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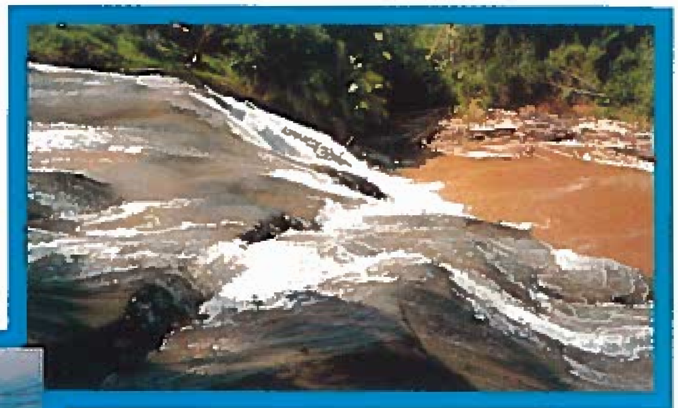

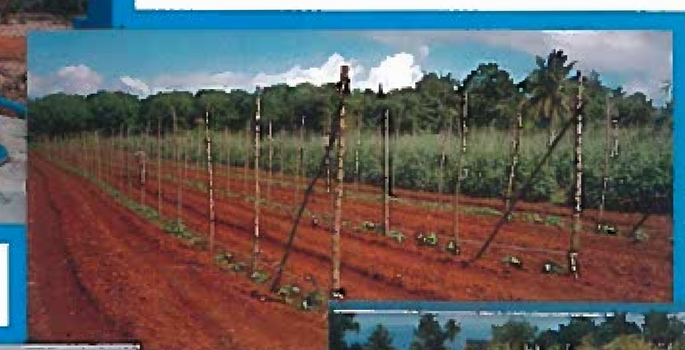

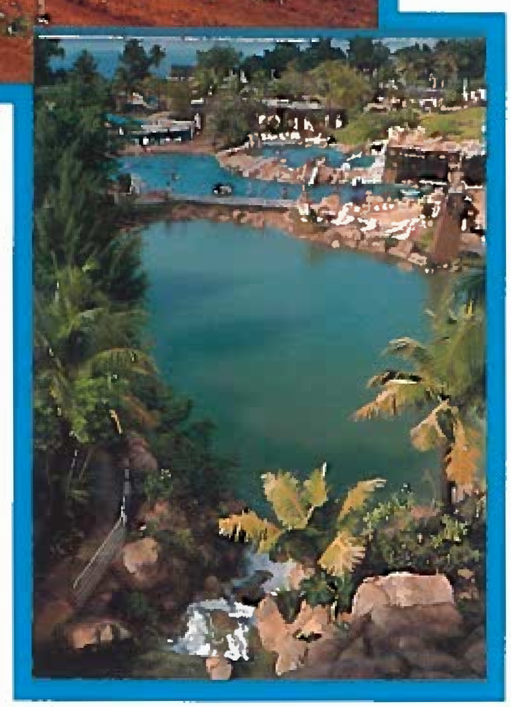

GUAM WATER FACILITIES MASTER PLAN UPDATE

PREPARED BY

BARRETT CONSULTING GROUP
AGANA, GUAM

WATER FACILITIES MASTER PLAN UPDATE

Prepared for the

PUBLIC UTILITY AGENCY OF GUAM
GOVERNMENT OF GUAM

February 1992

Prepared by:
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February 3, 1992

Bureau of Planning

Mr. Joseph F. Mesa
Chief Officer
Public Utility Agency of Guam
Government of Guam
P.O. Box 3010
Agana, Guam 96910

Mr. Mesa:

In accordance with our engineering agreement dated April 30, 1990, we are pleased to present, herewith, the *Guam Water Facilities Master Plan Update*. The report summarizes our review of the original "Water Facilities Master Plan", our investigations and analyses dealing with water supply, quality, transmission, storage and treatment and presents an updated program for meeting the Island's projected water needs.

We appreciate the assistance and cooperation provided by your staff and the Government of Guam agencies that participated in this planning effort. We look forward to discussing our findings with you at your earliest convenience.

Very Truly Yours,

BARRETT CONSULTING GROUP INC.

Edwin C. Pier, P.E.
Project Manager

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Principal In Charge

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TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES

LIST OF FIGURES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AF	Acre-feet
AWWA	American Water Works Association
BOP	Bureau of Planning
CCI	Construction Cost Index
cfs	cubic feet per second
DPS	Department of Public Safety
DPW	Department of Public Works
EC	Electrical Conductivity
ENR	Engineering News Record Magazine
EPA	U. S. Environmental Protection Agency
fps	feet per second
FSDWA	Federal Safe Drinking Water Act
GEDA	Guam Economic Development Agency
GEPA	Guam Environmental Protection Agency (also Guam EPA)
GHURA	Guam Housing and Urban Renewal Authority
GORCO	Guam Oil and Refinery Company
GovGuam	Government of Guam
GPA	Guam Power Authority
gpcd	gallons per capita per day
gprd	gallons per room per day
gpm	gallons per minute
GPSDWR	Guam Primary Safe Drinking Water Regulations
GSDWA	Guam Safe Drinking Water Act
HGL	Hydraulic Grade Line
HP	horse power
ISO	Insurance Services Office
l.f.	lineal feet
meq	milliequivalent
MG	millions of gallons
MGD	millions of gallons per day
mg/l	Milligrams per liter
mph	miles per hour
MSL	Mean Sea Level

LIST OF ABBREVIATIONS (con't)

MW	megawatt
NAS	Naval Air Station
O & M	Operation and Maintenance
OM & R	Operation, Maintenance and Replacement
ppm	part per million
psi	pounds per square inch
PUAG	Public Utility Agency of Guam
TC	Total Coliform Counts
TDS	Total Dissolved Solids
UOG	University of Guam
USACOE	U. S. Army Corps of Engineers
USGS	United States Geological Survey

I

INTRODUCTION

4. In general, much of the water system appears to receive little maintenance other than the bare minimum required to keep the system in operation.

5. Corrosion of exposed water system components is a continual maintenance problem on Guam. This is especially true on exposed piping at the well stations where corrosion has occurred to the extent that expensive pump control valves have been rendered inoperative.

6. Many of the existing PUAG facilities need renovations or design modifications to optimize operation. The following are examples:

   a. Some chlorination facilities and fluoridation systems are not adequately protected against direct sunlight and are subject to vandalism.

   b. The majority of PUAG's existing water storage reservoirs are unfenced and in need of repainting.

   c. Fire hydrants still receive insufficient maintenance and are often defective.

   d. Although some of the CIPs recommended in the original Water Master Plan have been implemented, the various PUAG water systems have considerable footage of small diameter pipelines (2 inches in diameter and smaller) which provide no appreciable fire protection.

   e. Existing water storage reservoirs have recently been provided with radio telemetry level monitoring equipment. However, the frequency must be changed as there is currently interference from other radio users. Many reservoirs still do not have effective float valves. This results in periodic reservoir overflows. As the Island's water demands increase, it will become increasingly important to prevent water wastage and to monitor the characteristics of the overall water system. Fully functioning automatic pump controls and reservoir water level monitoring equipment will be required to meet this need.

7. PUAG's leak detection program has been successful in locating and repairing an estimated 6 MGD in leaks throughout the Island. Even so, individual water service meters continue to be a source of leakage and "unaccounted-for" water losses resulting from defective meter readings. Many meters do not have meter boxes and are inadequately protected from damage and vandalism.

8. Although PUAG has prepared an operations and preventative maintenance program, the program has yet to be fully implemented. PUAG still utilizes corrective maintenance on an "as-needed" basis.

9. A need for future sanitary surveys of PUAG water systems has been demonstrated by the findings contained in GEPA's *Water System Sanitary Survey FY'88 and FY'89 Report*.

Water Requirements

1. A total of 124 source diversions are currently used as water supplies by the U.S. Air Force, U.S. Navy, PUAG, and private users. Of the total, approximately 94 percent are wells.

2. PUAG produces the majority of the Island's water supply, approximately 51 percent of the total. The Navy is the second largest producer with about 35 percent of the over-all production.

3. PUAG's residential user classification comprises 68 percent of PUAG's overall total water demand. The commercial classification is the next highest user accounting for just over 21 percent of the total.

