Draft

Groundwater Management and Protection Plan, Commonwealth of the Northern Mariana Islands

Prepared for

Commonwealth Utilities Corporation

Prepared by

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May 2015

Acknowledgements

The Commonwealth Utilities Corporation Drinking Water and Wastewater Master Plans project team would like to acknowledge the contribution and collaboration of the many individuals who contributed to the success of this project.

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Executive Summary

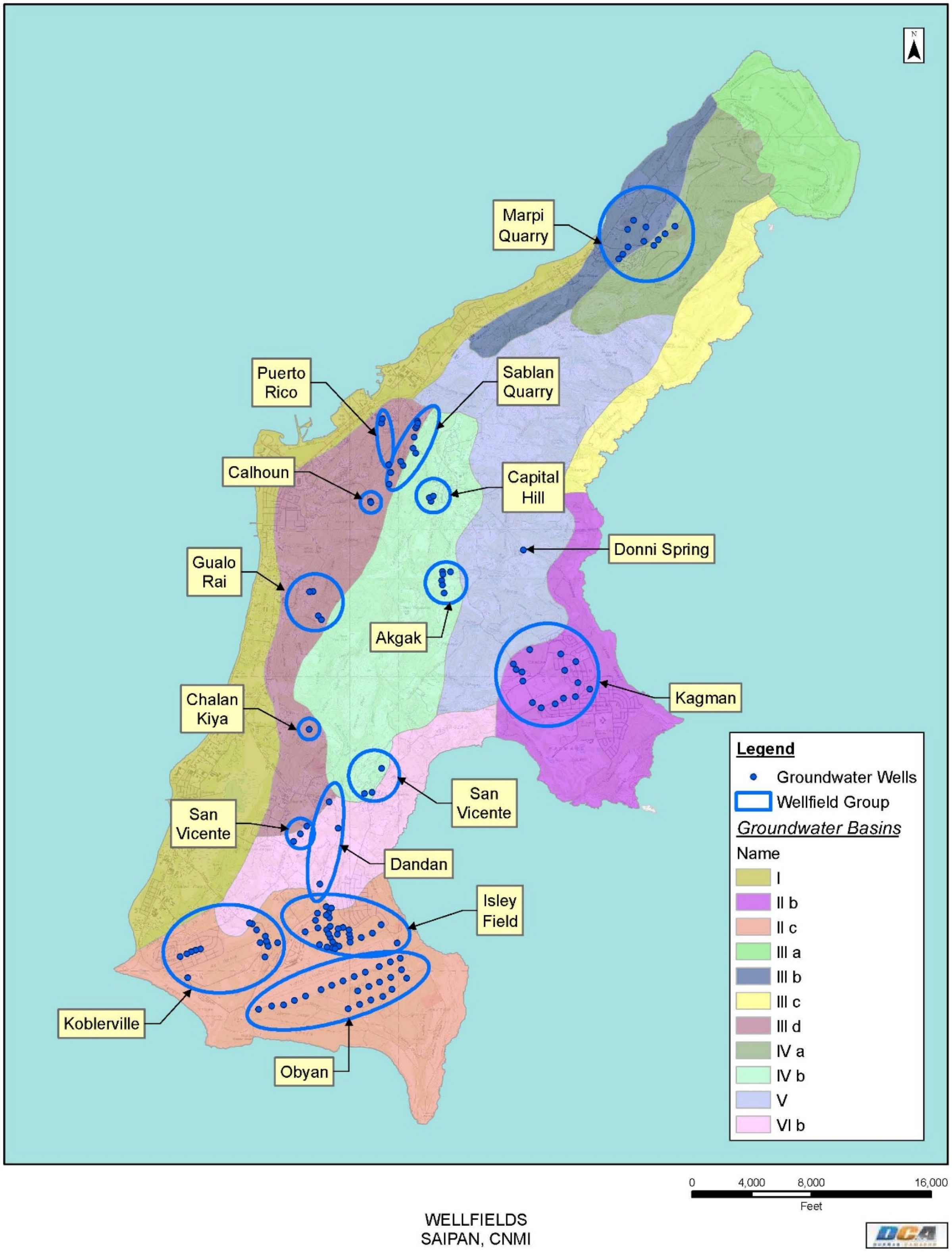
Section B4, “Groundwater Management and Protection Plan,” of the Stipulated Order specifies that, “The Master Plan shall include a section that addresses the development and implementation of a groundwater management and protection program by CUC.” This requirement is addressed by this Groundwater Management and Protection Plan (GWMPP).

The GWMPP provides background information and evaluation of critical groundwater-related issues for the islands of Saipan, Tinian, and Rota. The initial effort of the project team was to consolidate information from a number of sources, including the latest groundwater study conducted by the U.S. Department of the Navy for Tinian (2014). The plan provides a detailed description of the hydrogeology for each of the islands, providing a basic understanding of the different types of groundwater supplies available on each island.

An evaluation was conducted of the current groundwater wells and springs in use by the drinking water systems on each island, as well as wells and springs used in the past that were abandoned. This work provided the basis for the team to evaluate existing groundwater management activities, understand current constraints, and provide short- and long-term recommendations regarding management and operation of groundwater resources. The existing groundwater supplies for each island presently in operation include the following:

- On Saipan, 135 active groundwater wells (including the Maui horizontal well) and one spring located in basal and high-level aquifers produce 11.4 mgd (March 2014). These groundwater sources are located in eight of the eleven defined groundwater basins on the island (Figure ES-1).
- One hundred thirty-three private water supply wells are also in operation on Saipan, but most are located in lower-quality, coastal aquifer zones or are deep, high total dissolved solids (TDS) supply wells for desalination systems such as those operated by the large resort hotels. Thus, withdrawals from most of these wells are not likely to affect aquifer quality or quantity in wellfields operated by CUC. However, some freshwater wells are operated in the vicinity of CUC’s wellfields for purposes including agricultural and golf course irrigation, water bottling, and other uses. According to data from the Bureau of Environmental and Coastal Quality (BECQ) well permitting program, private wells currently in operation are permitted to withdraw more than 7.1 mgd (April 2015); however, there are many wells for which permitted withdrawal rates are not listed, and therefore actual withdrawals are likely to be significantly larger.
- The Tinian water system is supplied by one Maui Horizontal shaft located in the Marpo Swamp. The horizontal well, equipped with four 350-hp pumps, had an average daily production of 932,000 gpd from October 2011 through March 2012. In addition, two private agricultural wells are in operation and permitted by DEQ, but only one of which has a listed, permitted withdrawal rate of 28,800 gpd.
- On Rota, the Main Cave provides the primary water supply for the island; three groundwater wells provide supplemental water during the summer months. Water from the Onan Cave is still used at this time; however, it was determined to be surface water and is targeted for abandonment. In addition, six private wells used for golf course irrigation are permitted by BECQ to withdraw a total of 648,000 gallons of groundwater per day.

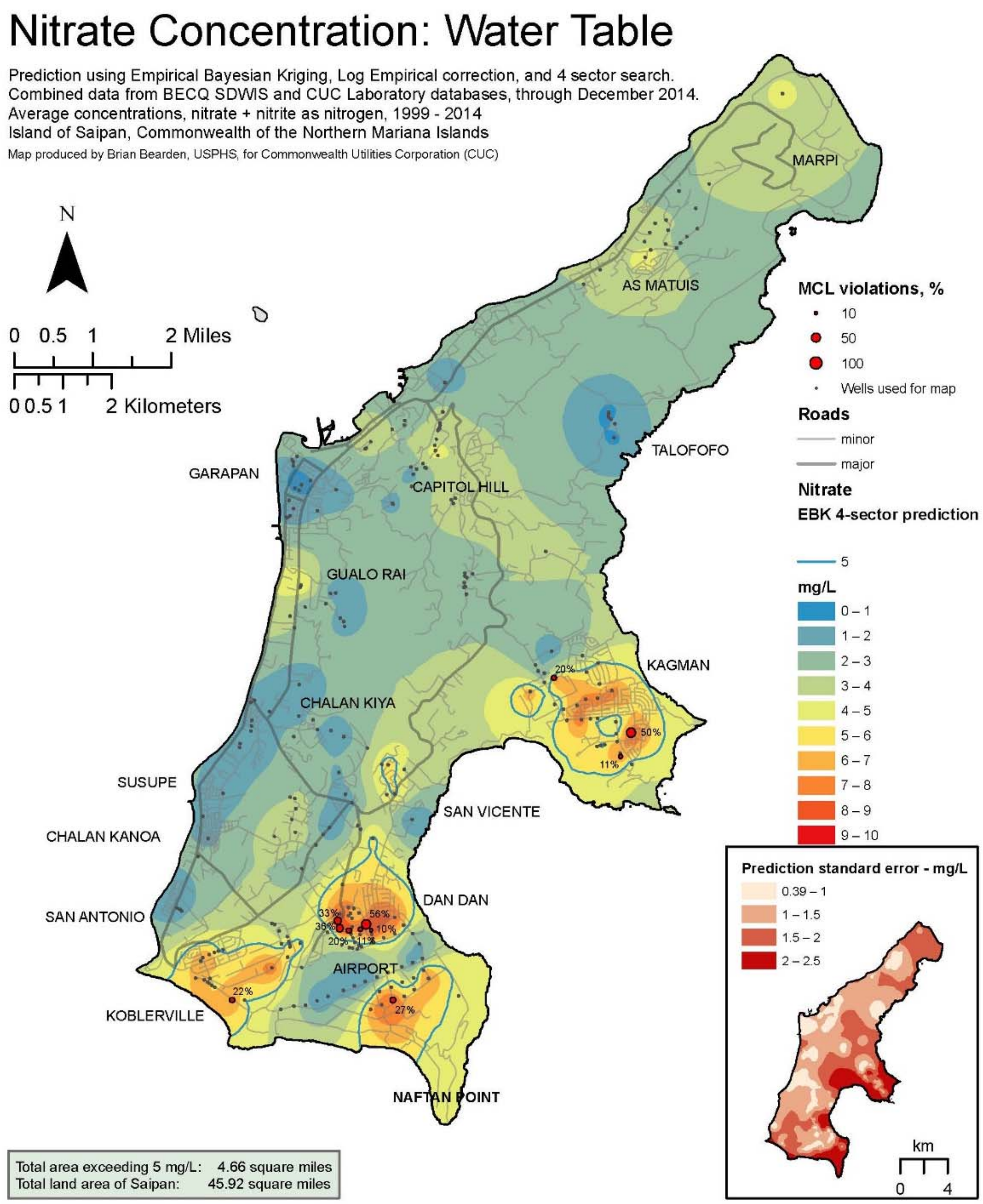
Figure ES-1. **Groundwater Areas and CUC Wells**



Two primary groundwater water quality problems exist on Saipan:

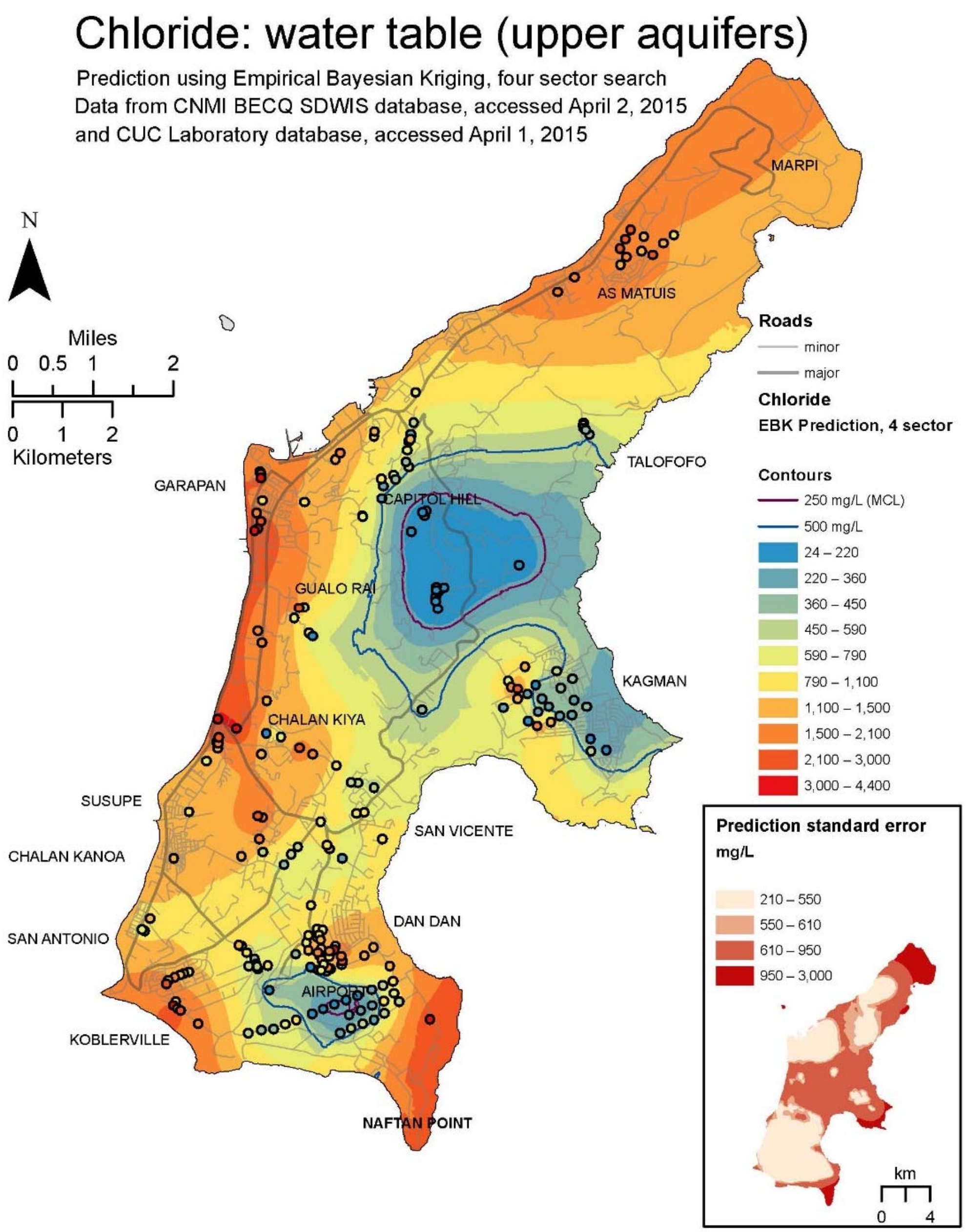
- **Nitrate.** Nitrate is an enforceable primary standard set by the U.S. Environmental Protection Agency (EPA) with a maximum contaminant limit (MCL) of 10 mg/L in the treated water system. Prior to a wellfield isolation project, the Saipan water system had a number of violations coming from a few individual wells that produced water above the MCL. The wellfield isolation project blends flows from wells in eleven of the twelve Tank Service Areas (TSAs) on the island into a dedicated raw water transmission line and tank. (The remaining tank service area only has a single well and no tank associated with it.) No MCL violations have occurred since the program has been completed. Figure ES-2 illustrates the nitrate profile for all of the wells in Saipan.

Figure ES-2**. Nitrate Concentrations, Saipan**
Source: Brian Bearden, CUC



- **Salinity.** Chloride is a non-enforceable secondary standard that is the main water quality parameter associated with elevated salinity levels in a large number of the water supply wells in Saipan. Although the chloride standard is not enforceable it does impact the palatability of the water and acceptance by customers. The highest salinity levels occur in the basal aquifers that have thin fresh water lenses which have progressively degraded since 1946 when the first water quality data was evaluated. The increase in salinity is believed to be caused by over-pumping in the basins. Recent groundwater mapping by CUC indicates that there are isolated areas within the basal aquifers of Kagman and Isley that still provide water that meets the secondary MCL, which indicates that water quality may be improved if pumping rates can be controlled. Figure ES-3 illustrates the chloride profile for all wells in Saipan.

Figure ES-3**. Chloride Concentrations, Saipan**
Source: Brian Bearden, CUC



The GWMPP also includes an evaluation of the current and future water system demands compared to the projected availability of water. This evaluation was most critical for Saipan due to the high percentage of water loss, groundwater quality problems, and projected population growth. Table ES-1 illustrates that there is adequate water being produced from the existing wells to meet 2030 demands. To achieve this requirement, CUC will need to significantly reduce the 70-percent systemwide water loss to less than 20 percent. If the water loss problem is not resolved, additional groundwater or surface water resources will need to be developed.

Table ES-1. **Average Daily Future Demand for Each Tank Service Area in Saipan**

Tank Service Area	Average Daily Demands 2015 (GPD/GPM)	Average Daily Demands 2020 (GPD/GPM)	Average Daily Demands 2030 (GPD/GPM)	March 2014 Production (GPD/GPM)
Calhoun TSA	554,750/385	685,459/476	842,632/585	234,720/163
Capitol Hill and TSA	286,500/199	392,369/272	588,890/409	1,008,000/700
Dan TSA	439,875/305	574,912/399	693,659/482	1,366,560/949
Gualo Rai TSA	97,875/68	138,767/96	165,283/115	293,760/204
Isley TSA	1,143,875/794	1,532,408/1,064	1,769,790/1,229	1,910,880/1,327
Kagman TSA	485,500/337	683,424/475	783,325/544	838,080/582
Kannat Tabla TSA (includes Chalan Kiya)	827,375/575	1,008,603/700	1,243,006/863	1,560,960/1,084
Koblerville TSA	401,250/279	590,537/410	785,434/545	730,080/507
Marpi TSA	328,250/228	396,419/275	534,737/371	578,880/402
Rapagao TSA	509,000/353	608,161/422	720,474/500	1,173,600/815
San Vicente TSA	216,375/150	306,653/213	360,281/250	591,840/411
Papago TSA	112,250/78	148,994/103	175,543/122	495,360/344
Total	**5,402,875/3,752**	**7,066,704/4,907**	**8,663,054/6,016**	**10,782,720/7,488**

The GWMPP includes a number of critical activities that, when performed, will provide CUC with the data, information, and knowledge needed to properly manage the available groundwater resources on Saipan, Tinian, and Rota. The majority of the recommendations identified are based on issues identified in Saipan, but the recommendations and practices can be transferred to Tinian and Rota as applicable:

- **Production and Monitoring Well Data Collection.** CUC should consider increasing the collection frequency for production well flows, amperage, water level, and specific water quality parameters and monitoring well water levels and specific water quality parameters.
- **Groundwater Resource Management Protocol**. The GWMPP provides a detailed description for a proposed protocol, which includes wellfield management, abandoned springs investigation and assessment, that CUC should consider adopting or modifying. Adhering to this protocol will generate the documentation needed to provide a strong understanding of all of the aboveground and below-ground assets for wells and springs.

- **Non-Revenue Water.** CUC should continue to aggressively attack water loss through active meter replacements, leak detection and repair, degraded pipeline replacement, reduced pressure surges and operation pressure in older pipelines, and work with the Attorney General to prosecute theft.
- **Water Quality Degradation.** Nitrate, chloride, and total dissolved solids (TDS) are the most prevalent water quality problems in Saipan groundwater. Nitrates are considered to be associated with both septic systems in unsewered areas and agricultural use of the land. Chlorides and TDS are associated with the increased well drilling over the last 75 years and increased pumping from the basal aquifers that have a thin fresh water lens.
- **Wellfield Source Protection Management Strategies.** Groundwater wells in each wellfield were evaluated. A number of corrective actions are listed in Table ES-2 to improve the sustainability and water quality of the wellfields.

Table ES-2. **Potential Modifications to Selected Wells to Lower Produced Chloride Concentrations**

Wellfield Name	Wells	Potential Modification
Marpi Quarry	MQ-5, MQ-12	Investigate whether the pumps could be raised. MG-12 may also be considered for replacement because the well is located on private land.
Puerto Rico	PR-162	Consider for replacement. This well was abandoned due to GWUDI determination.
Sablan Quarry	SQ-150	Consider lowering the pumping rate; consider plugging back the well.
	SQ-7, SQ-9, SQ-11, SQ-13	Consider for replacement due to wells being under lease agreements that CUC wishes to terminate.
Calhoun	CL-2	Consider lowering the pumping rate or plugging back the well.
Gualo Rai	GR-4	Consider lowering the pumping rate.
	GR-154	Consider lowering the pumping rate; investigate whether the pumps could be raised; consider relocation further inland.
Capital Hill	TP-1	Consider replacement due to low yield.
Agag	AGAG-45	Consider replacement due to low yield.
	AG-31B	Consider for replacement due to low yield and the well producing brown and muddy water.
Kagman	KG-3, KG-4, KG-6, KG-11, KG-12, KG-131	Consider lowering the pumping rate; investigate whether the pumps could be raised.
Chalan Kiya	Duenas	This well was inactivated as of March 2015 and CUC is contemplating full abandonment, thus it may be considered for replacement if additional groundwater yield is needed in this area.
San Vincente	SV-7	Consider lowering the pumping rate.
	SV-1, SV-2	CUC has terminated these lease agreements, and the wells have been abandoned.
Dan Dan	DD-7	Consider lowering the pumping rate.

Table ES-2. **Potential Modifications to Selected Wells to Lower Produced Chloride Concentrations**

Wellfield Name	Wells	Potential Modification
Koblerville	KV-13, KV-22, KV-23, KV-24, KV-25	Consider lowering the pumping rate.
	KV-16, KV-111	Consider relocation due to low yield.
Isley Field	IF-1, IF-16, IF-18, IF-217, IF-220, IF-3, IF-7, IF-06, IF-012, IF-19, IF-102	Consider lowering the pumping rate and/or raising the pump.
	IF-101, IF-105, IF-106, IF-201, IF-202, IF-204, IF-205	Consider plugging back the well and/or raising the pump.
	IF-4, IF-20	Consider for replacement. CUC abandoned both wells due to shallow water.
	IF-28	Consider for replacement due to poor condition of the casing. This is one of the wellfield's best producers in terms of both quantity and quality (low chloride and TDS).
Obyan	OB-1, OB-9, OB-16	Consider lowering the pumping rate.

Additional corrective actions include implementing a Supervisory Control and Data Acquisition (SCADA) system and replacing the meters on the well with ultrasonic meters that are more appropriate than traditional compound meters.

The last area evaluated as part of the GWMPP that resulted in significant recommendations focused on organizational structure and capacity building:

- **Organization Structure.** The most apparent organizational deficiency noted was the lack of coordination between the Water Task Force (WTF) and CUC. In the recent years, the WTF has continued to construct projects based on the 2002 Master Plan that are inconsistent with the way the system is being operated today. The result has been wells located in the wrong area and inappropriate construction materials being used on new tanks because of limited communications and dialogue between WTF and CUC. It is strongly recommended that the WTF be absorbed into the CUC Engineering Department so that future projects are consistent with the current Master Plan and utility operations and limited funds are used as efficiently as possible.
- **Capacity Building.** CUC needs to continue to develop local talent, including a Groundwater Engineer, to reduce the need to relocate employees from the mainland or contract outside consultants. This effort will take time because CUC will need to continue to comply with some significant EPA staffing requirements for key personnel. In the interim, these positions should be filled with off-island recruits, contract employees, or contracts through consulting firms.

In summary, CUC does not have a strong Groundwater Management and Protection Plan in place, but it is currently performing a number of activities that would be associated with one. CUC should use this document as a general roadmap for developing a formal plan. This will be a lengthy process that may take 5 to 10 years to have in place due to the economic constraints on both capital and operating dollars available to direct toward this effort. One early improvement that is suggested is to immediately start a formal documentation process, which could be incorporated into the new Computer Maintenance Management System to be implemented in 2015.

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Acronyms and Abbreviations

amsl	Above mean seal level
asl	Above sea level
BECQ	Bureau of Environmental and Coastal Quality
CMMS	Computerized maintenance management system
CNMI	Commonwealth of the Northern Mariana Islands
CRM	Coastal Resources Management
CUC	Commonwealth Utilities Corporation
DCA	Dueñas, Camacho & Associates, Inc.
DEQ	Division of Environmental Quality
EPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Agency
ft	Foot, Feet
GIS	Geographic information system
GPD	Gallons per day
gpm	Gallons per minute
GWUDI	Groundwater under Direct Influence
MG	Million gallons
mg/L	Milligrams per Liter
MGD	Million gallons per day
MSL	Mean sea level
NTU	Nephelometric turbidity unit
O&M	Operations and maintenance
SCADA	Supervisory Control and Data Acquisition
SDWIS	Safe Drinking Water Information System
TDS	Total dissolved solids
TSA	Tank Service Area
USACE	U.S. Army Corps of Engineers
USF&W	U.S. Fish & Wildlife Service
USGS	U.S. Geological Survey
UXO	Unexploded Ordinance
WTF	Water Task Force

Introduction

Section B4, "Groundwater Management and Protection Plan," of the Stipulated Order specifies that, "The Master Plan shall include a section that addresses the development and implementation of a groundwater management and protection program by CUC <Commonwealth Utilities Corporation>." This requirement is addressed by the plan provided here.

The plan is organized as follows:

- **Existing Hydrogeology of Saipan, Rota, and Tinian.** This subsection discusses the geology of each island as well as principal aquifers.
- **Existing Groundwater Resources, Wellfields, and Sources of Supply.** Topics in this section include wellfields, groundwater zones, springs, watershed catchments, and rainwater collection systems as applicable to each island.
- **Groundwater Water Quality.** Nitrate and chloride concentrations are presented here for each island, including the geographical location and groundwater elevation associated with specific areas on the islands.
- **Tank Service Areas.** Each distribution system and its associated wellfield are briefly described by island.
- **Demand versus Groundwater Supply.** This section compares anticipated future demand against current production by tank service area for each island.
- **Groundwater Management Program.** Topics in this section include the following:
  - Exploration for groundwater resources
  - Wellfield operations
  - Groundwater monitoring practices, including the recommended management strategies for production and monitoring wells
  - Recommended protocol for groundwater resource management, including investigation and assessment of wellfields and abandoned springs
  - Potential sources of groundwater contamination/degradation
  - Non-revenue water (loss/leakage)
  - Wellfield or source protection management strategies, including projects/programs to restore groundwater quality, and recommendations for sustainable withdrawal of groundwater resources
- **Regulatory Considerations.** Regulatory considerations include a list of involved agencies and a review of applicable regulations.
- **Existing Interagency Coordination and Corporation Policies and Activities.** This section discusses coordination with local agencies and federal agencies, and recommendations for strengthening interagency coordination and cooperation.
- **Capacity Building.** This includes a discussion of CUC organizational structure, workforce issues and recommendations, automation and technology, and overall recommendations.
- **Overall Recommendations.** This final section summarizes the overall recommendations to improve management of the groundwater resources on the islands of Saipan, Tinian, and Rota.

Existing Hydrogeology of Saipan, Tinian, and Rota

This section presents the general geology of Saipan, Rota, and Tinian, followed by a general description of the islands' aquifer systems and general surface water features.

Geology of Saipan

The topography of the island of Saipan is generally seen to be a series of elevated horizontal platforms and terraces. The western coast area begins as a coastal plain consisting of low elevation limesand with many wide beach areas. The land rises toward the east as limestone platforms and terraced benches. In the southern, central eastern, and northern areas, elevations of the limestone platforms range in elevation from about 120 to 240 feet. In the central area of Saipan, an uplands area exists that consists of terraced limestone separated by a volcanic ridge. The eastern, southern, and northern coasts exhibit limestone cliffs with small beaches and coves. (Carruth, 2003).

The Saipan subsurface is characterized by basal volcanic uplift overlain by younger sedimentary deposits. Volcanics are exposed on only about 10 percent of the island with the remaining land areas being limestone. The eight most significant geologic units as identified from a hydrologic perspective are as follows (Carruth, 2003):

- **Deposits of Pleistocene and Holocene Age.** Emerged limesand, beach, wetland, artificial fill, and volcanic outwash.
- **Tanapag Limestone.** Raised fringing-reef limestone, generally below elevations of 100 feet.
- **Mariana Limestone.** Clastic and reef limestone with argillaceous rubbly facies.
- **Tagpochau Limestone.** Dominated by a massive, compact, inequigranular pinkish limestone, but also includes rubbly, marly, tuffaceous and transitional carbonate facies. The Donni sandstone is an important facies within the Tagpochau Limestone as it serves to capture and channel groundwater from the much more permeable, overlying limestone facies to form a major water supply source for Saipan, Donni Spring. The Donni sandstone can be characterized as calcareous, tuffaceous, sand-sized sediments of low permeability (Cloud, 1956).
- **Fina-Sisu Formation.** Interlayered andesitic marine tuffs and andesite flow rocks.
- **Densinyama Formation.** Includes marine transitional rocks and volcanically derived conglomerates, tuffaceous sandstone, and andesitic breccia.
- **Hagman Formation.** Andesitic breccia, tuff, lava flows, conglomerate, and tuffaceous limestone.
- **Sankakuyama Formation.** Dacitic tuff, breccia, and flow rocks.

Saipan has undergone changes in elevation relative to the ocean as it formed. Normal faults exists along the island parallel to its long axis. Some of the faults are weathered, resulting in high permeability zones. In other areas, the faults have undergone compression, resulting in lower permeability zones (Carruth, 2003).

A geologic map of the island is shown in Figure 1 (Carruth, 2003).

