GROUNDWATER MODELING TECHNICAL MEMORANDUM

IN SUPPORT OF THE

COMMONWEALTH OF THE NORTHERN MARIANA ISLANDS JOINT MILITARY TRAINING ENVIRONMENTAL IMPACT STATEMENT

Department of the Navy
Naval Facilities Engineering Systems Command, Pacific
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1 INTRODUCTION

1.1. Background

The islands of the Commonwealth of the Northern Mariana Islands (CNMI) are strategically located in the United States (U.S.) Department of Defense (DoD) Indo-Pacific area of operations, as shown in Figure 1. Figure 2 shows the Military Lease Area on Tinian where the U.S. military has trained for several decades.

The Proposed Action would support the ongoing and evolving training requirements of U.S. Armed Forces forward deployed to the Western Pacific, and U.S. allies and partners, specifically for distributed operations training within the Military Lease Area on Tinian. Proposed training events would include both ground and aviation training within the Military Lease Area.

Non-live-fire offensive and defensive training actions would continue to be conducted in the Military Lease Area with an increase in existing land-based training events, including both ground and aviation training, which are the same or similar to those currently being conducted on Tinian.

Live-fire training would be conducted at two ranges that would be developed within the Exclusive Military Use Area:

- **Multi-Purpose Maneuver Range.** A live-fire range occupying approximately 200 acres at the northern tip of Tinian to support platoon-size live-fire and maneuver, including three surface radar facilities.
- **Explosives Training Range.** A live-fire range on approximately 2.5 acres for the employment of demolitions and military explosives in support of offensive and defensive training events.

The following are also included in the Proposed Action to support training events:

- Establishment of 13 Landing Zones, areas cleared of vegetation to 6–8 inches, and associated access roads to conduct training events and to provide staging, bivouac, and gathering and rendezvous areas.
- Ground and aviation improvements at North Field, including establishment of a drop zone and the placement of a metal airfield surface.
- Construction and operation of a Base Camp.
- Clearance and improvements of roads within the Military Lease Area.

1.2. Purpose

The purpose of this study is to evaluate the potential impact to the groundwater resources on Tinian associated with groundwater extraction to support the proposed CNMI Joint Military Training (CJMT).

1.3. Scope of Study

The goal of this study was to evaluate potential impacts to water quality on Tinian associated with the Proposed Action. The Proposed Action includes the installation of two optional CJMT well fields to provide potable and non-potable water for construction and operation of the proposed Base Camp and CJMT.

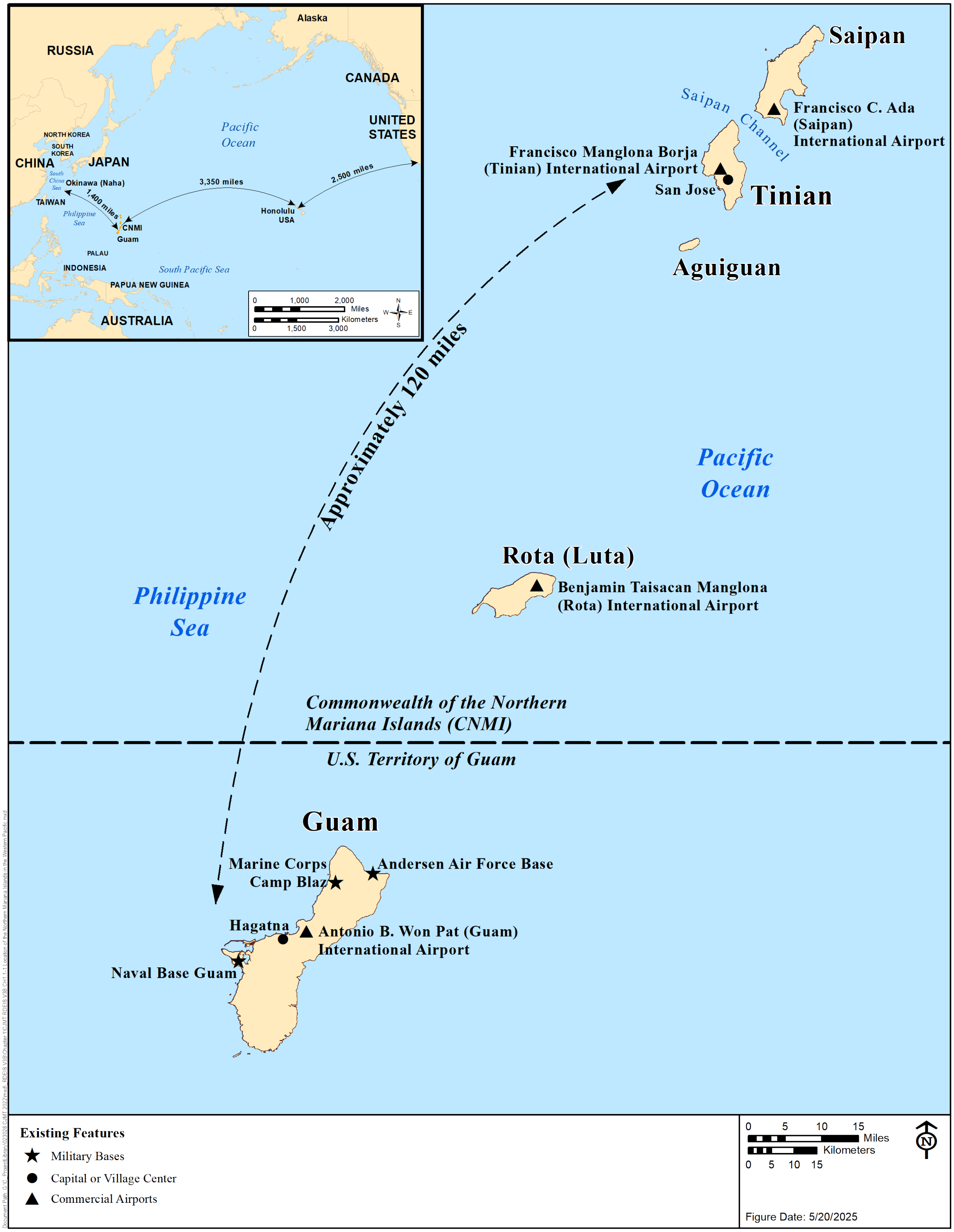

Figure 1. Island of Tinian – Location

Figure 2. Island of Tinian – Military Lease Area Boundaries

The scope of this study is presented below:

