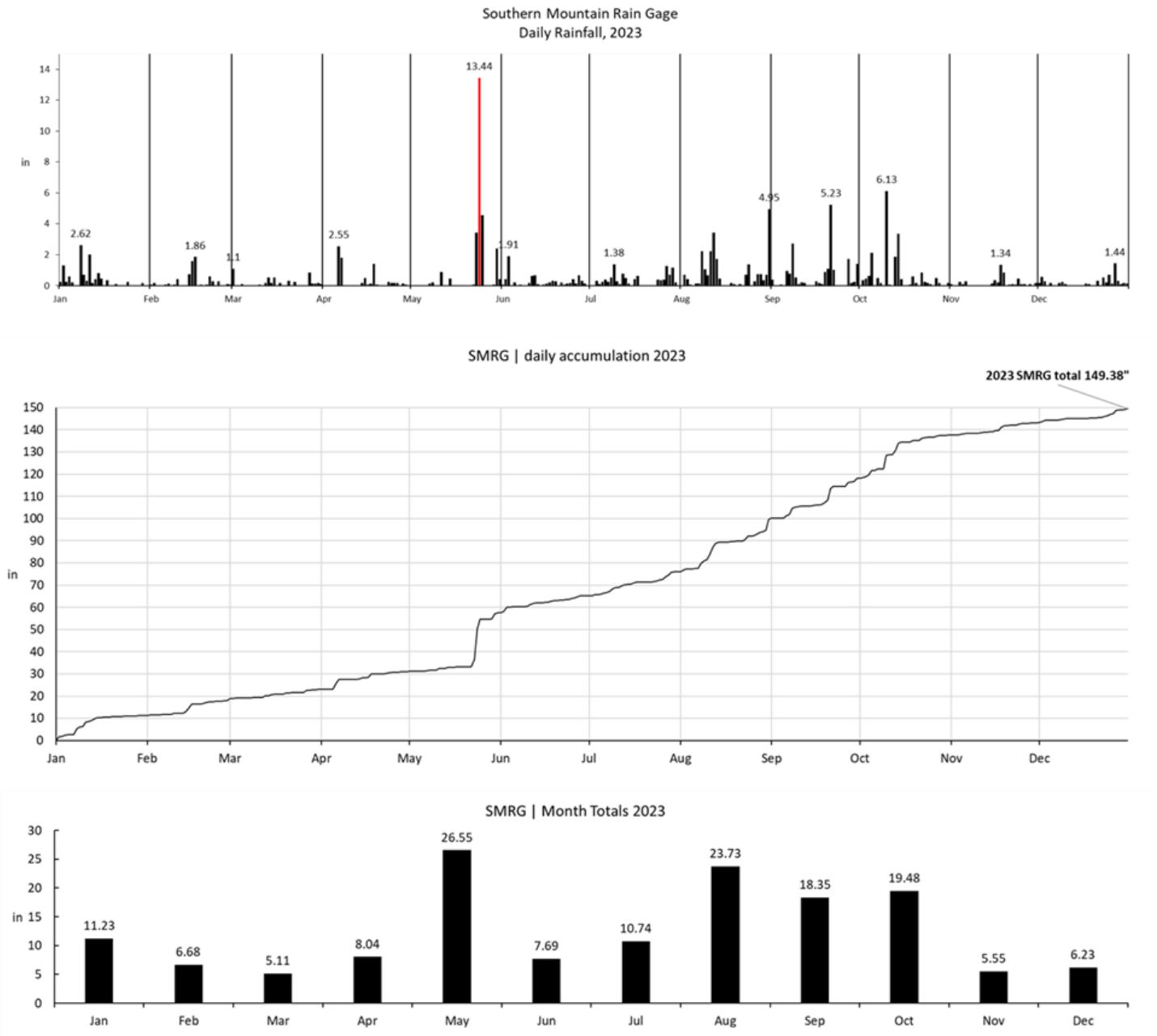
WERI Researchers continue to observe and study the island's water source. They focus on advancing hydrologic data-based research, going in depth into the components of Guam's hydrologic cycle. This section covers the year's research endeavors, organized along the componential lines of the hydrologic cycle and towards model development.

Climate and Weather

A meteorologist is determined to be of great importance to hydrologic research. Guam weather and climate is greatly influenced by ENSO, during stages of the event such that the island is positioned for experiencing periods of major storms or prolonged drought. Another importance is the invaluable collaboration and relative information discussion or data regarding hydrology, aquifer recharge, hydrologic modeling, studying and tracking typhoons, and developing a good meteoric database. However it may be, we like to think that the water or hydrologic cycle begins from the sky.

Currently, WERI awaits the opportunity to hire a new meteorologist. A job announcement and search committee are in place. In the meanwhile, WERI keeps a close information exchange and data collection relationship with the experts in the National Weather Service (NWS), Tiyan. WERI is well supported by the NWS with presenting the *State of the Climate* in workshops and advisory council meetings. NWS also includes WERI Groundwater Hydrologist (Habana) informed and invited to Pacific ENSO Application Climate (PEAC) services for monthly ENSO report and tracking meetings. Also, NWS keeps Habana informed weekly via e-mail messages about the climate, ENSO stage, and weather situation.

Also, WERI GWH and NWS field team, led by Clint Simpson and Isa Cruz, continue a monthly trek to the rain data collection station at the top of the Humåtac Watershed, a rain gage station called the Southern Mountain Rain Gage. This rain gage was first installed by the late WERI Meteorologist, Dr. Mark A. Lander. In 2023, the Southern Mountain Rain Gage recorded more than 149 inches of rainfall, which may be the highest known recorded rainfall for Guam. NWS and WERI continues the late Mark A. Lander rain gage station, a select site that receives much rainfall due to what Lander called the "island effect" and "rain bombs" that often occur in southern Guam.

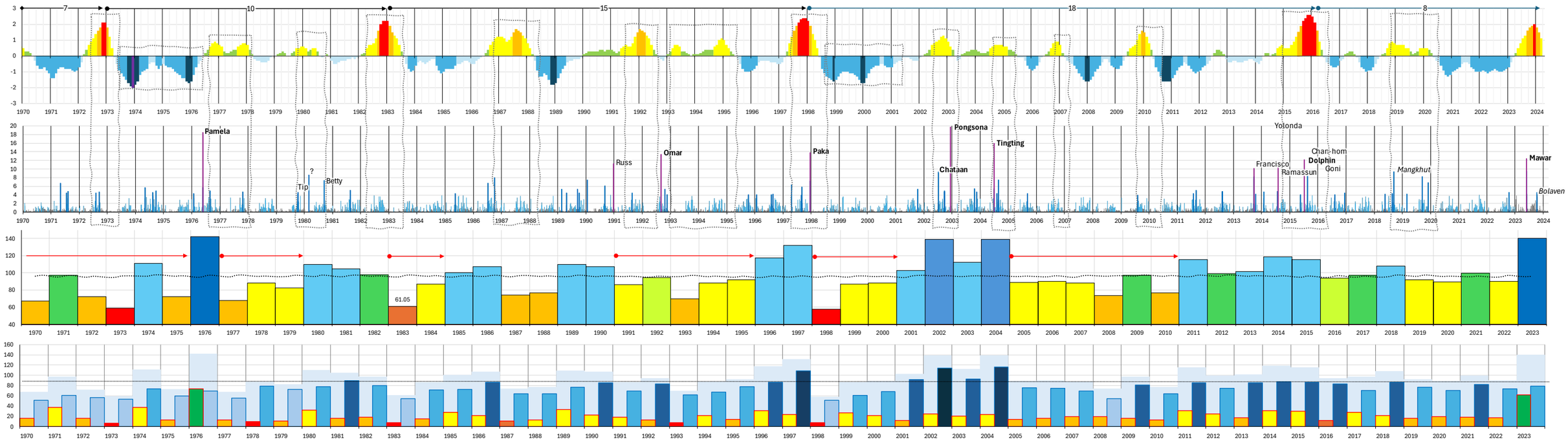


Southern Mountain Rain Gage 2023 (NWS - Simpson, Cruz, and WERI - Habana)

Hydrologic Analysis of ENSO and Rainfall Intensity

N.C. Habana, M-H. Yeo

In the meanwhile, WERI Groundwater Hydrologist and Surface Water Hydrologist (Yeo) make time to analyze rainfall as it is imperative to Guam's hydrologic research. Hydrologic research, whether in groundwater and solute transport modeling, hydrologic data analysis, or contaminant transport, fundamental meteoric information is vital reference. Such that now that necessity is the situation, Habana is organizing a historic multi-graphic rainfall database that includes the ENSO Oceanic Niño Index (ONI), daily, yearly, and seasonal rainfall, and soon—daily tide. This chart will be of great reference



The Big Picture—ENSO ONI and Rainfall History, 1970-2023, daily, annual, and seasonal

for storms, drought, seasonal weather, year total, and ENSO influence on Guam weather and climate. This information would be of great value for the NWS and Stakeholders and must be made available on the GHS website as an online interactive graphical data visualization interface.

In another study, Yeo is analyzing and interpreting rainfall intensity pertaining to climate change and flooding. Dr. Yeo presented his study in the *2024 WERI GHS Workshop*.

Surface Hydrology of Southern and Northern Guam

N.C. Habana, D.K.U. Valerio, and L.F. Heitz

The analysis of the surface hydrology of Northern and Southern Guam is a GIS application of hydrologic spatial analysis with delimited algorithms on a 2012 DEM of Guam. Phase II northern Guam analysis is complete, and a technical report and map is underway. Southern Guam requires more work before a technical report and map may begin. Both products were presented in their current state to interagency partners at the *Guam Forest Plan Summit 2024*, in the *Watershed Management Plan* session. The first deliverable for both north and south surface hydrology will be a pdf map, targeted completion is in 2025. A surface hydrology Web MApp for both regions will be available in 2026 (see Web MApps section, above).