Figure 1. **Geologic Map of Saipan**

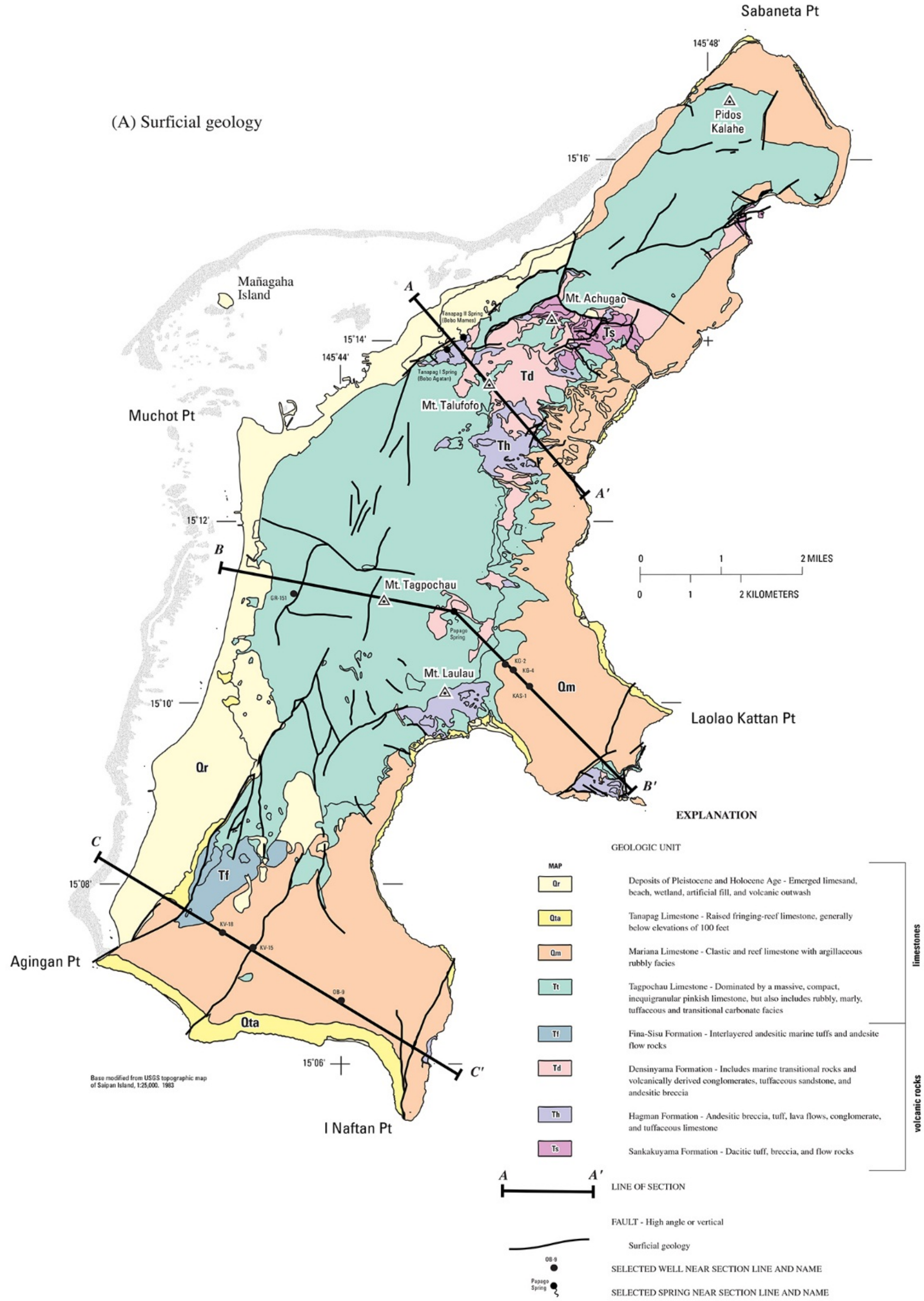


Figure 4. Generalized geology of Saipan, (A) surficial geology, and (B) geologic sections (modified from Cloud and others, 1956).

Principal Aquifers

Saturated limestone resulting from abundant rainfall and infiltration forms the principal aquifers on Saipan. Salt water exists beneath the fresh water in all of the aquifers. Most of the principal aquifers are limestone that overlies the volcanic basement rock with the limestone extending from the ground surface to beneath sea level. In these areas, the less dense fresh water floats on the salt water as a fresh water lens. The salt water forms a wedge thickening toward the sea, and a transition zone exists between the two where the fresh water is increasingly mixed with the sea water. The fresh water in this type of aquifer system is termed basal groundwater, and it is harvested by skimming the fresh water off of the top of the salt water.

In the Central Uplands area, fresh groundwater is found in limestone that overlies the uplifted volcanic rock above sea level (see Figure 2). The fresh water pools in the limestone that is trapped above the low permeability, saturated volcanic rock. Some springs and seeps drain this pooled water from these high-level aquifers, resulting in a varying seasonal springflow.

The different aquifer systems were categorized as either Coastal Aquifers or High-Level Aquifers (Carruth, 2003). The Coastal Aquifers contain basal groundwater, and the High-Level Aquifers found in the Central Uplands contain the pooled fresh groundwater. However, it is common terminology on the islands to refer to the Coastal Aquifers as Basal Lens Aquifers, and this term will be used in this report.

Basal Lens Aquifers

The basal lens aquifer on the western side of Saipan begins along the Philippine Sea and extends inland to the edge of the Central Uplands. The water from the lowest lying band of this aquifer (elevation 150 feet and below) from the sea inland is characterized by high chloride content and is not used for CUC's drinking water supply. Other fresh water wellfields do produce basal groundwater in this aquifer, but they are further inland, closer to the Central Uplands.

In the southern portion of Saipan, a limestone bench exists with an elevation between 100 feet and 200 feet above MSL. This bench overlies a basal lens aquifer that forms a large part of CUC's water supply for Saipan, including the Isley Field, Obyan, and Koblerville wellfields. This basal lens aquifer also extends north to the edge of the Central Uplands where the Dan Dan and San Vicente wellfields are located.

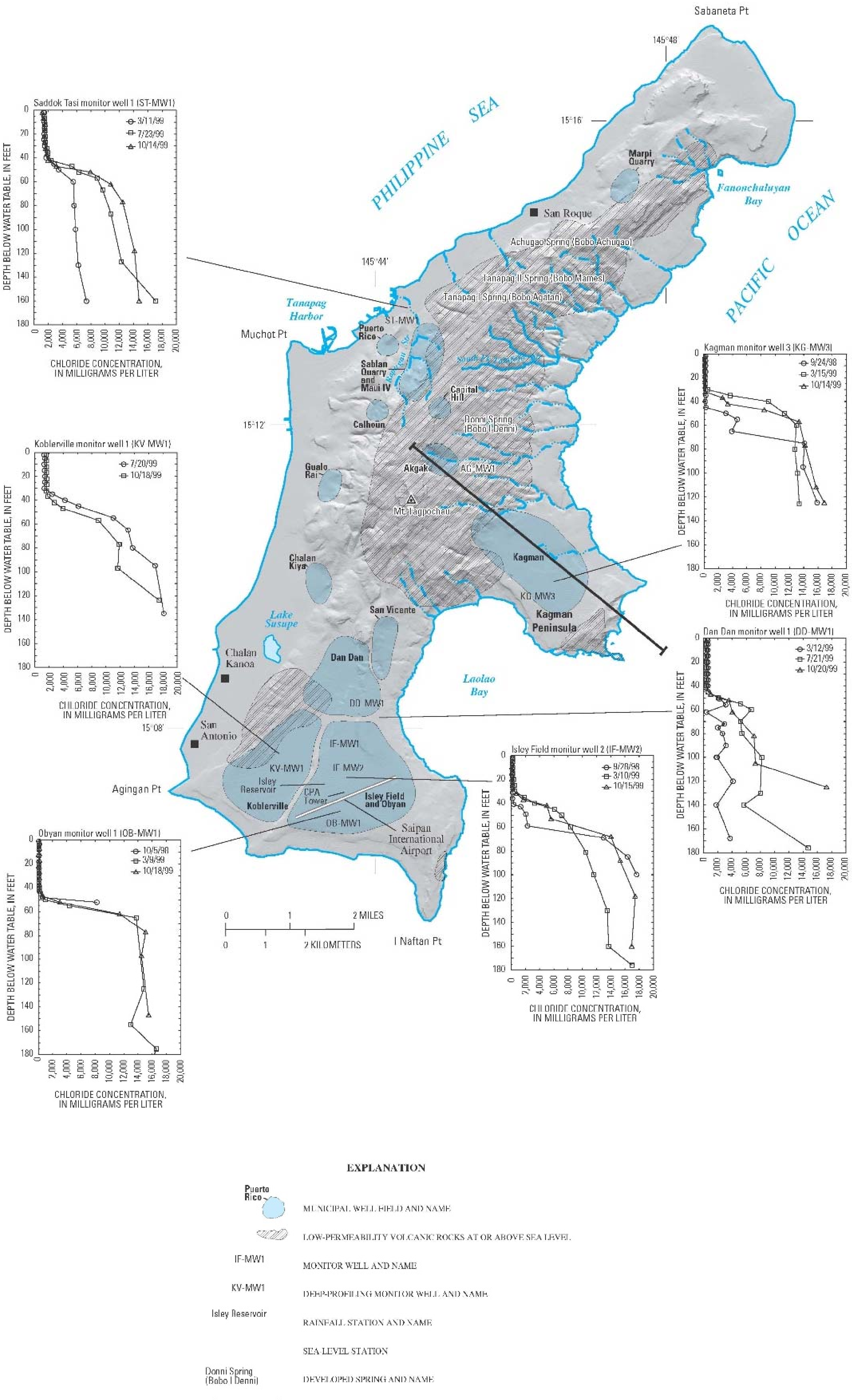
In the southeastern part of Saipan on the Kagman Peninsula near Laolao bay, a limestone platform exists with an elevation of about 200 feet MSL. Basal groundwater underlies this area from the coast inland to the Central Uplands. Closer to the Central Uplands, the groundwater is artesian and exists under confined conditions.

In the northern portion of Saipan, a basal lens aquifer exists under a limestone bench with a land surface elevation of about 370 feet. Basal groundwater exists in this area, although the chloride content is generally elevated, particularly so in the northernmost parts of the island.

High-Level Aquifers

In the ridge of the island, high-level limestone overlies volcanic rock and contains fresh and trapped groundwater. This groundwater is the source of several springs on the island and provides fresh groundwater to some of CUC's wells.

Figure 2. **Map of Saipan Showing Municipal Well Fields, Low-Permeability Volcanic Rocks, and Chloride Concentrations**
Source: Carruth, 2003



Groundwater in Volcanic Rock and Springs

Fresh groundwater in Saipan is mostly found in the limestone aquifers. It is reported that test drilling in the volcanic basement rocks indicates they also contain some fresh groundwater (Carruth, 2003). However, the volcanic rocks generally form the base of the limestone aquifers and serve as a low-permeability barrier. The low permeability of the basement volcanic rocks precludes them from being a viable source of fresh water supply.

There are three spring areas on Saipan. These springs occur where rainwater infiltrating downward into the limestone encounters a low permeability layer, such as the volcanic rocks. This results in the groundwater flowing horizontally where it can daylight out through the ground as a spring. The spring areas located on the east and northeast side of the central upland area are discussed later in this report.

Geology of Tinian

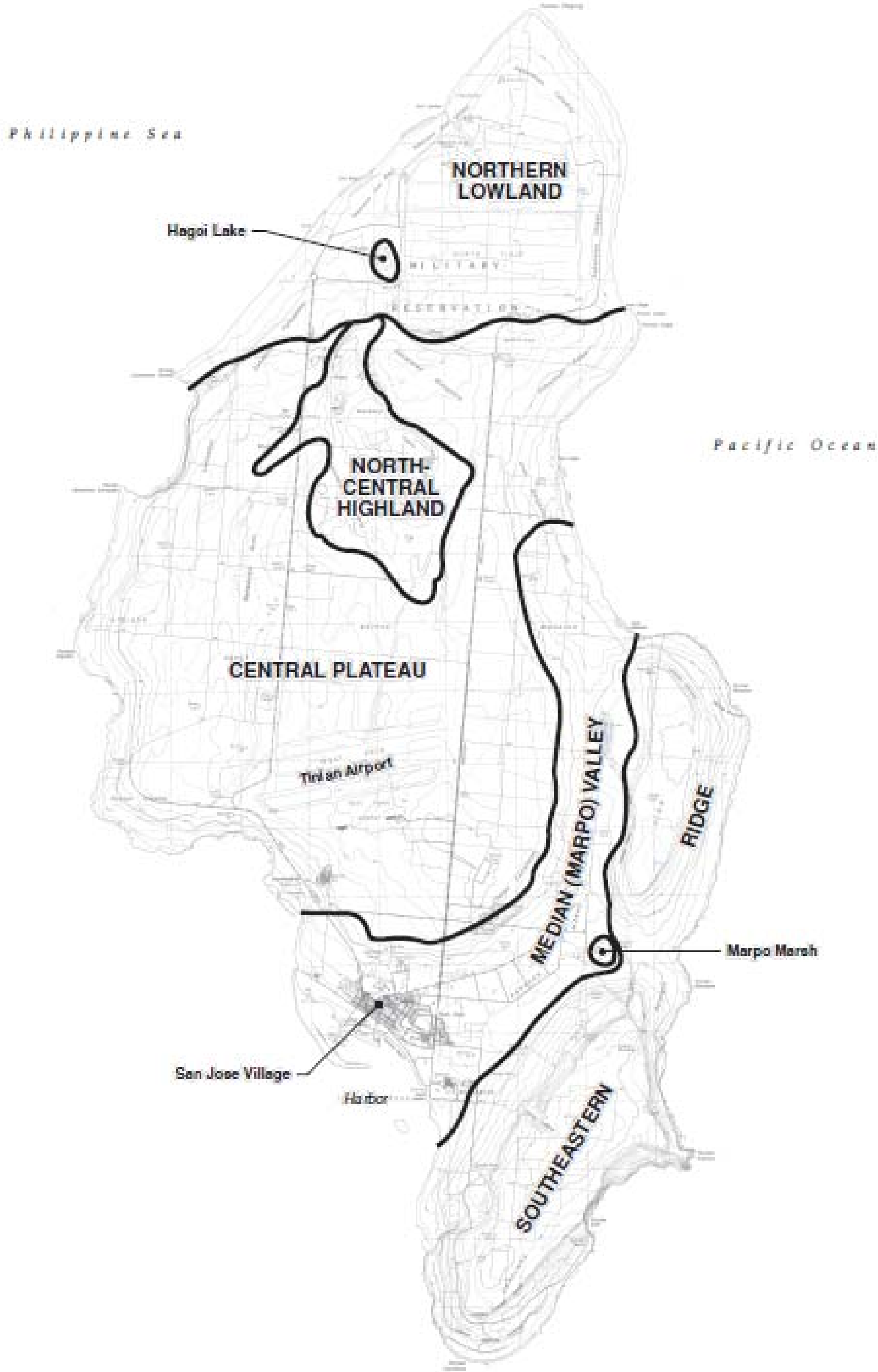
Tinian can be characterized similar to Saipan with limestone strata underlain by volcanic tuffs and breccias. Outcrops are coralline limestones including Mariana Limestone and Tagpochau Limestone. More than 95 percent of the surface of Tinian is composed of carbonates, which is a main factor in the high dissolution of the rocks known as epikarst.

The geologic units of Tinian are listed below (Gingerich and Yeatts, 2000):

- **Tinian Pyroclastic Rock.** Of Late Eocene age, this oldest exposed geologic unit is thought to underlie all other exposed rock units. The Tinian Pyroclastic Rock consists of fine- to coarse-grained consolidated ash and angular fragments of volcanic origin. Outcrops usually are highly weathered and altered to clay.
- **Tagpochau Limestone.** Of Early Miocene age, this limestone is exposed on about 15 percent of the surface on Tinian. The Tagpochau Limestone is composed of fine- to coarse-grained, partially recrystallized, broken limestone fragments, and about 5 percent reworked volcanic fragments and clays. Surface exposures are highly weathered.
- **Mariana Limestone.** Of Pliocene to Pleistocene age, this limestone is the most extensive unit, covering about 80 percent of the surface. Mariana Limestone is composed of fine- to coarse-grained fragmented limestone, commonly coralliferous, with some fossil and algal remains, and lesser amounts of clay particles. Small voids and caverns are common in surface exposures. The Mariana Limestone differs from the Tagpochau Limestone in its higher coral content and lesser degree of recrystallization.
- **Beach Deposits, Alluvium, and Colluvium.** Of Pleistocene to Holocene age, these deposits cover less than 1 percent of the surface of Tinian and may be as much as 15 feet thick. The deposits are composed of poorly consolidated sediments and mostly calcareous sand and gravel deposited by waves, but also clays and silt deposited inland beside Hagoi Lake and Marpo Marsh. Loose soil and rock material are deposited at the base of slopes, especially in the north-central highlands.

Physiographically, the land surface of Tinian consists of a series of five, generally level plateaus at various elevations (see Figure 3). High plateau areas are located at the south end and north central portion of Tinian, with relatively flat to sloping land separating these plateau areas.

Figure 3. **Physiographic Areas of Tinian where the Population Center (San Jose) and Freshwater Source (Marpo Marsh) are Both Located in the Median Valley**



In the southern portion is the Southeastern Ridge, known as Puntan Carolinas, with the highest point on the island at 584 ft asl. A border of faults separates the Median Valley (also known as the Marpo Valley), which extends from the western to eastern coast of the island. The valley has the most fertile lands and gently sloping geomorphic features. The groundwater table intersects the ground surface here creating the Marpo Marsh and surrounding wetlands. The main portion of the island is composed of the Central Plateau, which slopes towards the western coast. The north is primarily lowlands with the North Central Highlands jutting up from the plateau. These highlands are derived from the volcanic uplift of the Tinian Pyroclastics.

Principal Aquifers

A low, wide valley with gentle slopes, the Marpo Valley runs from the southwest to the northeast across the southern-central portion of Tinian. Rainfall recharges the limestone aquifer here, forming a basal lens aquifer. High-level aquifers are not known to exist on Tinian. Most of the island is a recharge zone, so groundwater enters the limestone, forms a basal lens, and migrates toward the sea. The Marpo Swamp is the lowest point in the valley and the groundwater here is at ground surface.

Groundwater in Volcanic Rock/Streams and Springs

The freshwater groundwater lens is in the limestone and volcanic rocks in some locations on Tinian, but the most important sources of groundwater are from the freshwater parts of the limestone rocks. Like Saipan, the volcanic rocks have low permeability and groundwater extraction would not be practical. Because of the high occurrence of karst on Tinian, there are no streams or springs on the island (Belt Collings Hawaii Ltd., 2003).

Geology of Rota

Rota has the same depositional environment as Saipan and Tinian where limestone carbonates form the overlying layer and are characterized by karstic features. There are several units of limestone formations, including the Mariana Limestone and an upper Holocene epoch coralgal limestone. Underlying the limestone is a volcanic pyroclastic rock formation like that found on Saipan and Tinian.

The geologic units of Rota as defined early are listed below (Sugiwara, 1934):

- **Recent Limestone.** Present day reef flats, beach rock, and coralgal limestone.
- **Mirikattan Limestone.** Additional present day reef flats, beach rock, and coralgal limestone.
- **Raised Beach Deposits.** Well-indurated grainstones.
- **Rota Limestone.** Detrital limestone.
- **Mariana Limestone.** Massive, coralgal limestone.
- **Ponia Limestone.** Stratified, detrital grainstone with abundant Halimeda fragments, foraminifera, coral debris, mollusks, and echinoid spines.
- **Hirippo Limestone.** Detrital grainstone containing foraminifera and coral debris.
- **Taihanom Limestone.** Brecciated limestones, calcareous sandstones, and detrital limestones.
- **Mariiru Limestone.** Sandy detrital limestone with increased levels on manganese.
- **Manila Agglomerate.** Pyroclastic rocks.

More recently, the geological units were grouped more similarly to those on the other Mariana Islands (Stafford, et al., 2002). The Recent and Mirikattan Limestones were combined into the Holocene Limestone, the raised beach deposits, Rota and Mariana Limestone into the Mariana Limestone with four facies, and the remaining units into the Tertiary substrate.

Principal Aquifers

The hydrogeology of Rota is similar to that of Saipan and Tinian in that permeable limestone overlies volcanic rocks that then uplifted the limestone. Basal lens groundwater also exists on Rota in the northeast and east central part of the island in the Sinapalu region. Currently five active wells serve the SNM Rota Resort as irrigation wells in the northwest, and CUC has three active wells in the east-central part of Rota.

A high-level aquifer exists in the Sabana region of Rota and feeds the Rota springs; however, aside from the springs, this aquifer is not used as a groundwater supply.

Groundwater in Volcanic Rocks

In the Sabana region of Rota, substantial springs exist at the base of the limestone and the top of the volcanic rocks, providing the majority of the fresh water supply from the Main and Onan Caves. These springs exist where the limestone/volcanic rocks outcrop. Numerous surface streams exist on the southern-facing volcanic and limestone slopes below these springs.

Existing Groundwater Resources, Wellfields, and Sources of Supply

The major fresh water resources of Saipan, Tinian, and Rota are discussed below. Wellfields are presented as well as major groundwater-bearing zones and sources of water supply.

Saipan

All sources of water supply on Saipan originate as rainfall. The average annual rainfall is about 85 inches, so given Saipan's area of approximately 48 square miles, an equivalent average of approximately 190 MGD of rain falls on the island annually. The rain is captured by collection systems, runs off to the ocean, infiltrates to recharge the groundwater table, or leaves the island as evapotranspiration. Approximately one-quarter to one-third of the precipitation becomes groundwater, which may mix with high salinity waters, degrading the quality of the groundwater. This freshwater dilution effect was observed as part of the 2012-2013 GWUDI Study with the groundwater basins becoming less saline during the rainy season.

Other sources of water supply, not all used by the CUC, originate from groundwater-fed origins such as springs and lakes. These surface features are influenced by rainfall and runoff during the wet season and may become intermittent or experience reduced flows during periods of decreased precipitation. Spring flow quantities may lag behind rainfall due to cycling times through the subsurface with peak flows expected from August through December. Donni Spring, for example, exhibited a possible lag time of approximately 8 hours following heavy rain events as evidenced by peak turbidity measurements recorded during the 2012-2013 GWUDI study.

Groundwater levels vary due to recharge, with levels rising following precipitation events and a subsequent thickening of the freshwater lens. Wells further inland on the island and in the High-Level Aquifers show this response directly with aquifer levels rising after precipitation events. Groundwater levels in the costal aquifer systems are affected by precipitation, but they also vary in response to tides and longer-term sea level changes.

The USGS estimates an average recharge of about 25 to 30 percent of the total rainfall on Saipan (Carruth, 2003); however, not all of this is available as fresh water supplies. Some of the rainfall mixes with the underlying seawater, and some discharges to the sea.

The municipal supply for the island primarily derives from groundwater, which includes approximately 135 active wells, including the Maui I horizontal well and Donni Spring, producing about 7,901 gpm (11.4 MGD) based on March 2014 data. Additional private wells exist for golf courses, resorts, and hotels, many of which are believed to be managed for high yields in potentially unsuitable areas. More than half the wells are situated in the high-permeability Mariana Limestone, producing fresh, relatively low salinity water.

Saipan currently has 14 defined wellfields across the island. The common wellfield names, number of wells, average withdrawal rates as listed by CUC for March 2014, and aquifer type are listed in Table 1 with the locations of the wellfields shown on Figure 4.

Table 1. **Wellfields on Saipan**

Wellfield Name[2]	Number of Wells	March 2014 Average Withdrawal Rate (gpm)	Aquifer Type
Marpi Quarry	11	428	Basal Lens, confined in the west
Puerto Rico	2	43	Basal Lens
Sablan Quarry	11	634	Basal Lens
Calhoun	2	235	Basal Lens
Gualo Rai	4	156	Basal Lens
Capital Hill	4	354	High Level
Agag	6	578	High Level
Kagman	16	873	Basal Lens; confined in the west
Chalan Kiya (also known as Duenas Well)	1	85[1]	Basal Lens
San Vicente	6	218	Basal Lens
Dan Dan	3	185	Basal Lens
Koblerville	16	1168	Basal Lens
Isley Field	33	1597	Basal Lens
Obyan	24	1097	Basal Lens

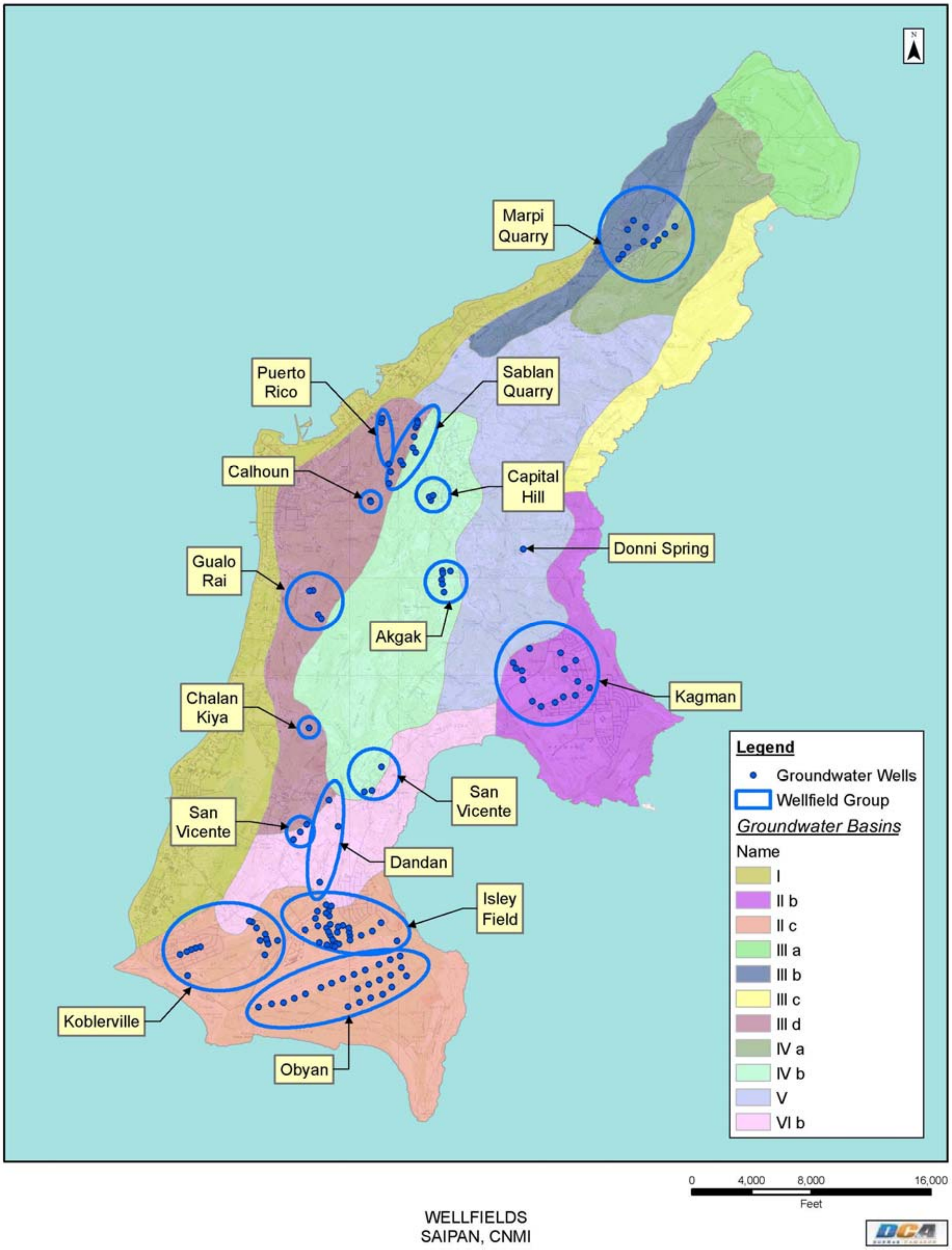
[1]Well has been inactivated as of March 2015.

[2]Donni Spring is not included in this list.

Groundwater Areas

The island of Saipan has been organized into eleven groundwater areas (Winzler and Kelly, 1996). These areas have been designated by aquifer type and similarity, and are labeled Areas I, IIb, IIc, IIIa, IIIb, IIIc, IIId, IVa, IVb, V, and VIb. Of these, Area I is the eastern coast of Saipan, and wells in this area are low yield and generally high in chloride concentration. Area IIIa is in the far north of Saipan, and groundwater in this area is also high in chloride concentration. Area IIIc has no operating CUC wells. Area VIa is rugged terrain in the northern part of the island; no CUC wells are located in this area. All groundwater areas and wellfields are shown on Figure 4.

Figure 4. **Groundwater Areas and CUC Wells**



The groundwater areas, the wellfields or springs within each area, and the estimate of sustainable fresh water yield available to each area as reported in the Saipan Drinking Water Master Plan prepared by Winzler and Kelly (March 1996) are listed in Table 2. The estimates of sustainable fresh water yield available to each area as reported by Winzler and Kelly are based on estimates prepared by others identified in the report as Cox 1956, Ayers 1981, Nance 1983, Mink 1987, and Davis 1959. Full references for these sources were not available in the version of the report acquired by CH2M. Based on CH2M's research and review of available data sources, the Winzler and Kelly report is the most comprehensive resource summarizing the estimated freshwater yields for the whole island of Saipan from existing sources and is the only resource found that breaks down the estimated fresh groundwater available by groundwater area as shown in Table 2.

Table 2. **Groundwater Areas and CUC Wellfields/Springs on Saipan**

Groundwater Area	CUC Wellfields/Spring	Estimated Fresh Groundwater Available (gpm/mgd)
I	None	69/0.1
IIb	Kagman	1,389/2.0
IIc	Isley Obyan Koblerville	2,778/4.0
IIIa	none	69/0.1
IIIb	Marpi Quarry	208 to 347/0.3 to 0.5
IIIc	None	208/0.3
IIId	Sablan Quarry Calhoun Gualo Rai Puerto Rico Chalan Kiya (Duenas)	347 to 521/0.5 to 0.75
IVa	None	139 to 208/0.2 to 0.3
IVb	Capital Hill Agag	1,389/2.0
V	Donni Spring	1,042/1.5
VIb	Dan Dan San Vicente	347/0.5
Totals		**7,986 to 8,368/11.5 to 12.05**

A comparison of the available freshwater yield per groundwater area compared to CUC's current pumping capacity based on March 2014 data in addition to the additional pumping capacity of private wells permitted by the Division of Environmental Quality (DEQ) in each groundwater area is discussed in a subsequent section.

Existing Spring in Use on Saipan

Donni Spring, located in the north central portion of the island at 260 ft above mean sea level (amsl), averages 250 gpm (0.36 MGD) but has been reported to produce up to 3,125 gpm (4.5 MGD). It is the only spring in use by CUC on Saipan. Donni Spring is located in Groundwater Area V and is a result of water moving downward through the overlying Tagpochau Limestone and reaching the less permeable Donni Sandstone. Donni Spring results from the groundwater moving along the top of the sandstone to where the two formations daylight in a hillside on the east side of the high-level aquifer area.