- Develop a new groundwater flow model based on the U.S. Geological Survey 2002 model.
- Use available data from Doan et al. 1960, Gingerich and Yeatts (U.S. Geological Survey) 2000, and Gingerich (U.S. Geological Survey) 2002.
- Use data from the CJMT *Aquifer Study Technical Memorandum* (Department of the Navy [DON] 2015).
- Use available head and production data for Maui Well No. 2 provided by the Commonwealth Utilities Corporation.
- Develop model scenarios based on water demands over the course of a typical training year.
- Use the model input sources, calibration, and sensitivity analysis primarily from the U.S. Geological Survey 2002 report. No additional sensitivity analysis will be performed.
- Use model output to evaluate directions of groundwater flow on island.
- Use the model to simulate chloride concentrations under five scenarios.
- Summarize model development, input sources, calibration, sensitivity, model limitations, and modeling results in a *Groundwater Modeling Technical Memorandum*. Include discussion of sea level rise's potential effects on the availability of freshwater via existing and proposed water wells that may assist planners in strategizing future contingency actions.

2 EXISTING AND PROPOSED WATER SYSTEMS

2.1 EXISTING WELLS

Currently, one potable water well and two groundwater wells are in use on Tinian. The agricultural wells are owned by the CNMI and are provided with electrical power by the Tinian Mayor's Office for the benefit of the cattle ranchers, who can fill potable containers used to provide water to cattle and construction contractors.

2.1.1 Current Potable Supply Wells

The sole supply of potable water on Tinian comes from the Makpo Marsh potential wetland complex's basal groundwater lens. Water is collected from the lens by Maui Well No. 2, discussed below. Tinian's public water system is owned and operated by the Commonwealth Utilities Corporation and serves the southern third of Tinian where the island's entire population resides. The currently operating public system consists of one horizontal Maui well for water supply, three storage tanks, one chlorine injection point, and approximately 38 miles of distribution pipes. A small distribution system serving Francisco Manglona Borja/Tinian International Airport is owned by the Commonwealth Ports Authority. The Commonwealth Ports Authority distribution system consists of a 60,000-gallon (227,100-liter) storage tank and a piping system that receives water from the Commonwealth Utilities Corporation's Maui well subsystem. In the past, additional wells for potable water supply were in operation, but they have since been taken offline and are not maintained in operable condition. Figure 3 shows existing wells on the island.

Maui Well No. 1, also located at the Makpo Marsh potential wetland complex, is currently out of service because the equipment is old and its repair parts have been difficult to obtain. The Maui Well No. 1 pump house was equipped with two 75-horsepower pumps and one 50-horsepower pump, and was originally designed to pump water to the Marpo Heights Tank. Previous plans to refurbish Maui Well No. 1 have been abandoned. Maui Well No. 1 is a Maui-type infiltration gallery constructed in Marpo Marsh within the Median Valley by the U.S. military in 1945. This well is the only well that was not abandoned after World War II; it supplied all of the potable water for Tinian until 1999, when two vertical wells were added to the system. Maui Well No. 1 produced about 1 million gallons per day from the shallow limestone aquifer. The well drew from the upper part of the aquifer over a large area, which tends to maximize the amount of freshwater that can be withdrawn from an area while minimizing upconing of the saltwater.

In 2000–2001, a new 400-foot-long infiltration gallery well (Maui Well No. 2) was constructed near Maui Well No. 1 to replace that well. According to the *2012 Water Quality Report* (Commonwealth Utilities Corporation 2013), Maui Well No. 2 supplied all Commonwealth Utilities Corporation water in 2012. Maui Well No. 2 has four 75-hp pumps, each capable of pumping about 350 gallons per minute for a total of 1,400 gallons per minute to both the Marpo Heights and Carolinas Tanks as well as the Commonwealth Port Authority Airport Tank. Currently, Maui Well No. 2 supplies the Commonwealth Utilities Corporation's entire Tinian water system, operating three of its four pumps almost constantly (Commonwealth Utilities Corporation 2013). Because one pump is kept on standby for maintenance purposes, Maui Well

No. 2 operates at near-full capacity. Additional information on Tinian's potable water system is provided in the *Potable Water Study* (DON 2025).

At various times, other vertical wells (e.g., TH-06 [capable of 60 gallons per minutes] and TH-04 [capable of 50 gallons per minute]) have been in use by the Commonwealth Utilities Corporation. Additional details, including ownership of the individual wells, are included in Attachment A – Known Current and Former Wells.

2.1.2 Existing Non-potable Supply Wells

Well M-21 was previously used by cattle ranchers. Currently, it is used primarily by the construction contractor for the U.S. Air Force Tinian Divert Activities and Exercises (Divert) Infrastructure Improvements at the Francisco Manglona Borja/Tinian International Airport. This well was permitted in 2024 to extract not more than 1.8 million gallons per month (DON 2025).

Well M-26 is primarily used by cattle ranchers and is not metered. Well M-26 agricultural water demand has been estimated at 59,178 gallons per day.

These wells are labeled M-21 and M-26 in Figure 3. Except for these two, no other wells within the Military Lease Area (the northern roughly two-thirds of the island) are known to be in use. During the aquifer study, M-21 and M-26 were used to produce about 25 gallons per minute each to cattle ranchers.