Water Quantity and Quality

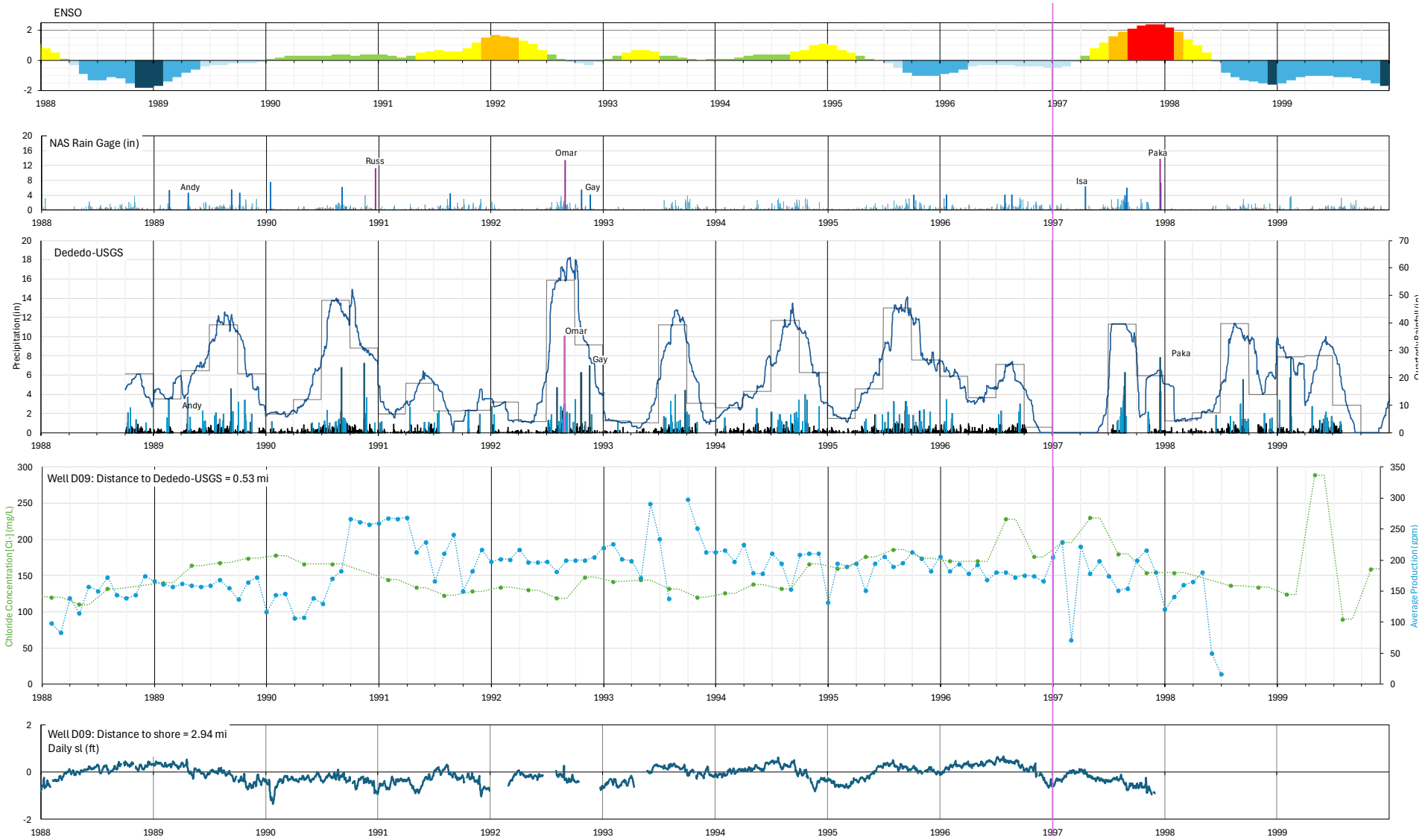
Water resource quantity may be limited by quality. In the Northern Guam Lens Aquifer, sustainable production can be influenced by both hydrology and quality. WERI studies both the quality and quantity of its water resources that may provide insight to improving its production capacity and contribute to advanced studies such as groundwater model development. The researched hydrologic information through the GHS and CWMP Program is centered on these studies.

Chloride and Production Study

H. Ko, Y. Wen, J. Jenson, D. Cabrera, G. Badowski, and N.C. Habana

Guam's Yigo-Tumon (Tomhom) Basin, a critical source of drinking water for approximately 150,000 residents, faces significant challenges related to groundwater quality, particularly concerning chloride concentrations. This study analyzes historical chloride data from nine production wells, revealing a consistent upward trend in eight wells over 49 years. While production rates are statistically significant predictors of chloride levels, increases only occur when pumping exceeds a threshold of 350 gpm, aligning with USEPA Safe Drinking Water guidelines.

Sea level changes also play a vital role, influencing the movement of the freshwater lens within the basal groundwater zone. Saltwater intrusion risks increase during elevated sea levels, affecting well water salinity. Despite rainfall intensity showing no statistical significance in predicting chloride concentrations, the study highlights the importance of capturing immediate rainfall effects through improved sampling frequency. Observations suggest that heavy rainfall events often lead to temporary decreases in chloride concentrations due to dilution from rainwater, although this effect may be obscured by infrequent sampling. Hydrological analyses indicate that significant



Hydrologic analysis of chloride and production, Well D-9

rainfall—approximately ten inches—can dilute chloride levels. The rapid recharge of the aquifer may contribute to this dilution, although slow discharge rates complicate the response dynamics. Instances such as chloride decreases following heavy rainfall events highlight the need for improved sampling to accurately capture these relationships.

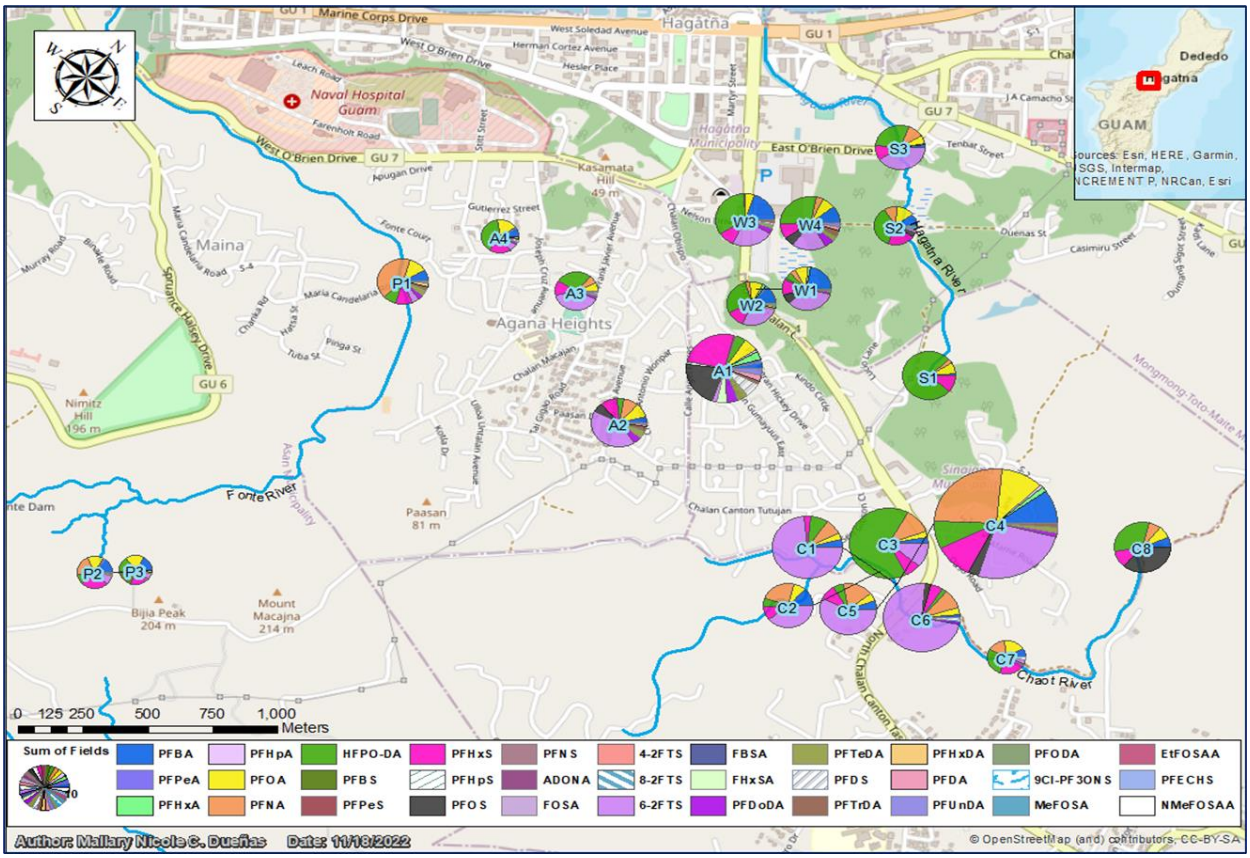
The findings underscore the importance of effective groundwater management strategies that balance production needs with sustainability. Enhanced monitoring and data collection are essential for understanding the aquifer's response to environmental and developmental pressures, ultimately informing practices that protect this vital resource. This research underscores the complex interplay between natural and anthropogenic factors affecting groundwater quality in Guam.

Ko defends her research thesis through the Environmental Science Program, Graduate Studies, UOG, in the Fall (Fanuchånan) Semester, 2024. This will add to WERI's list of research assistants who obtained a master's degree, sponsored through the Guam Hydrologic Survey Program.