Existing Springs Not in Use on Saipan

Two springs on Saipan—Tanapag Spring and Achugao Spring—are currently not in use:

- Tanapag Spring is composed of two springs that exist in the northern area of the island at elevations of 130 and 66 ft asl. Tanapag I is reported to average 115 gpm and Tanapag II is reported to average 15 gpm (0.02 mgd) (Carruth, 2000). The two Tanapag springs are being evaluated for long-term use as part of the Treatability Study.
- Achugao Spring is located at an elevation of 131 to 318 ft asl. No flow from this spring was observed during the 2014 rainy season during site visits in July and September.

Watershed Catchments

Talofofo River Basin and Lake Susupe are areas in Saipan that can be used to store water for future use:

- Construction of diversion structures in the Talofofo River Basin catchment to supplement supply into the Capitol Hill system and fill a 45 MG reservoir tank over 60 days of flow has been previously recommended by a feasibility study conducted in 1990 (Commonwealth Utilities Corporation, 1990). Additional studies have been carried out in 2014 as part of the Master Plan Treatability Study. This source has total dissolved solids (TDS) levels below 500 ppm.
- Surrounded by wetlands in the western coastal area of the island, Lake Susupe is considered to be a water table lake not affected by tidal fluctuations. The average chloride content of the lake water is 1,500 mg/L (ranging from 261 to 4,800 mg/L).

Rainwater Collection Systems

Rainwater collected via private rooftop collection and, in one case, an airport drainage system is diverted to storage tanks, including a 20MG catchment that is designed to feed a slow sand filter system at the Saipan International Airport. The slow sand filter is not currently operational, and the treatment process is being reexamined as part of the Master Plan Treatability Study. The average flow during the rainy season is about 50 gpm from this source.

Tinian

Like Saipan, all freshwater originates on Tinian as rain, which recharges the basal freshwater lens that overlies seawater within the limestone. Recharge has been estimated at 55.7 MGD. There are no separate groundwater zones, and all groundwater is located in the freshwater lens situated on top of the denser brackish and sea waters. However, an outcrop of the volcanic basement near the center of the island results in an isolated region of parabasal groundwater, which can thicken the freshwater lens. Flow is generally radial toward the Pacific Ocean and Philippine Sea.

There are currently no active vertical wells within Tinian CUC water system. In the past there were potable water supply wells in operation; however, they have been taken off line and are currently not in operable condition. A table and map summarizing all existing and abandoned wells on the island of

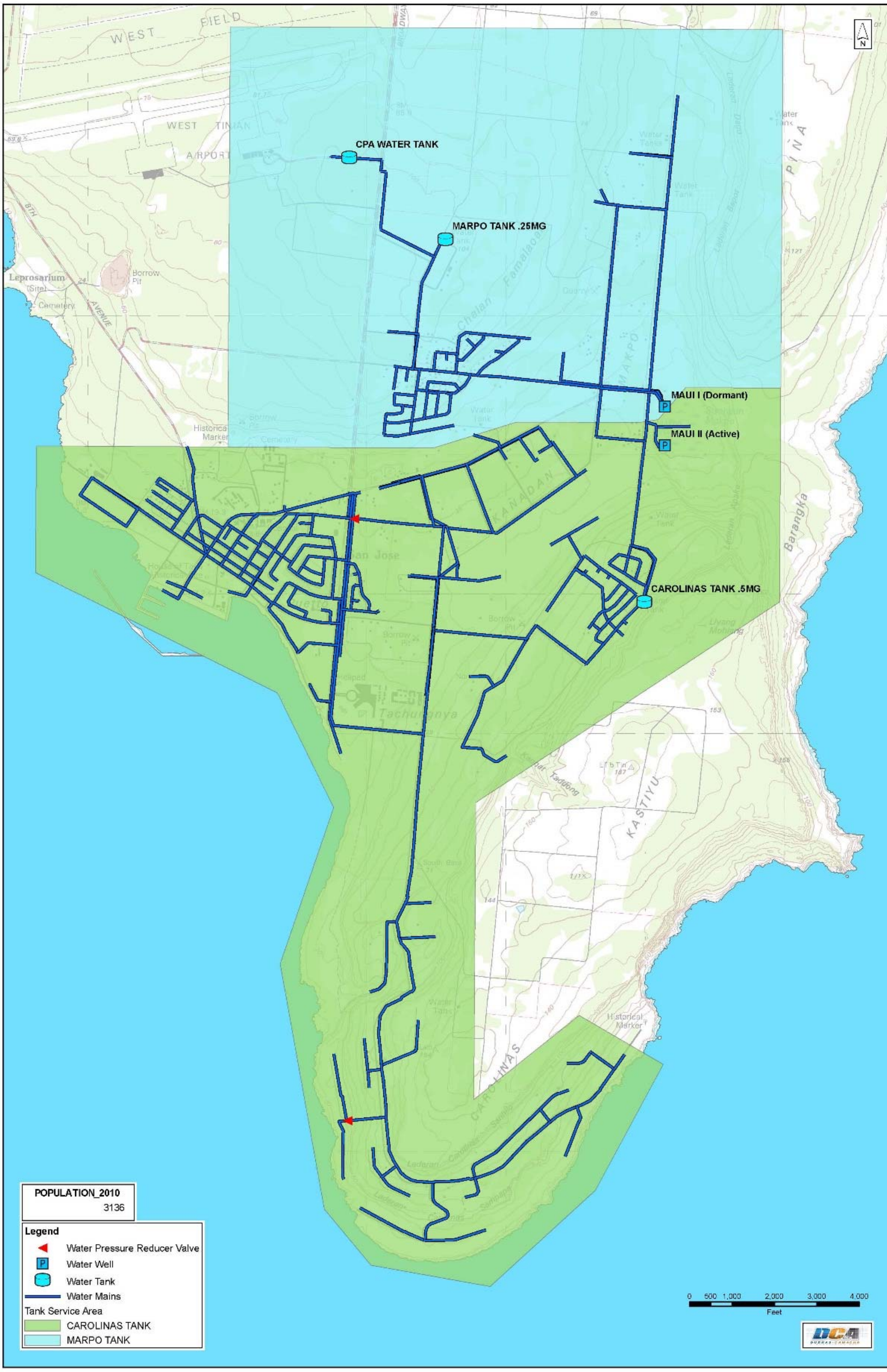
Tinian taken from the Commonwealth of the Northern Mariana Islands (CNMI) Joint Military Training Utilities Study (2014) is included as Appendix A.

The primary and only active water source for water production is the Maui II horizontal well. Potable water in Tinian is skimmed from the Marpo Swamp in the Median Valley by the Maui II horizontal well. The water at the surface of this wetland is exposed basal lens groundwater. A second horizontal well referred to as the Maui I horizontal well is also located in the Marpo Swamp; however, it is out of service due to equipment failures and the overall condition of the well, which does not meet BECQ sanitary survey requirements. Plans to refurbish the Maui I Well have been abandoned (CNMI Joint Military Training Utilities Study, 2014).

The Maui II well is located 7 ft asl and has four pumps, each with a pumping capacity of 350 GPM. It is connected to the Carolinas Reservoir by an 8-inch PVC transmission and distribution line. This water supply has short-term turbidity increases shortly following significant rain events. The U.S. Environmental Protection Agency (EPA) has recommended as part of the Groundwater Under the Direct Influence of Surface Water (GWUDI) Study that high turbidity water, defined as exceeding 1.0 NTU, be diverted back into the wetland and not pumped into the system. The Tinian water distribution system is shown on Figure 5.

Currently, there are plans to establish a series of live-fire and maneuver ranges, training areas, and supporting facilities within CNMI to address the U.S. Pacific Command Service Components' unfilled training requirements in the Western Pacific. One Range and Training area is proposed for the island of Tinian. The future potable water demand on the island of Tinian would be affected by the population increase and the new facilities. To meet the future potable water demand, the Navy is proposing to develop new groundwater wells and/or rehabilitate existing wells that are currently not in service (CNMI Joint Military Training Utilities Study, 2014) in the areas to the north of the existing Tinian airport.

Figure 5. **Tinian Water Distribution System**



Note: Population sum based on 2010 Census Designated Place

Tinian Water System

Rota

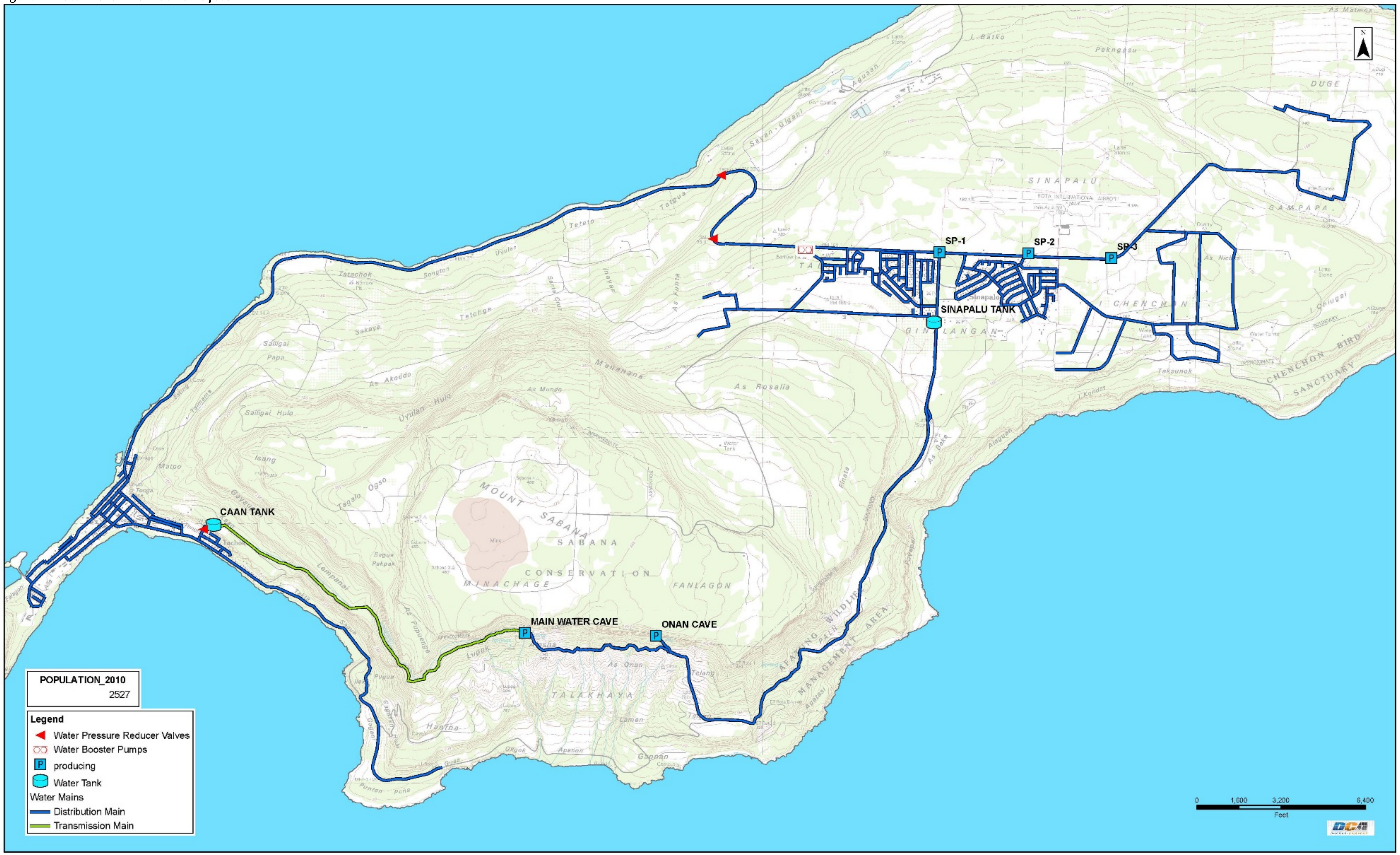
The hydrogeology of Rota provides a setting where most of the freshwater for municipal use originates from two water caves (springs) located in the Sabana region. The caves occur between low-permeability volcanic rocks and overlying high-permeability limestone rocks. Fresh water enters the limestone as precipitation and discharges at the volcanic contact at the southern steep face of Mt. Manira. The "Main Cave" is located at an elevation of 1150 ft asl, and currently provides most of the water delivered to the CUC system. The "Onan Spring" is located at a similar elevation and currently supplements the flow provided by the Main Cave. The Onan Spring is slated to be permanently taken off line because it has been determined to be a surface water by BECQ, and it is not feasible to properly seal the cave from the open atmosphere or cost effective to build a treatment facility on Rota with the water available from the Main Cave and CUC wells.

Basal lens groundwater also exists on Rota; this groundwater was developed and explored in the northeast and east central part of the island in the Sinapalu region. Currently five active wells serve the SNM Rota Resort as irrigation wells in the northwest, and CUC has three active wells in the east central part of Rota, which are used to supplement water from the Main and Onan Caves during dry periods.

The east central area (area of CUC wells) is at an elevation between 500 and 625 feet and depth to groundwater was found to be almost 600 feet below the land surface. This considerable depth is expected to provide substantial protection of the groundwater source from surface contamination, but little data is currently available to corroborate this.

The Rota water distribution system is shown on Figure 6.

Figure 6. **Rota Water Distribution System**



Note: Population sum based on 2010 Census Designated Place

Rota Water System

Groundwater Quality

The main concern with water quality on the islands of Saipan, Tinian, and Rota is heightened chloride concentrations indicative of saltwater intrusion and nitrate levels associated with human activities. The maximum contaminant level (MCL) for chloride per EPA regulations is 250 mg/L for potable water, but this "secondary" MCL (SMCL) is not enforced by EPA, meaning that it is related to taste and aesthetics, and waters exceeding the SMCL are not considered to constitute a threat to human health. In 1946, chloride concentrations in many of Saipan's groundwater sources were low (less than 100 mg/L) but with a combination of overpumping, spatially close wells, and periodic variations in rainfall, these levels have risen. The MCL for nitrate is 10 mg/L, which is a primary standard enforced by EPA.

Other concerns include microbiological contamination, fertilizers and pesticides, petroleum and chlorinated solvent plumes associated with underground storage tanks and dry cleaning operations, and solid waste disposal. Rainwater runoff can degrade water quality, especially around fuel stations, airports, and military operations.

The following sections summarize the specific water quality concerns for each of the islands of Saipan, Tinian and Rota.

Saipan

In 1946, chloride concentrations in many of Saipan's groundwater sources were low (less than 100 mg/L) but with a combination of overpumping, spatially close wells, and periodic variations in rainfall, these levels have substantially risen.

Saline groundwater can have levels between 250 and 10,000 mg/L in the transition zone between sea water and groundwater. According to the Groundwater Resources of Saipan Report (Carruth, 2003), the volume-weighted average for potable water wells ranged from 63 to 2,853 mg/L in basal lens aquifers in 1998. Chloride concentration is influenced by several factors including the thickness of the freshwater lens, which may change depending on influences from seasonal recharge, drought, and overpumping. Quality may also decrease with the upward displacement of the saltwater zone associated with rising sea levels into screened well areas.

Nitrate is an important indicator of groundwater quality. Sources of nitrate contamination include septic systems, fertilizers and animal wastes associated with agriculture use, and natural sources creating elevated nitrate concentrations. Elevated nitrate levels in groundwater can cause significant impacts to human health and the environment. Human health risks include methemoglobinemia, in which nitrate binds with hemoglobin in the blood, resulting in oxygen deficiency that in infants can be fatal (commonly referred to as "blue baby syndrome"), as well as other adverse health conditions. Environmental impacts associated with nitrate levels include increased algal growth and eutrophication in fresh and marine surface waters (Bearden, 2014). Table 3 summarizes the maximum nitrate and chloride concentrations observed in CUC wells completed into the basal lens and highland aquifers in Saipan as depicted in Figure 4. Data included in Table 3 represent the maximum concentrations for nitrate and chloride observed in water quality samples collected from CUC wells between the dates of December 1, 2005 to April 1, 2015.

Table 3. **Maximum Nitrate and Chloride Concentrations Measured at CUC Wells for the Aquifer Areas in Saipan**

Geographical Location	Groundwater Area	Groundwater Elevation (ft amsl)	Tank Service Area	Nitrate Concentration Max Measured (mg/L)	Chloride Concentration Max Measured (mg/L)
Northern Coastal	IIIb	2-5	Marpi Quarry	5.5	4,099
Central Highland	IIId/V	2-5, 400	Rapagao	6	2,299
	IIId	5+	Calhoun	2.2	1,311
	IIId	2-100	Gualo Rai	1.9	5,298
	IVb	100-600+	Capitol Hill and Agag	4.8	54.0
Eastern Coastal	IIb/VIb	5-100	Papago	4.2	3,068
	IIb	1-100	Kagman	11	2,352
Southern Coastal	VIb	2-100	San Vicente	6.4	1,400
	IIc/VIb	1-5	Dan Dan	11	1,938
	IIc	1-5	Koblerville	7.6	1,900
	IIc	1-5	Isley	11	1,900
	IIId/IIc	2-3	Kannat Tabla	11	5,148

Figures 7 and 8 were prepared by Brian Bearden of CUC and show the average concentrations of nitrate and chloride within the shallow freshwater zone of the aquifers across the island of Saipan using data from the CNMI Bureau of Environmental and Coastal Quality Safe Drinking Water Information System (SDWIS) and CUC Laboratory databases. Chloride concentrations are greatest near the villages of Garapan, north of Susupe located in the Western Coastal Plain physiographic region along with the village of Koblerville and areas near the airport and Naftan Point along the southern coast. The villages in the Western Coastal Plain rely on shallow groundwater resources that are impacted by the fresh water and saltwater interface. The elevated chloride levels also correspond to areas of increased population sizes that would require greater amounts of groundwater removal followed by displacement with seawater. However, areas within the Obyan and Kagman basal aquifers are still capable of meeting the secondary MCL for chlorides of 250 mg/L, as indicated by the predictive mapping performed by CUC. The mapping indicates that it may be possible to achieve lower chloride concentrations with good management of withdrawal rates.

Nitrate concentrations were generally highest in developed areas located near the Airport, Dan Dan, and Kagman. The increased nitrate concentrations are strongly correlated to unsewered developed areas and agricultural areas where livestock is raised and fertilizers are in use. Exceedances of the 10 mg/L MCL for individual wells were identified in these areas, which resulted in an MCL violation prior to the wellfield consolidation projects. Following the violation, water from individual wells was blended in reservoirs, resulting in lower concentrations at the regulated entry points.

Specific sources of contamination on the island of Saipan that have been documented by existing studies are discussed further in subsequent sections.

Figure 7. **Chloride Concentrations, Saipan**
Source: Brian Bearden, CUC

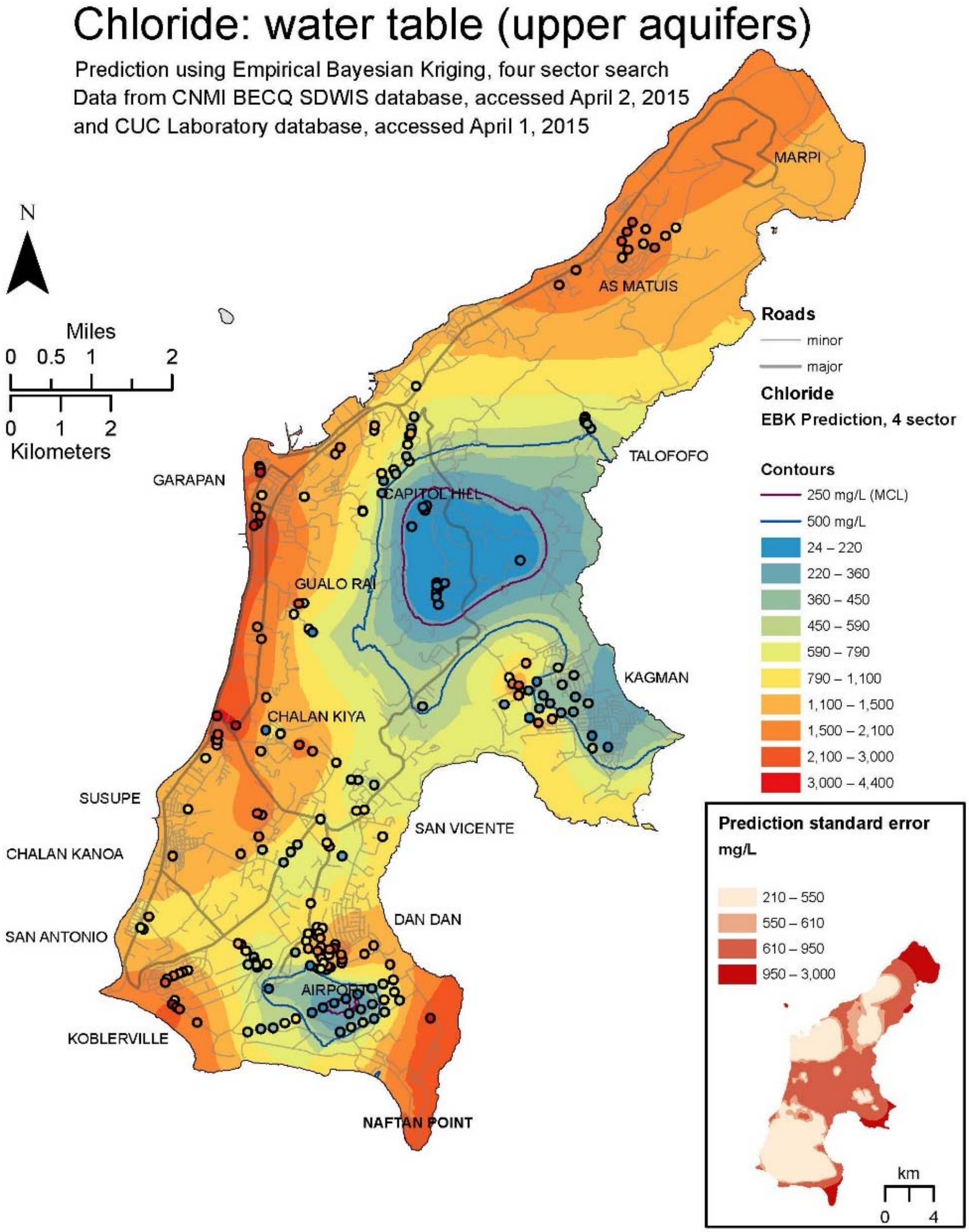
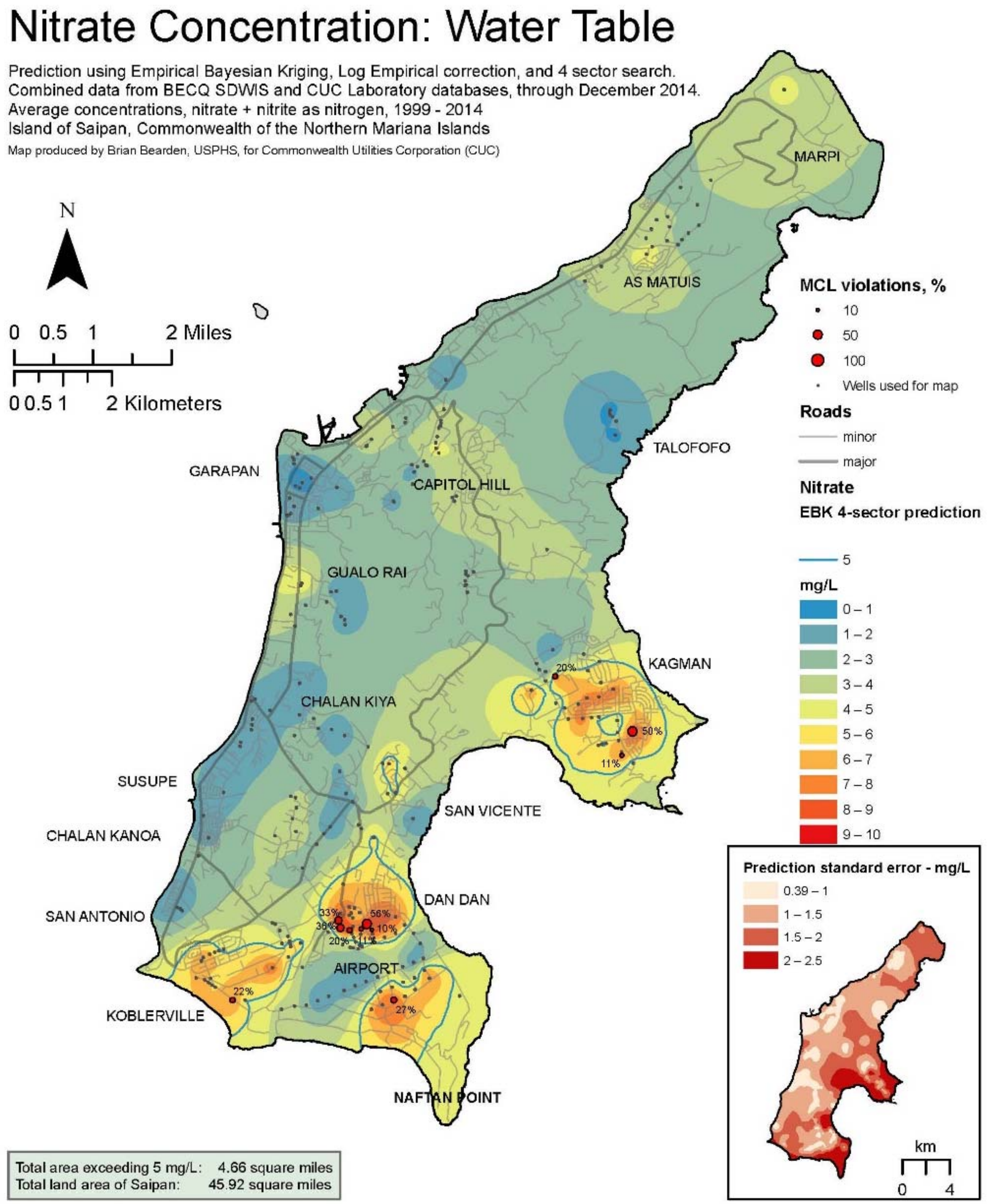


Figure 8. **Nitrate Concentrations, Saipan**
Source: Brian Bearden, CUC



Tinian

As discussed in previous sections, there are no separate groundwater zones in Tinian. The primary and only active water source on the island of Tinian is the Maui II horizontal well, which skims potable water from the Marpo Swamp in the Median Valley.

Similar to the island of Saipan, the main water quality concerns on the island of Tinian are chlorides indicative of salt water intrusion, nitrates, and microbiological contamination including the potential for Maui II to be under the direct influence of surface water.

From the Maui II horizontal well and the Marpo Wetland, chloride concentrations deviate by small amounts and have ranged from a minimum of 172 mg/L to a maximum of 306 mg/L based on water quality samples collected from December 1, 2005 to June 19, 2014. All samples collected were below the EPA MCL of 250 mg/L, with the exception of one sample collected on December 7, 2010.

Nitrate is also a concern for the same reasons as discussed for the island of Saipan; however, based on the water quality data reviewed for the same range of dates, the maximum nitrate level observed was 6.4 mg/L, below the MCL of 10 mg/L. Recent plans to install densely developed, unsewered homestead lots near the wetland has the potential to result in an increase to nitrate concentrations, which could be of very significant concern if levels exceed the MCL as there is presently no other source of water on Tinian with which blending could performed as is the practice on Saipan. An MCL exceedance would therefore require treatment, which would significantly increase the cost of operation for the Tinian water system.

Microbiological contamination is also an important concern related to water quality on Tinian as most of the sewage is treated and disposed to groundwater through septic systems.

A GWUDI study was performed by CH2M in 2012 with additional data collection in 2013. The results indicate Maui II is borderline GWUDI. Maui II has a relatively high background of total coliform and the eight samples collected during the 2013 study contained *E. coli* with seven of those samples having values between 1 and 2 colony-forming units. During a large storm event, turbidity and *E. coli* in one sample demonstrated short-term effects on Maui II from the storm. Refer to the GWUDI Phase II Study for Tinian prepared by CH2M for more details and recommendations.

Table 4 is a summary of maximum nitrate and chloride concentrations from the Maui II horizontal well. Data included in Table 4 represent the maximum concentrations for nitrate and chloride observed in water quality samples collected from December 1, 2005 to June 19, 2014.

Table 4. **Maximum Nitrate and Chloride Concentrations Measured at Maui II**

Geographical Location	Groundwater Area	Groundwater Elevation (ft amsl)	Tank Service Area	Nitrate Concentration Max Measured (mg/L)	Chloride Concentration Max Measured (mg/L)
Central	N/A	7	Carolinas	6.4	306

N/A – not applicable

Rota

As discussed in previous sections, the majority of the potable water on the island of Rota is obtained from the Main Cave, which is currently supplemented by the Onan Spring. It is noted that, due to a previous surface water determination by BECQ, Onan Spring, which was a second large source of fresh water supply for Rota, is planned to be taken off the system. In addition, three active CUC wells supplement the potable water supply with freshwater skimmed from a basal lens groundwater aquifer during dry weather periods.

Similar to Saipan and Tinian, the main concern with water quality in Rota is heightened chloride concentrations indicative of saltwater intrusion. Nitrate levels associated with human activity at the CUC groundwater supply wells, as well as microbial contamination and the potential for the water quality from the Main and Onan Spring to be directly influenced by storm events and surface water runoff, are also a concern.

Based on the data reviewed for Rota, the maximum chloride and nitrate levels measured in both water supplies (caves and groundwater wells) are significantly below the EPA MCLs of 250 mg/L and 10 mg/L, respectively, and is significantly lower than the chloride and nitrate concentrations measured on the islands of Saipan and Tinian.

A GWUDI study was performed on the Main Cave by CH2M in 2012 with additional sampling and data collection performed in 2013. The results of the study classified the Main Cave as non-GWUDI. The Main Cave has relatively low background levels of total coliform; additional sampling performed in 2013 also showed low levels of Total Coliform.