2.1.3 Existing Monitoring Wells

Some of the historical literature suggests that the Japanese military may have dug more than 100 wells during their occupation of Tinian. Most of these were reportedly filled in. The U.S. military constructed approximately 40 (M-series) groundwater wells in 1944 and 1945 on the island for water supply, including Maui Well No. 1. Most of these were reportedly drilled to 10 or 15 feet below mean sea level. The majority of the M-series wells have been inactive since shortly after World War II (Doan et al. 1960).

Between 1993 and 1997, the U.S. Geological Survey rehabilitated 16 of the inactive U.S. military wells. Rehabilitation involved retrieving the original pump and pipe, re-drilling as necessary, cleaning out the hole to near the original depth, and installing new surface casing/well head features, if necessary. In addition, between 1993 and 1997, U.S. Geological Survey drilled 17 new (TH-series) wells for groundwater monitoring in the Median Valley and the adjacent Southeast Ridge and Central Plateau. Of the 17 wells, 12 are open holes and 5 are cased with polyvinyl chloride pipe and screened below the water table. All wells were drilled into the top of the freshwater lens except wells TH-02, TH-04X, TH-08, and TH-09, which were drilled into the transition zone. The freshwater lens thickness and underlying transition zone fluctuate as a result of seasonal rainfall and groundwater withdrawal (U.S. Geological Survey 2000). At least one of the M-series wells (M-29) was deepened through the transition zone (to a depth of 168 feet below mean sea level) and used as a transition zone monitoring well for a period of time. However, no records of this transition zone monitoring have been located despite searches by U.S. Geological Survey staff.

Figure 3. Tinian Existing Wells

In 2012, a hydrogeologic assessment of groundwater conditions was completed at the planned Tinian landfill site and surrounding area (Tetra Tech 2012). The Tinian landfill site was a proposed municipal solid waste landfill northwest of the airport. The scope of work for the assessment included installation of three monitoring wells: WOP-197-01, WOP-197-02, and WOP-197-03. Although the basis for the well nomenclature used by the Bureau of Environmental and Coastal Quality is unknown, it is understood that these three refer to monitoring wells at the proposed landfill.

2.1.4 CJMT Proposed Action Water Wells

Potable and non-potable water for the Proposed Action are expected to come from four new wells located in Well Field A or B located northeast or northwest of the Tinian International Airport, respectively (Figure 4). Groundwater elevations in the area are generally less than 1 to about 2 feet above msl in the notional DoD well field.

Other On-island Wells

Following construction for U.S. Air Force's Tinian Divert Infrastructure Improvements at the Francisco Manglona Borja/Tinian International Airport, U.S. Air Force would use a newly installed firefighting well. The average demand for this well is estimated at 2,192 gpd.

U.S. Air Force plans to rehabilitate an existing well (assumed to be existing well M-05) for construction at North Field. The average demand for this well is estimated at 12,000 gallons per day.

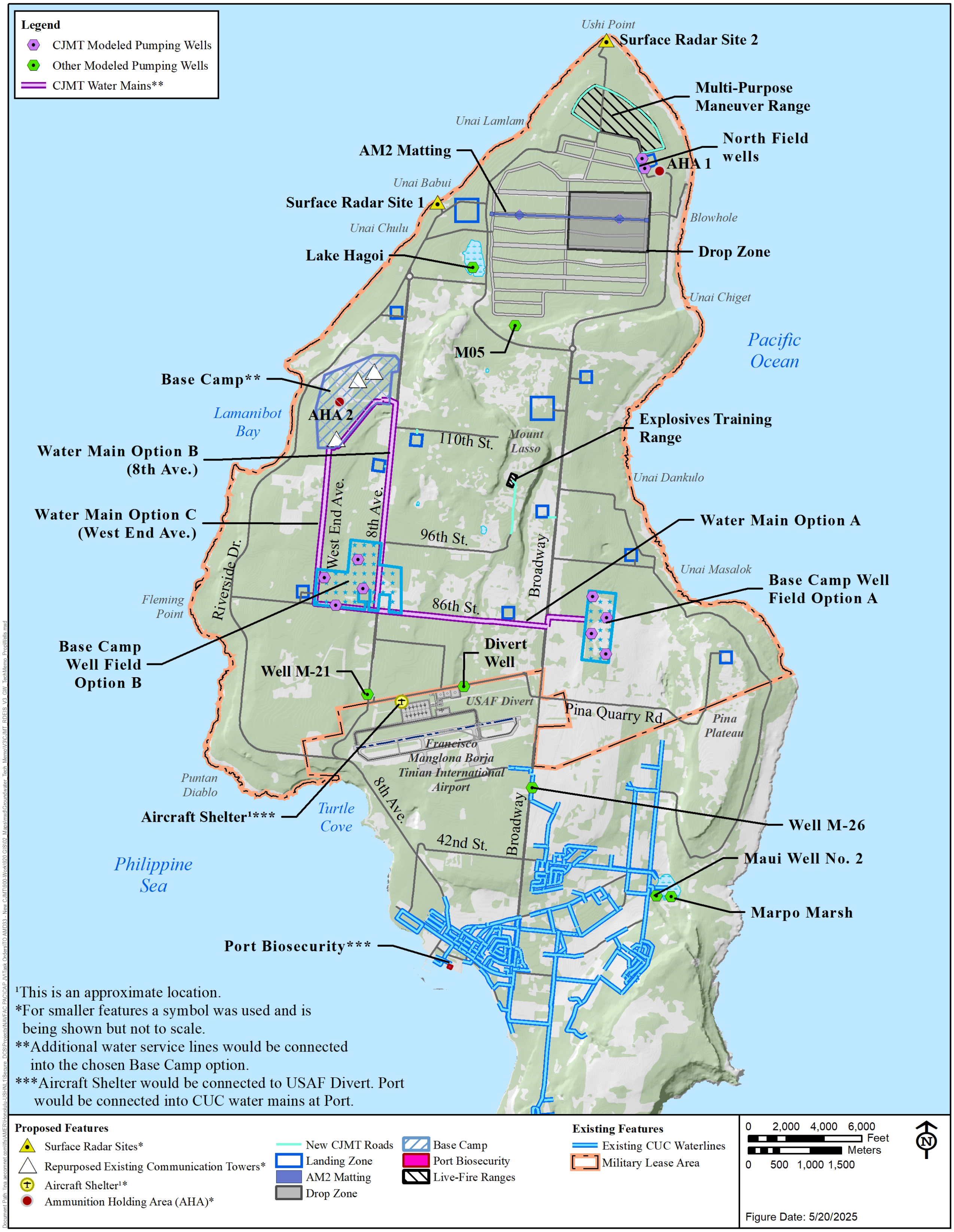

Figure 4. Tinian Future Wells

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3 WATER DEMANDS FOR PROPOSED ACTION