Contaminants – PFAS and Dieldrin

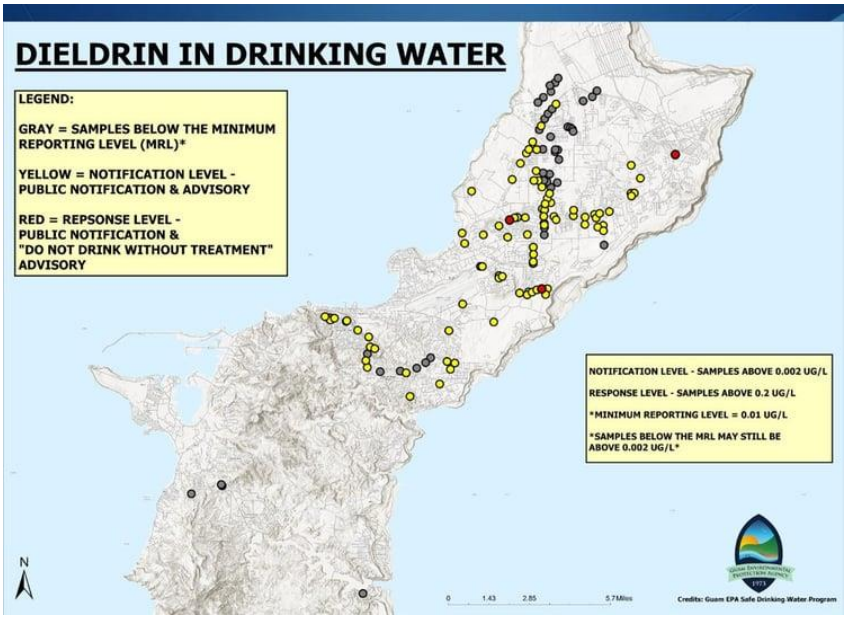
Y.S. Kim and M.N. Duenas

Other than chloride (saltwater) that can limit or even terminate utility water production, newly discovered contaminants are discovered. Two contaminants recently found in



WERI PFAS Research, site sample results

utility water are now of serious issue: Perfluoro Alkyl Substances (PFAS) and Dieldrin. PFAS is manufactured mainly for its special properties that the chemical is both hydrophobic and oleophobic – repels water and oil. PFAS come in many forms and are used to make non-stick pans, in food wrap or containers, and firefighting foam. PFAS is a health concern as the chemicals are found to accumulate in the body and in specific blood tests. In a WERI study, a form of PFAS was found present in every site tested (Duenas et al. 2023). Dieldrin is an EPA banned substance that was used as a pesticide chemical, up to the 1970s (except for use to control termites), and completely banned in 1987. These two contaminants have gained much attention in recent years, along with wastewater (nitrates). In January (2024) GWA had reported 34 GWA production wells were positive with PFAS (Guam PDN 2024). And in December 2023, GEPA reported of Dieldrin presence in some production wells (KUAM News 2023). While WERI had been advised by interagency partners of interest to further study and investigate the two contaminants and their sources, research and data is currently on hold until further notice.



GEPA production wells and dieldrin map

(GEPA 2024)

Geology and Hydrogeology

This year, technology for scanning the subsurface resistivity is of great value, especially a karst aquifer. Also, the historic profile of the phreatic zone provides insight to the lens thickness, which now brings a research assistant and a master's thesis proposal project.

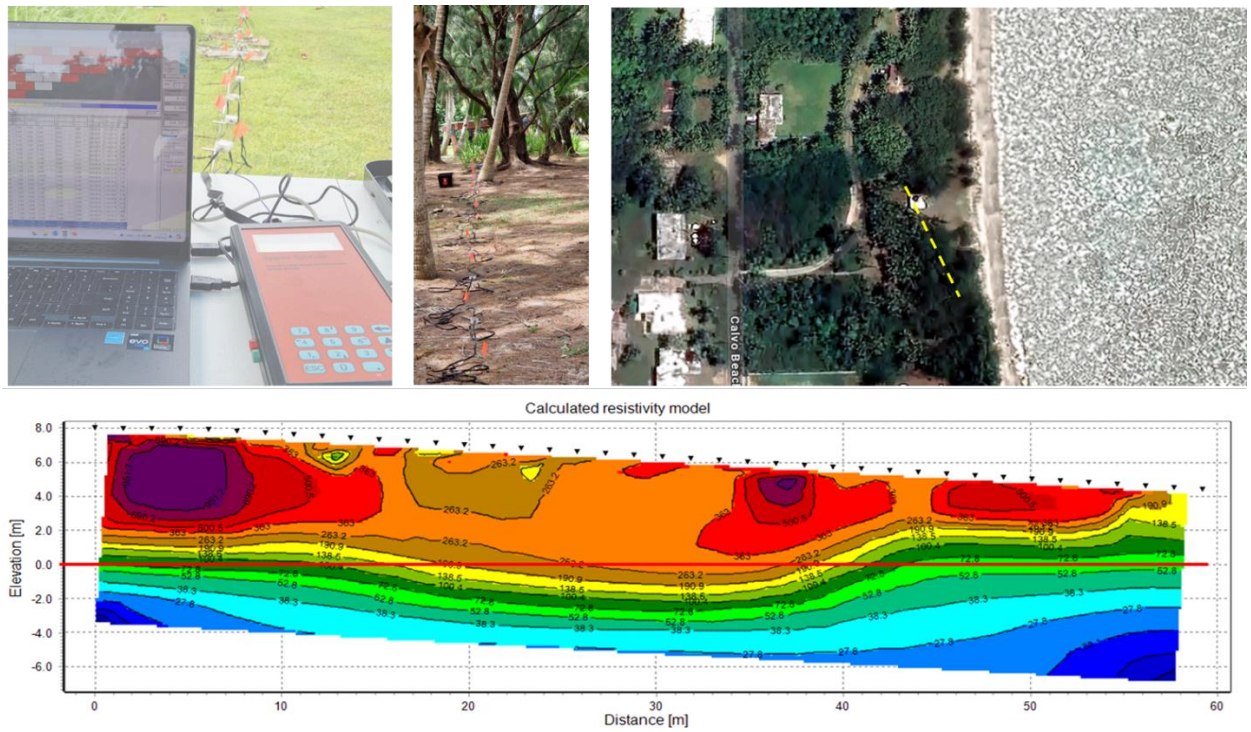
Electrical Resistivity Tomography

B. Miklavič, Y.S. Kim, and M.C. Snaer

The NGLA is a karstic bedrock, which means the porosity is non-homogenous. Although, the terrain may give clues from faults and depressions, the sizes of caverns and geologic transition beneath the surface is often left to the imagination and probability. Karst features in Guam are expected to have triple porosity of caverns,

faults, and matrix voids, however, knowing the actual site and significance of such beneath the surface is often considered a possibility. However, WERI Geologist, Dr. Miklavič has pursued an instrument that may help analyze the subsurface using a geotechnical instrument—Electrical Resistivity Tomography (ERT).

Miklavič is refining the skill and testing the instrument's capacity to provide subsurface hydrogeologic information. ERT can detect changes in electrical resistivity with depth, which may suggest the vertical extent of features and cavities along a transect. The instrument was recently used on solution pipes to check and verify whether the vertical shaft leads to a large cavity or if it has been soil filled. With the gained experience from testing, we may be able to one day see deep into the limestone and observe the transitions into the basement. The first site to be analyzed for a GHS research project is the Mataguac rise, in the Northern Guam Lens Aquifer. The team aims to use ERT in the area to see if the instrument can detect the transition to volcanics, where it may be reachable for the length of the probe line. The success of such may help the team to obtain a longer line, so to see the basement topography of the supra- and parabasal zones.

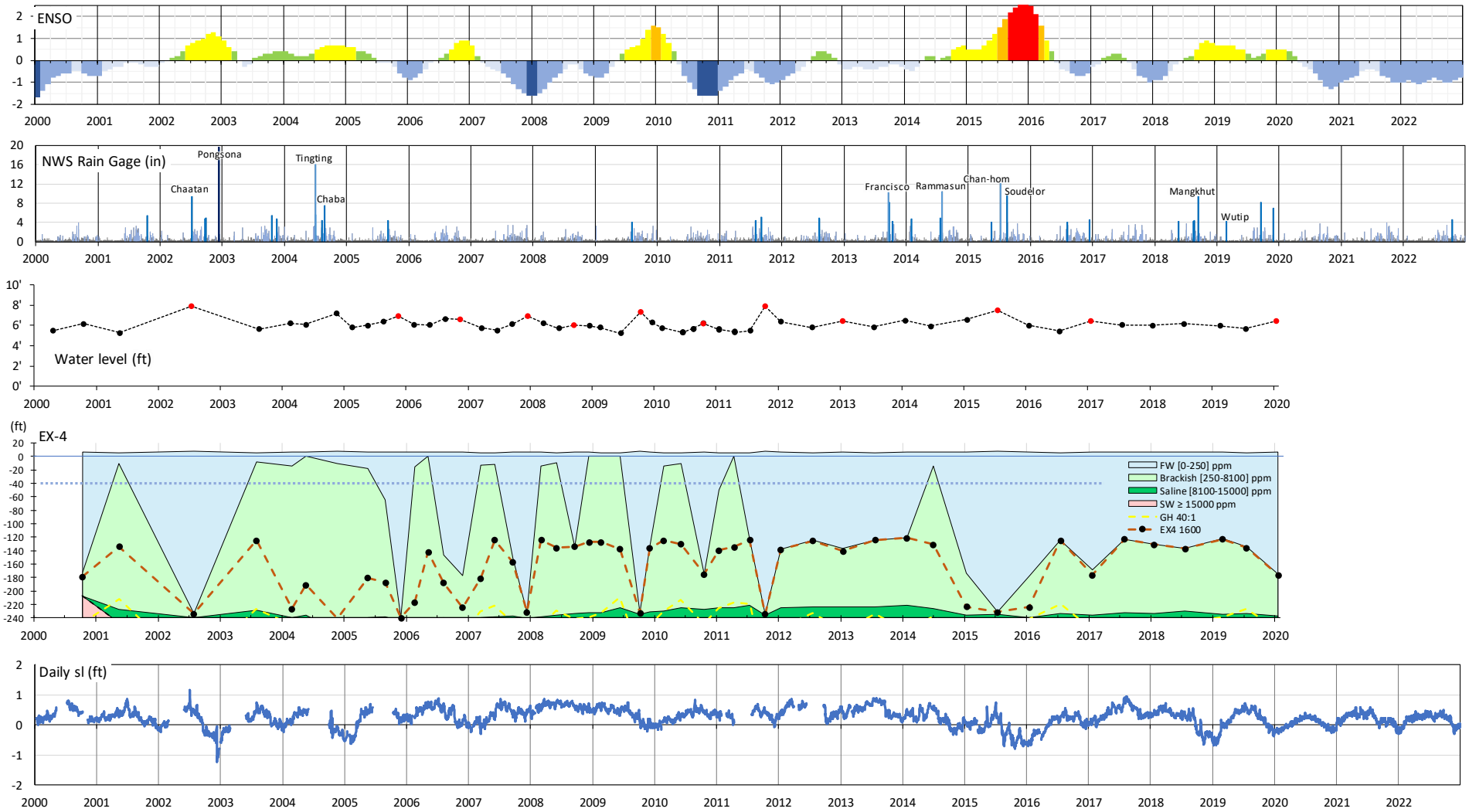


ERT cross-section analysis testing

Deep Observation Wells

M.C. Snaer, B. Miklavič, L. Aquino, and N.C. Habana

Deep observation wells (DOWs) are ports for obtaining a phreatic profile, using hydrologic instruments and measurement tools, in a lens aquifer. The NGLA has a freshwater lens that supplies 90% (42 of 45 MGD) of the island's utility water and responds to the recharge and the climate effects of ENSO. This island's karst aquifer's freshwater lens transitions to saltwater with depth. Eight DOWs extending into the



Hydrologic analysis of historic salinity profile in EX-4 DOW

saltwater portions of the phreatic zone are used to observe freshwater lens thickness via transducer, measuring conductivity, temperature, and depth (CTD). DOW data is analyzed into a historic profile of the phreatic zone, defined by conductivity (salinity) of the freshwater lens, transition zone, and saltwater, revealing a dynamic phreatic zone. This study investigates how rainfall, tides, and climate phenomena, such as El Niño and La Niña, affect freshwater lens dynamics, specifically on lens thickness, water level, and transition zone fluctuations, amid continuous extraction for drinking water production. The study also addresses how the freshwater lens and transition zones of the NGLA respond to prolonged drought and recharge events. The graphs depict a historic profile of the lens, demonstrating changes in thickness over time. Multi-graph time-series and hydrographic analyses align meteoric and climatic events that drive groundwater recharge and lens position. Freshwater lens dynamics observation and analysis are essential for determining the aquifer's integrity and resilience to drought over several areas in an aquifer basin. The study will also be utilized to assess groundwater model parameters and boundary conditions. Interpretations may assist with determining the optimum development and management of different aquifer basins and their water source.