Table 5 is a summary of maximum nitrate and chloride concentrations measured in the Main Cave and the CUC water supply wells that provide potable water for the island of Rota. Data included in Table 5 represent the maximum concentrations for nitrate and chloride observed in water quality samples collected from December 1, 2005 to June 19, 2014.

Table 5. **Maximum Nitrate and Chloride Concentrations Measured on Rota**

Geographical Location	Groundwater Area	Groundwater Elevation (ft amsl)	Tank Service Area	Nitrate Concentration Max Measured (mg/L)	Chloride Concentration Max Measured (mg/L)
South	Main Cave	1150	N/A	0.8	20
East Central	Basal Lens Aquifer (source CUC wells)	-100 to 25	N/A	2.2	29

N/A – not applicable

Tank Service Areas

A distribution system and its associated wellfield are termed a Tank Service Areas (TSA). Water can often be transferred and shared between TSAs as part of an overall groundwater management strategy.

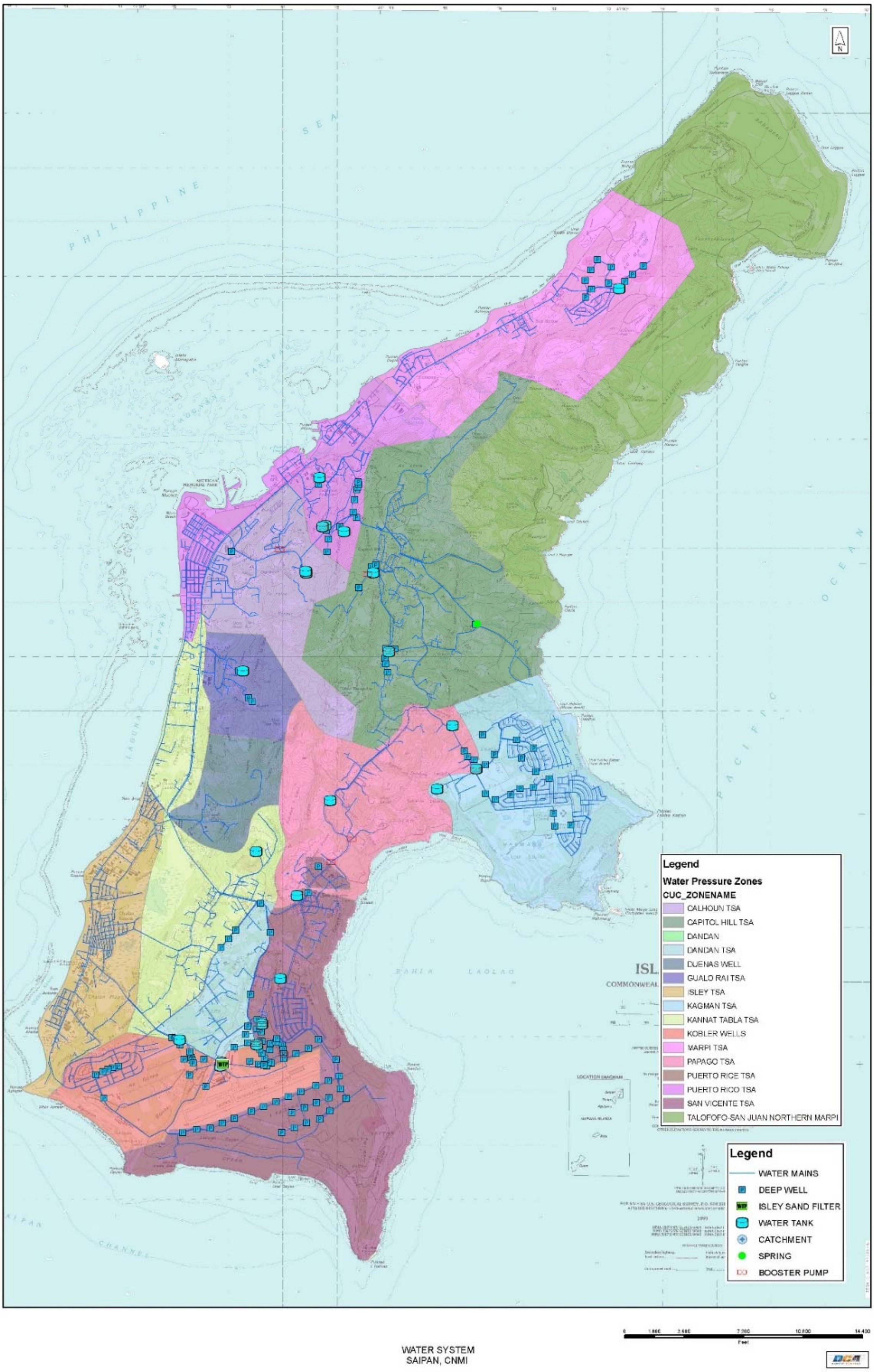
Saipan

All wellfields on Saipan pump to a storage tank or direct feed into the water distribution system that serves a particular part of the island. At the time this Groundwater Management and Protection Plan for Saipan was prepared, an inventory of the individual wells that served each tank was taken. The water use and sources of supply of the TSAs are discussed in this report based on the results of that inventory. However, as Saipan further develops its water supply system, the sources feeding each tank may be changed. Even under current conditions, they do change as needed to meet seasonal demands.

The wells serving the twelve TSAs at the time the 2013 Water Master Plan was prepared are shown in Figure 9 and are briefly discussed below:

- Calhoun TSA, located in the west-central part of Saipan, was being served by the Calhoun Wellfield. The Calhoun TSA can also be served through the Rapagao TSA.
- The Capitol Hill and Agag TSA is located in the area of High-Level Aquifers and was being served by the Capitol Hill and Agag Wellfields.
- Dan Dan TSA is located in the southern part of Saipan near the airport. It was being served by parts of the Dan Dan, Isley, and Obyan Wellfields. Water from the Kagman TSA can also serve the Dan Dan TSA.
- The Gualo Rai TSA is located in west-central Saipan. It was being served by the Gualo Rai Wellfield.
- The Isley TSA is located in the southern area of Saipan near the airport. It was being served by parts of the Koblerville and Obyan Wellfields.
- The Kagman TSA is located in the eastern part of Saipan. It was being served by parts of the Kagman Wellfield.
- The Kannat Tabla TSA is located in the southern part of Saipan near the airport. It was being served by parts of the Chalan Kiya and Isley Wellfields.
- The Koblerville TSA is located in the southwestern part of Saipan. It was being served by the Koblerville Wellfield, including the Maui I infiltration gallery.
- The Marpi TSA is located in the northern part of the island. It was being served by the Marpi Wellfield.
- The Rapagao TSA is located in east-central Saipan. It was being served by the Sablan Quarry, Puerto Rico Wellfields, Donni Spring, and Maui IV infiltration gallery. It also includes the Puerto Rico water storage tank (WST), which supplies the coastal areas of Garapan and southward, and to which water is transferred from the Rapagao WST.
- The San Vicente TSA is located in the southeastern part of Saipan north of the airport. It was being served by parts of the San Vicente and Dan Dan Wellfields. Water from the Kagman TSA can also serve the Dan Dan TSA.
- The Papagao TSA is located in the east-central part of Saipan. It was being served by parts of the Kagman and San Vicente Wellfields.

Figure 9. **Tank Service Areas on Saipan**



Tinian

Tinian's water system is interconnected and operates as one service area with two TSAs—the Carolinas TSA and the Marpo TSA:

- Water is pumped from the only water supply, the Maui II Infiltration Gallery, to the Carolinas Tank (also referred to as the Half-Million Gallon Tank, or "HMT"). The water line between the pump station and Carolinas Tank serves customers and therefore is considered a distribution line. The Carolinas TSA serves the southern part of the island.
- The Marpo Tank (also referred to as the Quarter-Million Gallon Tank, or "QMT") is fed through the distribution system connected to the Carolinas Tan, and helps serve the northern part of the island.

Rota

Rota's water system is interconnected and currently operates as one service area. Two water tanks—the Ginalangan Tank and the Kaan Tank—are located at different grades. Originally the system was designed to operate as two separate pressure zones, but a system of pressure-reducing valves allows the Kaan TSA to be served by the Ginalangan TSA, which is the current practice. The Kaan tank was typically used only during the wet season when the Main Cave discharge is adequate to serve the TSA.

- The Ginalangan tank currently serves the entire island, but was originally intended to primarily serve the village of Sinapalo, which includes the airport. Water is supplied to this tank through both the Main and Onan Caves and through three water wells located in Sinapalo. These wells are activated only as needed during the dry season.
- The Kaan tank serves the Songsong village and lower regions of Rota, which includes Teteto and Teneto villages. Water is supplied to this TSA through the Main Cave pipeline.

Demand versus Groundwater Supply

The average daily future demand expected for each TSA for 2015, 2020, and 2030 in Saipan, Tinian, and Rota are reported in the Drinking Water Master Plans (DCA/CH2M, 2013a, 2013b, 2013c). The projected population data on which this future demand is based were determined in the late summer 2014 and that update the data provided in the 2013 Master Plans. These values, shown in Tables 6 through 8 in units of gallons per day (gpd) and gallons per minute (gpm), are based on the high population projections to produce the most conservative outcome. The tables present a comparison of the March 2014 production rate of the groundwater wells and springs that served each TSA with the future demand estimated for 2015, 2020, and 2030.

Saipan

For the island of Saipan, 24-hour water service throughout the island is one of the highest priority goals of CUC. Since approximately 2003 when the Water Task Force was formed and along with a significant boost in efforts starting in 2008-2009 in response to EPA's Stipulated Orders, CUC has updated the water system and operations to reduce the non-24 hour customers from 80 percent to less than 15 percent, and has occasionally achieved close to 100 percent 24-hour water during some rainy periods. As summarized below, one of the 12 TSAs, Calhoun, currently cannot reliably meet 2015 average daily demands. In 2030 this number could increase to a total of two of the 12 TSAs based on their current production (Calhoun and Koblerville). The 2030 demands are estimated to total 4,090 gpm (6.0 MGD), which can be met by the total current production (based on March 2014 data provided by CUC) from the 12 TSAs of 7,901 gpm (11.4 MGD) (see Table 6).

One major issue with the water supply on the island of Saipan is very high water losses from malfunctioning meters, theft, and leaks. The projected demands do not include these water losses.

Table 6. **Average Daily Future Demand for Each Tank Service Area in Saipan**

Tank Service Area	March 2014 Production (GPD/GPM)	Average Daily Demands 2015 (GPD/GPM)	Average Daily Demands 2020 (GPD/GPM)	Average Daily Demands 2030 (GPD/GPM)
Calhoun TSA	338,400/235	526,146/365	557,937/387	612,087/425
Capitol Hill and Agag TSA	1,342,080/932	230,051/160	270,466/188	358,226/249
Dan Dan TSA	1,324,800/920	685,846/476	729,698/507	796,427/553
Gualo Rai TSA	224,640/156	86,476/60	105,450/73	112,355/78
Isley TSA	2,187,360/1,519	151,637/105	174,706/121	180,515/125
Kagman TSA	714,240/496	428,957/298	519,367/361	532,623/370
Kannat Tabla TSA (includes Chalan Kiya)	1,602,720/1,113	146,225/102	153,331/106	169,042/117
Koblerville TSA	681,120/473	319,067/222	403,942/281	480,610/334
Marpi TSA	616,320/428	290,021/201	301,246/209	363,581/252
East 670 TSA		122,259/85	140,981/98	161,478/112
Rapagao TSA	1,334,880/927	54,006/38	55,480/39	58,812/41
San Vicente TSA	468,000/325	579,821/403	670,037/465	716,623/498
Papago TSA	542,880/377	N/A	N/A	N/A
West TSA		1,153,237/801	1,288,110/895	1,347,747/936
Total	**11,377,440/7,901**	**4,773,750/3,315**	**5,370,750/3,730**	**5,890,126/4,090**

Tinian

Maximum daily demands are seen to be below the current production capacity of Maui II, the source of the supply as shown in Table 7.

Table 7. **Average Daily Future Demand for Each Tank Service Area in Tinian**

Tank Service Area (Existing)	Average Daily Demands 2015 (GPD/GPM)	Average Daily Demands 2020 (GPD/GPM)	Average Daily Demands 2030 (GPD/GPM)	Current Production (GPD/GPM)
HMT TSA	303,000/210	349,250/243	404,000/281	1,008,000/700 (Maui 2)
QMT TSA	109,750/76	100,625/70	158,625/110	See above
Total	**412,750/287**	**449,875/312**	**562,625/391**	**1,008,000/700**

Note:
HMT – Half-million gallon tank
QMT – Quarter-million gallon tank

Rota

For Rota, future demands in 2030 require 410 GPM, less than half the current capabilities of Main Cave's 860 GPM (see Table 8). However, flows from Main Cave are seasonal and the well supply is in a basal lens, thus pumping rates have to balance water quality concerns.

It is noted that, due to a previous surface water determination by BECQ, Onan Spring, which was a second large source of fresh water supply for Rota, is planned to be taken off the system and is therefore not included in the estimates below.

Table 8. **Average Daily Future Demand for Each Tank Service Area in Rota**

Tank Service Areas (Existing)	Average Daily Demands 2015 (GPD/GPM)	Average Daily Demands 2020 (GPD/GPM)	Average Daily Demands 2030 (GPD/GPM)	Current Production (GPD/GPM)
Sinapalo	267,875/186	408,000/283	516,000/385	1,238,400/860 (Main Cave) 648,000/450 (Wells 1, 2, and 3)
Songsong	80,750/56	75,000/52	75,000/52	See above
Total	**348,625/242**	**483,000/335**	**591,000/410**	**1,886,400/1,310**

Groundwater Management Program

A groundwater management program includes numerous elements, including the following:

- Exploration for groundwater resources
- Wellfield operations
- Groundwater monitoring practices, including the recommended management strategies for production and monitoring wells
- Recommended protocol for groundwater resource management, including investigation and assessment of wellfields and abandoned springs
- Potential sources of groundwater contamination/degradation
- Non-revenue water (loss/leakage)
- Wellfield or source protection management strategies, including projects/programs to restore groundwater quality, and recommendations for sustainable withdrawal of groundwater resources

Exploration for Groundwater Resources

The current water production in Saipan is 10.89 mgd based on March 2014 data, which exceeds the 2030 projected demands of 9.0 mgd and demonstrates that there is likely adequate water on the island through 2030 if the system is properly performing. Non-revenue water of 65 to 70 percent throughout the island needs to be the focus rather than constructing new wells within the existing wellfields or elsewhere on the island if feasible. However, if a significant portion of the non-revenue water turns out to be agricultural demand that is currently not being billed, then other sources of water for this use may need to be exploited, although this may not necessarily be a CUC function or responsibility. CUC is conducting a Treatability Study to evaluate the use of surface water to allow the poorer quality wells to be taken off line. These sources include the Airport Catchment, Tanapag Springs 1 and 2, and the Talofofo Stream. See the Treatability Study in Section 4.3 of the "Drinking Water System Master Plan for Saipan, Commonwealth of the Northern Mariana Islands" (2013) for additional information.

Wellfield Operations

Most wells on Saipan have been reported to operate 24 hours a day, 7 days a week. Currently, approximately 12 wells cycle on and off based on a level switch. CUC Water Operations staff visit each well site once a month to document whether each well is on or off.

On Tinian, the capacity of Maui II exceeds the average demand by a factor of about 1.8, and Maui II cycles to meet that demand. On Rota, Main Cave flows 24 hours per day to meet demand, and excess water is allowed to overflow. During the dry season, additional water is produced from the three active CUC wells to balance supply and demand.

The majority of the wells on all islands pump directly into their respective TSA tanks, which then serve the distribution systems based on the tank service areas described above with the following exceptions:

- Kagman (Kumoi booster and KG-131 direct-feed area)
- Koblerville
- Tinian transmission line

Groundwater Monitoring Practices

CUC performs routine monitoring of its groundwater supply wells. Based on discussions with CUC Engineering, CUC Water Quality Laboratory, and CUC Water Operations, Table 9 summarizes the monitoring practices implemented by CUC on all three islands to monitor its groundwater wells and groundwater resources. Due to the complexity and number of water supply wells in the system, it is recommended the monitoring frequency of certain parameters be increased and incorporate automated and on-line monitoring systems to monitor on/off status, water level, flow rate, and potentially conductivity and/or chloride levels. This will be the focus of a Pilot Supervisory Control and Data Acquisition (SCADA) project scheduled to begin in mid-2015 for the Kagman TSA.

Table 9. **CUC Groundwater Monitoring Practices**

Monitoring Location	Parameter	Current Frequency of Measurement	Minimum Recommended Frequency of Measurement
Production Well	Water Level	Monthly (if there is a sounding tube installed in the well)	Monthly for basal aquifer wells, weekly for non-basal aquifer wells
	Flow Rate	Monthly	Daily
	Electrical (Current and Amps)	Monthly	Monthly
	Water Quality (pH, temperature, conductivity, turbidity, nitrate, hardness, chloride, total dissolved solids and coliform)	Twice a Year (driven by EPA)	Continue EPA monitoring requirements Conductivity and/or chloride monthly
	Well On/Off Status	Only known when a physical check on the well site is performed	Continuously through remote telemetry system
Monitoring Wells	Water Level	None	As needed to assist with the evaluation and optimization of each wellfield
	Water Quality	None	As needed to assist with the evaluation and optimization of each wellfield

Production Wells

Water Level Measurement

Currently water levels are measured monthly by CUC Water Operations, but only if there is a sounding tube installed in a given well. The monitoring of water levels is important for proper wellfield operation to protect the equipment, monitor the water level of the aquifer, and determine the ideal operating water level that will provide the best water quality. It is recommended that water levels be monitored at a minimum on a monthly basis for wells in basal aquifers and weekly basis for wells in non-basal aquifers. Once each wellfield has been evaluated and optimized to target production and water quality goals, the recommended frequency can be re-evaluated. A database would need to be developed to track and trend the data for use by CUC Operations.

Production Rate Monitoring

Currently the flow rate is manually monitored by CUC performing a site visit once a month to each well or groundwater source site. This frequency is problematic because Operations staff do not know that a well is offline unless employees physically visit the site or someone notifies them. A remote telemetry system should be installed to, at a minimum, notify CUC of any interruptions in power. The installation of the remote telemetry system would remove the need to perform daily inspections to determine if the power is on/off at wells. Additionally, if a remote monitoring system could be installed in each production well, it would enable real-time monitoring of water levels and production rates. Based on the real time data, optimal well production and water quality goals could be achieved. At a minimum, the flow rate of each well could be monitored on a daily basis to achieve well production and water quality goals initially and re-evaluated on an ongoing basis. A database would need to be developed to track and trend the data for use by CUC Operations.

Water Quality Sampling/Monitoring

Currently select water quality parameters are monitored by CUC twice a year as directed by EPA. It is recommended to continue the EPA-required monitoring for pH, temperature, conductivity, nitrate, hardness, turbidity, chloride, total dissolved solids, and coliform. However, as water quality is an important concern, it is recommended that chlorides and/or conductivity be monitored more frequently, that is, at a minimum on a monthly basis long term and more frequently until each wellfield has been evaluated and optimized to target production and water quality goals.

Monitoring Wells

Water Level Measurement

Currently no water levels are measured or monitored in monitoring wells. Water levels in the monitoring wells could provide valuable data that could be used to monitor the groundwater aquifer levels, identify the fresh-salt water transition zone, and conduct future analysis and modeling exercises. It is recommended that water levels in the monitoring wells be monitored on an as-needed basis to fill data gaps if additional data at the monitoring well locations would provide valuable information to assist with the evaluation and optimization of each wellfield. At this time, if the recommendations for additional monitoring at the production wells are implemented, it is not anticipated that additional data from the monitoring wells is necessary.

Water Quality Sampling/Monitoring

Currently no water quality data are collected from the monitoring wells. Additional water quality data from the monitoring wells could be valuable data used to identify the fresh-salt water transition zone and conduct future analysis and modeling exercises. Because water quality is an important concern for the islands, it is recommended that chlorides and/or conductivity in the monitoring wells be monitored on an as-needed basis to fill data gaps if additional data at the monitoring well locations would provide valuable information to assist with the evaluation and optimization of each wellfield. At this time, if the recommendations for additional monitoring at the production wells are implemented, it is not anticipated that additional data from the monitoring wells is necessary.

Recommended Protocol for Groundwater Resource Management

The following sections summarize the data available and reviewed for the Saipan, Tinian, and Rota groundwater supply sources and identifies the data gaps. Recommendations for the collection of additional data, summarized below, are critical to confirming and finalizing the recommendations for sustainable groundwater withdrawal discussed in the subsequent sections.

Wellfield Investigation and Assessment

CUC Water Operations uses three main spreadsheets to track various information on the groundwater supply wells. Well characteristics tracked include well elevation, average flow, average pressure, depth of well, pump intake settings, static water level, static head, total dynamic head, well head diameter, drop pipe size, well casing diameter, motor horsepower, make and model, phase, volts, pump make and model, number of stages, date the equipment was installed, meter information and power usage. Copies of the spreadsheets provided by CUC are included for reference as Appendix B.

Based on a review of the data collected, in addition to discussions with the CUC Water Operations and DEQ, the current database is missing information for some wells, has many discrepancies when compared to other resources, and may include information that is not accurate or up to date.

To make informed decisions regarding wellfield operations and identify solutions to improve water quality, a complete and accurate set of data is required; thus, the following major data gaps have been identified:

1. Well As-Builts and Database. No master database or complete set of well as-builts is readily available that document the well construction details such as screened interval, total depth, and materials of construction. The “Well Data” spreadsheet included in Appendix B contains much of the well as-built and equipment data; however, it is recommended the database be expanded to include additional well construction information such as screened interval, materials of construction, etc.

   CH2MHILL developed the contents of Appendix C by reviewing seven well as builts, which were provided to CH2MHILL by DEQ, and the USGS Report titled, *Groundwater Resources of Saipan, Commonwealth of the Northern Mariana Islands* (Carruth, 2003). Upon review and comparison of all seven well as-builts to the USGS report, many discrepancies were found in the numbers presented for top and bottom of screen and well depths. Using available information, the table included in Appendix C was developed to summarize the pertinent well construction and equipment details.

   It is recommended that DEQ and CUC develop and maintain a master well construction database with the most recent and best available information for each well. In addition to a database, CUC should acquire and keep a hard copy or electronic copy of all well construction logs that DEQ has on file. The master database should be used to track all wells that CUC owns. The information in the database should be updated as wells are replaced or abandoned or as equipment is changed.

2. Well Condition Assessment. Currently the condition of the casing and screen in all wells is unknown. It was reported in the 2006 Inspection and Sanitary Survey Report prepared by EPA inspectors Barry Pollock and William Davis that video surveys were performed on up to 61 wells in 1993 and, at that time, many of the well casings and screens were in poor condition.

   It is not feasible to acquire and review the existing video surveys; however, at a minimum, it would be recommended to perform a new video survey on all wells with steel casings and screens which are 30 years old or older to confirm the overall condition of the well casing. Currently there are 36 wells 30 years old or older. This activity could be focused on select wells identified by CUC as potential problem wells.

3. Downhole Equipment Database. CUC tracks the downhole equipment installed in the majority of the wells (Appendix B); however, it was reported by CUC Water Operations staff that the records may not be accurate. CUC Water Operations began tracking and documenting the installation of new pump and motor equipment as equipment failed and was replaced, and there are a significant amount of equipment failures. CUC reported that it may have 7 well pump or motor failures in 1 week. This failure rate is indicative of equipment not properly sized for the well and its operating conditions. It was also reported that each time a new pump and motor is installed, a pump performance test is completed; however, the details of the pump performance tests were not provided. In addition, it was reported that when equipment is replaced in a well, it may not be properly sized, which leads to additional failures. Using available information, the table included in Appendix C was developed to summarize the downhole equipment installed in each well. It is recommended that all information presented be confirmed.

   It is also recommended that the following additional field investigation work be completed to clear up data discrepancies and develop a good baseline data set for all of the wells and springs:

   - The downhole equipment should be removed from each well to verify the pump setting depth, pumps/motor make and models, drop pipe material and diameter, and overall condition of the equipment.

   - For select wells, once the equipment is removed a video survey should then be performed as discussed above.

   - An aquifer test should be conducted on each well that is tailored to fit the specific issues related to the well being tested. Typically at a minimum, an 8-hour step test and 24-hour constant rate test would be performed to baseline the current well performance and assist with evaluation of pump and motor equipment. During testing, water levels, conductivity, and chloride concentrations should be monitored to identify the maximum pumping rate and pumping water level that would supply the best quality water from each well.

     It is recommended to use an online water quality meter to monitor conductivity in addition to collecting water quality samples for analysis of chloride concentrations. At a minimum one water sample would be recommended per hour during the step test and up to four during the constant rate test spaced 6 hours apart.

It is recommended to install a level transducer during the pumping tests to automatically monitor water levels in addition to manual monitoring. The frequency of manual measurements recommended would match what is recommended in the DEQ Well Drilling and Well Operation Regulations:

- 1 minute to 10 minutes: Measure at 1-minute intervals
- 12 minutes to 30 minutes: Measure at 2-minute intervals
- 40 minutes to 1 hour: Measure at 10-minute intervals
- 90 minutes to 8 hours: Measure at 30-minute intervals
- 9 hours to 24 hours: Measure at 1-hour intervals

4. Downhole Equipment Assessment and Design. Using the data collected above, an evaluation should be performed and the downhole equipment should be engineered for each well and its specific operating conditions. This would include identifying the appropriate pump and motor, identifying the drop pipe material and diameter required to move sand, identifying whether the motor requires a shroud to maintain the minimum velocity past the motor for cooling, sizing the shroud, and determining the pump setting depth. The pump setting depth will also be dependent on the results from Item 5 below.

   Following selection and installation of each pump and motor, a pump performance test should be conducted on each well to confirm that the pump and motor operate properly and performance matches the manufacturer's published pump curves. The pump performance test should include:

   - Operating the pump for a minimum of 1 continuous hour with one start and stop to verify successful performance.
   - Obtaining concurrent readings of motor voltage, amperage, well water level, pumping rate, and pump discharge head for at least five performance points. Check each power lead to the motor for proper current balance.
   - Plotting data collected from the test against the manufacturer's published pump curve and meeting the performance test acceptance tolerances.

5. Fresh-Salt Water Interface. The freshwater lens in the basal aquifers on Saipan, Tinian, and Rota is thickest in the interior of the islands, thinning out toward the coastal areas. Based on the result of water quality sampling in six deep profiling monitoring wells on Saipan, the 2003 USGS report (Carruth) states that the freshwater lens ranges from 30 to 45 feet thick near these wells. For the purpose of this report and analysis, a uniform thickness of 40 feet was used for all basal lens wellfields on Saipan. An attempt was made to estimate the elevation of the transition zone using the cross-sections from the USGS report; however, the data presented in the USGS report was not detailed enough to develop more accurate estimates of the freshwater lens for each of the basal lens wellfields.

   The estimated elevation of the transition zone compared to the screened interval for each basal lens wellfield is presented in Figures 10 through 22. On Tinian, (Gingerich and Yeatts, 2000) reports the basal lens is about 40 feet thick near the center of the island, and thins somewhat near the Marpo Valley due to the pumping of Maui II. A similar freshwater lens is expected to exist in the basal aquifer on Rota, although thickness data were not included in the resources consulted to prepare this plan.

The actual elevation of the transition from freshwater to salt water should be determined for each well. This can be accomplished by running a fluid resistivity log in each well and associated monitoring wells under static and pumping conditions (if possible).