The Proposed Action includes construction of new water infrastructure to fully support the U.S. Marine Corps' (USMC) proposed CJMT and to avoid impacts on the Commonwealth Utilities Corporation water system. This proposed new water infrastructure would supply the domestic, industrial, and fire protection demands of military training activities and the majority of water used during construction. This proposed new water infrastructure would be operated by the DoD and would not be connected to the Commonwealth Utilities Corporation water system.

Domestic demand on the Commonwealth Utilities Corporation water system would also increase because of the Proposed Action. Operations staff and construction workers would live outside the Military Lease Area or stay in hotels and become customers of the Commonwealth Utilities Corporation water system.

These future demands are summarized in Table 1.

Table 1. Summary of Average Future Annual Water Demands on Tinian

Owner	*Facility*	*Type*	*Average Annual Water Demand (gallons per year)*	*No. Wells*
Military	CJMT Base Camp [a]	Potable	7,971,440	4
Military	CJMT North Field	Non-Potable	800,000	2
Military	USAF North Field Rehabilitation	Non-Potable	4,380,000	1
Military	Tinian Divert Infrastructure Improvements	Potable	800,000	1
CUC	Maui Well No. 2 [b]	Potable	314,727,702	1
Tinian Mayor's Office	Well M-21 (CJMT Construction)	Non-Potable	21,600,000	1
Tinian Mayor's Office	Well M-26 (Existing Agriculture)	Non-Potable	21,600,000	1

Notes: [a]Total demand for all the wells.
[b]Average of production at Maui Well No. 2 from 2019 to 2023 and proposed CJMT demands on the CUC water system.
Legend: CJMT = Commonwealth of the Northern Mariana Islands Joint Military Training; CUC = Commonwealth Utilities Corporation; gpd = gallon per day; U.S. = United States; USAF = United States Air Force.
Source: *Potable Water Study Update* (DON 2025).

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4 GROUNDWATER AND GEOLOGY

4.1 GROUNDWATER SUPPLY

Rainfall is the primary source of fresh groundwater on Tinian. The U.S. Geological Survey estimates the average annual groundwater recharge for Tinian to be approximately 30 inches per year (U.S. Geological Survey 2002). This translates into approximately 62,000 acre-feet per year of recharge. The rapid downward percolation of rainwater into porous limestone rock (Doan et al. 1960) recharges Tinian's basal freshwater aquifer. Fresh groundwater on Tinian is primarily classified as basal, which is a body of fresh groundwater that floats on saline groundwater. The portion of the basal freshwater lens that is usable for potable water, which has chloride concentrations less than 250 milligrams per liter, is thickest south and southwest of Mount Lasso and becomes increasingly thinner approaching the coastline. The groundwater table on Tinian ranges from sea level around the perimeter of the island to over 3 feet above msl in the central portions of the island. Groundwater flows outward from the North Central Highland and the southeastern ridge, and generally seaward around the island (DON 2015). Most of the fresh groundwater slowly discharges naturally from springs around the perimeter of the island and submarine coastal springs. The basal freshwater lens underlying Tinian is the principal source of drinking water and meets the definition of an aquifer found in CNMI Title 65, Chapter 65-90-010, and U.S. Environmental Protection Agency (EPA) regulations.

4.1.1 Physical Environment of Tinian

Physical features relevant to the groundwater modeling include topography, climate, geology, hydrogeology, and the existing well network and water supply systems. These features are detailed in the *Aquifer Study Technical Memorandum* (DON 2015).

4.1.2 Topography

Tinian is about 12 miles long and 6 miles wide. It is separated from Saipan by the approximately 3-mile-wide Tinian Channel. Tinian comprises a series of limestone plateaus separated by steep slopes and cliffs (U.S. Department of Agriculture Soil Conservation Service 1989). The surface landforms (Figure 5) are divided into five major physiographic areas based on topography and spatial relations, as described below (U.S. Geological Survey 1999). These are depicted along with representative spot elevation in Figure 5:

- **Southeastern Ridge.** This land area is the southernmost and highest part of the island, with a maximum elevation of 614 feet at Mount Kastiyu. Steep slopes and cliffs up to 500 feet in height on the southeast characterize this area.
- **Median or Marpo or Makpo Valley.** This land area is a low, broad, elongated depression northwest of the Southeastern Ridge with a maximum elevation of 150 feet. In the valley, the land surface intersects the water table, resulting in a small potential wetland complex known as the Makpo Wetland or Makpo Marsh.
- **Central Plateau.** This land area extends northward from the Makpo Valley and includes central Tinian and portions of northern Tinian. The plateau is broad and gently sloping, with most of the vertical relief at its southern and northern boundaries.

- **North-Central Highland.** This land area is located within the northern part of the Central Plateau and midway between the east and west coasts of the island. The maximum elevation of the highland at Mount Lasso is 545 feet.
- **North Lowland.** This land area is located at the northern tip of Tinian. It is generally flat with an average elevation of approximately 100 feet, except for the Lake Hagoi wetland, where the land elevation is approximately at sea level.