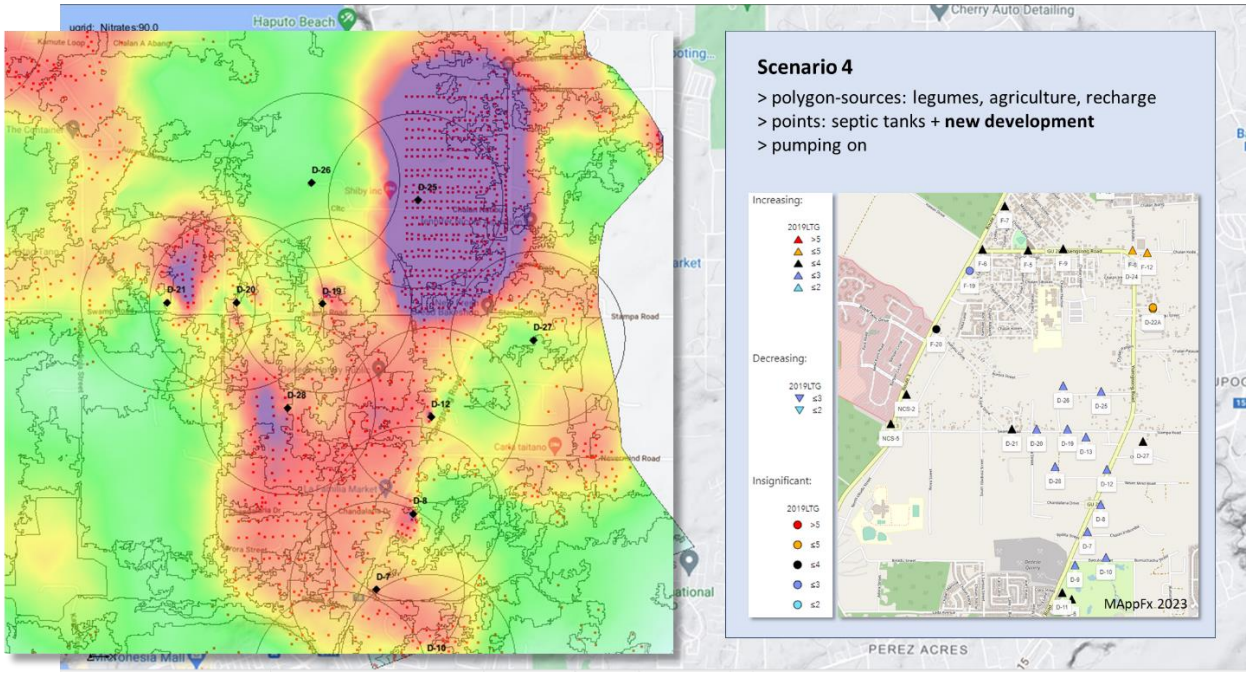
Groundwater Modeling

All the studies mentioned above are key components for ultimately developing a useful model of the island's sole source aquifer. Research provides important hydrologic and statistical information that is key to building a reliable model. Groundwater models can run an acceptable representation on a computer, simulating and testing scenarios for optimum development. Hydrologic models have limitations vs reality; however, they provide insight into capacities and vulnerabilities and may help with determining sustainable development and water resources management strategies, including enacting appropriate regulations/laws for protecting the aquifer.

N-Solute Transport Tomhom Aquifer

A. Bautista, J.A. Caasi, T. Wood, and N.C. Habana

The freshwater source in the NGLA is vulnerable to the island's wastewater system. Ongoing urban growth, aging established residential areas, and wastewater discharge above the water source via septic tanks and leaky/overflowed sewer mains have been a concern for a long time now. Production well nitrate analysis has shown many wells having an increasing trend in nitrate-N concentrations in production wells (The Guam Daily Post 2020). Application of a solute transport model, MODFLOW-USG, at Swamp Road tested current regulations on residential septic tank density and distance of buildings to wells. Model results revealed the extent of contaminant plumes near production wells, which may support refined regulations for development near production wells. This research continues to make model refinements of nitrate-N sources and scenarios, including agriculture, legumes, and septic tanks in a planned residential area near the Swamp Road production wells. The model includes testing the use of septic tanks in a new high density residential area plan. Results revealed insights to the high development density scenario that shows increased intensity. The results have been presented to many island agencies and venues and have gained much



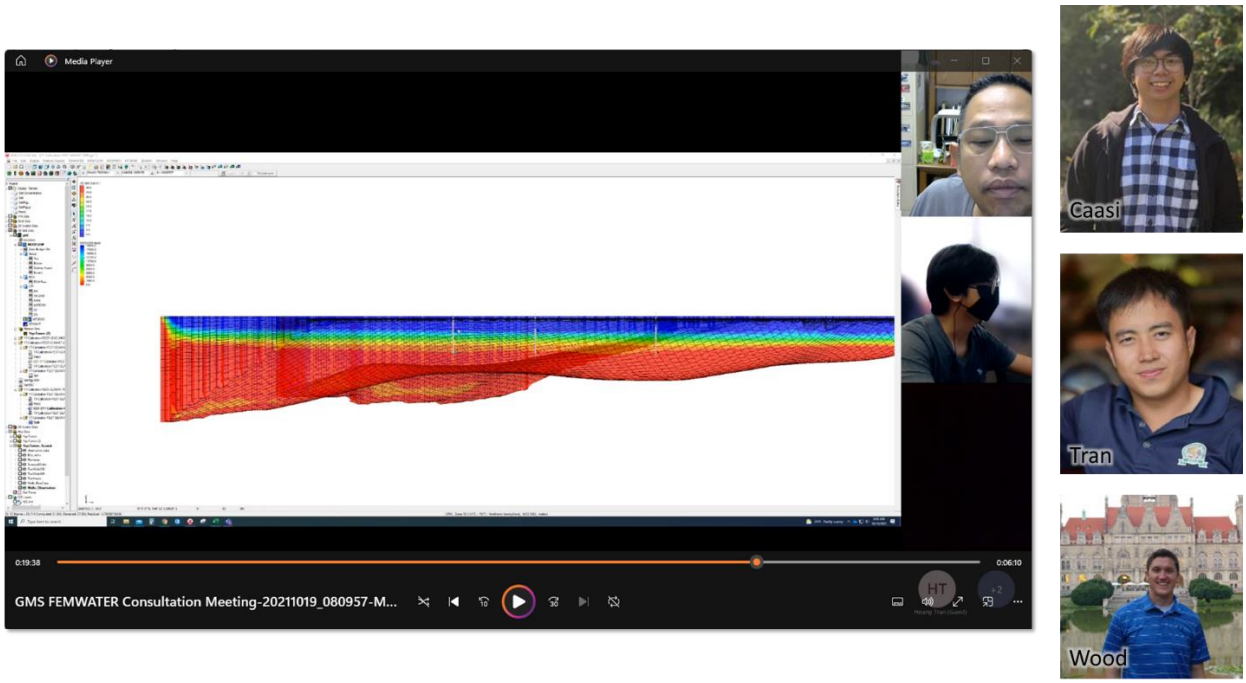
Nitrate-N solute transport model results of development density scenario

attention in the Guam Legislature. This project serves as the pilot study for other areas of groundwater contaminant transport concerns on the island.