Figure 10. **Freshwater versus Salt Water in Calhoun Wellfield**

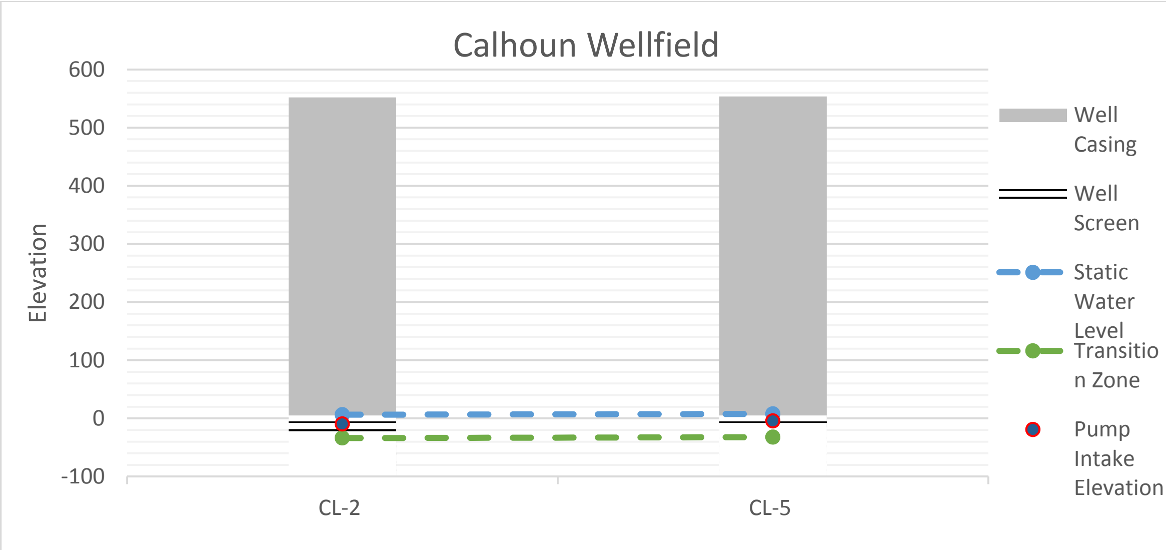


Figure 11. **Freshwater versus Salt Water in Dan Dan Wellfield**

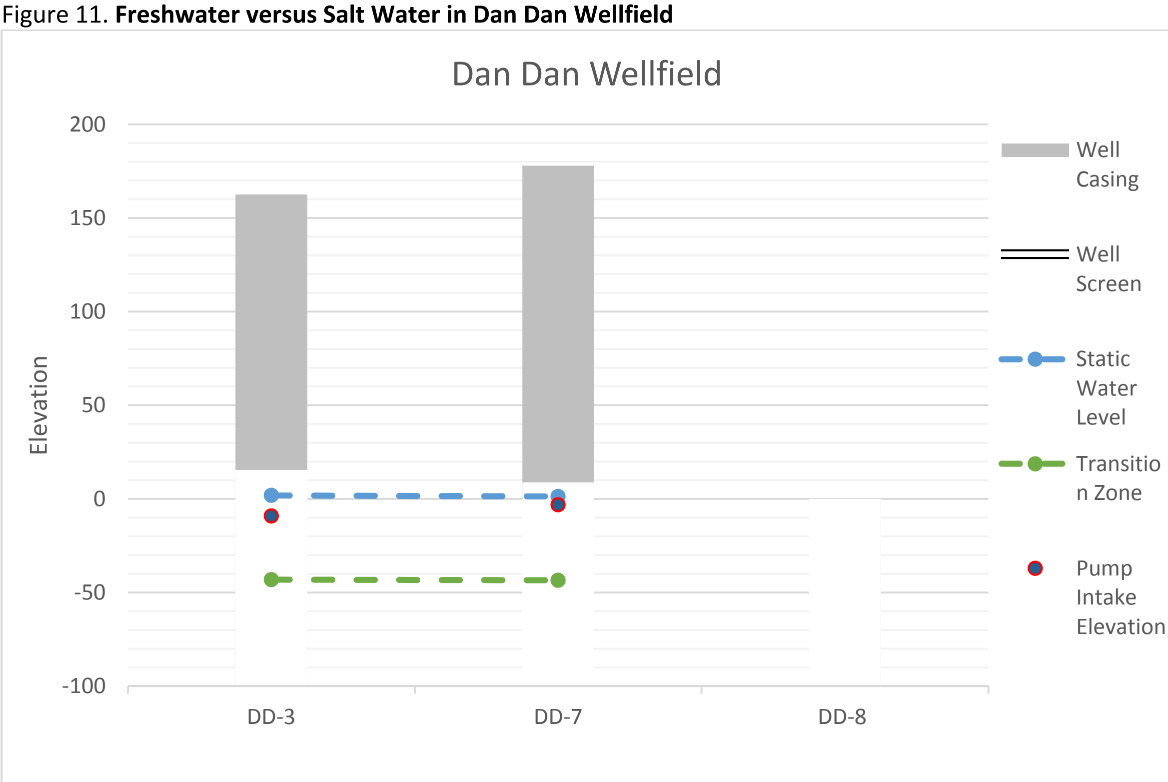


Figure 12. **Freshwater versus Salt Water in Gualo Rai Wellfield**

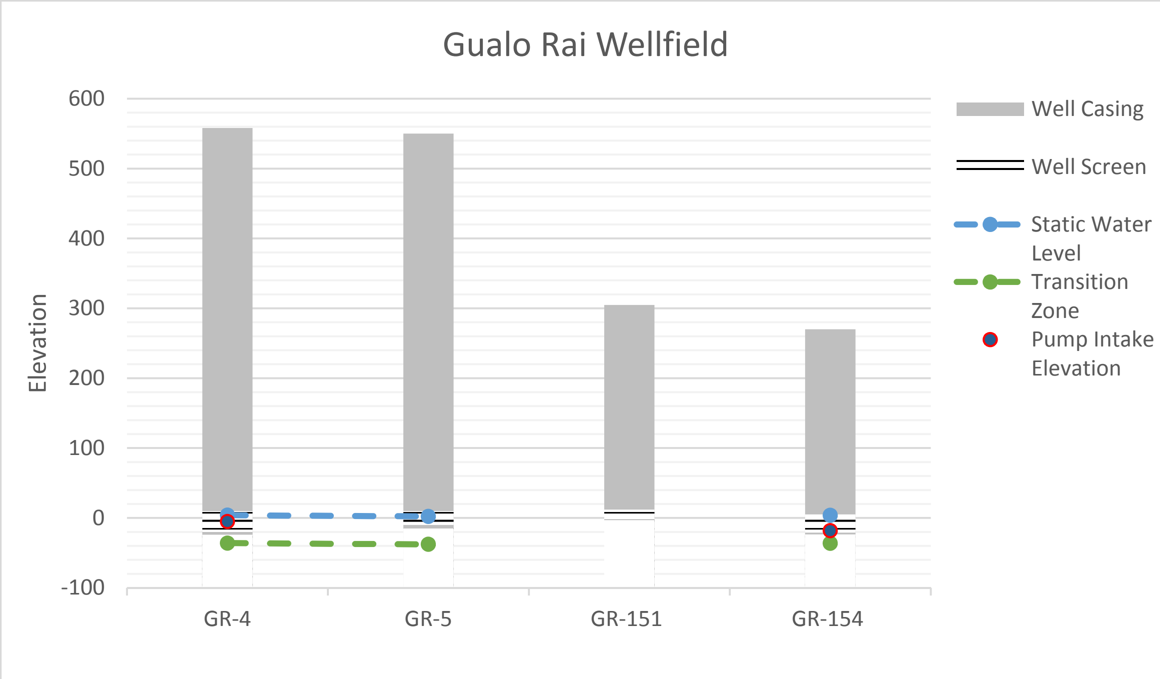


Figure 13. **Freshwater versus Salt Water in Isley Wellfield**

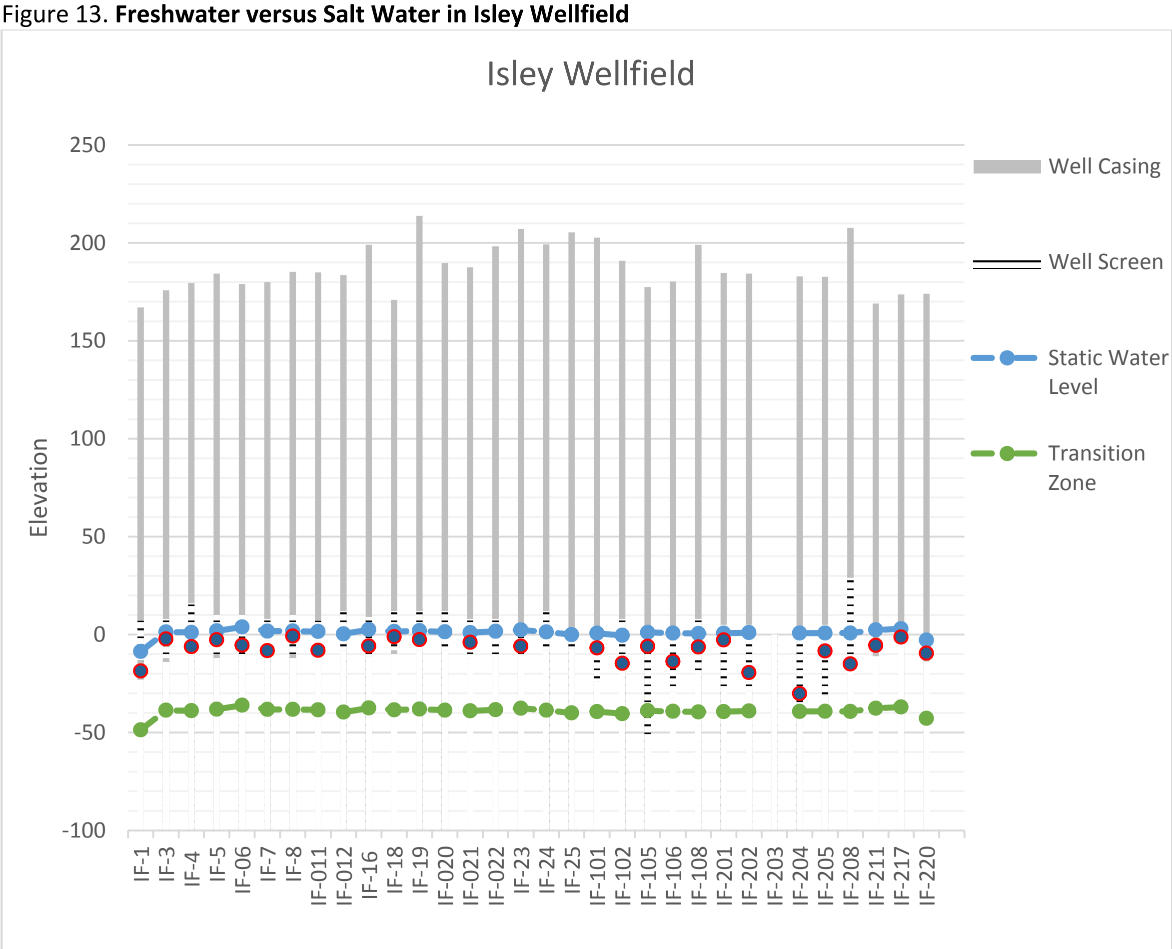


Figure 14. **Freshwater versus Salt Water in Kagman Wellfield**

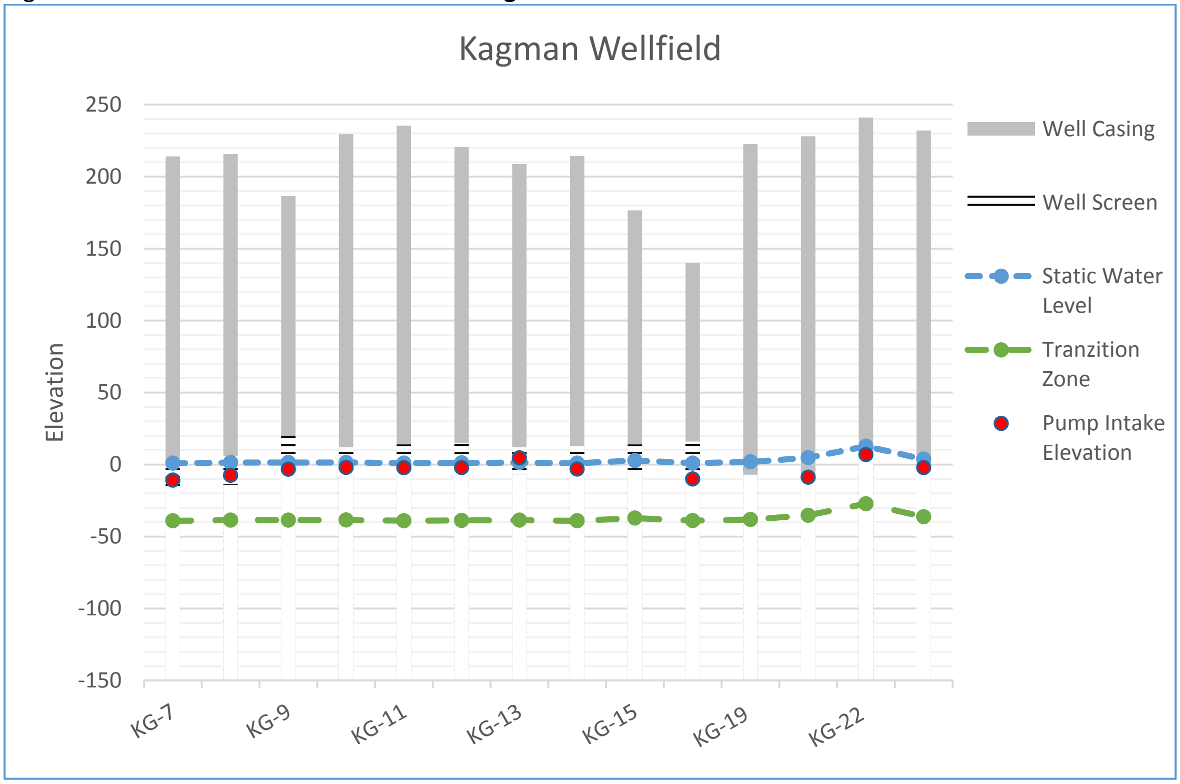


Figure 15. **Freshwater Wells Completed into the Artesian Aquifer (Kagman Wellfield)**

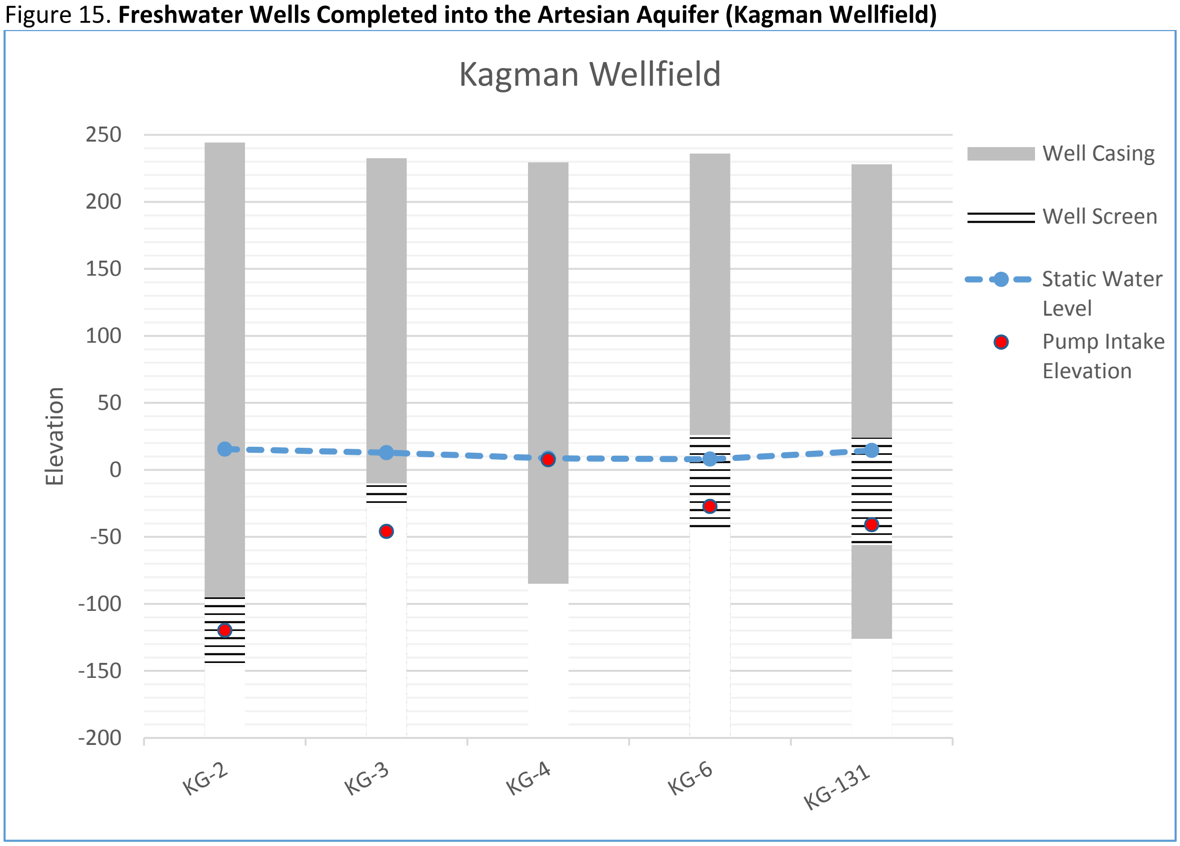


Figure 16. **Freshwater versus Salt Water Koblerville Wellfield**

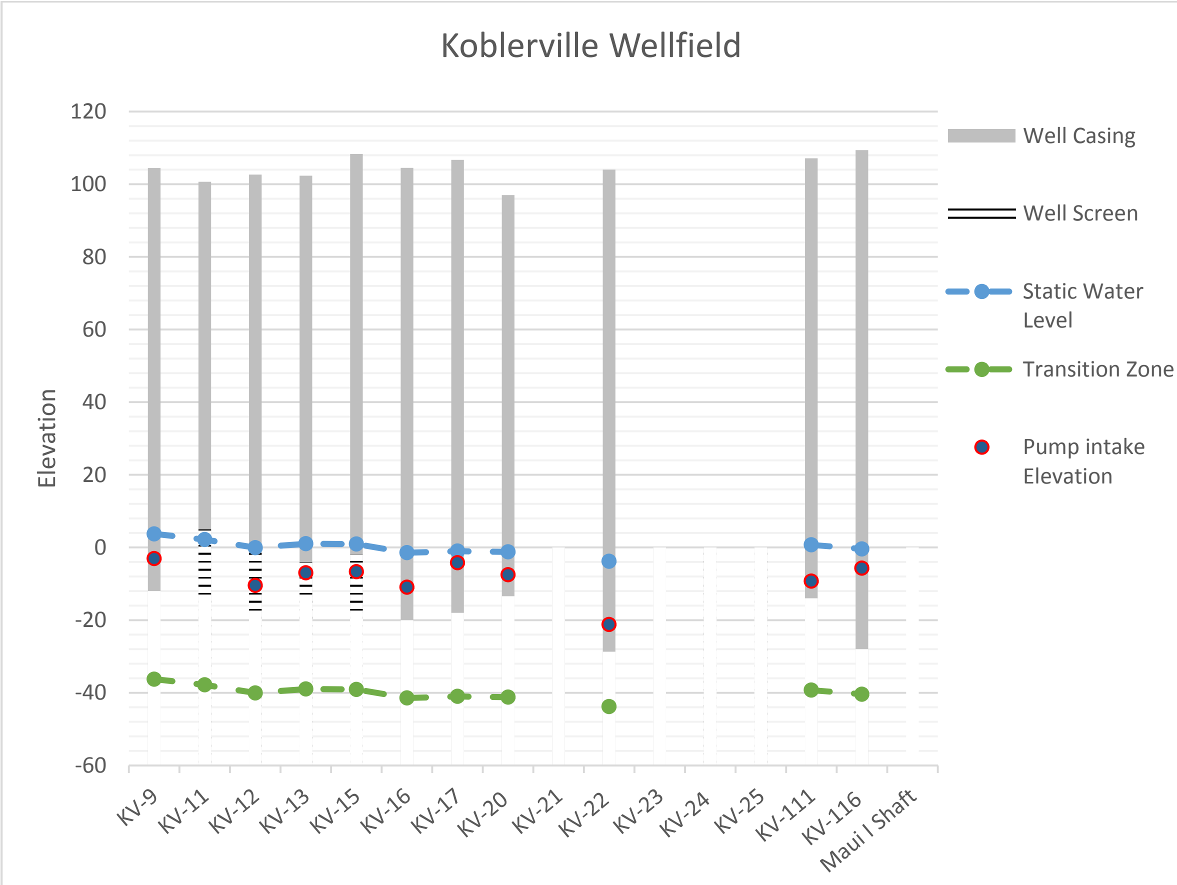


Figure 17. **Freshwater versus Salt Water in Marpi Quarry Wellfield**

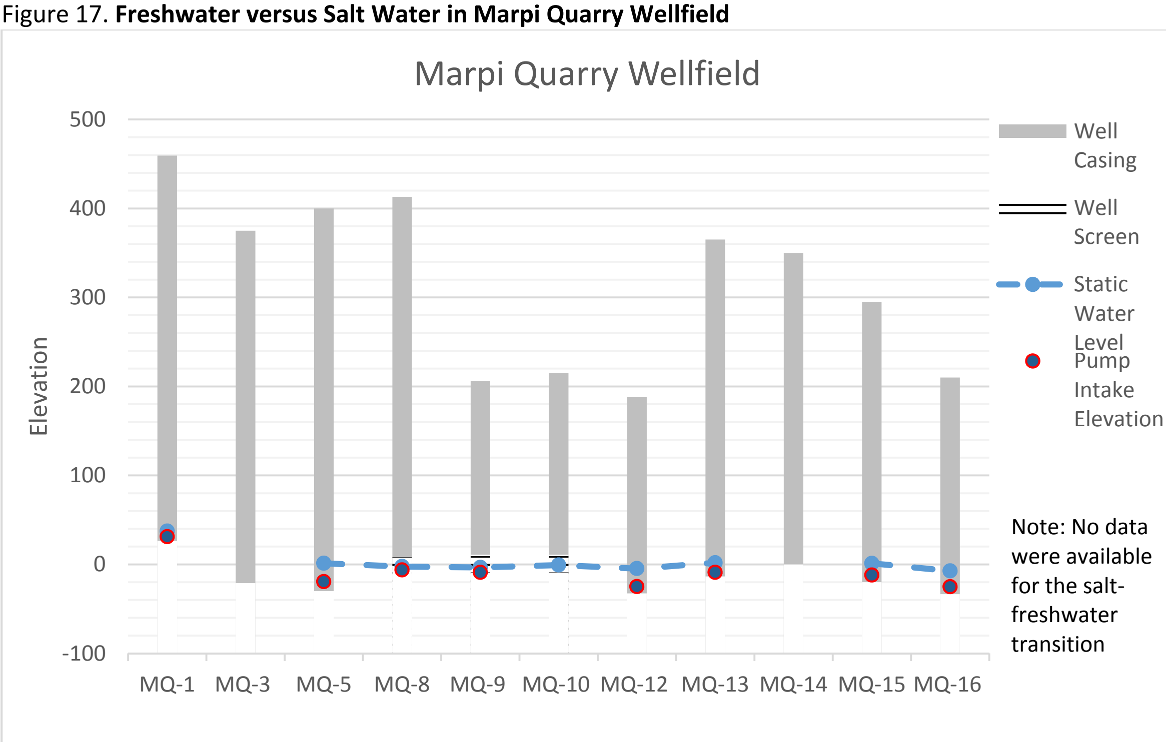


Figure 18. **Freshwater versus Salt Water in Sablan Quarry/Sadog Tasi Wellfield**