4. PUAG's water systems are plagued by a high "unaccounted-for" water component, comprising approximately 30 to 40 percent of the total water production. For the long term, it is assumed that the unaccounted-for water rate can be reduced to 15 percent by the year 2010. Comprehensive leak detection, meter maintenance, and water conservation programs will need to be implemented to obtain this objective. In light of the Island's limited water supply, formulation of a water conservation program in the immediate future should be considered a priority issue.

5. The per capita demands used for projecting civilian water use demands, excluding unaccounted-for water, varied from 99 gallons per capita per day (gpcd) to 138 gpcd with hotels consuming water at a typical rate of 450 gallons per room per day (gprd).

6. Based on the population projections and per capita demand, the projected Island-wide average daily water demand for the years 1990, 2000 and 2010 is 26 MGD, 60 MGD, and 75 MGD respectively.

7. The projected total PUAG demands for the average day, average day in the maximum month, and the maximum day in the year 2010 are 75 MGD, 90 MGD, and 113 MGD, respectively.

8. The military water demand, excluding water sold to PUAG, is assumed to remain constant to the year 2010 at 14 MGD.

9. Although the time schedule and size of the proposed commercial port/industrial park complex is uncertain, the average water demand projected for this use in the year 2010 by the Port's recent Commercial Port Master Plan is approximately 0.27 MGD.

10. Overall agricultural demand, including aquaculture, is expected to remain constant or to diminish in the future. Therefore the average annual water demand for agriculture is estimated to remain at 4.2 MGD through the year 2010.

11. It is estimated that a typical 18-hole golf course will require about 18,000 gpd to irrigate the greens alone. However, no projection of the number of golf courses for year 2010 could be made from available information.

12. Water consumption by hotels is expected to increase to about 26 MGD by the year 2010.

13. Production at privately-owned wells such as Foremost and Island Equipment is expected to remain relatively constant at 2 MGD over the foreseeable future.

14. The projected water demands are influenced by water consumption practices, availability of water supply, water quality, increased living standards, and related factors. It is important, therefore, that per capita use rates be evaluated on a yearly basis and the master plan be reviewed every five years to reflect any changes.

Water Quality

1. Guam's Safe Drinking Water Act of 1977 and the Safe Drinking Water Regulations of 1978 were adopted in response to the Federal Safe Drinking Water Act of 1974. Guam EPA administers these regulations. The 1986 Safe Drinking Water Act Amendments signed into law by President Reagan contain additional requirements that will impact PUAG as the public purveyor of water on Guam. The impacts are as follows.

   a. Expanded list of regulated contaminants along with maximum contaminant levels (MCL) for 83 initial contaminants, as well as for an additional 25 contaminants every three years.

   b. Designation of best available technology for control of each of the regulated contaminants.

   c. Requirements for filtration of surface water supplies which do not meet specific criteria.

   d. Requirements for disinfection of all public water supplies—both groundwater and surface water.

   e. Monitoring requirements for contaminants that are not regulated.

   f. Prohibition of the use of lead solders, flux and pipe in public water systems.

   g. Requirements for development and maintenance of groundwater protection programs.

2. In accordance with recommendations presented by the *Northern Guam Lens Study* in 1982, a new water quality monitoring program has been instituted by the Guam EPA which analyzes each of the PUAG wells for pH, alkalinity, color, turbidity, taste, hardness, chlorides, and conductivity. The results of the groundwater analyses for 1988 are as follows.

   a. Five wells (A-13, A-14, A-17, A-18 and A-19) produced water with chlorides in excess of 250 mg/l.

   b. All wells have some nitrates present but none are approaching the Maximum Contaminant Level (MCL).

   c. Results of organic analyses consistently showed most levels were below the detectable limits of the tests. Inorganic analyses also show all sources below the MCL.

   d. Concentrations of Selenium in wells A-17, A-19 and A-21 are now significantly below the 10 mg/l MCL concentration.

   e. Concentrations of lead in the range of 10 to 40 parts per billion have been detected in production wells islandwide. The sources of the lead have not been identified and may be derived from the volcanic formation of the Island.

3. The use of chemicals such as pesticides and fertilizers on golf courses and the increasing number of golf courses being developed in northern Guam raises concerns that groundwater quality will be affected. A plan for addressing these concerns should be adopted by the government of Guam.

4. With one or two exceptions Guam's surface water quality is satisfactory for all domestic and irrigation uses as well as most industrial uses contemplated in this master plan.

5. Guam EPA also monitors PUAG's water distribution system. The results of this monitoring in 1988 and 1989 are as follows.

a. The most common water quality problem is chloride contamination from saltwater intrusion into wells.

b. Occasional instances of bacterial contamination and turbidity occurred generally in the South where surface supplies are used.

c. A review of PUAG's practices in sampling for water quality analyses indicates the need for revision to the number of samples taken in each service area and locations of the sampling points.

d. On many occasions, PUAG was not in compliance with the reporting requirements of Guam's Safe Drinking Water Regulations. A computerized data processing system is recommended to aid PUAG in the sampling, monitoring and reporting tasks, as well as in the investigation of violations.

Water Supply and Treatment Alternatives

1. As a result of the findings of *Northern Guam Lens Study (NGLS)*, the northern Guam aquifer is estimated to have a sustainable yield of about 60 MGD. This is believed to be a conservative estimate. An ongoing review of well production data collected since the NGLS was released indicates that the sustainable yield may be higher with 60 MGD of sustainable yield available to PUAG alone. Apparently, the sustainable yield may be stressed for limited periods of time without damaging the integrity of the northern Guam groundwater lens. Therefore it is projected that PUAG will be able to produce an average day supply of 60 MGD by the year 2010 which may be temporarily stressed to 90 MGD under maximum day demands.

2. Based on available data, there appears to be sufficient water resources on Guam to meet the needs of the Island through the year 2010 if they are developed and managed wisely. However, the groundwater supply will not be sufficient to meet the demands imposed by projected hotel development and hotel-induced populations. Consequently, alternative water supplies must be developed.

3. The development of any significant surface water supply will be quite costly as compared with development of groundwater supplies.

4. The potential Ugum and Inarajan Reservoirs lie in close proximity to the bulk of lands zoned for agriculture. The possible use of such supplies for irrigation purposes might well be appropriate considering the fact that treatment would not be required. Although this could reduce the amount of water needing treatment, the bulk of the water collected by the dams would be required for potable water consumption by the year 2010. Dam development and treatment costs, in addition to the environmental regulations to be addressed, make development of surface waters on Guam a formidable undertaking. Consequently, the process of their development should begin immediately if this source of water is to be on line by year 2010.

5. Because the potential for wastewater reclamation on Guam is so closely tied to the future of commercial agricultural and golf course activities, it is clear that a more detailed analysis of both subjects must be made before definitive conclusions can be drawn.

6. The unit cost of brackish water desalinization appears to be comparable to the unit cost of surface water production on Guam. However, available desalinization processes would require a large commitment of Guam's scarce power resources. Further investigation into the cost of desalinization on Guam should be performed to conclusively determine the feasibility of the process.

Proposed Water Distribution System Improvements

1. Substantial pipeline improvements are needed to provide the necessary transmission facilities to meet potable water demands in the year 2010. In addition, surface water supplies will have to be developed. If reclaimed wastewater or untreated surface water is to be used for irrigation, separate transmission facilities will have to be provided.

2. By the year 2010, approximately 55 MG of additional storage will be required to provide 24 hours of average day demand.

3. It was assumed that the overall "net use" of military water by PUAG would remain constant to the year 2010. This condition could change dramatically depending on decisions made by the U.S. Department of Defense, such as the relocation of forces

from the Philippines. There is a definite potential for "trading" water and the shared development of water resources with the military which should be pursued.

4. The PUAG production deficit will be approximately 89 MGD by the year 2010 based on present supply capability and projected maximum day demand.

5. A groundwater management program has been developed for the Northern Lens by the NGLS which also recommends the proper sizing and location of new wells. In light of approximately 10 years of well production data that has been collected since the NGLS was done, reevaluation of the program is required to provide an updated program of well development and redevelopment.

6. PUAG is currently reviewing historical production and exploratory well data to update the groundwater management program recommended in the NGLS. The resulting well development and redevelopment program should be implemented immediately to meet projected water demands.