4.1.3 Climate

The seasons on Tinian are defined by distinct differences in rainfall. During the wet season, which occurs between the months of July and October, the island receives roughly 60 percent of its annual precipitation. February through May comprise the dry season, when only about 10 percent of Tinian's annual rainfall occurs. The remaining months (November, December, January, and June) are the transitional months when the island receives the remaining 30 percent of its rainfall. Rainfall from tropical storms and typhoons, in years when they occur, can comprise a significant percentage of the total annual rainfall, and a lack of storms can significantly contribute to drought conditions. Typical temperatures range from 76 degrees Fahrenheit to 88 degrees Fahrenheit (U.S. Geological Survey 2002).

Precipitation averaged about 81 inches per year at the airport weather station from 1988 to 1994 and in 1996, years for which complete daily rainfall records were available. Because the highest point on Tinian is only 614 feet above mean sea level, orographic effects (increased rainfall related to mountain ranges) appear to be minimal. Gingerich and Yeatts measured rainfall at four sites on Tinian from 1993 to 1996, and the measured amounts ranged from 72 to 82 inches across the island (U.S. Geological Survey 2000). Gingerich used an average rainfall of 82 inches per year in the water budget for the numerical groundwater flow model (U.S. Geological Survey 2002).

Figure 5. Tinian Physiographic Areas

4.1.4 Geology

Tinian is a composite carbonate island (Jenson et al. 2006) consisting of geologically young coralline and algal limestone strata overlying an older core of volcanic tuff and breccias, small portions of which crop out at the surface in two small places on the island (Figure 6). The limestone retains substantial primary porosity but also exhibits regional- to local-scale fractures (secondary porosity) associated with regional tectonic stresses and local loading/unloading from uplift-subsidence and deposition-erosion cycles. Regional high-angle normal faults result in offset limestone plateaus that characterize the island (Figure 6). Figure 7 shows geologic cross sections of Tinian.

Tinian comprises the following four major geologic units, shown in Figure 6 (U.S. Geological Survey 2002):

- **Tinian Pyroclastic Rocks.** Tinian Pyroclastic rocks are the oldest rocks exposed on the island (Late Eocene age; about 38 million years old), which likely underlie all other exposed rock units there. These fine- to coarse-grained ash and angular fragments represent explosive volcanic materials ejected from an ancient volcano that formed the core of the island. These rocks are exposed on the North-Central Highland and Southeastern Ridge where they occupy about 2 percent of the surface of Tinian today. Surface exposures are generally highly weathered and typically altered to clay minerals.
- **Tagpochau Limestone.** Of Early Miocene age (approximately 23–20 million years old), Tagpochau Limestone rocks are exposed on about 15 percent of Tinian’s surface, generally in the North-Central Highland and the southern part of the Southeastern Ridge. These rocks range up to about 600 feet in thickness. They are 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, and this unit extends from the unconformity with the volcanic rocks below to the ground surface in the North-Central Highland and the southern part of the Southeastern Ridge, mentioned above. Across most of the island, this unit is capped by the Mariana Limestone.
- **Mariana Limestone.** These Pliocene to Pleistocene age (about 5–3 million years old), Mariana Limestone rocks cover approximately 80 percent of Tinian’s surface, forming nearly all of the North Lowland, the Central Plateau, and the Makpo Valley. These rocks range up to about 450 feet in thickness. They are composed of fine- to coarse-grained fragmented limestone, with some fossil and algal remains, and small amounts of clay particles. Small voids and caverns (tertiary porosity) are common in surface exposures. Overall, the Mariana Limestone has a higher coral content than the Tagpochau Limestone.
- **Beach Deposits, Alluvium, and Colluvium.** Shallow Pleistocene to Holocene age (approximately 2 million years old to the present) sediments mantle less than 1 percent of Tinian’s surface and range up to approximately 15 feet thick. The deposits consist of poorly consolidated sediments, which are mostly calcareous sand and gravel deposited by waves. However, they also contain clays and silts deposited inland surrounding Lake Hagoi and the Makpo Marsh potential wetland complex. Loose soil and rock material (talus) are found at the base of slopes.