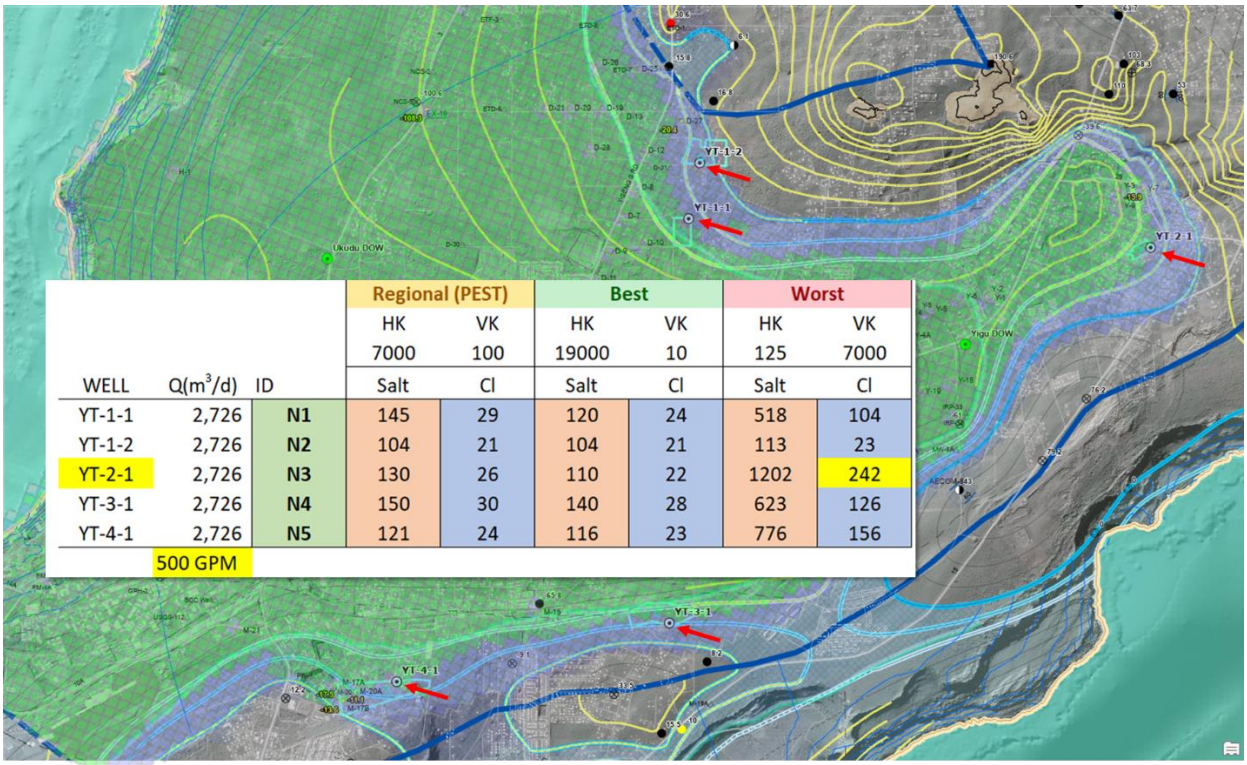
Groundwater Model of the Tomhom Aquifer

J.A. Caasi, N.C. Habana, B. Railey, T. Wood, and H. Tran

WERI GHS groundwater model research team and Aquaveo® GMS produced a SEAWAT phreatic model of the Tomhom Aquifer, NGLA. The Tomhom Aquifer supplies nearly 20 MGD, about half of the total utility water from the NGLA. The model was created to test a GWA Master Plan, well relocation option, which terminates and moves the poor performing production wells to the aquifer "sweet spot," also known as the parabasal zone. Production wells in the parabasal zone are less susceptible to saltwater intrusion (McDonald 2003, WTR 98), and may allow increased production rate. The poor performing production wells are low pump rate that is limited by chloride (saltwater) updraw. Five wells were chosen, based on GWA production well chloride and pump rate data. And five relocation sites in the parabasal zone were selected. The model was "calibrated," local hydraulic conductivity (vertical and horizontal) was adjusted to match the well chloride concentration, using the latest pump rate for each well. Then, the existing parabasal wells were analyzed with the model hydraulic conductivities, in search for the hydraulic conductivities of its worst and best performing wells in the zone. The regional hydraulic conductivities were included in the test as well. Pumping each relocated well at 500 gpm, model results showed that in each case of hydraulic conductivities, the chloride concentration was below 250 mg/L in each well. A technical report needs to be produced for this GHS research work.



WERI and Aquaveo, 3-D SEAWAT phreatic model of the Tomhom Aquifer, showing the freshwater lens (dark blue), transition zone (colors between), and saltwater (red)



			Regional (PEST)		Best		Worst	
			HK	VK	HK	VK	HK	VK
			7000	100	19000	10	125	7000
WELL	Q(m^3/d)	ID	Salt	Cl	Salt	Cl	Salt	Cl
YT-1-1	2,726	N1	145	29	120	24	518	104
YT-1-2	2,726	N2	104	21	104	21	113	23
YT-2-1	2,726	N3	130	26	110	22	1202	242
YT-3-1	2,726	N4	150	30	140	28	623	126
YT-4-1	2,726	N5	121	24	116	23	776	156
	500 GPM							

Model results for the relocation of 5 production wells in select parcels over the parabasal zone

Guam Hydrologic Survey Outreach - Presentations, Tours, and Workshop

WERI includes education and outreach programs to government and private sector employees and stakeholders, and to educators as well. In this fiscal year, WERI and Global Learning and Engagement (GLE, UOG) brought back the Northern Guam Lens Aquifer Tour and The GHS WERI Workshop. WERI also presented their GHS research work and products in the WERI Guam Advisory Council Meeting (2023, FY 2024), and showcased data visualization products in the WERI CNMI Advisory Council Meeting. WERI also appeared before the Governor and the Legislature to present the State of the Aquifer Report. Furthermore, WERI presented GHS research and products in conferences in both the local and national stage. The GHS program was well received in all outreach endeavors and continues to grow the GHS Program.

NGLA Tour

B. Miklavič, N.C. Habana

The NGLA Tour resumes. As we all know, the COVID-19 Pandemic situation required enforcing social distancing protocol, which cancelled the NGLA tour. Prior to 2020, WERI presented and conducted the NGLA tour to many interagency partners, educators, and island leaders. In its soft return with WERI Geologist Dr. Blaž Miklavič, WERI hired Global Learning Engagement (UOG) to coordinate and organize the tour logistics, food, and venues. The tour began with greetings and a *Virtual Tour into the Northern Guam Lens Aquifer* presentation that provides a hydrogeologic aquifer basics to prepare for a simulation approach into Guam's virtual freshwater lens. The tour attendees received a 3' x 4' map-poster of the NGLA and map and provided a tour set of recommended literature/brochure and maps in the GHS website (scroll: NGLA Tour). The tour then continued to see the sites onboard a 30-passenger bus to select tour sites: Mt. Alutom, Dededo Quarry, Mataguac Hill, and Mt. Santa Rosa.

NGLA Tour 2024 Dr. Habana begins with a virtual tour into the NGLA (left). Dr. Blaž Miklavič and Habana in a clear day on Mt. Alutom, basement rock formation that continues beneath the aquifer (right).

The tour had a total of 22 registered attendees. The attendees were comprised of 4 local agencies, 2 military units, and 2 from the private sector.

- GEPA – Guam Environmental Protection Agency
- GWA – Guam Waterworks Authority
- NGSWCD – Northern Guam Soil and Water Conservation District
- WERI – Water and Environmental Research Institute of the Western Pacific
- NAVFAC MAR – US Naval Facilities Marianas
- USAF 36TH CES – US Air Force, 36th Civil Engineering Squadron
- ENGEO
- HDR, Inc.

Next year, WERI plans to include teachers from the Department of Education.

GHS GLE-WERI Workshop

WERI GHS Workshop also made its return in 2024. The workshop was limited to 40 seats; however, we were able to squeeze in about 10 more attendees. The sectors in attendance were from local, federal, and private. The following lists the presentations and department attendance.

Presentations:

- Aquifer Basics
- The Northern Guam Lens Aquifer Map
- Geologic Map of Guam and subsurface surveying
- The GHS website
- Data visualization, MAppFx products
- Chloride and Production
- Deep Observation Wells
- Island's water security
- Rainfall analysis and climate change
- Surface hydrology maps of Guam
- Water Quality Lab services
- Wastewater-Nitrate transport model
- GEPA – Perfluoro Alkyl Substances and Dieldrin
- GWA – Production wells
- NWS – State of the Climate

Department Attendance:

- DOA – Department of Administration
- BSP – Bureau of Statistics and Plans
- DLM – Department of Land Management
- GCMP – Guam Coastal Management Program
- GEPA – Guam Environmental Protection Agency
- GWA – Guam Waterworks Authority
- NGSWCD – Northern Guam Soil and Water Conservation District
- UOG CLASS – College of Language Arts and Social Science
- UOG WERI – Water and Environmental Research Institute of the Western Pacific
- NAVFAC MAR – US Naval Facilities and Engineering Marianas

- USAF 36TH CES/CEIOU – Civil Engineering
- USGS PIWSC – US Geological Survey, Pacific Islands Water Science Center
- AECOM
- EA
- EMPSCO
- GFSRD
- HDR

Conference/Meeting Presentations

Guam Advisory Council Meeting (November 2023 Westin | Tumon, Guam) Presentations included GHS and USGS sponsored research projects. The event was posted on the WERI website:

2023 WERI Guam Advisory Council Meeting

The following were the GHS projects and interagency partner presentations. The GHS website the GACM presentations:

- Tomhom Aquifer Phreatic Model, and GWA Master Plan for Production Well Relocation (Presenter: N.C. Habana)
- Nitrate-N Solute Transport Model of Swamp Road Area Development Plan Septic Tank Scenario (A. Bautista)
- MAppFx: Production Well Nitrate-N, NGLA (D.K.U. Valerio)
- MAppFx: Southern Guam Flow Duration Curves (D.K.U. Valerio)
- Production Well Chloride Update (H. Ko)
- Freshwater Lens (N.C. Habana)
- NWS: The Year in Rainfall, and next year's forecast (W. Aydlett)
- GEPA: Package Wastewater Treatment (B. Bearden)
- GWA: Groundwater Protection Zone, Ground Water Resources Development Group (V. Lujan)

National Groundwater Association (Groundwater Week, December 2023, Las Vegas, Nevada) showcased GHS research project of chloride and production study, nitrate-N solute transport model, and data visualization products.

- Production well chloride (H. Ko)
- Nitrate-N solute transport model (A. Bautista)
- MAppFx – production well nitrate (D.K.U. Valerio)

Guam Forest System Plan Summit (June 2024 Hyatt Hotel | Tumon, Guam) includes a discussion about watersheds, showed watershed maps, and the GHS website. Much interest from BSP, USACE, NOAA, and Silver Jackets to obtain surface hydrology analysis files and maps. WERI Groundwater Hydrologist and GISP are now appointed members of the *Watershed Planning Committee*, under the Guam Forest System Plan. WERI was also called to attend follow up meeting in August for the Watershed Planning Committee at the Governor's Conference Room, Adelup.

UOG Inaugural Research Forum (August 2024, SBPA UOG | Mangilao, Guam) Habana showcased WERI personnel, Water Quality Lab, and Faculty recent research focus.

Groundwater Resources Development Group (August 2024 GPWA | Fadian, Guam) In the return of the GWRDG, also known as the Northern Guam Aquifer Working Group meeting, hosted by GWA's V. Lujan, Habana unveiled the online data visualization product: MApp production and chloride.

American Water Works Association, Hawaii Western Pacific Section Conference *Emerging Challenges for Pacific Island Water Producers* (September 2024 Hyatt, Tumon Guam) WERI (Habana and Zapata) and CNMI Bureau of Environment and Coastal Quality (Spaeth) shared the floor to present the challenges of water management in Saipan. Habana and Zapata presented the latest MAppFx products (Production well chloride and nitrate-N) for CNMI that emerged from GHS, WERI data visualization development of MAppFx database system.