7. Service Area "A" is the major water-producing area on Guam. In this area it will be necessary to install large diameter pipe lines to carry exported water to the other three water service areas.

8. Service Areas "B", "C", and "D" have some water production capability but apparently not enough to be self-sufficient. Water exported from Service Area "A" must travel through Area "B" to Areas "C" and "D".

9. Based on the results of an evaluation of existing facilities and a hydraulic analysis, numerous capital improvements were identified. The proposed capital improvements are shown in Figures 9-2A, 9-2B, 9-2C, and 9-2D, located at the end of this document, and are described in Appendix H.

10. It appears beneficial for the military and the Government of Guam to share in the development of water supplies and to exchange obligations to serve various water service areas rather than to continue to make major capital and operating expenditures to convey the water to users located great distances from a particular source. In order

to consummate such agreements, it is essential that the reliability and quality of the exchanged water supplies be assured.

Conclusions and Recommendations

The primary consideration in developing the Water Facilities Master Plan was to create a workable system that could be implemented in phases within reasonable economic limits as the Island develops to the year 2010. The recommended improvements are shown on Figures 9-2A, 9-2B, 9-2C, and 9-2D at the end of this document and are summarized in detail in Appendix H of this report. The improvements consist, in general, of the following features:

- Supply facilities consisting primarily of the groundwater supplies in the northern aquifer and southern surface water as well as water purchases from military sources;
- A comprehensive network of pipelines for distribution of water throughout the Island; and
- The necessary pumping facilities and storage reservoirs to meet normal development of the Island as well as to supply tourist demands and meet fire flow requirements.

It is recommended that the Water Facilities Master Plan for the Island of Guam, as shown in Figure 9-2, be adopted as the engineering basis for the development of an Island-wide water system for the Government of Guam.

- PUAG is presently undertaking an analysis of well production data in the northern groundwater lens. The objective of this Groundwater Program Evaluation is to more precisely identify the location and quantity of fresh water available and will update the groundwater management plan for proper development and operation of well fields in the area.

Upon completion of the update of the Groundwater Program Evaluation, it is recommended that the Water Facilities Master Plan be reviewed and modified as necessary to reflect the findings of this Study.

- There is a need to periodically revise water facilities plans to reflect changing conditions, trends, new goals and objectives, and technological developments. As mentioned in this report, long-range planning is a valuable tool if it continues to reflect changing conditions. This *Water Facilities Master Plan* has been based on population projections, per capita water demands, and groundwater supply estimates which will undoubtedly vary to some extent during Guam's economic development. This, of course, can affect size and location of pipelines as well as capacity requirements of pumping and storage facilities.

It is recommended that the Water Facilities Master Plan *be updated at least every five years and at more frequent intervals if any major changes in anticipated growth patterns occur. It is also recommended that per capita use rates established herein be reviewed annually for any changes in water use trends. System maps, prepared as part of the original* Water Facilities Master Plan, *should be kept current by noting changes as they are made in the system and by periodically updating the original maps to reflect the new conditions.*

- A potential source of water supply for agricultural, golf course and other nonpotable uses such as groundwater recharge is wastewater reclamation. Much of the wastewater generated on Guam is presently treated and discharged through underwater outfalls to the ocean. Based on the economics involved, this water may, at some time in the future, be suitable for utilization for agricultural, commercial, industrial, groundwater recharge, or other purposes on Guam. Separate transmission facilities would undoubtedly be required to put this source to use.

It is recommended that a study be undertaken to identify potential uses of reclaimed wastewater on Guam. It is further recommended that the Guam Environmental Protection Agency (GEPA) develop and adopt wastewater reclamation criteria for potential uses.

- The investigation undertaken as part of this project indicates the need to implement a comprehensive preventative maintenance program. Sanitary surveys over the past 10 years have documented significant deterioration of physical facilities as well as substantial water losses which exceed reasonable standards. Vandalism has also created operational difficulties with the water system and procedures should be adopted to minimize this problem. Significant recoveries of lost water appear to have been made by PUAG's recent leak detection and repair program. An operations and maintenance program has been developed within PUAG and portions have been implemented. This plan is included as Appendix C. By adopting an effective preventative maintenance program, it is hoped the service life of existing facilities can be increased, thereby resulting in substantial savings in capital expenditures as well as a reduction in the cost of corrective maintenance. In addition, by continuing the leak detection and establishing a meter repair program, the operation of Guam's water supply can be optimized.

It is recommended that a comprehensive preventative maintenance program involving leak detection surveys, meter testing, repairs and replacement, routine inspection of all facilities, and periodic replacement of deteriorated facilities, be fully implemented on an Island-wide basis.

- Because of the lack of a preventative maintenance program in the past, many facilities have been allowed to deteriorate to a point where replacement is needed. By delaying the replacement of worn-out facilities, the chance of serious disruption of system operations caused by equipment failure is greatly increased.

It is recommended that a comprehensive inventory of all existing facilities be undertaken and that a replacement schedule be prepared and implemented that establishes priorities for replacement of inadequate equipment.

- Many agencies and individuals have been involved in the development of Guam's water system. Over the years, a variety of design standards have been utilized which have resulted in the use of many different pipe materials, types of equipment, and instrumentation. Because of Guam's isolated location, it is important that improvements to the water system be standardized to allow a ready inventory of parts when replacement is needed. PUAG recently completed preparation of design standards for its water system.

It is recommended that after careful review of the proposed water system design standards, an appropriate set of standards be adopted for all construction.

- While the planning, design, and construction of a water system takes extensive effort, the efficient operation of the completed system is vital to ensure delivery of high quality water in adequate quantities. Personnel must receive proper training and have adequate support to properly operate the system.

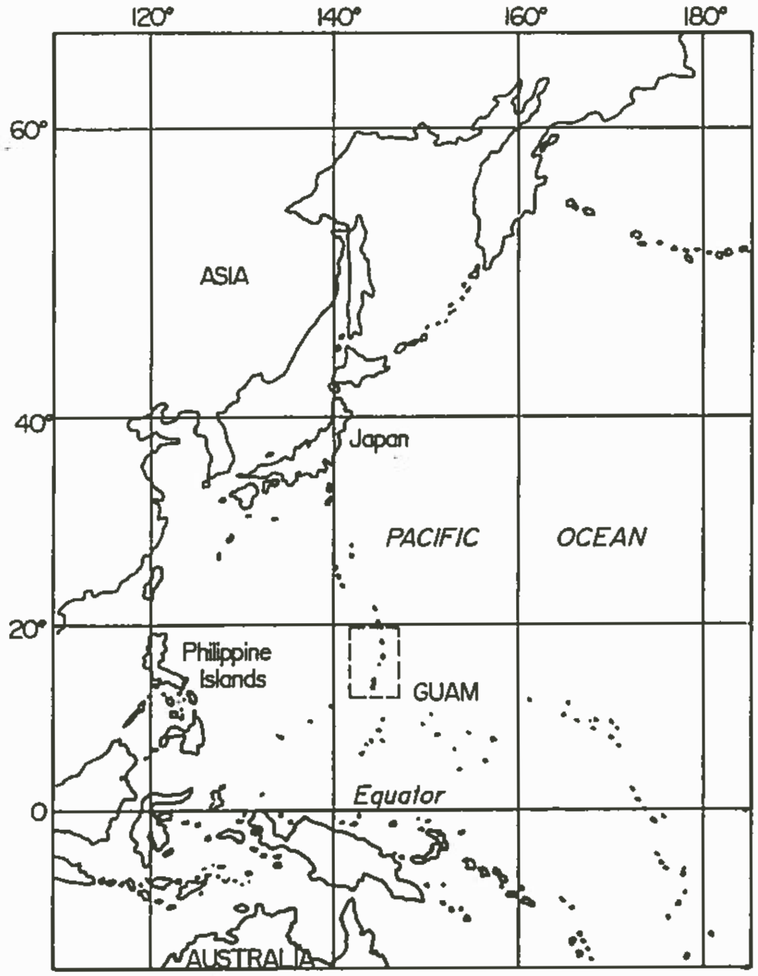
Considerable improvements have been achieved in PUAG operations since the original Water Master Plan through implementation of an operator training and certification program. It is recommended that this program be continued and expanded as well as requiring certification as a condition for classification and advancement.