Figure 6. Tinian Generalized Surficial Geology

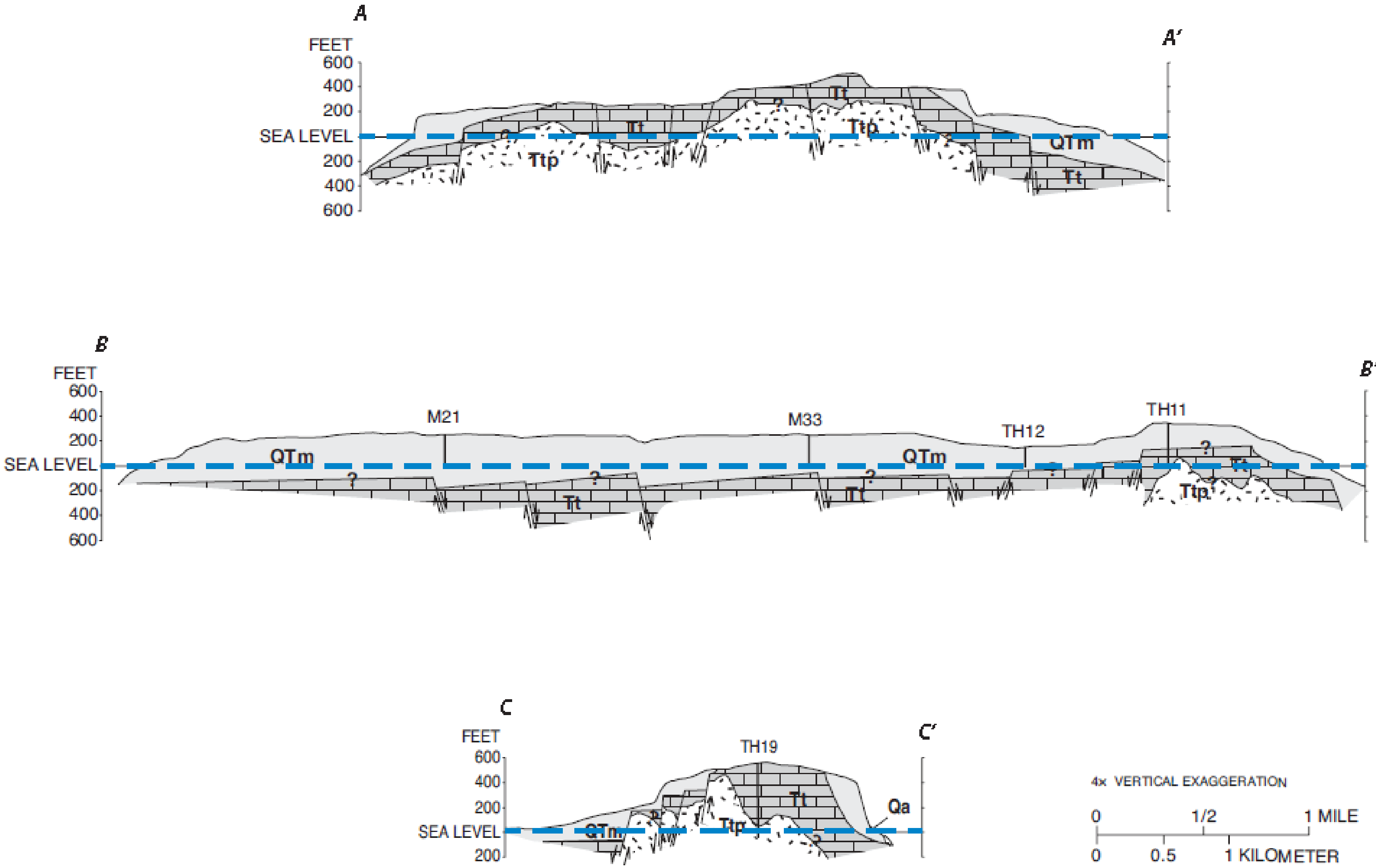

Figure 7. Tinian Geologic Cross Sections

Source: U.S. Geological Survey 2000 (after Doan et al. 1960).

4.2 GROUNDWATER RESOURCES OF TINIAN

4.2.1 Overview

Groundwater is recharged by rainfall infiltration over most of Tinian. Water that recharges the groundwater system flows from zones of higher to lower hydraulic head. Ideally, fresh groundwater (chloride less than 250 milligrams per liter) forms a double-convex lens in a cross section and is underlain by denser saltwater (chloride concentration of 19,000 to 20,000 milligrams per liter); however, the base is distorted where it contacts the relatively impermeable volcanic basement rock. The Ghyben-Herzberg relationship (Baydon-Ghyben 1888–1889, Herzberg 1901) is commonly used to relate the thickness of a freshwater lens in an ocean-island aquifer to the density difference between freshwater and saltwater. A generalized cross section of the freshwater lens is presented in Figure 8. Doan et al. (1960) reports the existence of such a basal freshwater lens in areas near the north end and center portion of the island. The theoretical interface between freshwater and saltwater will be at a depth below sea level about 40 times the height of the water table above sea level. Instead of a sharp freshwater/saltwater interface, however, freshwater is separated from saltwater by a transition zone in which salinity grades from freshwater to saltwater. In many field studies, the theoretical Ghyben-Herzberg interface depth within the transition zone is generally defined as the depth of about a 50 percent mix of freshwater and saltwater (i.e., roughly equal to a chloride concentration of 9,500 to 10,000 milligrams per liter). Under equilibrium flow conditions in permeable aquifer systems, the Ghyben--Herzberg relationship may provide a reasonable estimate of freshwater depth if the transition zone is comparatively thin (U.S. Geological Survey 2002). Pumping freshwater tends to disturb this equilibrium, resulting in a thinner freshwater lens and thicker transition zone. Freshwater lens thickness is affected by aquifer permeability and recharge rates. A reduction in recharge rate or an increase in permeability will reduce the thickness of the freshwater lens.

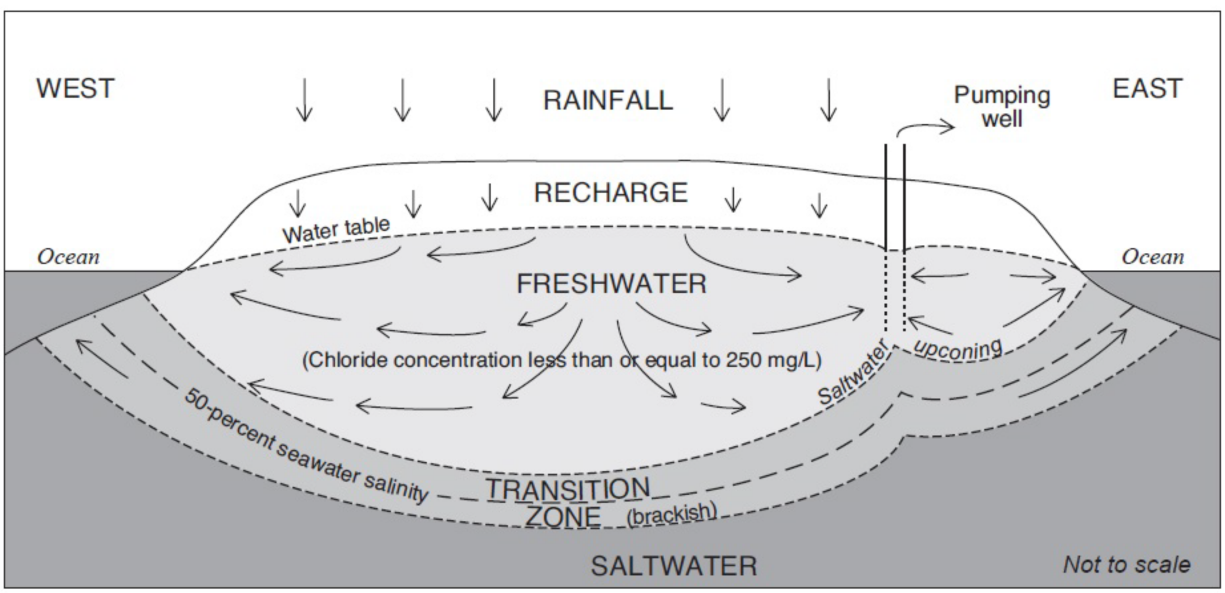

Figure 8. Generalized Depiction of a Freshwater Lens above Saltwater

Source: U.S. Geological Survey 2000.