University Council On Water Resources, NIWR, AWRA Conference (September 2024 Hyatt Regency St. Louis Arch | St. Louis, Missouri) The conference organizers selected the data visualization and deep observation well projects. However, paid for travel was only available for students and the data visualization project presenter had graduated and did not qualify for the free travel. We selected an undergraduate RA (Bautista) in place, who presented the nitrate-N solute transport model.

State of the Aquifer Report

WERI GHS Program also presented a State of the Aquifer Report (SOTAR) to both the Governor and Legislature. SOTAR was presented at the Governor's Conference Room in November 2023 before the Governor and Lieutenant Governor, and at the Legislature in January 2024. WERI Interim Director and GHS Advisor presented the status of Chloride and Production, Typhoon Mawar, total rainfall, recharge, nitrates and solute transport model, and the PFAS research. WERI also showcased the solute transport model of nitrate-N that demonstrated the case for increasing development density and use of septic tanks, resulting in increased nitrate-N intensity. WERI research assistant also provided the spatial and temporal statistical analysis and history of production wells and chlorides.

Legislation support

N.C. Habana, Y. Wen, and H. Ko

WERI provides scientific research and best available hydrologic data-based information to the Governor and Legislature, recommending best and sustainable advice on developing over the water source. The GHS Program and CWMP gives WERI the research capability to conduct and provide data based hydrologic information. This year, WERI Interim-Director submitted two letters that advised on mining and development density and wastewater disposal.
In November (2023) and January (2024), WERI GHS Advisor and Interim Director were called upon to the Governor's office and to the Legislature to present and report the *State of the Aquifer*. In both reports, WERI presented a nitrate-N solute transport model demonstrating the use of septic systems with increased development density. Model results were an intensified nitrate-N concentrations in the groundwater right below. Mitigation plan for such was to use a nitrate reducing system, however, WERI supported GEPA's rebuttal that nitrate-N is more of an indicator suggesting the presence of

domestic wastewater. However, the N-reducing system does not truly clean wastewater discharge. Also, removing nitrate-N reduces the chance of better-knowing the state of wastewater in the water source. WERI Research Assistant presented the statistical and historic spatial analysis of production and chloride in the NGLA.

WERI was also present in a July 2023 hearing, where WERI supported the importance of conducting hydrologic and hydrogeologic assessments of land use for mining. Hydrologic and hydrogeologic assessments presents detailed maps and discusses the nature, identifiable vulnerabilities, and potential impacts to the water sources. GEPA added that laws are already in place for such development activities. Two WERI written testimonies and presentations were submitted.

(Photo: Guam PDN, Rick Cruz)

WERI, GWA, and GEPA at the Legislature

- Bill 116-37 Committee Report
- Bill 175-37 Committee Report

Bill 175-37, increased development density and use of nitrate reducing systems, was a very divided issue involving GWA, GEPA, WERI, and realtors/developer. The subdivision of an acre lot into 8 was heavily debated. In June, 6 per acre and application of nitrogen reducing system, Public Law 37-105 was enacted (Guam PDN 2024).

WERI News

WERI Information Management posts news of WERI participation in or hosting of events. Below is a list and links to WERI News in the (WERI website) and local news that involved showcasing GHS funded research and products, hosting outreach events, information transfer, and legislature matters.

- WERI at UCOWR/NIWR/AWRA Conference | September 30
- WERI hosts workshop for local agencies on Guam's water res… | September 30
- Proposed alternative solutions for securing Guam's water res… | September 13
- WERI at the 2024 AWWA Conference | September 13
- WERI at UOG's Inaugural Research Forum | August 12
- WERI at the Guam Forest Plan Summit | June 25
- WERI's NGLA Tour makes its return | May 13

- Feng Chia University and WERI UOG share research work presentations | May 6
- 34 GWA Wells may need treatment for toxic ‘forever chemicals’ | January 4
- WERI at NGWA’s Groundwater Week 2023 Conference | December 13
- 2023 WERI Guam Advisory Council Meeting | November 30

Comprehensive Water Monitoring Program Activities

USGS-PIWSC continues the CWMP hydrologic data collection. New DOWs were constructed to improve our phreatic models, historic profile assessment, and insight into freshwater availability. However, addition of new wells means more gaging and collecting, which will require increased support for operations and logistics. The Government of Guam funds 50% of the CWMP share cost with USGS-PIWSC according to the public law (P.L. 24-247). This fiscal year, USGS-PIWSC has made four returns to Guam. The latest posted approved data goes up to 2020.

USGS-WERI Observation Well Data Collection

CWMP data collection was done in Fiscal Year 2024. The following is the summary of FY2024 Quarterly Progress Updates from USGS PIWSC.

Summary of FY24 Quarterly Progress Updates provided by USGS PIWSC.

For the period of October 1, 2023 to December 31, 2023, USGS:

- Measured water levels and performed maintenance on continuous water-level-monitoring equipment at 16 wells: A-16, A-20, Andersen AFB DW-1, BPM-1, EX-4, EX-7A, EX-8, EX-10, GHURA-Dededo, M-10A, NW Field DW-1, Marbo-1, MW-2, NCSF-1, NCFS-2, and Yigo.
- Checked the accuracy of fixed-depth conductivity and temperature sensors deployed in five wells: EX-4, EX-7A, EX-8, EX-10, and GHURA-Dededo.
- Completed routine maintenance at each well listed above and troubleshooted equipment issues at selected wells.
- Measured water levels and installed pressure transducers needed to collect continuous water-level data at AECOM-3 well.
- Measured water levels in EX-1 and EX-9, which do not have continuous monitoring equipment.
- Collaborated with Guam Land Survey Division and searched for roadside benchmarks. Developed preliminary plans to survey from roadside benchmarks (with known altitudes) to references marks (with unknown or uncertain altitudes) at 7 new wells and at selected existing wells.
- Measured water levels in AECOM-7 and AECOM-6 wells and investigated feasibility of including one of these wells for a week-long synoptic water-level survey tentatively planned for 2027.
- Developed preliminary plans to gain access to and deploy equipment in NCS-A well.
- Evaluated safety concerns at NCSB-1 well, which is in an antenna field, and discussed next steps for ensuring safety when driving to and working at the well.
- Continued to process, review, and load data collected at the wells into USGS National Water Information System and GeoLog.
- Discussed logistics related to a new well planned for Yigo area and that is intended to replace NCS-3 well.
- The reporting requirements for this project have been completed with the approval and release of the geophysical logs to GeoLog. The data from these

logs will be used to further inform and refine the existing groundwater model and water budget as part of the One Guam Water Resources Information Program (OGWRIP).

For the period of January 1, 2024, to March 31, 2024, USGS:

- Downloaded data and performed maintenance on continuous water-level-monitoring equipment at 17 wells: A-16, A-20, AECOM-3, Andersen AFB DW-1, BPM-1, EX-4, EX-7A, EX-8, EX-10, GHURA-Dededo, M-10A, NW Field DW-1, Marbo-1, MW-2, NCSF-1, NCFS-2, and Yigo.
- Checked the accuracy of 10 fixed-depth conductivity and temperature sensors deployed in five wells: EX-4, EX-7A, EX-8, EX-10, and GHURA-Dededo.
- Collected CTD profiles in 13 wells: Andersen AFB DW-1, EX-1, EX-4, EX-7A, EX-8, EX-9, EX-10, GHURA-Dededo, NW Field DW-1, Marbo-1, NCSB-1, NCSF-1, and NCFS-2.
- Measured water levels and completed routine maintenance at each well listed above and troubleshooted equipment issues at selected wells.
- Manufactured and installed a new well cover at NCS-A well. Measured water levels and installed pressure transducers needed to collect continuous water-level data at NCS-A and NCSB-1 wells.
- Met with staff at Guam Land Survey Division to discuss preliminary plans to survey from roadside benchmarks (with known altitudes) to references marks (with unknown or uncertain altitudes) at 7 new wells and at selected existing wells.
- Continued to process, review, and load data collected at the wells into USGS National Water Information System and GeoLog. This is a major effort that has been hindered by staffing challenges.

For the period of May 1, 2024, to June 30, 2024, USGS:

- Downloaded data and performed maintenance on continuous water-level-monitoring equipment at 19 wells: A-16, A-20, AECOM-3, Andersen AFB DW-1, BPM-1, EX-4, EX-7A, EX-8, EX-10, GHURA-Dededo, M-10A, NW Field DW-1, Marbo-1, MW-2, NCS-A, NCSB-1, NCSF-1, NCFS-2, and Yigo.
- Checked the accuracy of 10 fixed-depth conductivity and temperature sensors deployed in 5 wells: EX-4, EX-7A, EX-8, EX-10, and GHURA-Dededo.
- Cooperatively worked with Guam Land Survey Division to establish references marks (with unknown or uncertain altitudes) at selected wells. Collected and verified survey information needed to determine the altitude of reference marks and measuring points, at 11 wells: Andersen AFB DW-1, EX-8, M10-A, NW Field DW-1, Marbo-1, MW-2, NCSB-1, NCS-A, NCSF-1, NCFS-2, and Yigo.
- Measured water levels and completed routine maintenance at each well listed above and troubleshooted equipment issues at selected wells.
- Continued to process, analyze, review, and load data collected at the wells into USGS National Water Information System and GeoLog.

For the period of July 1, 2024, to September 30, 2024, USGS:

- Downloaded data and performed maintenance on continuous water-level-monitoring equipment at 19 wells: A-16, A-20, AECOM-3, Andersen AFB DW-1,

BPM-1, EX-4, EX-7A, EX-8, EX-10, GHURA-Dededo, M-10A, Marbo-1, MW-2, NCS-A, NCSB-1, NCSF-1, NCFS-2, NW Field DW-1, and Yigo.

- Checked the accuracy of 10 fixed-depth conductivity and temperature sensors deployed in 5 wells: EX-4, EX-7A, EX-8, EX-10, and GHURA-Dededo.
- Collected vertical profiles of conductivity, temperature, and depth (CTD profiles) in 13 deep monitor wells: Andersen AFB DW-1, EX-1, EX-4, EX-7A, EX-8, EX-9, EX-10, GHURA-Dededo, Marbo-1, NCSB-1, NCSF-1, NCFS-2, and NW Field DW-1.
- Cooperatively worked with the National Geodetic Survey to process our May 2024 survey data and determined the altitude of reference marks and measuring points at 11 wells: Andersen AFB DW-1, EX-8, M10-A, Marbo-1, MW-2, NCSB-1, NCS-A, NCSF-1, NCFS-2, NW Field DW-1, and Yigo.
- Measured water levels and completed routine maintenance at each well listed above. Disabled telemetry equipment, which is used to produce real-time data at three wells (EX-7A, EX-8, and A-20), to simplify the data-collection platforms and possibly eliminate intermittent problems that may be caused by telemetry-related equipment.
- Continued to process, analyze, review, and load data collected at the wells into USGS National Water Information System and GeoLog. This is a major effort that has been hindered by staffing challenges.