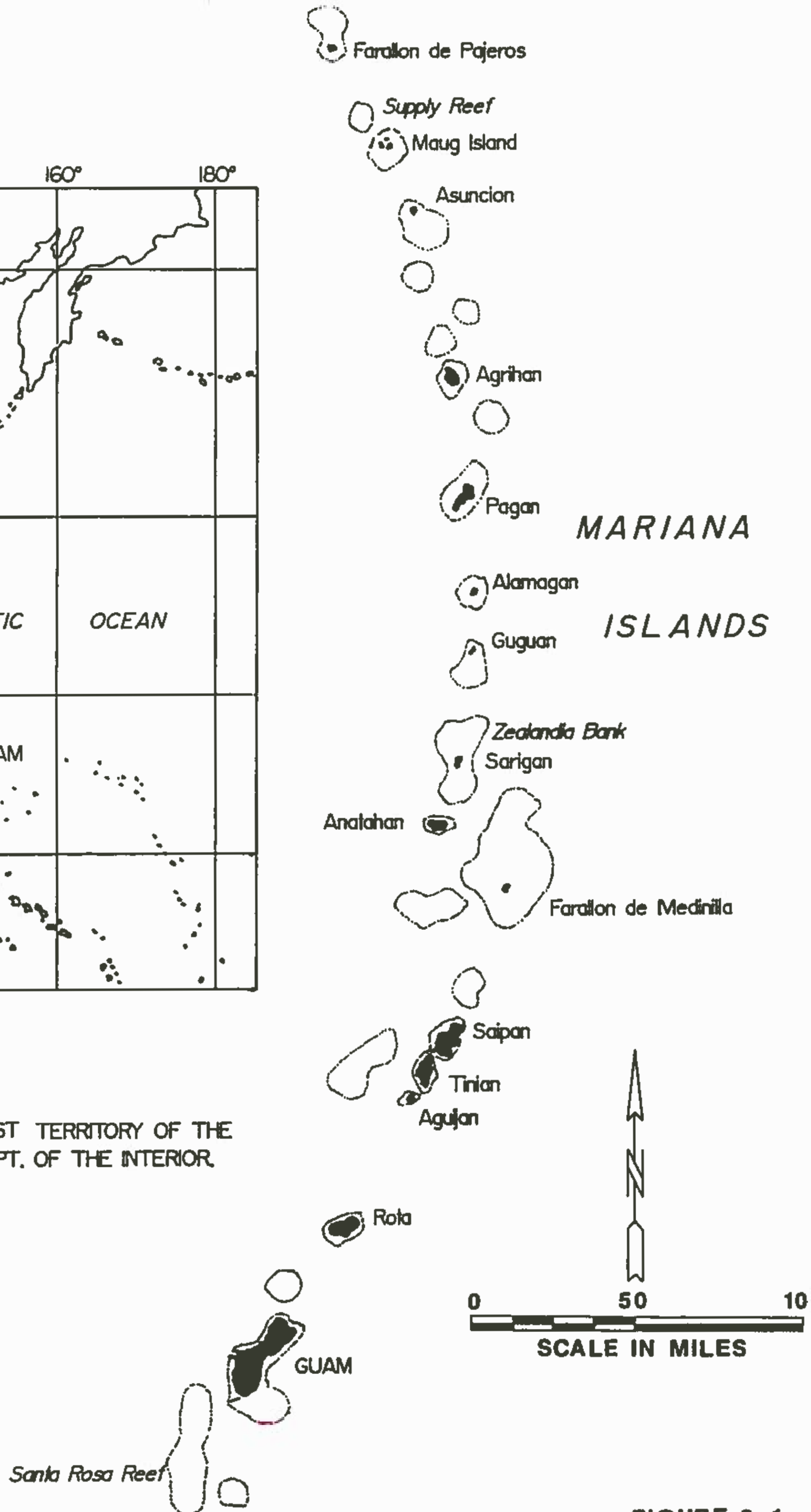
- Both the Government of Guam and the military provide water service to large segments of the Guam population. To ensure a continued supply in the event of emergency, it is important that close cooperation be maintained between the military and GovGuam water supply agencies.

It is recommended that routine meetings be continued between military and GovGuam to update emergency procedures, resolve operating difficulties which relate to both agencies, and to establish criteria for utilization of Guam's limited available water resources.

- An estimated 40 percent of the additional storage required for year 2010 is directly related to projected hotel needs. Considerable advantage to both PUAG and commercial operations could be realized if heavy commercial water consumers supplied their own water storage in conformance to PUAG standards. PUAG would save in capital improvement and maintenance costs and the commercial operator would be assured of control over the continuity and adequacy of supply as well as the timeliness of the provision and maintenance of the storage facility. In addition, it would seem appropriate that provision of their own storage would decrease the impact fee assessed such a developer.

It is recommended that criteria be established to designate a level of water use at which it would be appropriate to require commercial operations to provide and maintain their own storage. Once the criteria is established, require all qualifying commercial institutions to provide their own storage facilities and provide appropriate adjustment to their impact fees or water service rates.





REFERENCE: MAP ENTITLED "TRUST TERRITORY OF THE PACIFIC ISLANDS," BY THE U.S. DEPT. OF THE INTERIOR, UNDATED

FIGURE 3-1

LOCATION MAP

CHAPTER III

DESCRIPTION AND CHARACTERISTICS OF THE STUDY AREA

General

Physical and environmental characteristics, as well as land use and growth trends, are essential considerations in water facilities planning. In this chapter each of these factors is discussed as it relates to Guam's water system evaluation and future needs.

The Mariana Islands group, consisting of fifteen individual islands, form an arch approximately 500 miles long which separates the Pacific Ocean from the Philippine Sea. As shown on Figure 3-1, there are four major islands in the Mariana chain: Saipan, Tinian, Rota and Guam, with Guam being the southernmost located at an approximate latitude of 13° 38′ and longitude of 144° 45′. Guam is the largest island having an area of approximately 212 square miles (550 square kilometers). The island is approximately 30 miles in length with a width of 8-1/2 miles at the northern tip and a maximum width in the south of 11-1/2 miles. The northern and southern land areas taper at the Island's center to a width of 4 miles as shown on Figure 3-2. The boundaries of the Island's 19 villages are indicated on Figure 3-3.

Based on archaeological evidence, Guam was inhabited by Chamorros as early as 1500 B.C., who emigrated from Islands in Southeast Asia. The Island was territorially divided and governed by individual chieftains. The Chamorros flourished as an advanced fishing, horticultural and hunting society, eventually developing to a population of between 80,000 and 100,000, approximately the size of the Island's present civilian population.

The Island was discovered during Ferdinand Magellan's expedition in 1521 and was claimed as a Spanish possession in 1565. The Spanish colonization was characterized by a period of warfare, disease and missionary activity. The population rapidly declined. As Guam emerged as a link in the early trade route between Mexico and the Philippines, the influence of Mexico was permanently implanted in the Guamanian culture.

In 1898, following the Spanish-American War, a U.S. Navy vessel sailed into Apra Harbor, landed and seized the Spanish Governor. The Spaniards quickly surrendered. In 1899, the United States formally purchased Guam, ending more than 300 years of Spanish rule.