In very permeable limestone, the water table is no more than a few feet above sea level, and the slope of the water table is nearly flat (U.S. Geological Survey 2002). Based on the Ghyben-Herzberg Principle, the depth to the 50% isochlor on Tinian should vary from a maximum of about 80 feet below mean sea level around the Central Plateau where the groundwater stands about 2 feet above mean sea level, decreasing radially to sea level around the perimeter of the island.

Potable and non-potable water for the proposed action is expected to come from one of two new well fields (Well Fields A and B, shown in Figure 4).

The groundwater surface has been mapped (Doan et al. 1960; USGS 2000) in the notional DoD well field to range from about 0.8 to 1.6 feet above mean sea level. Assuming an ideal freshwater lens, the 50 percent isochlor would vary from about 32 to 64 feet below mean sea level in the center of the island and would thin toward the coast. The portion of the lens that is useful for potable water (i.e., with a chloride concentration of less than 250 milligrams per liter [approximately 1 percent isochlor]) is likely thinner than the theoretical 50 percent isochlor depth.

Most of the fresh groundwater discharges naturally from the aquifer at onshore and submarine coastal springs. Stafford et al. (2004, 2005) documented caves, fractures, and coastal springs on Tinian, which can be locally important for groundwater development. A small amount of groundwater may be lost locally to evaporation and transpiration at the Makpo Marsh potential wetland complex and Hagoi Lake (U.S. Geological Survey 2002).

4.2.2 Hydrogeology

Hydraulic conductivity is a quantitative measure of the capacity of a rock to transmit water. Limestone units tend to have high hydraulic conductivities because of the porous and well-washed character of coral reefs, as well as secondary porosity as a result of dissolution. In contrast, pyroclastic rocks tend to have much lower hydraulic conductivities as a result of poor sorting and the high susceptibility of some volcanic minerals to chemical weathering and alteration to clays (U.S. Geological Survey 2002), as is the case on Tinian.

Tinian, a composite karst island aquifer (Jenson et al. 2006), is a triple-porosity aquifer. The young limestone retains substantial primary (interparticle or matrix) porosity, which makes the dominant contribution to storage and usually local transmission to wells. Regional transmissivity is dominated by widened fractures, which may develop along faults or along tension fractures. Where wells intercept the fracture network, performance can be one or more orders of magnitude higher than for wells that draw their production exclusively from local matrix porosity. The third source of porosity in composite islands is conduits (cave systems) that can develop along the contact between the overlying soluble limestone aquifer and the underlying insoluble volcanic basement. Such conduits can develop along the flanks of the basement rises and ridges where they stand above sea level or have been above sea level during ice-age, sea-level low-stands (Vann et al. 2013). Hydraulic conductivities in carbonate island karst aquifers can range from local values of 1 to 10^3 feet per day to regional values of 10^3 to 10^4 feet per day (Rotzoll et al. 2013).

The Tinian pyroclastic rocks are generally believed to have much lower permeability than limestone because of their texture and density and are essentially considered non–water-bearing for the purposes of this study. The overlying Tagpochau Limestone, where it exists beneath current ocean levels, and the Mariana Limestone that overlies it are both considered viable aquifers in this study. The minor beach deposits, alluvium, and colluvium are not situated in areas or at elevations that make them viable as groundwater resources for the purposes of this study. Doan et al. (1960) reported historical well productions from the military wells ranging from nil to 100 gallons per minute, with the majority being in the 60 to 100 gallons per minute range. The U.S. Geological Survey performed aquifer tests on Tinian between 1994 and 2000 to estimate the hydraulic conductivity of the Tinian aquifers (Tagpochau Limestone and Mariana Limestone). Pumping rates for the tests ranged from 3 to 165 gallons per minute. Resulting estimates of hydraulic conductivity in Tagpochau Limestone and Mariana Limestone on Tinian ranged from 21 to 23,000 feet per day.

The U.S. Geological Survey prepared a groundwater model in *Geohydrology and Numerical Simulation of Alternative Pumping Distributions and the Effects of Drought on the Ground-Water Flow System of Tinian, Commonwealth of the Northern Mariana Islands* (U.S. Geological Survey 2002). For modeling purposes, Tinian was divided into three horizontal hydraulic conductivity zones: (1) highly permeable limestone, (2) less permeable, clay-rich limestone, and (3) low-permeability volcanic rocks. The two-dimensional, steady-state groundwater flow model was developed to enhance the understanding of: (1) the distribution of aquifer hydraulic properties, (2) the conceptual framework of the groundwater flow system, and (3) the potential effects of various pumping distributions and drought on water levels and the freshwater/saltwater zones. For the modeling, the U.S. Geological Survey used values of 10,500 feet per day for highly permeable limestone, 800 feet per day for less permeable limestone, and 0.2 feet per day for volcanic rock (U.S. Geological Survey 2002). This 4 to 5 order-of-magnitude contrast is not unusual in composite islands. The U.S. Geological Survey monitored and contoured ambient groundwater elevations for further understanding of the groundwater flow regime (U.S. Geological Survey 2000). Groundwater generally flows radially away from the North-Central Highland and the Southeastern Ridge.