USGS field team conducted hydrologic measurements and retrieved logger information in the following dates:

- October 19-29, 2023 | All observation wells
- January 19 – February 2, 2024 | All observation wells
- April 19 – May 11, 2024 | All observation wells except EX-9
- July 14-28, 2024 | All observation wells

USGS conducts 37 hydrologic gaging sites, 24 in the aquifer and 13 in the watersheds. A table lists the gaging stations in the aquifer and watersheds, accompanied by an aquifer and watershed map, and link to the USGS online Mapper (last 4 pages).

GHS funded WERI Research Assistant and UOG Environmental Science Graduate Student, Mary Clare Snaer, also visited most of the DOWs with the field team. Snaer is

USGS Field Team and WERI GHS Research Assistant fish CTD data in EX-1 DOW

conducting a hydrologic analysis of the phreatic zone (see *Deep Observation Wells*, section above), noting the data collection process and location.

The following observation wells were visited:

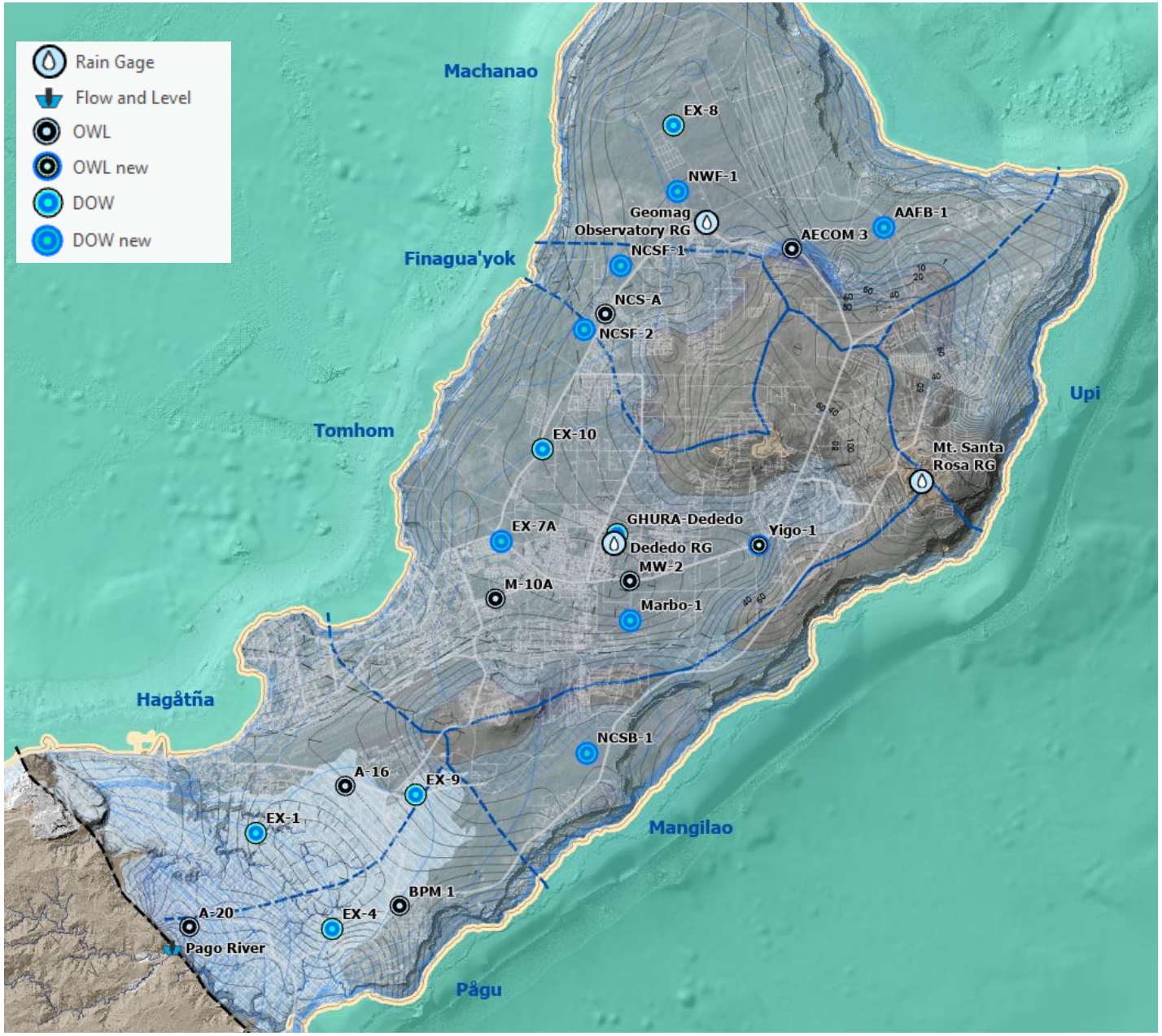
- January 31: EX4
- May 6: EX4
- July 15-25: EX1, A16, EX9, BPM1, NWF-1, A-20, EX-4, GHURA-Dededo, and EX-7A'

Snaer's project anticipates the processing of 8 DOW CTD data, for the last 4 years, 2021-2024. USGS is now processing DOW data and will soon have approved CTD data available. The latest available and approved DOW CTD data is 2020.