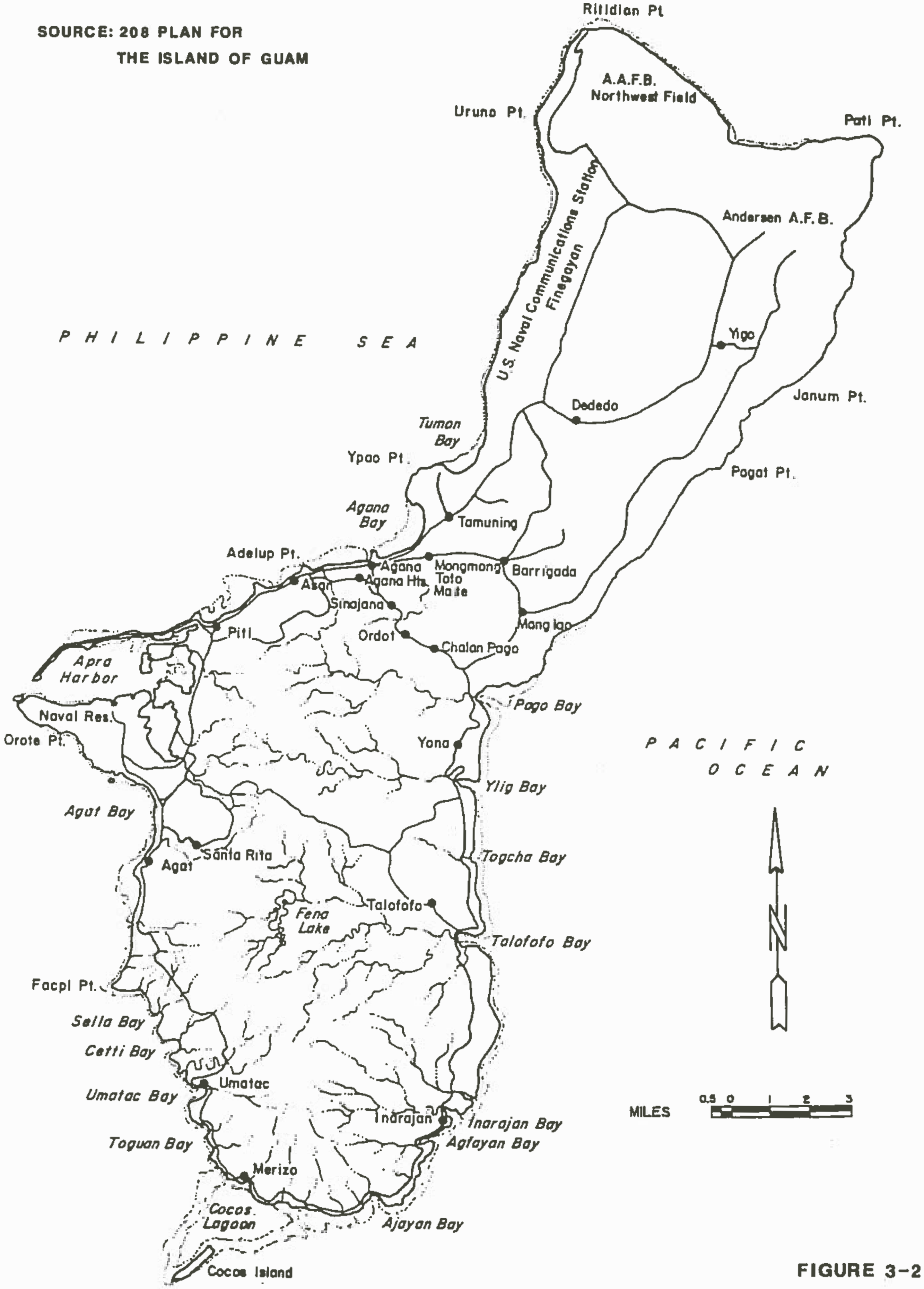


FIGURE 3-2

VICINITY MAP

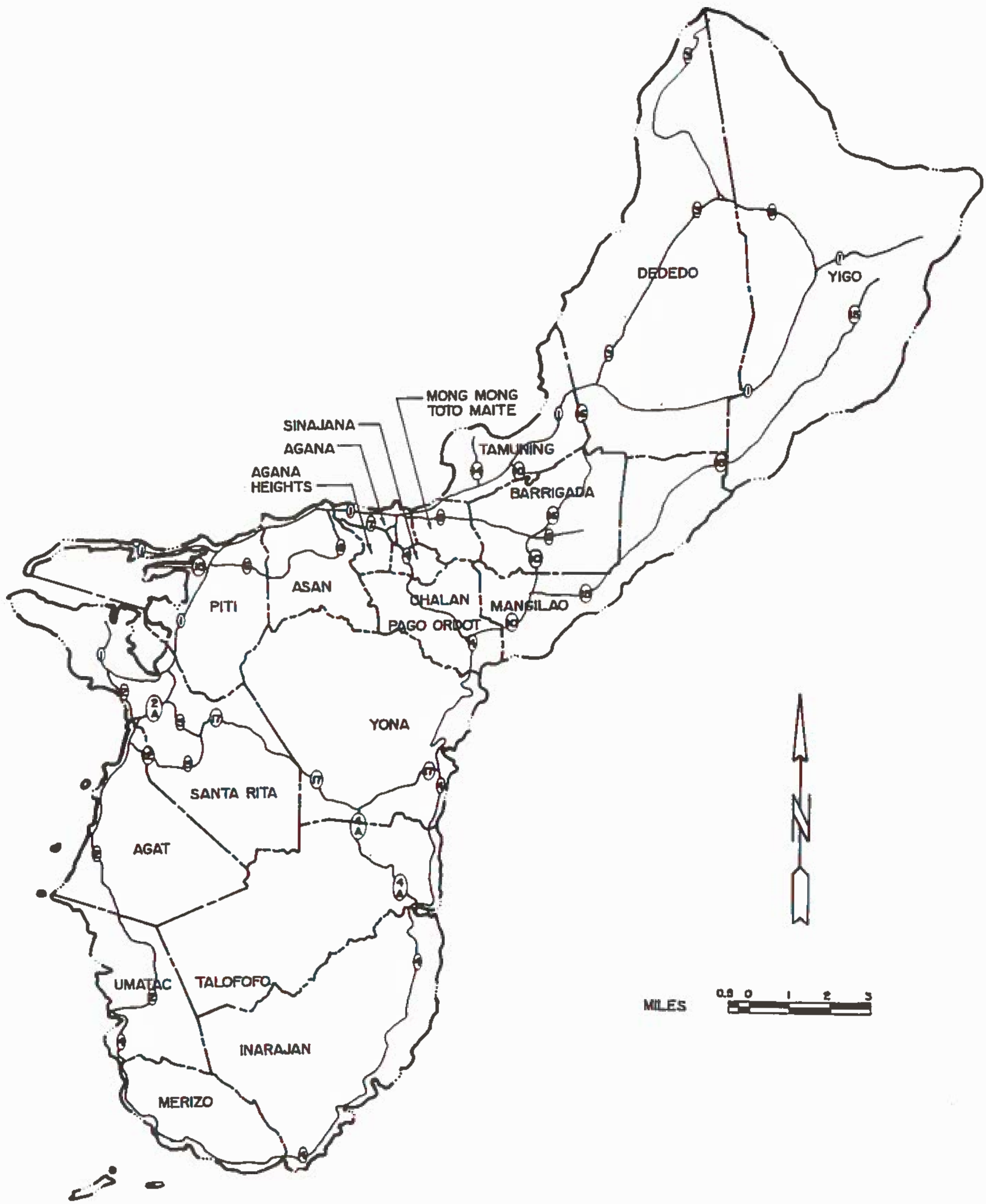


FIGURE 3-3

VILLAGE BOUNDARIES

- With water resources rapidly becoming a scarce commodity on Guam, conservation and reclamation of wastewater will probably become a necessity. As an example, water-cooled air conditioners on hotels have been found to require as much as 33 percent of the hotel's total water demand. This demand could be significantly reduced with the use of air-cooled air conditioners. Other areas for conservation include the design and installation of separate "gray" water systems and package wastewater treatment equipment within hotel or similar commercial structures for the reuse of wastewater for flushing and landscape irrigation.

It is recommended that PUAG, GEPA and DPW develop provisions to be included in Guam's building code that require the design and installation of appropriate water conservation fixtures and equipment for the permitting of new hotel, commercial and industrial projects. It is further recommended that incentives such as tax or service fee credits be given to institutions voluntarily installing such equipment or systems.

- The potential for contamination of Guam's groundwater lens from application of pesticides and fertilizers to proposed golf courses as well as agriculture is serious but may be controlled with proper regulatory measures and permitting requirements.

It is recommended that a set of qualifications for golf course development similar to the eight criteria required by the State of Hawaii's Department of Health, shown in Appendix G, be developed for use in reviewing and approving permits for golf course development.

- The Tumon area is experiencing explosive growth in hotels, condominiums, apartments and commercial facilities.

It is recommended that PUAG continue to improve the water distribution facilities in the Tumon area.

In December, 1941, the Japanese gained control of the Island. The Japanese occupation during World War II was relatively short-lived. In August, 1944, the United States regained control of Guam and thereafter Guam was utilized as a strategic military command post for Western Pacific operations. Upon signing of the Organic Act in July, 1950, Guam became an unincorporated territory of the United States. The act declared that the new territory should be known officially as Guam. The act additionally established a civil government, created a legislature with full lawmaking powers, established a District Court of Guam, enacted a Bill of Rights for the people of the territory, and granted United States citizenship to the people of Guam. In 1967, the first governor elected by the people took office and Guam became a self-governing territory of the United States.