4.3 WATER QUALITY

Chloride concentration is an important secondary standard for Maui Well No. 2 because it has the potential to indicate the quantity of freshwater available at that location. The secondary maximum contaminant level for chloride is 250 milligrams per liter. Table 2 provides chloride concentrations at Maui Well No. 2 between 2012 and 2023.

Table 2. Chloride Concentrations at Maui Well No. 2

Year	*Chloride (mg/L)*	
	Average	*Range*
2012	196	175–223
2013	190	172–217
2014	213	212–214
2015	213	212–214
2016	190	184–196
2017	184	184
2018	176	176
2019	146	NA
2020	145 [a]	NA
2021	176 [a]	158–176
2022	176 [a]	158–176
2023	177	NA

Notes: [a]Value revised to highest instead of average.
Legend: mg/L = milligrams per liter; NA = not available; No. = Number.
Source: Commonwealth Utilities Corporation 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023, 2024.

U.S. Geological Survey 2002 reported that chloride concentration at the Municipal well [Maui Well No. 1] did not change significantly during 1992–1997, averaging about 180 milligrams per liter, and ranging from 160 to 220 milligrams per liter. The average chloride concentration is about 100 milligrams per liter higher than initially measured during non-pumping conditions after construction in 1945 (Lawlor 1946), and 100 milligrams per liter higher than at other wells in the median valley.

Salinity in a freshwater lens is gradational, consisting of an upper freshwater core through an underlying transition zone to saltwater below. However, depending on aquifer permeability and the strength of tidal influence, the transition from freshwater to saltwater can be gradual or sharp. On small islands, mixing in the transition zone results mainly from tidal fluctuations superimposed on the gravity-driven flow of freshwater toward the shore. In areas near the coast where mixing is thorough, a freshwater lens may not form and brackish water may exist even at the water table. Under conditions of steady recharge, no pumping, and no ocean-level effects, the steady-state lens would have fixed dimensions. In reality, rainfall is episodic and seasonal, and lens volume fluctuates naturally with time. Tidal fluctuations, variable recharge, and episodic pumping all combine to create a thicker transition zone than would be present without these influences (U.S. Geological Survey 2002). Figure 8 shows a generalized graphic depiction of a freshwater lens above a saltwater wedge on a small island.

Based on monitoring performed by the U.S. Geological Survey in the 1990s, the transition zones in wells TH-08 and TH-09 (monitoring wells installed by the U.S. Geological Survey in 1993) varied from approximately 30 to 50 feet thick in 1993 and 1994. Doan et al. (1960) report 20 pre-pumping chloride concentration results ranging from 16 milligrams per liter to 650 milligrams per liter. Two of the samples exceeded the EPA's secondary maximum concentration level for chloride of 250 milligrams per liter. Ten pairs of pre-pumping and post-pumping chloride concentration results are also reported (U.S. Geological Survey 2000). Prior to pumping, 1 of the 20 wells (with pre- and post-pumping data) exceeded the secondary maximum concentration level and, after pumping, 2 to 3 wells exceeded that standard. One of the post-pumping results was simply recorded as "high," but it is assumed this refers to a concentration higher than 250 milligrams per liter. Seven to 8 of 10 wells remained below the secondary maximum concentration level at the end of pumping.

Bureau of Environmental and Coastal Quality provided the following information in Captain Brian Bearden's email to Jacqueline Rice from Headquarters, USMC, forwarded to Doug Gilkey on March 3, 2025:

> [Bureau of Environmental and Coastal Quality]'s previous review comments raised a number of concerns with the proposed location near the airport, primarily related to the potential to contaminate valuable groundwater resources. That location was within an area where we have documentation and other data that would support classification as a Class I Aquifer Recharge Area/Groundwater Protection Zone as established or references [sic] in several CNMI regulations. Our primary documentation supporting this concern is the 2000 USGS Water investigations Report 00-4068 which shows the area on the north side of the airport as being within the boundaries of the +1.0 feet groundwater elevation contour, which the CNMI Well Drilling and Well operations regulations (NMIAC [Northern Mariana Islands Administrative Code] § [Section] 65-140-2010) utilize as the boundary of the Class II groundwater protection zones, which also contains the Class I zones which are more loosely defined to include "municipal wellfields" and other resources that are either currently in use for water supply, or meet specific other criteria.
>
> In contrast to this, the IBB [International Broadcasting Bureau] site is in an area that appears to not be within either a Class I or II Aquifer Recharge Area/Groundwater Protection Zone. Even though the USGS report does not show groundwater elevation contours in this particular area due to lack of data, the map contours can be reasonably extrapolated, supported by general knowledge of island freshwater lens hydrology, to strongly suggest that the IBB site is located outside the potential boundaries of any future Class I or II groundwater protection zone designation. Thus, the IBB site would not trigger the same level of concern stated in [the Bureau of Environmental and Coastal Quality]'s previous comments related to the locations closer to the airport and would be a preferred location to minimize such concerns.

Table 3 summarizes water production (i.e., extraction) quantities from Maui Well No. 2 as recorded by the Commonwealth Utilities Corporation at the well site. Production includes water delivered into the distribution system, which is inclusive of water billed to customers, unmetered uses, leaks, losses, and overflows.

Table 3. Commonwealth Utilities Corporation Water Production from Maui Well No. 2

Year	*Total Annual (MG)*	*Average Daily (MGD)*
2019	313	0.86
2020	312	0.85
2021	307	0.84
2022	321	0.88
2023	306	0.84
2019 to 2023 Average		0.85

Legend: CUC = Commonwealth Utilities Corporation; MG = million gallons; MGD = million gallons per day; No. = Number.
Source: Commonwealth Utilities Corporation 2024a.

The EPA has stated that the sustainable yield at Maui Well No. 2 in drought conditions is 1.0 million gallons per day. The average production at Maui Well No. 2 for the last 5 years was approximately 0.85 million gallons per day. This sustainable yield value from EPA only applies to the Maui Well No. 2 location and is not an indication of the sustainable yield of all of Tinian.