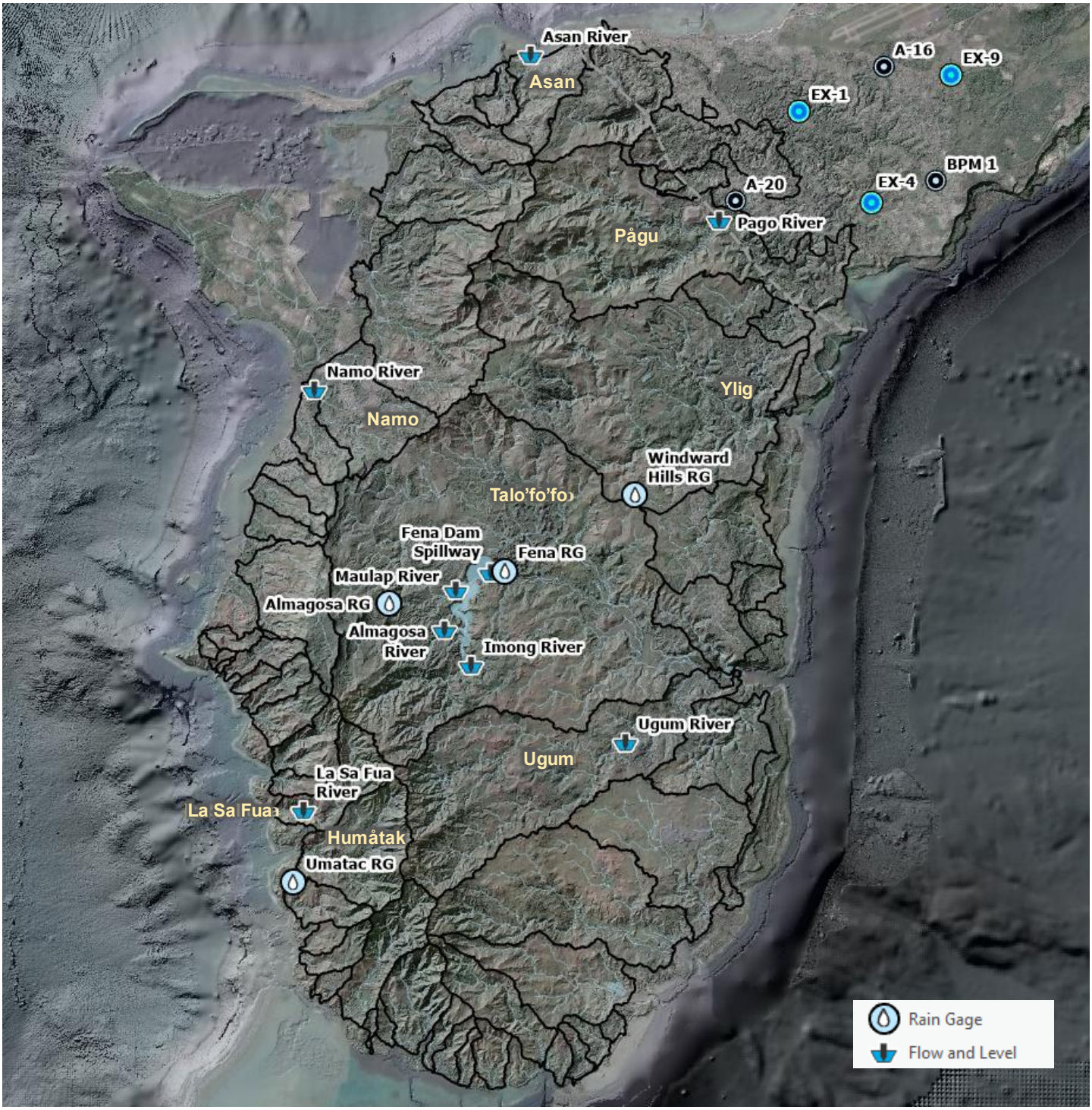
Hydrologic Observation Stations

	Station ID	USGS Site Number	Gage	Hydrologic Class	Observation	Aquifer/ Watershed	Village	nearby Landmark/Facility/Road	Land Property	Lat	Lon	USGS Data Site
Northern Guam Aquifer	AAFB-1	133519144542201	DOW new	GW	CTD, WLML*	Machanao	Yigo	Andersen AFB, 5th Street	Military			https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=133519144542201
	EX-7A	133121144493101	DOW new	GW	CTD, WLML	Tomhom	Dededo	Rt. 1, between Rt. 3 & Calle De Fatima	GG GWA	13.522542	144.825278	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=133121144493101
	NCSB-1	132843144503801	DOW new	GW	CTD, WLML	Mangilao	Barrigada	NCS Barrigada	Military			https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=132843144503801
	NCSF-1	133448144510101	DOW new	GW	CTD, WLML	Finagua'yok	Dededo	NCS Finegayan	Military			https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=133448144510101
	NCSF-2	133400144503301	DOW new	GW	CTD, WLML	Finagua'yok	Dededo	NCS Finegayan	Military			https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=133400144503301
	NWF-1	133545144514401	DOW new	GW	CTD, WLML	Machanao	Dededo	Pott's Junction, Rt. 3A	Military			https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=133545144514401
	EX-1	132736144461671	DOW	GW	CTD, WLM*	Hagåtña	MTM	J.Q. San Miguel Elementary School	GG GWA	13.461389	144.773611	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=132736144461671
	EX-4	132626144471771	DOW	GW	CTD, WLM	Pågu	Mangilao	Father Duenas Memorial School	GG GWA	13.441583	144.790028	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=132626144471771
	EX-9	132806144481871	DOW	GW	CTD, WLML	Hagåtña - Pågu	Barrigada	P.C. Lujan Elementary School	GG GWA	13.469667	144.807528	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=132806144481871
	EX-10	133224144495271	DOW	GW	CTD, WLML	Tomhom	Finegayan	Swamp Road, Rt. 3	GG GWA	13.541833	144.833889	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=133224144495271
	EX-8	133628144513271	DOW	GW	CTD, WLML	Machanao	Dededo	Northwest Field	Military			https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=133628144513271
	GHURA-Dededo	133120144505471	DOW	GW	CTD, WLML	Tomhom	Dededo	GHURA 501, GICC	GG GWA	13.524250	144.849917	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=133120144505471
	Marbo-1	133023144511001	DOW new	GW	CTD, WLML	Tomhom	Dededo	Marbo, UC Training Facility	Military			https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=133023144511001
	Yigo-1	133120144524801	OWL new	GW	WLML	Tomhom	Yigo	Yigo Fire Station	GG GWA	13.522239	144.880122	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=133120144524801
	A-16	132813144472771	OWL	GW	WLML	Hagåtña	Barrigada	Canada Toto Loop Rd	GG GWA	13.471361	144.792528	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=132813144472771
	A-20	132624144452771	OWL	GW	WLML	Hagåtña - Pågu	Ordot - Chalan Pago	Judge Sablan St, Chalan Vicente C Blas, and Ramirez Dr.	GG GWA	13.441750	144.759639	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=132624144452771
	AECOM 3	133502144531101	OWL	GW	WLML	Machanao	Dededo	Andersen AFB, Route 9, AAFB Gate	Military			https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=133502144531101
	BPM 1	132644144480871	OWL	GW	WLML	Pågu	Mangilao	Abing St.	GG GWA	13.446528	144.804333	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=132644144480871
	M-10A	133032144491871	OWL	GW	WLML	Tomhom	Dededo	Harmon Loop School	GG GWA	13.510611	144.824139	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=133032144491871
	MW-2	133047144510171	OWL	GW	WLML	Tomhom	Yigo	Marbo, Rt. 1	GG GWA	13.514556	144.852722	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=133047144510171
	NCS-A	133412144504901	OWL	GW	WLML	Finagua'yok	Finegayan	Noyes St., Rt. 3, NCS	Military			https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=133412144504901
	Dededo RG	133100144504966	Rain Gage	Rain	RF*	Tomhom	Dededo	GICC Golf Course, D-4	GG GWA	13.522250	144.849306	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=133100144504966
	Geomag Observatory RG	133522144520601	Rain Gage	Rain	RF	Machanao	Dededo	Pott's Junction	Military			https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=133522144520601
	Mt. Santa Rosa RG	133209144545301	Rain Gage	Rain	RF	Tomhom	Tomhom-Upi	Comm Dome	Military			https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=133209144545301
Southern Guam Watersheds	Asan River	16807600	Flow and Level	River/Stream	PSF*	Asan	Asan	National Asan Park	GG	13.472639	144.713556	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=16807600
	Namo River	16808120	Flow and Level	River/Stream	PSF	Namo	Agat - Santa Rita	Rt. 2A, Namo River	GG	13.398917	144.665944	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=16808120
	La Sa Fua River	16809600	Flow and Level	River/Stream	SFL	La Sa Fua	Humåtak	Rt. 2, La Sa Fua River	GG	13.306944	144.664417	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=16809600
	Imong River	16847000	Flow and Level	River/Stream	SFL	Talo'fo'fo	Talofofo	South Fena Reservoir, Imong River	GG	13.339000	144.701528	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=16847000
	Almagosa River	16848100	Flow and Level	River/Stream	SFL	Talo'fo'fo	Hågat	South-east Fena Reservoir, Almagosa River	Military			https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=16848100
	Maulap River	16848500	Flow and Level	River/Stream	SFL	Talo'fo'fo	Hågat	East Fena Reservoir, Maulap River	Military			https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=16848500
	Fena Dam Spillway	16849000	Flow and Level	River/Stream	SFL	Talo'fo'fo	Santa Rita	Fena Reservoir dam spillway	Military			https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=16849000
	Ugum River	16854500	Flow and Level	River/Stream	SFL	Ugum	Talofofo - Inarajan	Talofofo Falls	GG	13.322417	144.736139	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=16854500
	Pago River	16865000	Flow and Level	River/Stream	SFL	Pågu	Ordot - Chalan Pago	Lonfit and Sigua Rivers junction, Pago River	GG	13.436806	144.756028	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=16865000
	Umatac RG	131729144393766	Rain Gage	Rain	RF	Humåtak	Humåtak	Umatac Fire Station	GG	13.291778	144.662194	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=131729144393766
	Almagosa RG	132105144405166	Rain Gage	Rain	RF	Talo'fo'fo	Hågat	High Road, trail	Military			https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=132105144405166
	Fena RG	132132144422366	Rain Gage	Rain	RF	Talo'fo'fo	Santa Rita	Pump Station, Fena Researvoir	Military			https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=132132144422366
	Windward Hills RG	132234144441966	Rain Gage	Rain	RF	Ylig	Yona	Windward Hills Country Club, Fairway Dr.	Private	13.377167	144.737806	https://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=132234144441966

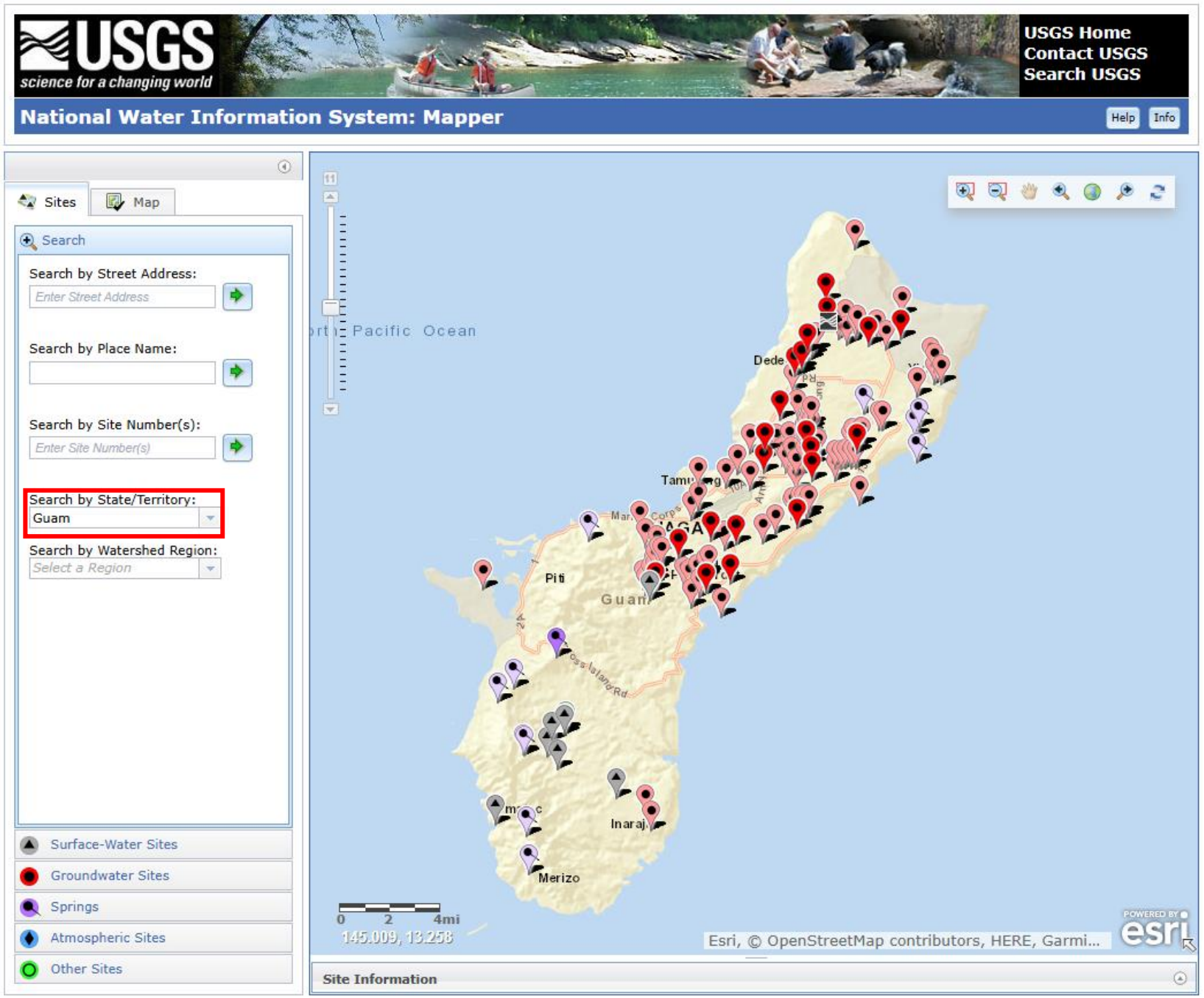
* CTD = Conductivity, Temperature, Depth | WLML = Water Level Measured, Logger | WLM = Water Level Measured | RF = Rainfall Logger | PSF = Peak streamflow | SFL = Streamflow and Level logger



Northern Guam aquifer observation well and rain gage stations – OWL (Observation Water Level) and DOW



Southern Guam watersheds, stream and rain gage stations



USGS Mapper, Guam's active and inactive hydrologic gage and measurement stations

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