Climate

As in most tropical islands in the Western Pacific, the weather on Guam is warm and humid throughout the year. The mean annual temperature near sea level is about 81°F (27.2°C) with monthly means ranging from 80°F (26.7°C) in January to a little over 82°F (27.8°C) in June. Rarely does the temperature exceed 90°F (32.2°C) during the daytime hours or fall below 70°F (21.1°C) at night. The relative humidity commonly exceeds 84 percent at night, year-round, with the average monthly humidity being at least 66 percent.

Guam's climate is characterized by two distinct seasons: a dry season from January to May and a wet season from July to November, with June and December being transitional months. The mean annual rainfall varies from about 80 inches on the central and coastal lowlands to about 110 inches on the uplands in southern Guam as indicated in Table 3-1. The average monthly precipitation at the Naval Communications Station (NCS) monitoring station is shown on Figure 3-4. A wide variation in rainfall can occur from year to year. In 1952, a maximum of 145.45 inches was recorded while the minimum rainfall recorded was 60.42 inches in 1955. Severe droughts are common during the period of February through April.

The easterly trade winds with velocities between 4 and 12 miles per hour (mph) are dominant throughout the year. Only occasionally do winds exceed 24 mph except during major tropical storms or typhoons. Small scale storms or squalls can occur at any time with little notice. The likelihood of typhoons is greatest during July through September, but they can occur during any month of the year. In May, 1976, Typhoon Pamela caused extensive destruction on the Island with recorded sustained winds of 115 mph and recorded gusts to 159 mph.

TABLE 3-1
AVERAGE ANNUAL RAINFALL BY LOCATION

Location	Years of Record	Average Annual Rainfall (inches)
National Weather Service	1985-1988	97.73
Andersen Air Force Base	1985-1988	96.83
Naval Air Station	1985-1988	81.93
Naval Communications Station	1960-1989	101.13
U.S. Oceanography (CTR)	1985-1988	92.35
U.S. Oceanography (DET)	1985-1988	89.69
GHURA Dededo	1987-1988	63.73
Mangilao	1985-1988	86.57
Tamuning	1951-1962	85.97
Adelup Station	1947-1957	81.85
Pago River	1947-1967	90.78
Nimitz Hill EWC	1945-1974	95.40
Mt. Chachaco Rain Gauge	1985-1988	74.56
Mt. Tenjo Station	1947-1956	81.78
Windward Hills	1985-1988	73.18
Ylig Filter Plant	1953-1974	96.32
Fena Dam	1950-1969	98.70
Fena Filter Plant	1985-1988	71.55
Almagosa Springs	1947-1968	111.79
NASA Tracking Station	1985-1988	81.93
Inarajan	1947-1966	85.48
Umatac	1985-1988	99.87

Source: U.S. Geological Survey; GEPA, *Groundwater Management Program*, Annual Reports; WSMO Guam National Weather Service Meteorological Observatory, Finegayan, Guam NCS.

CHAPTER I

INTRODUCTION

Background

On October 31, 1989, Barrett Consulting Group Inc., submitted a proposal in response to the Request for Proposals published for the preparation of a Water Facilities Master Plan by the Public Utility Agency of Guam (PUAG). After consideration of proposals and an interview, a contract was negotiated with Barrett Consulting Group Inc. in April, 1990

Purpose of Study

Guam is unique in many ways including the water supply situation. Because of its island setting, Guam must make full use of its available water resources. In order to optimize development of the Island, it is critical that the quantity of water available from various sources be defined as accurately as possible. The capacity of the northern groundwater aquifer is, of course, limited, as are all freshwater lenses on Pacific islands. Surface water runoff is also limited and varies with rainfall, topography and other physical characteristics of the various Island watersheds. One of the key elements addressed in the Water Facilities Master Plan is the impact of projected hotel and resort development on the available water supply on the Island, and its relationship to Island water facilities and supplies required to the year 2010.

A second element which played a major role in the master planning program is the interrelationship of the water systems serving the civilian Guam population and the systems serving the various military facilities on the Island. In the past, the military have developed their own water supplies which for the most part are separate from those of PUAG. While the nature of military operations on the Island requires self-sufficiency to be assured of meeting critical situations, it is nevertheless vital that the total available water resources of the Island be allocated both for civilian and military needs to ensure that the water is fairly and equitably distributed.

Because of Guam's isolation as an island community, it is totally reliant on its own resources under all situations. This becomes readily apparent when typhoons periodically ravage the Island. One of the major tasks in the review of existing facilities was to evaluate the ability of PUAG's facilities to meet water demands under maximum day demand conditions. Such an evaluation requires consideration of power supplies, water storage facilities, pumping equipment and interconnections between various water systems.

Many of the community water systems on Guam have, in the past, experienced operational problems. A high unaccounted-for water rate, widely fluctuating water pressures and periodic poor water quality are some of the difficulties encountered within the system. Consequently, the Guam Environmental Protection Agency (GEPA) and the Public Utility Agency of Guam have performed an in-depth sanitary survey of the water system entitled *Public Utility Agency of Guam, Water System Sanitary Survey FY'88 and FY'89 Report* (WSSSR), which was conducted by GEPA and completed in 1989. The purpose of the survey was to identify problem areas and to evaluate existing facilities so that system improvements and procedures could be identified that would, when constructed and implemented, guarantee water service to the affected communities that meets all current standards.

Scope of Work

A detailed scope of work was prepared to define the tasks necessary to prepare the Water Facilities Master Plan. Specific tasks that comprise the scope of work are described in Appendix B.

Organization of Report

The report consists of nine chapters plus Appendices A through I. Chapter I, the Introduction, describes the purpose of the study and the scope of work. Chapter II summarizes pertinent conclusions reached during the study and makes recommendations. Chapter III is a generalized description of the study area and includes population projections. Chapter IV describes in detail all physical facilities reviewed, evaluates the condition and operation of the facilities as reported by PUAG and GEPA, documents deficiencies and describes possible remedies. Chapter V describes study findings in the areas of water production, water demands by type of customer, unaccounted-for-water, per capita demand values, and ultimately develops Island-wide water requirements to the year 2010. Chapter VI enumerates the basic design criteria used in the evaluation and planning of proposed water system improvements. Chapter VII discusses study findings regarding bacteriological, physical and chemical quality of raw water supplies and potable water as delivered to customers and also discusses the impacts of the Safe Drinking Water Standards. Chapter VIII includes an evaluation of the Island's available water resources and discusses the feasibility and need for future development of alternate sources. Chapter IX discusses the adequacy of the existing water distribution system in light of future water requirements and includes a discussion of needed improvements.

II

CONCLUSIONS AND RECOMMENDATIONS

CHAPTER II

CONCLUSIONS AND RECOMMENDATIONS

The following paragraphs summarize the contents of the report. Conclusions and Recommendations begin on Page 2-11.

The Study Area

1. The weather on Guam is warm and humid throughout the year. The mean annual temperature is about 81°F with rainfall ranging from 80 inches on the central and coastal lowlands to about 110 inches on the uplands in southern Guam. Minor storms or squalls can occur at any time with little notice and typhoons are not uncommon.

2. Topographic and geologic features divide Guam into contrasting northern and southern areas. The north is characterized by a porous limestone plateau bordered by steep cliffs. The southern portion of Guam is volcanic and mountainous and is covered by ravine forests and savanna grasslands. Unlike the north, southern Guam has numerous streams draining into the ocean.

3. Guam's non-military owned land is classified into four land use districts; urban, rural, agricultural, and conservation. The Bureau of Planning has recommended that no new water facilities be located within conservation areas because of the tendency to stimulate growth.

4. It is probable that the tourist industry will continue to grow in the future at a gradually decreasing rate. For water system master planning purposes, it has been estimated that the number of hotel rooms will increase from over 4,000 in 1990 to over 48,700 by the year 2010.

5. Utilizing the population projections presented in the Growth Trends Analysis conducted for this study, it is estimated that Guam's population, including the current "base" civilian, hotel-induced civilian and military segments, will increase to approximately 336,000 by the year 2010.