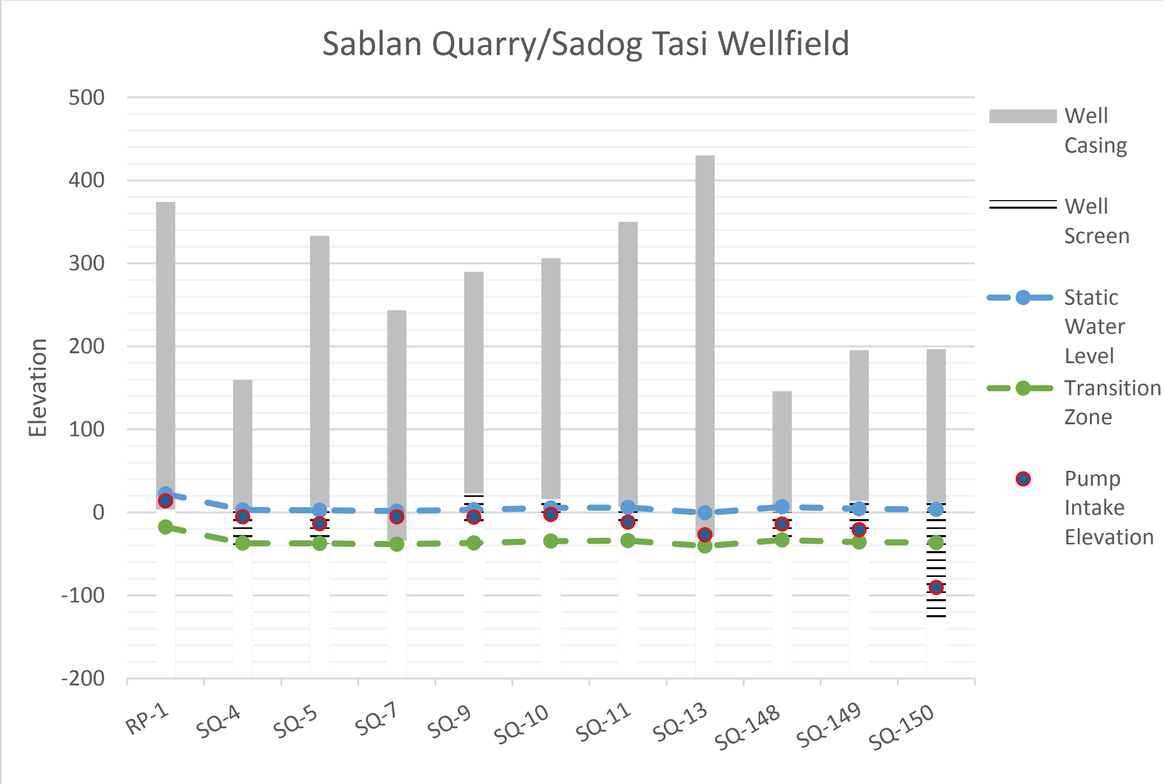


Figure 19. **Freshwater versus Salt Water in San Vicente Wellfield**

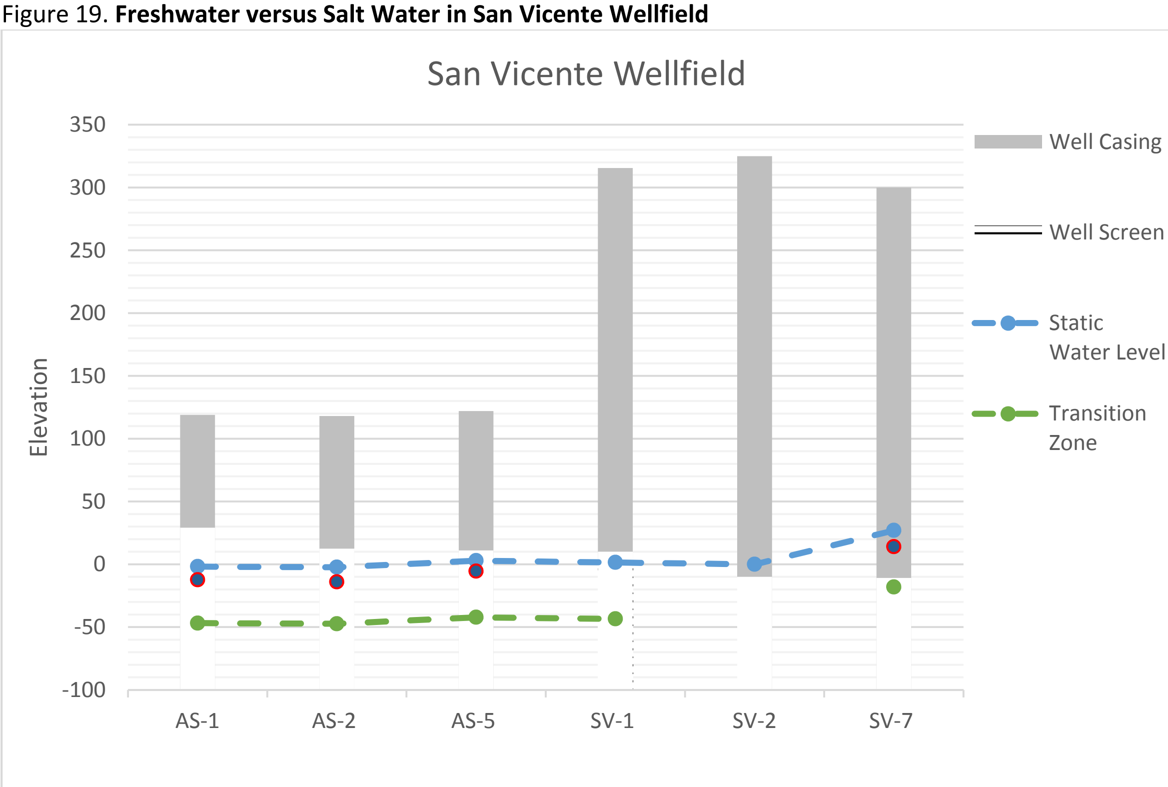


Figure 20. **Freshwater versus Salt Water in Obyan Wellfield**

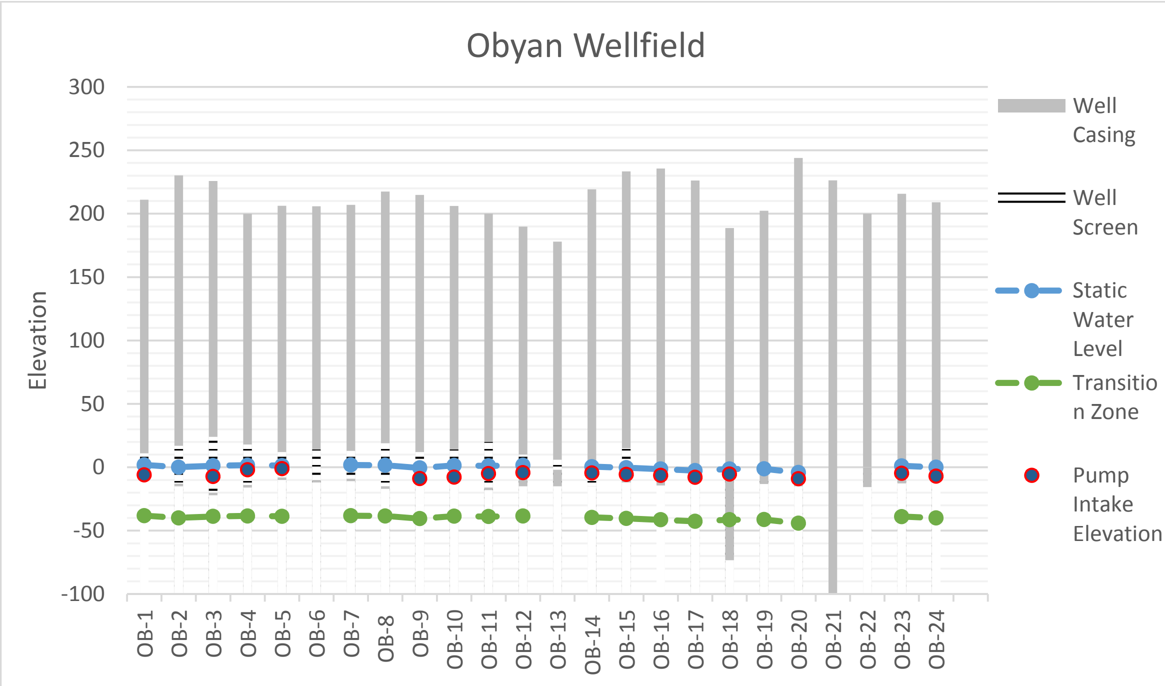


Figure 21. **Freshwater versus Salt Water in Duenas Wellfield**

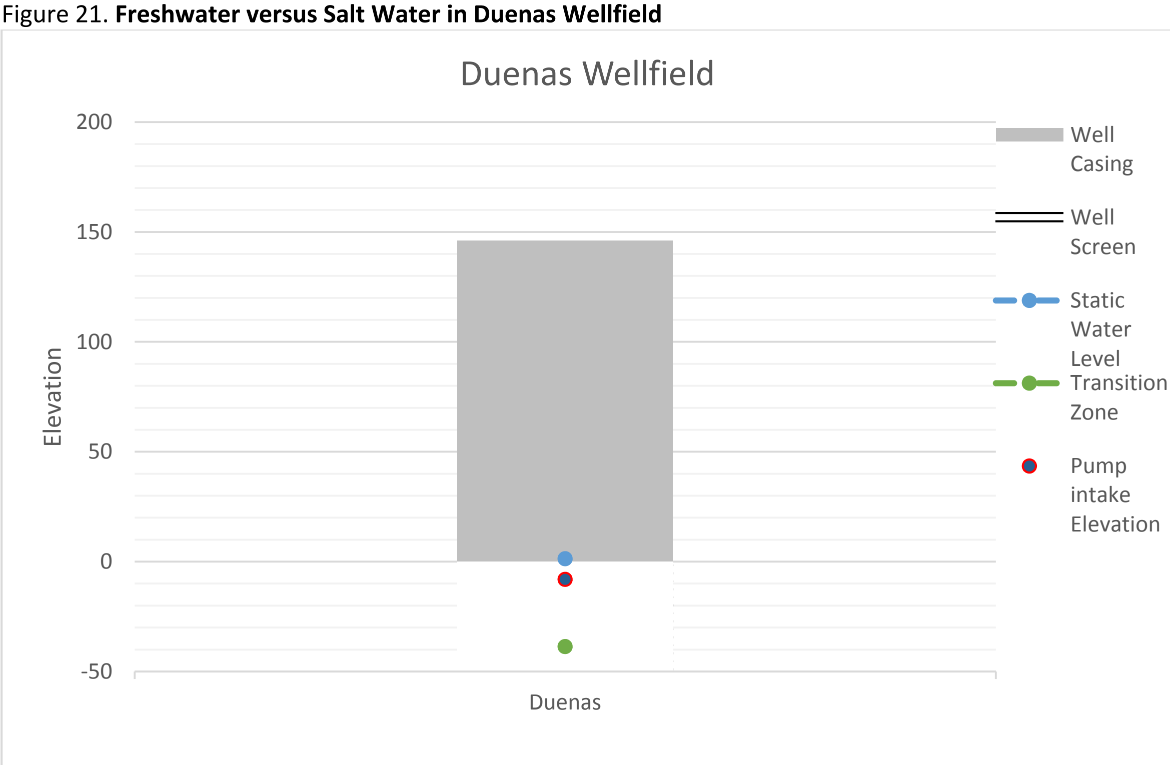
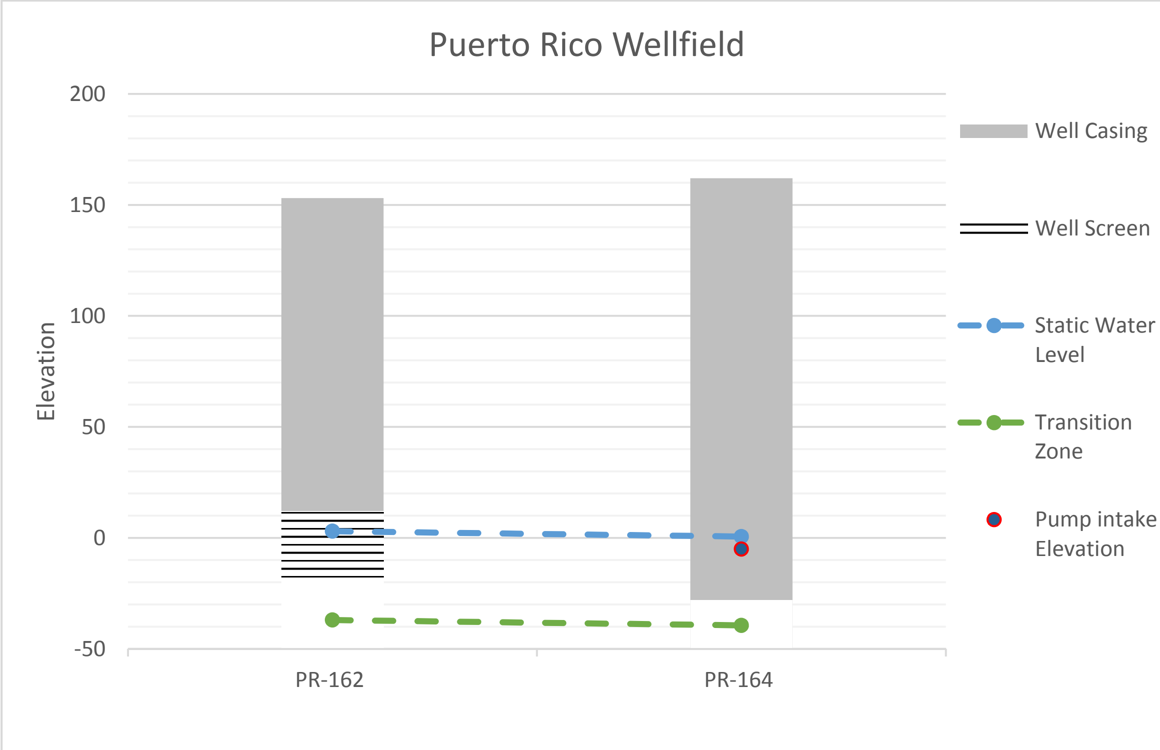


Figure 22. **Freshwater versus Salt Water in Puerto Rico Wellfield**



Abandoned Springs Investigation and Assessment

Other portions of this Water Master Plan, including the Treatability Study, should be reviewed for additional recommendations and findings on the springs. The abandoned springs are recommended for further investigation to serve as an alternative water supply source specifically for the island of Saipan.

The capacity and water quality of the available springs should be measured over the course of a year to confirm and verify the potential quantity of water available from each spring. At a minimum a water quality sample and flow rate should be collected once a month for a year to monitor the seasonal fluctuations. To measure flow rate, the discharge from the spring will need to be modified to collect the water in a pipeline or channel where flow rate can be measured via a flow meter or flume.

Based on available literature the following has been reported on the available capacity and water quality of the springs:

- Donni Springs, Saipan. Reported in USGS 2003 report to fluctuate seasonally between 416 gpm (0.6 mgd) and 3,125 gpm (4.5 mgd); however, the Inspection and Sanitary Report (EPA, 2006) states 120 gpm (0.2 mgd) to 350 gpm (0.5 mgd). Currently used by CUC as a water source for Saipan with a reported capacity of 250 gpm (0.36 MGD).
- Tanapag Springs I and II, Saipan. Tanapag I is reported to average 115 gpm and Tanapag II is reported to average 15 gpm (0.02 mgd) (Carruth, 2000). Currently neither spring is used by CUC as a water source for Saipan, and no method to record capacity is available.
- Achugao Spring, Saipan. Reported to produce anywhere from 20 gpm (0.03 mgd) to 50 gpm (0.07 mgd) (EPA, 2006). This spring was observed to have zero flow during the July and September 2014 site visits.

- Main and Onan Caves, Rota. The Main Cave provides the majority of the water for Rota except during extended dry periods. The Onan Cave was determined to be a surface water by BECQ and will be permanently taken off line with regard to being a drinking water source. CUC reports that the flow rate of the caves is monitored, but that the flow meter was currently broken. Flow rates can fluctuate by as much as 50 percent. Past information provided by CUC indicates an average flow rate of 806 gpm from the Main Cave.
- Tinian. No springs or water caves are present on Tinian.

Potential Sources of Groundwater Contamination/Degradation

The content in this section is based on existing information and water quality studies performed by CUC, DEQ, and EPA in addition to data from the CNMI Bureau of Environmental and Coastal Quality Safe Drinking Water Information System (SDWIS) database. Pertinent maps from the 2009 Groundwater Sampling Report for Saipan are included as Appendix C. Maps prepared by Brian Bearden with CUC from the CNMI Bureau of Environmental and Coastal Quality Safe Drinking Water Information System (SDWIS) database are included as Appendix E. No additional water quality sampling was performed to complete this section.

Below are the known sources of groundwater contamination previously reported are summarized by specific locations on the islands.

Saipan

San Antonio

- Sources of contamination: Illegal dumping of oil in 1999, garment factory, and resort hotel.
- In 2000, VOCs including TCE were detected in well water sample and traced back to the Hollywood/Suntex Garment Factory and a nearby resort hotel.
- In 2009, TCE and arsenic were detected above the MCL.
- Based on the maps prepared using the SDWIS database, the following observations are made:
  - Slightly elevated concentrations of arsenic compared to the rest of the island in the 4.3 to 8.2 µg/mL range and one well with a reported level of 75 µg/mL.
  - Generally the area has higher fluoride levels compared to the rest of the island in the 0.66 to 1 mg/L range.

Koblerville (CUC) Wells

- In 2000, VOCs were detected above the MCL.
- In 2009, VOCs were again detected but not above the MCL.
- This area has poor water quality and the freshwater lens is thin.
- Area is high in chlorides and nitrates.
- Based on the maps prepared using the SDWIS database, the following observations are made:
  - Average chloride levels in the upper aquifer generally range from 1,100 to 3,000 mg/L.
  - Average nitrate levels in the upper aquifer generally range from 5 to 7 mg/L.
  - Average TDS levels in the upper aquifer generally range from 3,100 to 4,100 mg/L.
- Area is farmed, which could be a source of the high nitrates. There are also areas of unsewered development, another likely source.

Chalan Kiya

- In 2009, arsenic and selenium were detected above the MCL.
- Based on the maps prepared using the SDWIS database, the following observations are made:
  - Average chloride levels in the upper aquifer generally range from 1,300 to 3,400 mg/L with two wells reporting an average chloride level in the 4,000 mg/L range.
  - Generally the area has elevated coliform levels compared to other areas with 61 to 100 percent of samples collected reporting positive for coliform.
  - Average TDS levels in the upper aquifer generally range from 3,100 to 4,100 mg/L.

Airport

- In 2009, VOCs were detected northwest of the airport, but not above the MCL.
- Based on the maps prepared using the SDWIS database, the following observations are made:
  - Average chloride levels in the upper aquifer generally range from <250 mg/L up to 500 mg/L around the airport area.
  - Average nitrate levels in the upper aquifer generally range from 5 to 7 mg/L. Based on the most recent data from CUC, one well south of the airport (OB-22) has exceeded the MCL, plateauing at 11 mg/L since mid-2013 through December 2014. There are no septic systems in the vicinity of this well, but there is a known cattle-grazing operation that is the probable cause of this exceedance.

As Matuis

- In 2000, thallium was detected above the MCL. The source is unknown but could be either naturally occurring, from rat poisoning, or from manufacturing of electronic devices.
- The area has poor water quality and some of the water with the highest salinity.
- This area consists of dense development on septic systems that could be a source of nitrate contamination.
- Based on the maps prepared using the SDWIS database, the following observation is made: generally, the area has elevated coliform levels compared to other areas with 61 to 78 percent of samples collected reporting positive for coliform.
- Based on the maps prepared using the SDWIS database, the following observations are made:
  - Average chloride concentrations in the upper aquifer generally range from 1,500 to 2,100 mg/L, with several wells reporting an average chloride concentration in the 2,100 to 3,000 mg/L range.
  - Generally 47 to 61 percent of samples collected from both shallow and deep wells reported positive for coliform.
  - Average TDS levels in the upper aquifer generally range from 3,100 to 5,500 mg/L.

Susupe

- In 2000, thallium was detected above the MCL. The source is unknown but could be either naturally occurring, from rat poisoning, or from manufacturing of electronic devices.
- In 2009, only arsenic and selenium were detected above the MCL.
- Based on the maps prepared using the SDWIS database, the following observation is made: generally, the area has elevated coliform levels compared to other areas with 61 to 100 percent of samples collected reporting positive for coliform.

As Lito Area

- In 2000, TCE was detected above the MCL and traced back to nearby garment factories.
- In 2009, only arsenic and selenium were detected above the MCLs.

Lower Base

- In 2000, TCE was detected above the MCL and traced back to nearby garment factories.
- In 2000, cis-1,2-DCE, trans-1,2-DCE, and vinyl chloride were detected above the MCLs and traced back to the nearby garment factories.
- In 2000, thallium was detected above the MCL. The source is unknown but could be either naturally occurring, rat poisoning, or from manufacturing of electronic devices.

Puerto Rico

- In 2000, TCE was detected above the MCL and traced back to nearby garment factories.
- In 2000, PCE and cis-1,2-DCE were detected above the MCLs and traced back to nearby garment factories and laundry facilities.
- In 2000, thallium was detected above the MCL. The source is unknown but could be either naturally occurring, from rat poisoning, or from manufacturing of electronic devices.
- In 2009, VOCs were detected but not above the MCL.
- PR164 has slightly elevated coliform.
- Well PR162 was determined to be GWUDI and is currently abandoned. The well also has high coliform and turbidity.
- The source of contamination may be from a nearby pig farm, located on or near faulting documented in the USGS geology map of Saipan.
- Based on the maps prepared using the SDWIS database, the following observation is made:
  - PCE concentrations in this area are elevated compared to the rest of the island with concentrations generally ranging from 16 up to 80 µg/L.
  - Thallium concentrations in this area are slightly elevated compared to the rest of the island with concentrations generally ranging from 1.2 to 1.4 µg/L.
  - Turbidity concentrations in this area are elevated compared to the rest of the island. Concentrations generally range from 3.4 to 7.1 NTU.

Tanapag

- In 2000, TCE, vinyl chloride and cis and trans-1,2-DCE were detected above the MCL.
- In 2000, thallium was detected above the MCL. The source is unknown but could be either naturally occurring, from rat poisoning, or from manufacturing of electronic devices.

Marpi

- Potential sources of groundwater contamination in Marpi include the Marpi Solid Waste Landfill, the Marpi Unexploded Ordnance (UXO) storage and detonation area, public and veteran's cemeteries, and widespread WWII development including munitions storage and a Naval Air Station.
- The Marpi Landfill discharges treated leachate to groundwater through a wetland treatment system with underground infiltration fields. According to BECQ records, however, there have been numerous instances where untreated leachate has been discharged to the ground surface, and presumably to groundwater, since 2006. Groundwater monitoring at the Marpi Landfill has

resulted in statistically significant increases for lead, nickel, chromium, barium, and acetone in 2008 and 2009.

Garapan

- In 2009, arsenic and selenium above the respective MCLs were detected south of Garapan.
- Based on the maps prepared using the SDWIS database, the following observations are made:
  - One well identified with slightly elevated arsenic concentrations compared to the rest of the area of 19 µg/L.
  - Average chloride levels generally range from 1,700 to 2,700 mg/L with four wells in the 3,700 mg/L range.
  - Generally the area has elevated coliform levels compared to other areas with 61 to 100 percent of samples collected reporting positive for coliform.
  - Generally the area has higher fluoride levels compared to the rest of the island in the 0.43 to 0.66 mg/L range.
  - Average TDS levels in the upper aquifer generally range from 3,100 to 4,100 mg/L.
  - Turbidity concentrations in this area are elevated compared to the rest of the island. Concentrations generally range from 3.4 to 7.1 NTU.

Kagman

- In 2006, it was noted that this area is susceptible to high nitrates due to water runoff being concentrated in areas that feed the aquifer, large population, and lack of sewer collection system.
- This area consists of dense development that relies on septic systems.
- There is also a concentrated area of farming overlying the principle Kagman wellfield, which may be a source of both nitrates and pesticides.
- Based on the maps prepared using the SDWIS database, the following observation was made:
  - The average nitrate levels in the upper aquifer generally range from 5 to 8 mg/L.
  - Average chloride levels in the upper aquifer generally range from 220 to 1,100 mg/L with roughly half of the area meeting the secondary MCL of 500 mg/L.

Capitol Hill and Agag

- No specific sources of contamination noted. A portion of the homes in the Capitol Hill area are sewered; the remainder in Capitol Hill and all of Agag area are unsewered.

Dan Dan

- Based on CUC water quality database dated June 23, 2014 with water quality data ranging from December 1, 2009 through June 19, 2014, three wells (IF-4, IF-5, and IF-7) have historically exceeded the nitrate MCL of 10 mg/L. Based on the maps prepared using the SDWIS database, the average nitrate levels in the upper aquifer generally range from 5 to 7 mg/L.
- This area is densely developed and served only by septic systems, with the exception of the Saipan International Airport and a few establishments located along the Airport Road, bordering the eastern part of Dan Dan.

Gualo Rai

- This area has a large number of unsewered homes that could be a potential source of contamination. Based on the maps prepared using the SDWIS database, nitrate concentrations in groundwater exceed the half-MCL of 5 mg/L in this area.

Isley

- Maui I has been reported to have low levels of coliform. Recommendations have been made to seal around shaft, building upgrades, and provide chlorination.

Rapagao

- Based on the maps prepared using the SDWIS database, the following observation was made:
  - The average nitrate levels in the upper aquifer generally range from 2 to 5 mg/L.
  - Average chloride levels in the upper aquifer generally range from 500 to 790 mg/L with a low of 246 mg/L reported in one well and a high of 1,434 mg/L reported in another well.
  - Generally the area has elevated coliform levels compared to other areas with 36 to 61 percent of samples collected reporting positive for coliform.
  - Generally the area has slightly elevated *E. coli* levels compared to other areas with 9 to 21 percent of samples collected reporting positive for *E. coli*.

San Vicente

- The area consists of densely located homes served by septic systems. Mapping based on SDWIS data shows that groundwater in this area exceeds the half-MCL for nitrate of 5 mg/L.

Tinian

- There is the potential for high chloride levels resulting from saltwater intrusion into the freshwater basal lens aquifer due to excessive pumping.
- Underground storage tanks (USTs) and above-ground storage tanks (ASTs) for fuel and chemicals provide a potential source of groundwater contamination.
- One leaking UST (LUST), the Mobil Tinian Bulk Fuel Storage Facility (Facility Registration System ID# 110043671354) located in the San Jose area on Tinian, had a documented petroleum release impacting groundwater according to an article in the Saipan Tribune dated May 2002 (also noted on EPA's Facility Registry Service Facility Detail Report (2014a). The Bulk Fuel terminal distributes Jet A-1, gasoline, and auto diesel fuels. According to the CNMI Bureau of Environmental and Coastal Quality (BECQ) September 2014 Water Quality Report, the petroleum release has been addressed.
- UXO and munitions constituents associated with the Emo Tinian UXO Treatment Disposal Site (EPA Registry ID# 1100117775077) present a potential groundwater contaminant source if chemicals related to munitions and explosives migrate into groundwater sources. According to the EPA's Enforcement and Compliance History Online website, no violations have been reported at this facility (USEPA, 2014b). Additionally, the North Field air field was used during World War II and may contain a potential groundwater contamination source associated with UXO, munitions constituents, metals, and petroleum fuels associated with military activities up to 1947. In 2013, the United States Marine Corps performed a demonstration exercise on the North Field with a potential for petroleum fuels to affect groundwater.
- The U.S. Marine Forces Pacific (MARFORPAC) has submitted a proposal to establish an expeditionary-type base for live-fire ranges and training areas. The proposal would include live-fire training on approximately 15,353 acres of military-leased lands owned by the Department of

Defense (DoD). This proposal if carried out could create potential groundwater contaminant sources associated with military activities as follows: UXO and explosives hazards, munitions constituents, petroleum/oil/lubricant (POL) releases, metals leaching into groundwater, chlorinated solvents releases, leaky septic systems, landfill leachate leaks, and overpumping of freshwater creating elevated chloride levels (Navy, 2014). The U.S Pacific Command is preparing a CNMI Joint Military Training (CJMT) Environmental Impact Statement/Overseas Environmental Impact Statement to assess the proposed risks in accordance with the National Environmental Policy Act (NEPA) before a decision is reached. Based on the available data researched online, the expeditionary base has not been approved or constructed.

- Various sites of potential environmental concern were identified in the CNMI Joint Military Training Utilities Study. The pertinent information and maps are included as Appendix F.
- Fertilizer and pesticide application during current and historical activities provides a potential groundwater contaminant source. An unknown amount of fertilizer and pesticides were stored at the Bio Pacific Company inside the military-leased area in the North Field of Tinian (Navy, 2014). Historical activities at the Micronesian Development Company in 1990 indicated several chemicals including pesticides were inventoried and may have been applied to cattle grazing area (Navy, 2014). Small farms outside the military-leased area would use fertilizer and pesticides for crops, which could infiltrate into groundwater sources.
- Septic systems provide a potential contaminant source to groundwater especially when installed directly into limestone beneath the thin soil horizons that are common in most developed areas of Tinian.
- Total coliform was detected in two samples taken in September 2010 and November 2011. Inappropriate sample taps and leaks were thought to be the cause of the coliform detections. In 2012, no coliform bacteria were detected (CNMI Joint Military Training Utilities Study, 2014).
- Groundwater sampling conducted between 2010 and 2012 did not detect any other Safe Drinking Water Act violations other than the total coliform discussed above (CNMI Joint Military Training Utilities Study, 2014).

Rota

- According to the September 2014 Water Quality Report published by BECQ, there are no known groundwater contamination issues on the island of Rota.
- Septic systems installed directly in limestone beneath the thin soil horizons common to most developed areas in Rota are a potential source of groundwater contamination including nitrate and bacteria. In the Sinapalu area, where CUC’s three groundwater wells are operated, the ground surface is close to 600 feet above the water table. It is thought that this provides a greater degree of protection against such contamination than areas of lower elevation, such as those in Saipan and Tinian, where nitrate levels due to septic systems installed in similar soils and geology can exceed the MCL. However, there are not enough data to verify this for Rota.

Non-revenue Water (Loss/Leakage)

Sources of water loss and leakage are based on information previously presented in this Groundwater Management and Protection Plan.

Saipan

As previously presented, once the water from the groundwater supply wells enters the distribution system, it is categorized as either metered or non-revenue water. Metered water is water consumed by an end user that has been measured through the use of a water meter. Metered account charges for customers are based on set rates and total consumption, and generate income for the utility. Non-revenue water is the water that does not generate any income and is considered “lost” in the system. Lost water can mean many different things but it is normally defined as:

- Leaks. Either due to damaged pipes, improper connections, or faulty appurtenances.
- Non-metered customers. Customers that are legally connected to the distribution system that do not have a meter installed at the point of use but rather pay a bulk water charge. Agricultural use is an example of much legal non-revenue water use.
- Illegal connections (theft). People illegally connect to the system at some point along the distribution system.
- Broken or unread meters. Meters that are estimated because they are either broken or not read on a monthly basis.
- Overflowing tanks can be caused by faulty control valves at tanks, faulty or no pump controls tied to tank levels, or overproduction of water, such as the case with the Rota water caves during peak wet season.

Table 10 presents a summary of the 2011 production, metered, and non-revenue water at each of the TSAs. Non-revenue water represents a large percentage, nearly 75 percent, of total water production on Saipan alone and 73 percent on Saipan, Rota, and Tinian overall. Most of the water used for agriculture is not metered, therefore, a portion of the non-revenue water can be accounted for by agricultural use although the exact amount is unknown. For CUC to be able to eliminate the need for additional groundwater exploration, it is imperative that the non-revenue water problem be rectified. This will result in CUC being able to provide adequate water through 2030, and the utility will save a significantly in energy costs that were associated with pumping lost water multiple times.

Table 10. **CUC Production and Meter Data for Saipan**

	Production Data (gpm)					**Unaccounted for Water Demands**	
Tank Service and Direct Feed Areas	**2011 Sept**	**2011 Oct**	**2011 Nov**	**Average**	**Meter Data (gpm)**	**Average Month**	**Worse-Case Month**
Marpi	395	395	290	360	101	72%	74%
Capitol Hill/Agag	655	658	799	704	130	82%	84%
Agag	392	399	455				
Capitol Hill	263	259	344				
Calhoun	163	0	275	219	183	16%	33%
Puerto Rico	1111	972	916	1000	125	87%	89%
Rapagao	1015	854	868				
Puerto Rico	96	118	48				
Gualo Rai	62	136	90	96	61	36%	55%
Kagman	502	502	453	486	154	68%	69%
Duenas Well	96	94	96	95	30	69%	69%

Table 10. **CUC Production and Meter Data for Saipan**

Tank Service and Direct Feed Areas	Production Data (gpm) 2011 Sept	2011 Oct	2011 Nov	Average	Meter Data (gpm)	Unaccounted for Water Demands Average Month	Worse-Case Month
Papago (Kumoi)	216	300	277	264	72	73%	76%
Kannat Tabla	692	692	993	792	212	73%	79%
Booster I Sump	123	123	135				
Kannat Tabla	569	569	858				
Isley	1379	1465	1355	1400	394	72%	73%
San Vicente	641	657	568	622	155	75%	76%
DD-8	70	69	75				
IF 105	80	86	86				
San Vicente	491	502	407				
Koblerville	193	194	189	192	127	34%	35%
Dan Dan	819	769	799	796	117	85%	86%
Unknown	N/A	N/A	N/A	N/A	267	N/A	N/A
Totals (gpm)	**6924**	**6834**	**7100**	**6953**	**2128**	**69%**	**70%**
Totals (MGD)	**10.0**	**9.8**	**10.2**	**10.0**	**3.1**		

Notes:
(1) Tank Service Areas are shown in bold; direct feed wells are presented in regular font.

Tinian

As previously presented, groundwater on the island of Tinian is pumped from the Maui II well where it is disinfected before being sent to the half-million gallon tank (HMT) and then to customers in the distribution system. The amount of water produced is measured using a flow meter installed at the Maui II site. This meter is manually read at various times during the month. Once the water enters the distribution system, it is categorized as either metered or non-revenue water.

Table 11 presents a summary of the production, metered, and non-revenue water for the Tinian tank service areas (TSAs). Non-revenue water represents a large percentage, nearly 75 percent, of total water consumed in Tinian.

Table 11. **CUC Production and Meter Data for Tinian**

Month Year	Monthly Billing Gallons	Production Gallons	Daily Billing (gal)	Daily Production (gal)	Average Billing GPM	Average Production GPM	Percent Unmetered
Oct-11	7,191,030	24,549,900	239,701	818,330	166	568	71%
Nov-11	7,673,927	25,211,800	255,798	840,393	178	584	70%
Dec-11	7,567,859	27,854,200	252,262	928,473	175	645	73%

Month Year	Monthly Billing Gallons	Production Gallons	Daily Billing (gal)	Daily Production (gal)	Average Billing GPM	Average Production GPM	Percent Unmetered
Jan-12	7,380,133	29,859,600	246,004	995,320	171	691	75%
Feb-12	7,354,985	30,340,400	245,166	1,011,347	170	702	76%
Mar-12	6,910,581	30,020,300	230,353	1,000,677	160	695	77%
Average	**7,346,419**	**27,972,700**	**244,881**	**932,423**	**170**	**648**	**74%**

Rota

Groundwater collected from the Main Cave can be transmitted to the Kaan Tank, and simultaneously to the Ginalangan tank, along with discharge from the Onan cave, and then distributed to customers within each distribution system during the wet season. During the dry season, water from both caves is limited and transmitted only to the Ginalangan Tank. During the rainy season, production from the caves is often much higher than demand, and considerable tank overflow can occur, accounting for some of the non-revenue water (this is not metered presently and cannot be quantified).

The three groundwater wells located in the Sinapalo Homestead area can also supply the Ginalangan Tank with source water. Disinfection for the Ginalangan Tank service area is provided along the Onan Cave transmission line in order to serve customers between the Onan Cave and Ginalangan Tank. The amount of water produced is measured using flow meters installed at the Main Cave, Onan Cave, and each of the three water wells. These meters are manually read at various times during the month, and those values are combined to measure the overall water production for all of Rota during a given time period. Once the water enters the distribution system, it is categorized as either metered or non-revenue water. See the previous section for a description of metered and non-revenue water.

Table 12 presents a summary of the production, metered, and non-revenue water in Rota. Non-revenue water represents a large percentage, nearly 83 percent, of total water production.

Table 12. **CUC Production and Meter Data for Rota**

Month-Year	Monthly Billing Gallons	Production Gallons	Daily Billing (gal)	Daily Production (gal)	Average Billing GPM	Average Production GPM	Percent Unmetered
Oct-11	5,840,235	34,804,754	194,675	1,160,158	135	806	83%
Nov-11	6,340,637	34,804,754	211,355	1,160,158	147	806	82%
Dec-11	6,120,989	34,804,754	204,033	1,160,158	142	806	82%
Jan-12	6,049,549	34,804,755	201,652	1,160,159	140	806	83%
Mar-12	5,579,661	34,804,755	185,989	1,160,159	129	806	84%
Average[1]	**5,986,214**	**34,804,754**	**199,540**	**1,160,158**	**139**	**806**	**83%**

1. The date provided for February 2012 indicated a negative value for the amount billed this month. This was an apparent error in the information provided and was not used for this analysis.

Wellfield or Source Protection Management Strategies, including Improvement of Overall Groundwater Quality and Recommendations

The following sections outline the water quality and wellhead protection standards developed to protect groundwater resources and identify the wells that are not in compliance with these standards.

Drinking Water Quality Standards

The well water quality database dated June 23, 2014 provided by CUC was reviewed and compared to the BECQ drinking water quality standards. The results are presented in Appendix C, and wells that exceed certain parameters are highlighted. It is important to remember that the majority of the wells no longer directly feed into the distribution system with the completion of the well consolidation program. The compliance point now is where the blended wells enter the system. This has completely eliminated all historical problems with nitrate MCL violations.

Wellhead Source Protection

Wellhead protection areas around all public and non-public water supply wells are defined in Section 6 of the DEQ Well Drilling and Well Operation Regulations. The well siting criteria require all new public and non-public water supply wells to be set back a specified distance from potential sources of contamination. The setback distances define the wellhead protection area.