6. Four regional water service areas designated "A", "B", "C", and "D" and conforming to the Bureau of Planning's *Land Use Plan* and the original *Water Facilities Master Plan* are utilized herein as a basis for water system planning. Regional Water Service Area "A" is located at the northern end of the Island. The communities served by Area "A" include Yigo, Manchano (Agafa Gumas), Dededo and Harmon Village. Regional Water Service Area "B" consists of the north central portion of Guam including Asan, Piti, Agana Heights, Sinajana, Chalan Pago-Ordot, Mongmong-Toto-Maite, Mangilao, Barrigada and Tamuning. Regional Water Service Area "C" is located along the west central coast of Guam and serves Agat-Santa Rita. Regional Water Service Area "D" encompasses the southern end of the Island. The areas served in Area "D" include Yona, Talofofo, Inarajan, Merizo and Umatac.

Existing Water Systems

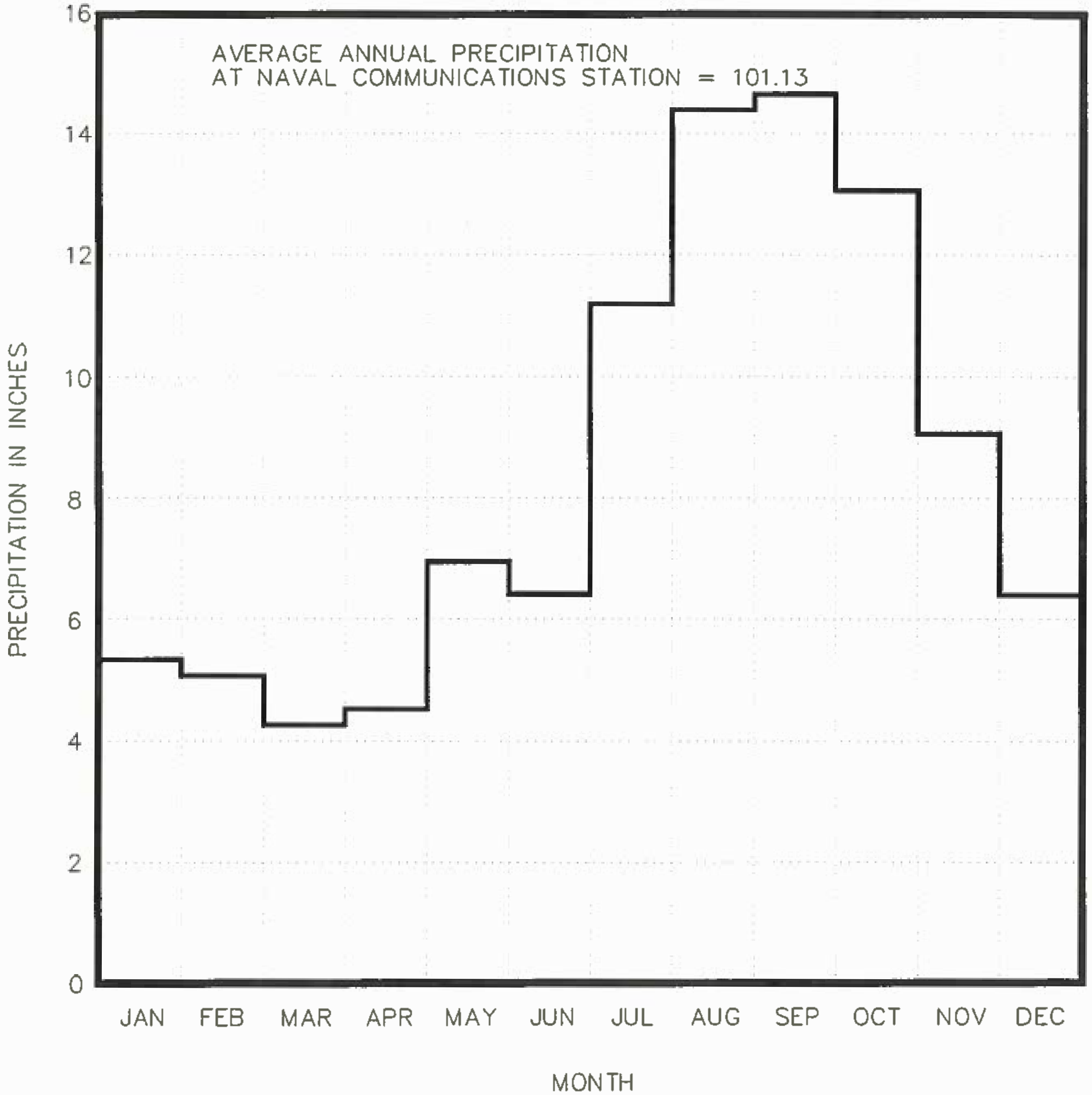
1. The northern aquifer, or lens, is Guam's primary source of potable water. PUAG currently operates a total of 91 producing deep wells in the northern aquifer; an additional 14 wells have been converted from production to observation wells. A total of 105 wells (including the 14 not in operation), and two infiltration tunnels, one of which is abandoned, comprise the northern aquifer supply. The U.S. Air Force, U.S. Navy, and private water systems presently withdraw over 8 MGD from the northern aquifer. Only 25 well stations are provided with standby-power, therefore most community water supplies are quickly depleted during power outages.

2. Historically, the southern villages of Guam have relied on local streams and springs for their water supply. The majority of these production facilities are marginal, at best. The completion, by PUAG, of a major water transmission line to southern Guam in 1985 now allows water from northern Guam to be transferred as far south as Merizo. The local water supply for the village of Merizo is currently augmented by water imported from the northern groundwater supply, while Yona, Inarajan, and Talofofo are now totally dependent on imported water. The Geus River supply, serving the Merizo community, does not receive adequate treatment.

3. The PUAG system has connections to the U.S. Air Force and U.S. Navy water systems at numerous locations, many of which have not been used since the expansions of PUAG's distribution system.

III

DESCRIPTION AND CHARACTERISTICS OF THE STUDY AREA



AVERAGE PRECIPITATION, YEARS 1960–1989

SOURCE: WSMO GUAM

FIGURE 3-4

PRECIPITATION BY MONTH

Topography

Topographic features divide Guam into a northern and southern portion as shown on Figure 3-5. In the north, a limestone plateau, bordered by steep cliffs, slopes southwesterly from an elevation of 600 feet to less than 100 feet at the midsection of the Island. The plateau surface is generally uniform and is interrupted by just three hills; Barrigada Hill (elevation 665 feet), a broad limestone dome; Mount Santa Rosa (elevation 858 feet) and Mataguac Hill (elevation 630 feet) both composed of volcanic rock. There are no perennial streams within the northern plateau area due to the high permeability of the limestone. During heavy rains, drainage can be seen flowing in ditches and channels, but the water quickly disappears into numerous sink holes and fissures.

In contrast, the southern portion of Guam is volcanic and mountainous, covered by ravine forests and savanna grasslands. A nearly continuous mountain ridge parallels the coastline from Piti to the Island's southern tip. Several peaks in the ridge, which is approximately one to two miles inland from the western shoreline, are a thousand feet or more above sea level, the highest of which is Mt. Lamlam with an elevation of 1,332 feet. Unlike the northern part of the Island, southern Guam has more than 40 streams draining into the sea. The streams on the western slope of the mountain ridge are short and generally characterized by steep gradients and drainage areas of less than three square miles. The streams on the eastern slope of the ridge have lower reaches resulting in wide, fertile valleys. Drainage areas of the eastern streams range from less than one square mile to about 28 square miles. Fena Reservoir, the Island's only major surface impoundment for potable water, is located approximately 2-1/2 miles to the southeast of Santa Rita. Guam's physiographic divisions are shown on Figure 3-6.

Soils and Geology

The islands composing the Mariana Islands chain are the high points of submarine ridges that are paralleled by deep trenches. Faulting has been prominent, causing uplift and tilting in the northern land areas and steep western cuestas in the southern Guam areas. Due to its close proximity to the Marianas Trench, Guam is subject to unpredictable earthquakes of high intensity. Since 1902, at least 100 earthquakes in the Marianas/Guam region have been recorded with a magnitude of 6.0 or greater on the Richter Scale. A minimum of 16 destructive earthquakes have taken place since the 1800's.