As a part of development of this Drinking Water Master Plan, the project team, in consultation with CUC, selected 43 wells and springs to inspect as part of the Water Master Planning Project. Based on an inspection of each well site, the wells were assigned an overall rating to represent the condition of the wells. The overall rating was based on the number of areas where deficiencies were identified as depicted in Table 2.2.3-2 of the Drinking Water System Master Plan for Saipan (DCA/CH2M, 2013a). The well condition was rated on a scale of 1 to 4: Low (1), Moderate (2), High (3), and Severe (4). Wells with the fewest number of severe repairs needed received Low scores, while those with the greatest number of severe repairs needed received High and Severe scores.

As a result of the inspections, deficiencies were noted with the above grade improvements including the wellhead seals at many well sites. See Section 2.2.3 of the Drinking Water System Master Plan for Saipan (DCA/CH2M, 2013a) for the detailed assessment of the well sites and recommendations.

In addition, it has been reported that a few wells not improved under the Federal Emergency Management Agency (FEMA) grants still exist around the airport, Obyan, and Isley areas. These wells are within the airport or on Commonwealth Ports Authority leased property, thus gaining access is an issue.

Projects/Programs to Restore Groundwater Quality

This section responds to paragraph B4.67.b, “Groundwater Restoration,” of the Stipulated Order by providing recommendations to protect groundwater supplies as well as to slow or reverse the trend of increasing salinity concentrations in the basal aquifers.

Well Site Assessment Recommendations

Maintaining a high level of integrity in the aboveground facilities and sanitary seals is the best approach to eliminating contamination associated with wellhead failures. Two recommendations going forward are as follows:

- Continue the well site assessments of all remaining well sites to develop complete condition assessments and recommendations.
- Improve or abandon/seal the non-improved wells to avoid potential sources of contamination due to inadequate well sites and wellhead protection.

Maintenance Program Recommendations

It was reported by CUC Operations staff that its maintenance program consists of the monthly readings at each of the well sites, which are included as Appendix A. In 2005, a more thorough check on the downhole equipment was started, but it does not appear that this work was completed. It was also reported that CUC does not own the proper equipment to pull the submersible pumps and motors, but instead relies on Water Task Force personnel to conduct the work. The WTF personnel are technically CUC employees and the equipment is owned by CUC. ***It is recommended that the Water Task Force crew and equipment be reassigned to CUC so that it may perform the required and recommended maintenance on a more efficient, frequent, and regular basis.***

In addition, an O&M plan should be developed for all groundwater supply wells and associated equipment. Proper maintenance is important for proper upkeep and to increase the operational lifespan of equipment. This section presents a summary of typical maintenance procedures for specific equipment; however, detailed information should be acquired from the related vendor and/or manufacturer manuals for each piece of equipment.

Submersible Pumps and Motors. There are 147 wells that make up CUC's groundwater supply. Of these 147, 140 are noted to be operational and are equipped with submersible pumps and motors.

The operating instructions should include recommendations to monitor and record the pumping water levels, yield, and discharge pressures; never run a pump against a closed valve for more than 1 minute; follow the manufacturer's specifications for pump operation; and repair the pumps or motors as soon as problems are detected to extend the pump operating life.

Startup procedures should include recommendations to verify that all valves are open on the discharge line, run the pumps in local mode to verify pumping parameters are normal, verify that water is flowing through the pump, verify the run lights turn ON for the pumps, and check the operating pressure to verify that it is normal. The primary purpose of these procedures is to verify that the pump is operating normally and is not pumping against a closed valve. After a long-term shutdown, it is recommended that all startup procedures be performed again to verify that all equipment in the field is operating normally.

Preventative maintenance recommendations include following a proper maintenance schedule and the manufacturers' guidelines for pump and motor equipment operations, and checking the electrical system. The following should be checked on regular basis and according to manufacturer's specifications: motor currents, motor voltages, motor insulation resistance, flow, pressure, running time, on/off pump cycle, power consumption, wire-to-water efficiency, static water level, pumping water level, water sand content, and well-specific capacity.

Valves. The valves at the wellheads include small ball valves, gate valves, air and pressure relief valves. All valves are manually operated valves. It is generally recommended that valves in the system be regularly exercised to extend the operable life of the valves and maintain operability during ongoing procedures. Typical manufacturer recommends exercising valves every 30 days.

However, it is important that the isolation valves in the system are not closed completely during system operation and that system pressure is monitored during all valve operations. Generally the valves should be exercised when the system is not operating and is at zero flow.

Control Panels. All well site control panels should be inspected on a weekly basis to verify the integrity of the control panel and look for any leakage or indication of equipment failure. Annual removal of any accumulation of dirt and dust from the panel is recommended, as well as removal of dirt and dust from the panel lighting and replacement of light bulbs as needed. Maintenance should be performed as needed or documented during the weekly inspections to be performed on subsequent visits to maintain proper equipment operation and safe working conditions.

Electrical. Typical manufacturer instructions recommend periodic checking of switches, fuses, oil levels in transformers (if applicable), and transformer placement (tilting), and periodic visual inspections of the general condition of the electrical components in addition to periodic cleaning.

CUC is planning to implement a computerized maintenance management system (CMMS) by VueWorks in 2015. The wells should be incorporated into this system as quickly as possible, and written standard operating procedures and maintenance practices should be developed.

Sustainable Withdrawal of Groundwater Resources

This section responds to paragraph B4.67.d, “Sustainable Withdrawals of Groundwater,” of the Stipulated Order. It is extremely important for CUC to optimize the pumping frequencies and withdrawals from each of the wellfields to provide a sustainable water supply in both quantity and quality.

Table 13 summarizes the estimated sustainable yield of freshwater per groundwater basin compared to the total pumping capacity from CUC wells and the additional capacity of all other wells permitted by DEQ on the island of Saipan. As summarized, five of the 11 groundwater areas are being over-pumped when compared to the estimated sustainable yield. These areas correlate with the areas that have higher chloride concentrations.

Table 13. Estimated Freshwater Yield and Withdrawals per Groundwater Basin

Ground-water Area	CUC Wellfields Located in Groundwater Area[1]	Available Water with <500 mg/L Chloride (gpm/mgd)	Total CUC Well Capacity (gpm/mgd)	Total Capacity Other Wells Permitted by DEQ (gpm/mgd)	Net Difference (gpm/mgd)	Water Quality Notes
I	None	69/0.1	0/0	2,986/4.3	-2,917/-4.2	High chlorides
IIb	Kagman	1,389/2.0	880/1.3	278/0.4	208/0.3	Some high chlorides High nitrate
IIc	Isley Koblerville (including Maui I) Obyan	2,778/4.0	3,785/5.5	347/0.5	-1,354/-1.9	Some high chlorides High nitrate
IIIa	None	69/0.1	0/0	0/0	69/0.1	

Table 13. Estimated Freshwater Yield and Withdrawals per Groundwater Basin

Ground-water Area	CUC Wellfields Located in Groundwater Area[1]	Available Water with <500 mg/L Chloride (gpm/mgd)	Total CUC Well Capacity (gpm/mgd)	Total Capacity Other Wells Permitted by DEQ (gpm/mgd)	Net Difference (gpm/mgd)	Water Quality Notes
IIIb	Marpi Quarry	208 to 347/ 0.3 to 0.5	428/0.6	278/0.4	-359 to -498/- 0.5 to -0.7	High Chlorides
IIIc	None	208/0.3	0/0	28/0.04	180/0.3	Low chlorides and nitrate
IIId	Calhoun Gualo Rai Puerto Rico Chalan Kiya (Duenas) Sablan	347 to 521/ 0.5 to 0.75	1,153/1.7	625/0.9	-1,257 to -1,431/-1.8 to -2.1	Some high chlorides Some moderate nitrate
IVa	None	139 to 208/ 0.2 to 0.3	0/0	0/0	139 to 208/ 0.2 to 0.3	High chlorides
IVb	Capitol Hill Agag	1,389/2.0	932/1.3	56/0.08	401/0.6	Good water quality
V	No Wells (Donni Springs)	1,042/1.5	250/0.4	208/0.3	584/0.8	Low chlorides and nitrates
VIb	Dan Dan San Vicente	347/0.5	403/0.6	42/0.06	-98/-0.1	Some high chlorides Some moderate nitrate
TOTALS		**7,986 to 8,368/ 11.5 to 12.05**	**7,901/11.4**	**4,847/6.98**	**-4,380 to -4,762/ -6.3 to -6.9**	

[1]Modified from Water Master Plan, 1996.

The estimated freshwater sustainable yield per groundwater basin is based on available information obtained from the 1996 Saipan Water Master Plan (Winzler and Kelly Consulting Engineers). An attempt was made by CH2M to update these estimates based on the wellfield data provided by CUC and other available publications; however, the discrepancies and gaps in the wellfield data made this effort impossible.

Transmissivity data are needed to calculate spacing between wells so they do not interfere with each other. Well yield and spacing need to be verified and, most importantly, the depth to the seawater interface needs to be known.

CUC pumping rates dated March 2014 were provided by CUC Operations staff and are included in Appendix A. DEQ permitted wells and permitted capacities were provided by DEQ in a Microsoft® Excel® database titled, “GWUsage_non_CUC_Wells_DEQ.”

Sustainable Withdrawal Programs

Programs that should be considered to manage groundwater withdrawals and optimize groundwater quality are summarized below. Each program would be affected by the results from the other programs, and they are not listed in any particular order for completion.

The additional data recommended in "Wellfield Investigation and Assessment" above is required prior to finalizing the recommendations presented in Program 1.

Program 1: Modification to Existing Wells

CUC provided a list of 13 wells that should be considered for replacement/re-drilling due to various factors including issues with wells being located on private lands, lease agreements, shallow groundwater, and overall condition of the well.

In addition to the wells identified by CUC, select well pumping rates could be reduced to minimize overpumping and improve the overall water quality of the individual tank service areas. Two methodologies for determining the wells that should be targeted for reduced pumping rates are discussed below.

Analytical Calculation

First**,** an attempt was made to calculate the sustainable pumping rate that would produce freshwater on a well-by-well basis. The methodology required first estimating the salt water interface using the best available information, which was obtained from *Groundwater Resources of Saipan* (Carruth, 2003). The hydraulic conductivity for each well was then calculated using the pumping rates and estimated drawdown in wells observed at that pumping rate based on the information provided by CUC (Appendix B). A simple calculation was used to determine the specific capacity of the wells. An analytical solution for upconing of freshwater and seawater below pumping wells was then utilized to try to estimate an associated pumping rate that would not cause upconing (Schmorak and Mercado, 1969). The basic equation for seawater rise beneath a well is as follows:

$$Z = \frac{\mathrm{Q}}{2 * \mathrm{pi} * \left(\frac{\rho}{\rho \mathrm{f}}\right) * \mathrm{P} * \mathrm{d}} * \left(1 - \frac{1}{(1+Y)}\right)$$

With:

Z = Rise of the seawater interface

Q = Well pumping rate

P = Horizontal hydraulic conductivity

Pv = Vertical hydraulic conductivity

d = Distance from bottom of well screen and salt water interface

Y = $\frac{(\rho/\rho f) * \mathrm{Pv}}{2 * n * d} * t$

ρ = Density of seawater

$\rho \mathrm{f}$ = Density of freshwater

t = Time of pumping

n = porosity

It is thought that the hydraulic conductivity values calculated were inaccurate due to the simplicity of the method of calculation. The method used was an approximation based on the wells' specific capacity, and a very wide range of specific capacities were seen in some of the wellfields. The calculation did not produce consistent recommendations or results.

To perform this evaluation in the future, the following needs to be confirmed or collected as outlined in "Wellfield Investigation and Assessment":

- Depth to saltwater interface
- Hydraulic conductivity of the wellfield areas
- Static and pumping water levels

Once these data have been collected and confirmed, the optimal pumping rate, pump setting depth, and well depth to produce freshwater for each individual well could be estimated and compared to existing conditions.

General Approach

To provide guidance to CUC regarding operation of the water supply wells, existing well information was reviewed by wellfield and, overall, a more general approach was taken.

First, individual well depth and static water levels were compared to sea levels. Pumping rates, the wellfield location relative to the coast, and general well spacing were reviewed and then compared to the chloride concentrations produced by each well. Observations were made relative to pumping rates, well locations, and well depths that may be causing elevated chloride concentrations in individual wells.

Upconing is related to well depth, pumping rate, and the distance from the screen bottom to the sea water interface. Moving a well pump should not affect the amount of upconing beneath a well. However, in existing wells that have long screen lengths (i.e., greater than 20 feet), setting the pump higher may improve water quality. Upconed water will tend to enter the well screen near the bottom. A well may produce more water from an area in the well screen if the pump suction is set adjacent to the screen interval. Raising the pump in wells where this condition exists could somewhat improve the produced water quality.

Candidates for further investigation for raising the pump were selected from the available data as those wells that produce chloride concentrations greater than 1,000 mg/L, and have well screens 20 feet or longer. The available data on pump settings and pumping water level were not used as much of this data may not be accurate. In some wellfields, for example, many of the wells had identical pumping water levels and some of these were below the reported pump setting. Candidates for raising the pump in an attempt to lower the produced water chloride concentrations are included in the discussion below.

These observations are discussed by wellfield below. Possible well modifications to reduce elevated chloride concentrations are discussed in addition to the wells CUC identified for replacement or re-drilling; this information is summarized in Table 14.

Marpi Quarry. The wells that exist in the Marpi Wellfield are generally completed 10 to 30 feet below sea level; however, one well, MQ-1, is completed 26 feet above sea level. Static water levels generally appear to be 1 to 7 feet below sea level. Three wells—MQ-5, MQ-13 and MQ-15—have static water levels reported 1 to 2 feet above sea level; Well MQ-1 has a static water level of 37 feet above sea level based on the ground surface elevations and static water level depths provided by CUC (see Appendix B). These static water levels suggest that only a very thin freshwater lens exists in this area. Pumping rates range from 20 to about 50 gpm, with Well MQ-1 reportedly pumping 125 gpm. Average chloride concentrations produced from the wells range from approximately 1,000 to 2,700 mg/L and suggest the groundwater in this area is generally of poor quality. A possible modification to lower the produced chloride concentrations would be to determine whether the pump should be raised in Wells MQ-5 and MQ-12.

CUC noted that Well MQ-12 is located on private land and thus may also be considered for replacement.

Puerto Rico. The two wells in the Puerto Rico Wellfield (162 and 164) are generally completed 20 to 30 feet below sea level. Static water levels appear to be 1 to 3 feet above sea level, suggesting a freshwater lens exists in this area. Pumping rates for PR-162 and PR-164 are reported to be 0 and 43 gpm, respectively, and the chloride concentrations produced from the wells ranged from 950 to 1,300 mg/L.

The Puerto Rico wells are located about halfway between the Sablan Quarry Wellfield and the west coast of Saipan and are similar to the Sablan Quarry wells in well bottom elevations and pumping rates. However, the Sablan Quarry wells generally produce lower chloride concentrations.

Puerto Rico Well 162 was determined to be GWUDI, and the well has been abandoned and sealed. This abandoned well may be replaced. It would appear that modifications to the remaining Puerto Rico well would not significantly lower the chloride concentrations as it may be located too close to the coast.

Sablan Quarry. Ten of the 11 wells that exist in the Sablan Quarry Wellfield are generally completed from 4 feet above to 40 feet below sea level. Static water levels appear to be 0.5 below to 7 feet above sea level, with one well, RP-1, reporting a static water level of 22 feet above sea level, suggesting a freshwater lens exists in this area. Pumping rates range from 30 to about 50 gpm. Chloride concentrations produced from these nine wells range from 250 to 700 mg/L.

One other well, SQ-150, exhibits higher chloride concentrations, about 1,430 mg/L, respectively. The depth of Well SQ-150 is reported to be about 133 feet below sea level, and the pumping rate is much higher than the other wells at 195 gpm. Modifications that may lower the chloride concentration in Well SQ-150 would include lowering the pumping rate and plugging back the well to a shallower depth.

CUC has noted Wells SQ-7, SQ-9, SQ-11, and SQ-13 are under lease agreements that CUC intends to terminate, thus these wells may be considered for replacement.

Calhoun. The two wells that exist in the Calhoun Wellfield are completed approximately 20 feet and 30 feet below sea level. Static water levels appear to be 6 to 8 feet above sea level, suggesting a freshwater lens exists in this area. Pumping rates for CL-2 and CL-5 were reported to be 75 and 160 gpm, respectively. Chloride concentrations produced from the wells are seen to be 1,099 mg/L and 646 mg/L, respectively. The Calhoun wells are located a similar distance from the coast as the Sablan Quarry Wellfield. Modifications that may lower the elevated chloride concentrations of Well CL-2 would be to lower the pumping rate or plugging back the well to a similar depth as CL-5.

Gualo Rai. The four wells that exist in the Gualo Rai Wellfield are generally completed 3 feet to 24 feet below sea level. Static water levels appear to be about 2 to 4 feet above sea level, suggesting a freshwater lens exists in this area. Pumping rates range from 30 to about 45 gpm. Chloride concentrations produced from these wells range from approximately 220 to 2,430 mg/L. Wells GR-154 and GR-4 have the highest chloride concentrations at 2,428 and 863 mg/L, respectively, with the remaining two wells GR-5 and GR-151 being below 500 mg/L in chloride concentration. A possible modification to lower the chloride concentrations produced from GR-4 would be to lower the pumping rate. GR-154 and GR-151 are located the closest to the coast in this wellfield, and GR-154 pumps at a slightly higher rate than GR-151. Possible modifications to lower the chloride concentration in GR-154 would be to reduce the pumping rate and investigate if the pump could be raised. If these failed to lower the chloride concentrations, consideration should be given to abandoning the current location and moving this well inland closer to GR-4 and GR-5.

Capitol Hill. The wells that serve the Capitol Hill Wellfield are located in a high-level limestone aquifer and not a basal aquifer. This high-level limestone aquifer produces fresh water and production should follow normal procedures for an inland-type aquifer, that is, pumping from the aquifer should not exceed recharge to the basin. Pumping should be redistributed and rates modified to eliminate long-term groundwater level declines. Well TP-1 is listed as operating on level control and turns off at a set level. This well has a low yield and should be considered for replacement.

Agag. The wells that serve the Agag Wellfield are located in a high-level limestone aquifer and not a basal aquifer. This high-level limestone aquifer produces fresh water and production should follow normal procedures for an inland-type aquifer, that is, pumping from the aquifer should not exceed recharge to the basin. Pumping should be redistributed and rates modified to eliminate long-term groundwater level declines. Well AG-45 is listed as operating on a float switch. This well has a low yield and should be considered for replacement.

CUC has noted that Well AG-31B has been pumping brown muddy water and has a low yield, thus it may be considered for replacement.

Kagman. Of the 19 wells that exist in the Kagman Wellfield, 5 wells are located in the far west part of the wellfield, and 14 wells are located further east. The western wells—KG-2, KG-3, KG-4, KG-6, and KG-131—are generally completed 28 feet to 146 feet below sea level. Static water levels in the west wells appear to be about 8 to 15 feet above sea level, suggesting a freshwater lens exists in this area. Pumping rates range from 20 to about 230 gpm. Chloride concentrations from these wells are between 670 and 2,720 mg/L. The westernmost wells in the Kagman Wellfield are completed into the Tagpochau Limestone and are confined by the Donni Sandstone member.

The 14 wells further east are generally completed 4 feet to 16 feet below sea level with one well, KG-22, reportedly completed 7 feet above sea level. Static water levels in these west wells appear to be about 1 to 12 feet above sea level, suggesting a freshwater lens exists in this area. Pumping rates range from 12 to about 50 gpm. Chloride concentrations from 12 of the wells are between 300 and 530 mg/L However, Wells KG-11 and KG-12, which are closer to Laulau Bay, produce water with chloride concentrations over 1,000 mg/L. The easternmost wells in the Kagman Wellfield are completed into the Mariana Limestone.

The possible modification to lower the chloride concentrations in wells KG-3, KG-4, KG-6, and KG-131 would be to reduce the pumping rate. KG-6 and KG-131 are the furthest downgradient of those wells completed into the Tagpochau Limestone in the Kagman wellfield. Lower pumping rates should also be considered for Wells KG-11 and KG-12 as they are thought to have a stronger possibility of causing chloride concentration to rise in nearby wells. Additional possible modifications to lower the produced chloride concentrations would be investigating if the pumps in Wells KG-3, KG-4, KG-6, KG-11, KG-12, and KG-131 could be raised.

Chalan Kiya. One well makes up the Chalan Kiya Wellfield: the Duenas well. The well is listed as producing water at 85 gpm in the 2013 Master Plan, (DCA/CH2M, 2013a). Information received from CUC indicates the produced water has a chloride concentration of 2,265 mg/L. Additional data related to depth and screen interval for this well were not provided in CUC's well data spreadsheet (Appendix B). It has been reported by CUC that this well has been shut down following completion of a project that put its area under gravity feed from the Kannat Tabla tank service area. CUC has no plans to reactivate this well. If additional capacity is needed in this area, this well may be considered for replacement.

San Vicente. Six wells make up the San Vicente Wellfield. Three of the wells, AS-1, AS-2, and AS-5, are located about halfway between the Koblerville Well Field and Wells SV-1, SV-2, and SV-7, which are at a higher elevation about 1,000 feet to the northeast. The three AS wells that exist in the San Vicente Wellfield are generally completed 11 to 29 feet below sea level. Static water levels appear to range from 3 feet above to 2 feet below sea level. Pumping rates range from 48 to about 67 gpm. Chloride concentrations produced from these wells are less than 500 mg/.

The three SV wells that exist in the San Vicente Wellfield are generally completed 10 feet above to 11 feet below sea level. Static water levels appear to range from 2 feet to 27 feet above sea level. Pumping rates range from 0 to about 55 gpm. Chloride concentrations produced from the wells range from 480 mg/L and 825 mg/L.

Five of the wells produce water with a chloride concentration less than 500 mg/L. Well SV-7 produces water with a chloride concentration of 824 mg/L. There is no obvious reason that Well AS-5 has acceptable chloride levels and the others are elevated. A potential modification to lower the chloride concentrations in Well SV7 would be to lower the pumping rates.

CUC noted that Wells SV1 and SV2 have been abandoned as the lease agreements for these wells have been terminated; as such, these wells may be considered for replacement.

Dan Dan. The three wells that exist in the Dan Dan Wellfield are generally completed 9 to 15 feet below sea level. Static water levels appear to be 1 to 2 feet above sea level, suggesting a freshwater lens exists in this area. Pumping rates range from 52 to about 78 gpm. Chloride concentrations produced from the wells range from 649 to 1,212 mg/L. A potential modification to lower the chloride concentrations in Well DD-7 would be to lower the pumping rate.

Koblerville. The 15 wells that exist in the Koblerville Wellfield (not including Maui I) are generally completed 12 to 29 feet below sea level. Static water levels appear to range from approximately 4 feet above to 4 feet below sea level, suggesting a freshwater lens exists in this area. Pumping rates range from 25 to about 75 gpm. Chloride concentrations produced from the wells range from about 370 to 1,500 mg/L.

KV-13, KV-22, KV-23, KV-24, KV-25 may be experiencing upconing. To lower the chloride concentration of the produced water, lower pumping rates could be tested. Well KV-16 and KV-111 are listed as operating on level and they turn off at a set level. These wells apparently have a low yield and should be considered for replacement.

Isley Field. Thirty-two wells exist in the Isley Field Wellfield. The wells are generally completed between 4 feet to 36 feet below sea level; however one well, IF-105, is completed 51 feet below sea level. Static water levels mostly appear to be 1 to 4 feet below sea level, suggesting a freshwater lens exists in this area; however, four wells have a static water level that is slightly below sea level and one well has a static water level about 9 feet below sea level. Pumping rates range from 0 to about 82 gpm, with most of the wells pumping about 40 to 50 gpm. Chloride concentrations produced from the wells range from 161 to over 3,700 mg/L, with 18 of the 32 wells exceeding 1,000 mg/L chloride concentrations and three of those 18 wells exceeding 2,000 mg/L. It is suspected that the large amount of pumping and the high density of wells in this area have resulted in area-wide upconing. Possible modifications to reduce the chloride concentrations will involve reducing pumping from this wellfield and investigating if the pump could be raised in Wells IF-1, IF-3, IF-6, IF-7, IF-12, IF-16, IF-18, IF-19, IF-102, IF-217 and IF-220, and if wells IF-101, IF-105, IF-106, IF-201, IF-202, IF-204, and IF-205 could be plugged back to depths similar to the other wells in the field and if the pumps are raised.

CUC noted that Wells IF-4 and IF-20 have been abandoned due to shallow water. The Water Task Force tried to rehabilitate Well IF-4 but was unsuccessful. These two wells may be candidates for replacement.

CUC also noted that the casing of Well IF-28 was in very poor condition due to rusting and scaling, and therefore it should be considered for replacement. Well IF-28 produces water with an average chloride content of 210 mg/L and at a relatively high production of close to 80 gpm. The well may in fact be producing from a parabasal portion of the aquifer where a ridge of volcanic basement rises to near sea level as indicated by nearby well logs. As such, Well IF-28 is one of the best wells in this wellfield and should be prioritized for rehabilitation or replacement as near to its current location as possible.

Obyan Field. Twenty-four wells exist in the Obyan Field Wellfield. The wells are generally completed between 9 and 22 feet below sea level with one well, OB-18, completed to 73 feet below sea level. Static water levels mostly appear to be 3 feet below to 2 feet above sea level with seven wells reporting static water levels 1 to 4 feet below sea level. Pumping rates range from 30 to about 60 gpm. Chloride concentrations produced from the wells are all less than 1,000 mg/L. However, three of the wells, OB-1, OB-9, and OB-16, produce chloride concentrations over 900 mg/L.

The Obyan Field Wellfield is adjacent to the Isley wellfield, but produces much lower chloride concentrations. This is likely attributed to the relative density of wells in the two wellfields. If the area each of these two wellfields is compared, the Obyan Wellfield occupies about 10 percent more area than the Isley Wellfield and has 25 percent fewer wells.

A potential modification to wells OB-1, OB-9, and OB-16 to lower the produced chloride concentrations would be to reduce the pumping rates in those wells.

Table 14. **Potential Modifications to Selected Wells to Lower Produced Chloride Concentrations**

Wellfield Name	Wells	Potential Modification
Marpi Quarry	MQ-5, MQ-12	Investigate whether the pumps could be raised. MG-12 may also be consider for replacement because the well is located on private land.
Puerto Rico	PR-162	Consider for replacement. This well was abandoned due to GWUDI determination.
Sablan Quarry	SQ-150	Consider lowering the pumping rate; consider plugging back the well.
	SQ-7, SQ-9, SQ-11, SQ-13	Consider for replacement due to wells being under lease agreements that CUC wishes to terminate.
Calhoun	CL-2	Consider lowering the pumping rate or plugging back the well.
Gualo Rai	GR-4	Consider lowering the pumping rate.
	GR-154	Consider lowering the pumping rate; investigate whether the pumps could be raised; consider relocation further inland.
Capital Hill	TP-1	Consider replacement due to low yield.

Table 14. **Potential Modifications to Selected Wells to Lower Produced Chloride Concentrations**

Wellfield Name	Wells	Potential Modification
Agag	AGAG-45	Consider replacement due to low yield.
	AG-31B	Consider for replacement due to low yield and the well producing brown and muddy water.
Kagman	KG-3, KG-4, KG-6, KG-11, KG-12, KG-131	Consider lowering the pumping rate; investigate if the pumps could be raised.
Chalan Kiya	Duenas	This well has been inactivated as of March 2015 and CUC is contemplating full abandonment. It may be considered for replacement if additional groundwater yield is needed in this area.
San Vincente	SV-7	Consider lowering the pumping rate.
	SV-1, SV-2	CUC has terminated these lease agreements, and the wells have been abandoned.
Dan Dan	DD-7	Consider lowering the pumping rate.
Koblerville	KV-13, KV-22, KV-23, KV-24, KV-25	Consider lowering the pumping rate.
	KV-16, KV-111	Consider relocation due to low yield.
Isley Field	IF-1, IF-16, IF-18, IF-217, IF-220, IF-3, IF-7, IF-06, IF-012, IF-19, IF-102	Consider lowering the pumping rate and/or raising the pump.
	IF-101, IF-105, IF-106, IF-201, IF-202, IF-204, IF-205	Consider plugging back the well and/or raising the pump.
	IF-4, IF-20	Consider for replacement. CUC abandoned both wells due to shallow water.
	IF-28	Consider for replacement due to poor condition of the casing. This is one of the wellfield's best producers in terms of both quantity and quality (low chloride and TDS).
Obyan	OB-1, OB-9, OB-16	Consider lowering the pumping rate.

Program 2: Installation of New Wells

Guidelines should be developed for the design of groundwater supply wells specific to the different groundwater basins discussed above, and future wells should be engineered based on the specific aquifer parameters of the groundwater basin or area in which the well will be installed.

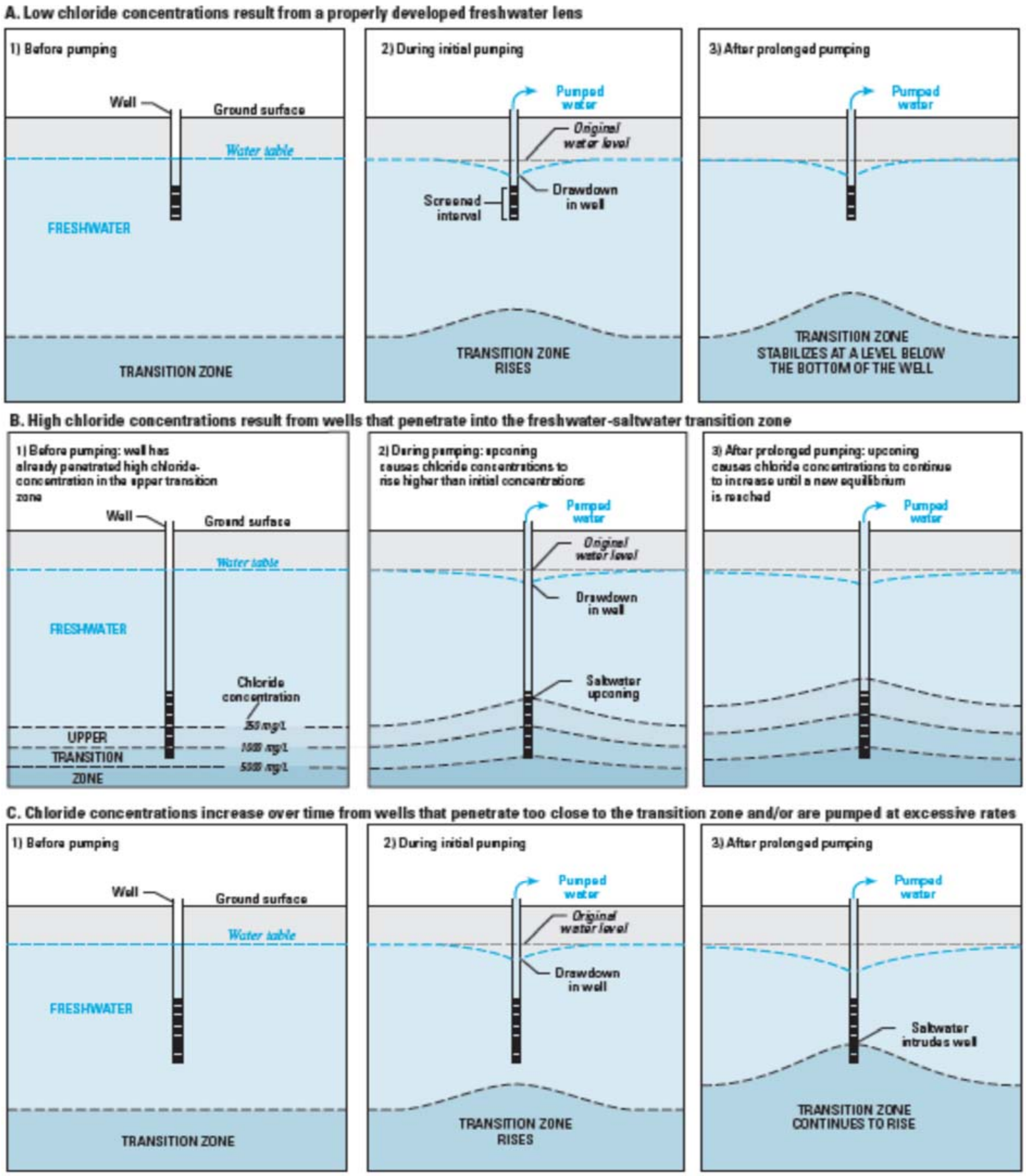
The goal is to skim freshwater off of the top of the salt water. If a well is not properly sited or engineered for the specific aquifer conditions, the following issues will occur:

- If a well is installed too deep and over pumped, the result is upconing where the cone of depression starts pulling up the lower saltwater layer.
- Wells will affect one another, so if one well is drilled too close to another well and causes upconing, that cone of depression may extend to the adjacent well and raise the fresh-salt water interface at the adjacent well.

Figure 23 graphically depicts the concepts of upconing and over-pumping compared to a properly constructed well.

Figure 23. **Well Construction Concepts**

Source: Groundwater Resources of Saipan, USGS, 2003



The well siting and construction guidelines can be finalized once the data inconsistencies and data gaps discussed previously have been addressed; however, the following general steps are recommended:

- Well Siting Guidelines. Based on the recommended data collected from existing CUC wells (see "Wellfield Investigation and Assessment"), the analytical calculation for upconing can be completed for each groundwater basin area and each well. Based on the results of the calculations, guidelines for well spacing, depth, and allowable capacity can be determined for each groundwater basin or area. These guidelines can be incorporated into the DEQ Well Construction Rules and Regulations and used by CUC for installation of future wells.
- Well Construction Guidelines. These guidelines would recommend first drilling a pilot hole, running a fluid resistivity log to identify the fresh-salt water interface at that exact well location, and then engineering the well design to minimize upconing.

Program 3: Leakage Reduction

This section responds to paragraph B4.67.e, "Leakage Reduction," of the Stipulated Order.

Non-revenue water accounts for nearly 70 percent of the water produced on Saipan. Leak detection projects that have been completed within the last 5 to 7 years by the CUC and Water Task Force (WTF) were reviewed to assist in the development of an island-wide leak and detection program.

The future program should consist of regular leak detection activities to identify pipelines that are abandoned but still connected to the distribution system as well as other sources of water loss (e.g., improper connections, damaged/cracked pipe, or leaky valves). The details of the program should be developed in conjunction with CUC personnel and in consideration of CUC practices, and should include a program to research and implement new leak detection approaches. Current responsibilities for leak detection are split between WTF and CUC Operations staff with limited coordination efforts, resulting in lower efficiency.

Additionally, deploying real-time sensors for meter consumption, pressure, flow, and tank level would provide important information on the location and types of non-revenue water that is occurring. This would allow for a more focused approach to the repair and replacement of defective systems, identification of theft, and meter accuracy.

An evaluation using 2011 data was performed to quantify and identify water that is lost due to leaks, theft, etc. The results of this evaluation and recommendations are presented in Section 2.3 of the Drinking Water System Master Plan for Saipan (DCA/CH2M, 2013a).

Program 4: Installation of a SCADA System

Presently, CUC operates all of the wells manually because no SCADA system is in place. The lack of a SCADA system results in a very labor-intensive effort to check the operation of the well facilities daily to ensure proper operation. Installation and use of a robust SCADA system would decrease the time spent by CUC Operations staff to inspect remote facilities on a daily basis, which would allow repurposing of staff for more pressing problems. In addition, SCADA alarms would provide an "early warning" if an operational issue was developing that would otherwise be unknown for hours or days.

A pilot SCADA project will be designed and deployed in the first half of 2015 to evaluate and test the performance of appropriate technologies. If the pilot program is successful, a detailed evaluation of the cost-benefit will be assessed prior to moving forward with a system-wide SCADA program. See Section 3.4.3 of the Drinking Water System Master Plan for Saipan (DCA/CH2M, 2013a) for more details regarding the pilot SCADA system recommendations.

Program 5: Replacement of Wellhead Flow Meters

Accurate flow rate readings for all of the wells are critical to completing further analysis and recommendations on sustainable groundwater withdrawal. Currently the wellhead meters are compound meters, which are not the appropriate meter for this application. These meters are affected by sand and other debris in the groundwater and tend to lose accuracy over time.

CUC Operations staff reported that the flow rates documented for each well are estimated based on the meter totalizer. It was also reported that the flow rate from each well may not be measured but just estimated and recorded based on the previous month's recorded flow rate reading. Inaccurate meters or estimation of usage contributes to the overall amount of non-revenue water and needs to be corrected.

Regulatory Considerations

The following sections summarize the existing regulatory structure with regard to groundwater management, including involved agencies and their roles and responsibilities.

Involved Agencies

The six entities described in this section all contribute to groundwater management in CNMI.

Bureau of Environmental and Coastal Quality

Bureau of Environmental and Coastal Quality (BECQ) was established in November 2013 to enhance efficiency and collaboration between Coastal Resources Management and DEQ.

Coastal Resources Management

Coastal Resources Management (CRM) is responsible for mitigating environmental impacts to coastal aquifers, beaches, and estuaries; maintaining and improving coastal water quality; and compliance with all local and federal water quality laws and regulations in the CNMI.

CNMI Division of Environmental Quality

DEQ oversees CUC's well drilling and well operations, and issues well permits for new wells. DEQ has seven branches: waste water, earth moving, and erosion control; pesticides and storage tanks; safe drinking water and groundwater; site assessment and remediation; laboratory; toxic waste management; water quality surveillance and non-point source. The safe drinking water and groundwater branch regulates three main areas related to groundwater (and the Master Plans): drinking water, water quality standards, and well drilling and well operations.

EPA Region 9

EPA Region 9 (Pacific Southwest) serves Arizona, California, Hawaii, Nevada, the Pacific Islands (which includes CNMI), and 148 Tribal Nations. EPA supports the CNMI Division of Environmental Quality (DEQ) and has worked with DEQ and others within CNMI to address water supply and quality issues. EPA also provides significant infrastructure funding to CUC through the Clean Water Act and Safe Drinking Water Act State Revolving Fund (SRF) program, which in the islands operates as a grant program providing funds for the construction of infrastructure.

Commonwealth Utilities Corporation

CUC is responsible for the electric power, water, and wastewater services on Saipan, Tinian, and Rota. It operates groundwater supplies across the islands and has the authority to regulate their own water supply wells.

Water Task Force

The Water Task Force was started in 2003-2004 to develop groundwater resources across the island during a time when CUC resources and engineering staff were inadequate. The Water Task Force hired the U.S. Army Corps of Engineers (USACE) to develop a Master Plan to lay out a plan for drilling more groundwater supply wells and complete water system improvement projects. Over time, the Water Task Force transformed into an agency with drilling personnel, equipment and funding for capital improvement projects that are separate from CUC's capital improvement projects.

The Water Task Force currently coordinates with DEQ to obtain well permits and with USGS to locate the new wells; however, CUC and DEQ have little input or control over when or where the Water Task Force drills a new well or the water system improvement projects they complete. It is recommended that the Water Task Force be integrated into CUC to create a robust groundwater resources team and reduce the coordination problems that have occurred in the past.

Review of Applicable Regulations

Applicable regulations include the Safe Drinking Water Act and the Clean Water Act, in addition to well drilling and operation regulations.

Safe Drinking Water Act

The Safe Drinking Water Act (SDWA), enacted by the U.S. Congress in 1974, gives EPA the power to oversee and set standards for drinking water to ensure the quality of public drinking water. EPA has jurisdiction over contaminant levels in all public water systems, including groundwater wells, that are used for public consumption. Owners of public wells are required to monitor and report groundwater contaminant concentrations to the EPA. Contaminants are organized in six categories: microorganisms, disinfectants, disinfection byproducts, inorganic chemicals, organic chemicals, and radionuclides.

The Office of Ground Water and Drinking Water was created by the EPA to help execute national drinking water standards, manage state drinking water and source water protection programs, help small drinking water systems, protect underground sources of drinking water through the Underground Injection Control Program, and provide information to the public.

In November 2006, the Ground Water Rule (GWR) was enacted to provide increase protection of groundwater from surface water contaminants, especially microbial pathogens that may interact with the groundwater basin. The GWR also applies to any water system that combines surface and groundwater for public consumption without treatment. The Rule requires additional monitoring of source water and nearby sanitary systems as well as corrective actions for source water with fecal contamination.

However, the SDWA and other rules do not govern private groundwater wells. EPA recommends that the private owners test their water for contaminants, but this testing is not under the jurisdiction of or required by the SDWA.

Clean Water Act

The Federal Water Pollution Control Act, or Clean Water Act (CWA), was enacted by the U.S. Congress in 1972 to restore and govern the integrity of the nation’s waters by regulating point and nonpoint pollution sources, assisting water and wastewater treatment works, and preserving the integrity of the nation’s wetlands. However, the Clean Water Act does not directly address groundwater contamination because it focuses on navigable waters of the United States such as streams, rivers, lakes, etc.

Well Drilling and Well Operation Regulations

Under the Commonwealth Groundwater Management and Protection Act of 1988, Public Law 6-12, DEQ is authorized to permit the siting, design, construction, testing, and repairs or improvements of wells; manage the withdrawal and use of groundwater through well operation permits; and promulgate rules and regulations to implement the Act. As a result, the Well Drilling and Well Operations Regulations were developed by DEQ, with the latest version dated September 2005.

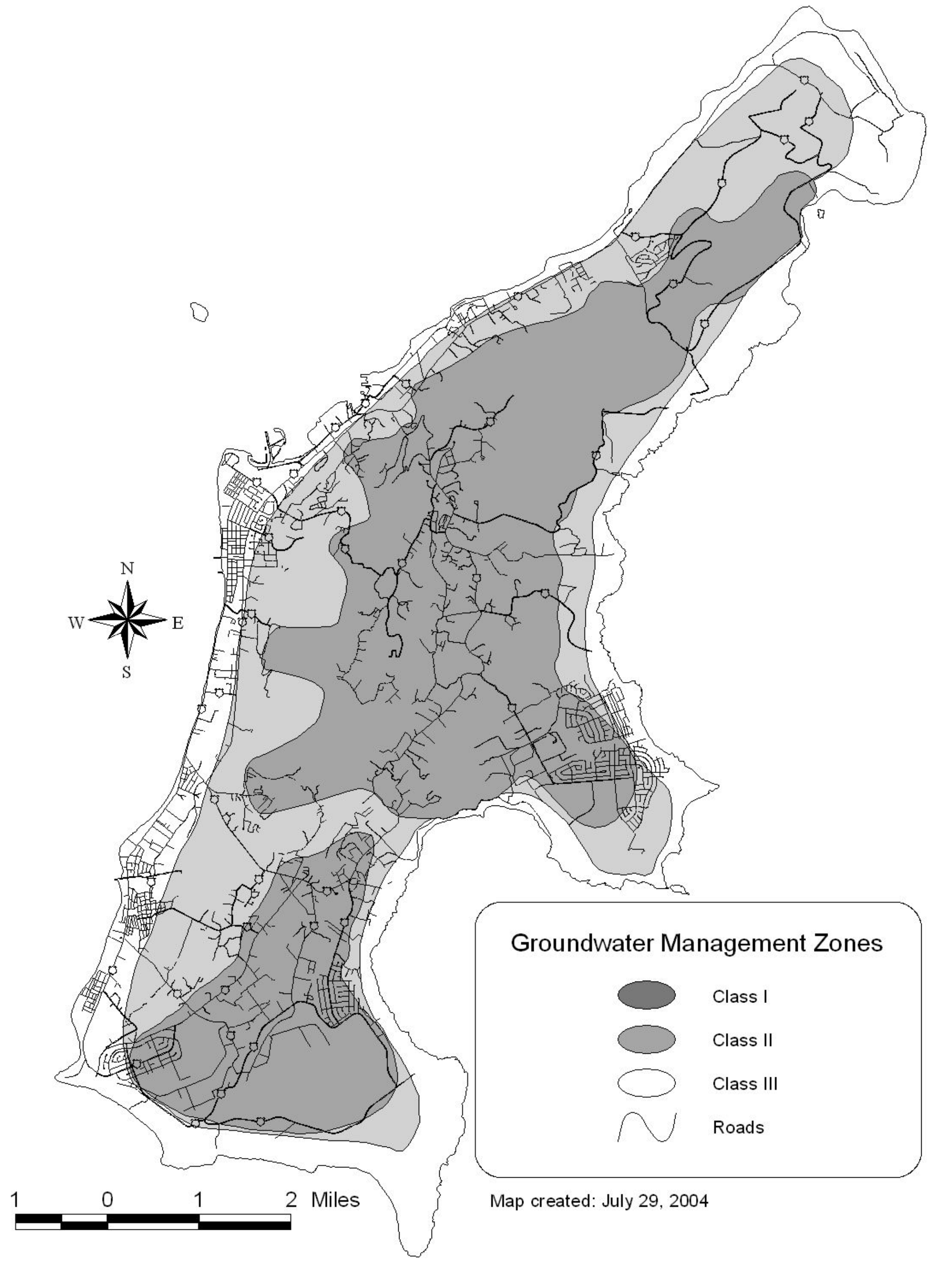
Section 25 of the Well Drilling and Well Operations Regulations (DEQ, 2005) identifies three groundwater Management Zone (GMZ) classifications that have been designated on the basis of groundwater quality, availability of recharge, susceptibility to degradation, and present and future land use. Chloride concentrations are used as an indicator of water quality to delineate GMZs. The three classes of GMZs and their associated boundaries, shown on Figure 24, are summarized below:

- Class I GMZ. Class 1 represents the most important groundwater resources that are considered vital for current and future water supplies and that are considered particularly vulnerable to degradation and contamination. Class I GMZ areas include areas of high-level perched groundwater, municipal wellfields, and watersheds contributing surface infiltration to springs and fresh surface systems.
- Class II GMZ. These important protection areas are considered capable of supplying good quality groundwater but of lower quality than Class I. Chloride concentrations in Class II GMZs are less than 500 mg/L.
- Class III GMZ. These areas recharge primarily brackish aquifers, including groundwater resources with chloride concentrations in excess of 500 mg/L. Class III GMZs are primarily coastal groundwater that has been significantly impacted by saltwater intrusion.

The specific requirements for activities in the GMZs are not included in Section 25 of the regulations. Section 27 has been reserved for future addition of requirements for certain activities in GMZs. The existing requirements summarized below for activities in designated GMZs are found in the specified CNMI regulations:

- Underground Storage Tank Regulations. Areas where tanks are prohibited include within 500 feet of a private or municipal wells.
- Water Quality Standards. There are two groundwater recharge zones: Primary and Secondary. Primary zones include Class I GMZs. Secondary zones includes Class II GMZs. Wastewater to be discharged in Primary zones must meet drinking water standards. Discharge limitations for wastewater to be discharged in Secondary zones is determined on a case-by-case basis and dependent on the volume of wastewater to be discharged.
- Wastewater Treatment and Disposal Regulations. These regulations govern the siting, design, and construction of on-site wastewater disposal systems to protect residents on the island and establish minimum standards to ensure that the discharge of wastewater will not contaminate groundwater, surface water, etc. An onsite wastewater treatment system (i.e., more than a traditional septic system) must be installed within Class I GMZs and for flows greater than 5,000 gallons per day.

Figure 24. **Saipan Groundwater Management Zones**
Source: CNMI DEQ Safe Drinking Water Program, September 2005



Existing Interagency Coordination and Cooperation Policies and Activities

This section responds to paragraph B4.67.a, "Interagency Coordination," of the Stipulated Order. The following sections summarize coordination among the major agencies to implement the rules and regulations related to management and protection of groundwater resources.

Local Agency Coordination

The three local agencies that need to work closely together to create an effective groundwater resources management and protection program are CUC, the Water Task Force, and DEQ. Below is a discussion on recommendations on strengthening the interagency coordination on the island.

Federal Agency Coordination

CUC to a lesser extent works with three federal agencies—EPA, USACE, and the U.S. Fish & Wildlife Service (USF&W)—for groundwater resources development and system operations. Below is a discussion on recommendations on strengthening coordination with the federal agencies.

Recommendations for Strengthening Interagency Coordination and Cooperation

CUC and the Water Task Force

There is currently an overlap in responsibilities between CUC and the Water Task Force; however, a lack in coordination between the two entities exists regarding completion of water projects and drilling of new groundwater supply wells. It was reported that the Water Task Force is drilling new wells based on the plan outlined by the Army Corps of Engineers and sometimes drills these wells without regard to whether they can be connected to CUC's water system. Consolidation of the Water Task Force into CUC would eliminate the coordination problems and also provide a more robust team for groundwater management of the CUC water system.

CUC, DEQ, and the Water Task Force

DEQ has the legal authority to regulate groundwater resources of Saipan. As such, DEQ should enforce or require all new wellfield projects that the Water Task Force designs and constructs (if they remain independent) to be initiated by CUC. The Water Task Force should be restructured into an organization working under the direction of CUC. CUC has the necessary technical data and staff resources to provide assistance to DEQ with determining safe yields for new wells.

CUC and EPA

CUC works effectively with EPA Region 9 through DEQ for the condition inspection of wellhead facilities. The working relationship with EPA Region 9 staff has been very good, and there are no recommendations for improving coordination.

CUC and U.S. Army Corps of Engineers

CUC will coordinate with the Corps when a project is located in or adjacent to wetlands or waters of the United States. The sooner that the Corps can be brought into the discussion, the sooner any potential impact can be discovered and reduced or eliminated through construction practices or relocation of the potential site.

CUC and U.S. Fish and Wildlife Service

CUC works with the USF&W when it involves the need to permit new well locations that are in or adjacent to sensitive habitat areas. The most important thing that CUC can do to maintain good coordination with USF&W is to bring them into the process as early as possible to understand its concerns and reduce or eliminate them to the extent practical.

Capacity Building

This section responds to paragraph B4.67.f, "Capacity Building," of the Stipulated Order and summarizes the review of current CUC staffing and organizational structure and the most prominent obstacles to CUC management in terms of successfully operating the groundwater supply wells and complying with the Stipulated Order. The information for this review was derived from the following sources:

- Workshop with CUC on June 25, 2014
- Final Draft of the Drinking Water Master Plan – Saipan, Commonwealth of the Northern Mariana Islands, prepared by DCA and CH2M, February 5, 2013

This section is organized as follows:

- CUC Organizational Structure
- Workforce Issues and Recommendations
- Automation and Technology
- Overall Recommendations

CUC Organizational Structure

CUC has approximately 90 employees who work within the water and wastewater division.

Engineering Organization within CUC

Traditionally, the Engineering Department has the responsibility for executing design and construction management of new and replacement Capital Improvement Projects, providing support to Operations Department, and managing specialized technologies. Additionally, the Engineering Department has assigned liaisons with the Operations Department in the past to enhance communications between the two groups and integrate operational requirements into all designs. The Chief Engineer and the Water/Wastewater Operations Division Manager (DM) work closely together to coordinate activities between the two departments.

Operations Organization within CUC

The Operations Department within CUC operates under the direction of the Water/Wastewater Operations DM and has the responsibility for operation and maintenance of the water and wastewater facilities and infrastructure including the groundwater supply wells and associated above-grade and downhole facilities. Within the Operations organization, there are staff designated to focus on:

- Chlorination. Staff are responsible for checking the chlorination systems and assisting the laboratory with grabbing water quality samples from all points of entry into the water system.
- Troubleshooters/Plumbers. Staff are responsible for fixing all pipeline breaks and installing flow meters.
- Water Watch. Staff are responsible for control of the water levels in the tanks and adjustment of valves throughout the system to provide regular water service to customers in non-24 hour areas.
- Well Maintenance. Staff are responsible for operation and maintenance of the groundwater supply wells. This group and their capacity and roles and responsibilities are discussed further below.

- Meters. Staff coordinate with customer service and are responsible for the installation of new meters and replacing existing meters.

CUC currently has approximately 12 employees who focus on operation and maintenance (O&M) of the 147 groundwater supply wells. The wellfield O&M group is further split into two crews; one crew focuses on the downhole equipment including the submersible pumps and motors, and the second crew focuses on the above-grade facilities including wellheads and wellhouses.

The crew that focuses on the downhole equipment currently consists of four employees. These four employees are responsible for the operation and maintenance of the downhole equipment and responsible for removing and replacing the pumps and motors when they fail. It has been reported by CUC that there is a high rate of pump and/or motor failures and the well maintenance crew may have to remove and replace up to seven pumps/motors in one week. The replacement equipment is selected by the operations and maintenance crew, and it was reported that the equipment selected for installation is based on availability and not necessarily well performance and operating conditions. Also, each time a pump/motor is replaced, the well maintenance crew conducts a pump performance/aquifer test on the well.

Due to lack of capacity and qualified staff, CUC is currently unable to stay ahead of the maintenance requirements for the groundwater supply wells and is operating in a reactive mode, meaning that they fix things as they break. In addition, CUC is limited in its capacity to perform maintenance based on the equipment owned. CUC owns and operates a small boom truck that has the capacity to pull the majority of the pumps and motors; however, for the deeper set pumps and motors, CUC relies on WTF employees and the WTF’s larger-capacity pump-pulling rig.

Workforce Issues and Recommendations

CUC’s current maintenance workforce lacks the training needed to fully understand how the wells should be operated and how to properly evaluate and select appropriate downhole equipment based on the well capacity and the specific operating conditions for each well site. There is a lack of communication and understanding between the Engineering and Operations Departments regarding well pump and motor requirements. Operations staff reviews all engineering documents; however, they do not consult with the Engineering Department on matters such as the pumps and motors to be installed in the wells, etc.

CUC reported that it currently lacks approximately 20 percent of the manpower needed to successfully operate and maintain its facilities. The main issues CUC faces with recruiting and training new workforce are as follows:

- Inadequate funding to provide specialty training in areas such as SCADA, geographic information system (GIS), online water quality monitoring technologies, and hydraulic modeling.
- Difficulty finding employees who will remain employed at CUC in the long term. CUC experiences a relatively high turnover rate with employees typically staying for only a couple of years. The turnover can be partially attributed to employees who are not local to the island and who decide to return to their homes.
- Off-island hires (used at higher level positions) are difficult to recruit because of the political climate, which does not reflect a stable work environment. Additionally, they are only given 2-year contracts, which may not entice someone looking for a long-term position.
- Lacks incentives for recruitment of a local workforce.
- Lacks a career progression structure.
- Lack of rewards for staff who excel or gain certifications.

One of CUC's biggest challenges is building a qualified workforce with an understanding of the wellfields and overall groundwater system. A key gap in its organizational structure is the need for a groundwater engineer whose overall responsibility would be consulting on operations and maintenance of the wellfields and coordination with the operations and maintenance group to accomplish the work required to keep the individual wells operating properly and efficiently. The qualifications for a groundwater engineer would include both an engineering background and a hydrogeology background. An individual with this broad background would be able to address issues related to the hydraulics of the system such as pump selection, wellfield operation and troubleshooting, as well as address issues with well drilling and construction.

Recommendations for CUC to strengthen its workforce and increase its efficiency and effectiveness include the following:

- Development of a Groundwater Engineer. Internally, CUC needs to strengthen coordination between the Operations and Engineering Departments regarding the management of groundwater resources. When maintenance or repair is required on a well specifically related to pulling and replacing the downhole equipment (pump and motor), the Engineering Department should be involved in the evaluation of the replacement equipment to ensure that the capacity of the equipment is appropriate and operates efficiently. Hydraulic models of all wells and all well-to-tank transmission systems should be developed and maintained for this purpose. These responsibilities would be assigned to a Groundwater Engineer position (after this position is created) or an on-call consultant.
- Refocus the Water Watch Crew. The Water Watch Crew consists of four employees whose sole responsibility is to manually check the water system infrastructure. To reduce labor costs, an automated monitoring system could be implemented that would automatically monitor select parameters at each well site. These parameters, including well status (on/off), flow rate, tank water level, discharge pressure, and conductivity, would be used to indicate remotely whether there is an issue at a well site that requires maintenance. Because site visits to wells would be reduced to only those needed to correct a problem or conduct maintenance, the Water Watch Crew could be refocused to take on the responsibility of maintenance of the automated monitoring system or conduct other operations and maintenance tasks.
- Electrician. It has been noted by CUC that it lacks electricians and Electrical Engineers. To fill this void, an additional employee with an electrical background may be required to take on responsibility and maintenance of the automated monitoring system.
- Integrate and Manage Technology. As discussed above, integrating an automated monitoring system could free up a significant portion of the workforce currently needed to manually maintain and operate the system while also improving overall operation of the system. This would require a dedicated person to oversee the new technology so that CUC continues to receive the benefits of deploying automation.
- Regional Groundwater Models. The groundwater basins need to be managed in terms of sustainable yields. Currently DEQ does not track the basin-wide quantities that have been permitted compared to sustainable yields for each basin. Once all the recommendations outlined in "Review and Recommendations for Sustainable Withdrawal of Groundwater Resources" have been completed, the data collected can be used to develop a series of regional groundwater models for each sub-basin to assist CUC and DEQ with tracking and estimating permitted well capacities versus sustainable yields. If a series of regional groundwater models were developed, CUC would need to designate staff to maintain and update these models as additional wells are constructed and data are collected. The Groundwater Engineer, once this

position is created, could oversee management of these models; however, CUC should hire staff or a consulting firm that specializes in groundwater modeling to develop the models.

- Build Local Resident Workforce. Building a local resident workforce is critical to recruiting employees who are more likely to stay employed for the longer term instead of someone coming from elsewhere. Recruiting young engineers and operators who left the island for their education is a great way to start creating a strong, stable local resident workforce. Engineering has been very effective at this during the past year.

Automation and Technology

As previously recommended by CH2MHILL, data collection and monitoring of the wellfield operations could be greatly improved with the incorporation of remote monitoring equipment and a SCADA system. If CUC were to incorporate remote monitoring of information such as pipeline pressures, wellhead pressures, flow rate from each well, on-off status for each well, tank levels, and well water levels, the Water Watch Crew could be reassigned; however, CUC would likely need to designate staff and specifically someone with an instrumentation and controls or electrical background to maintain the new equipment.

Overall Recommendations

The following overall recommendations are made regarding groundwater management for Saipan, Tinian, and Rota:

- Coordination between the Water Task Force, CUC, and DEQ needs to be formalized with regard to any future well drilling operations. Drilling new wells in locations prior to obtaining CUC approval negatively impacts the overall goal to sustainably withdraw groundwater and improve the overall water quality of the groundwater withdrawn. New wells improperly located will negatively affect existing public and private wells by interference and result in decreased capacity as well as increased upconing of the fresh-salt water interface.
- CUC should implement the recommendations outlined in "Recommended Protocol for Exploration of Groundwater Resources." Develop a solid database for all of the well and wellfield data that can be used to refine the recommendations made in "Review and Recommendations for Sustainable Withdrawal of Groundwater Resources."
- As outlined in "Review and Recommendations for Sustainable Withdrawal of Groundwater Resources," a set of guidelines should be developed specific to each groundwater basin or area based on analytical calculations to identify optimal well spacing, recommended well depths, and recommended withdrawal capacities.
- As outlined in "Review and Recommendations for Sustainable Withdrawal of Groundwater Resources," all new wells constructed should include the following preparatory steps: drill a pilot hole, perform a fluid resistivity log to identify the fresh-salt water interface, and design the well to minimize upconing by identifying the proper depth, screen interval, pumping rate, and pump intake setting.
- If desired, using the data collected from recommendations above, a series of groundwater models could be developed for each groundwater basin or sub-basin to assist CUC and DEQ with making decisions regarding well permitting, siting, and tracking and estimating permitted well capacities versus sustainable yields. Designated staff or a consultant experienced with groundwater modeling would need to be hired to operate and maintain the groundwater models.
- Continue to develop local talent, including a Groundwater Engineer, to reduce the need to hire from off-island. This will take time because CUC will need to continue to comply with some significant EPA staffing requirements for key personnel. In the interim, these positions should be filled with off-island professionals, contract employees, or contracts through consulting firms.
- Provide incentives, such as an educational reimbursement program, for local staff to work at CUC.

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