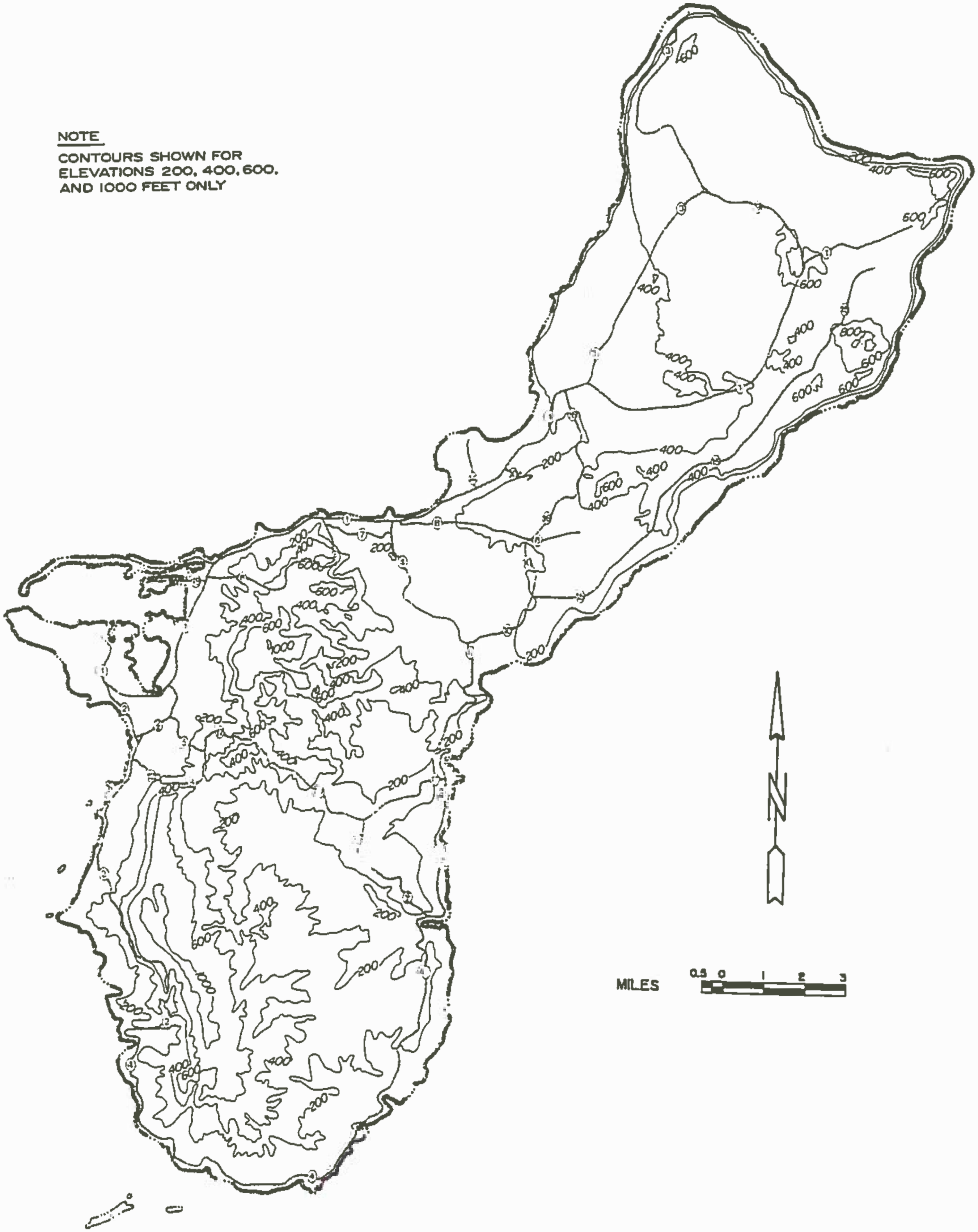


FIGURE 3-5

TOPOGRAPHY

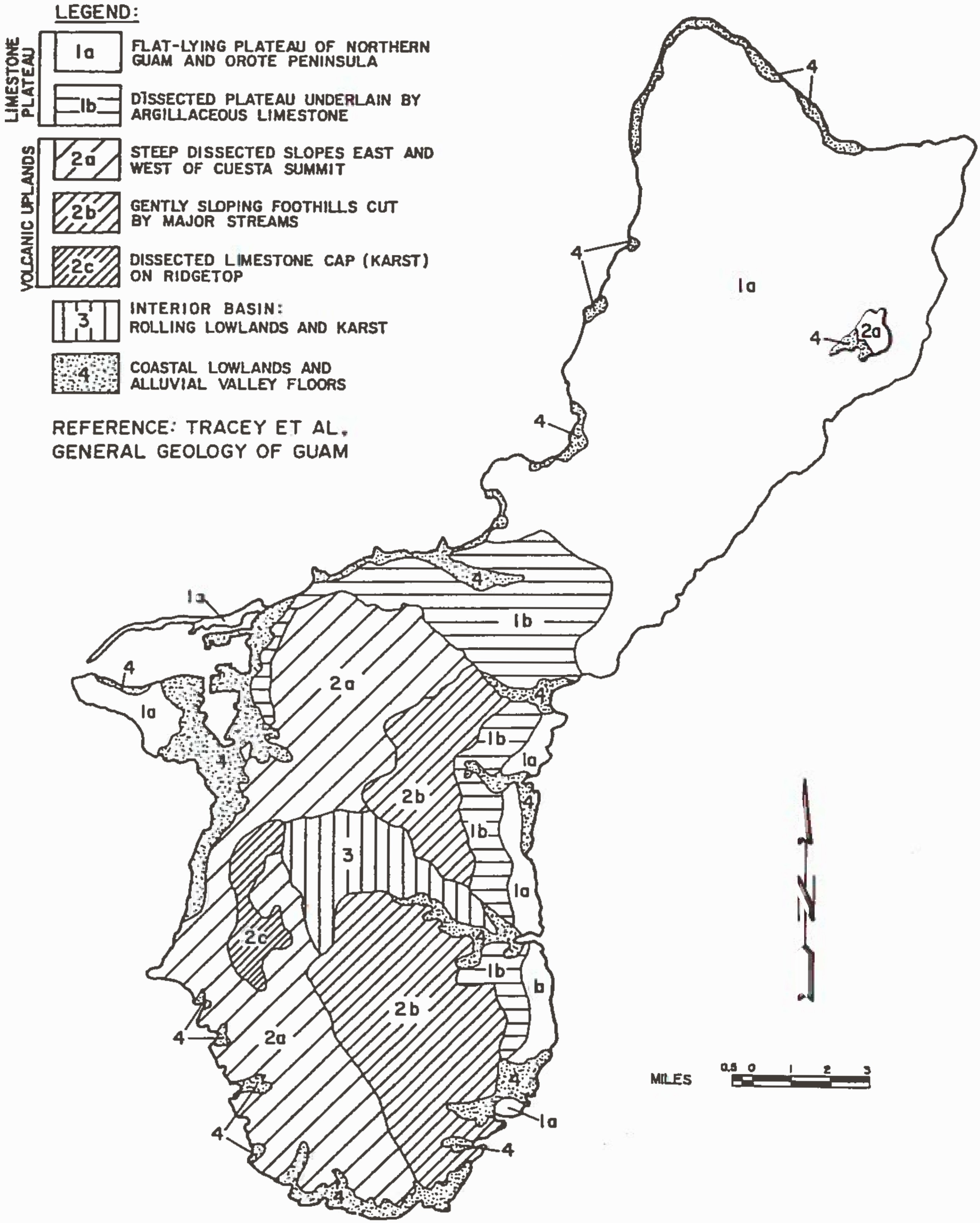


FIGURE 3-6

PHYSIOGRAPHIC DIVISIONS OF GUAM

The northern plateau's principal geologic formation is the Barrigada Limestone. Lying on an irregular surface eroded in volcanic rock of the Alutom Formation, the Barrigada Limestone is overlain by a thin layer of the Marianas Limestone formation. The volcanic rock base of the Barrigada Limestone is generally below sea level. It extends, however, above sea level in an area of several square miles near the northern end of the Island and projects through the limestone at Mt. Santa Rosa and Mataguac Hill. The limestone plateau is characterized by numerous caverns, fissures and other solution openings, thus giving the rock a high overall permeability. Table 3-2 describes the various geological formations of Guam and their water-bearing properties.

The Agana Argillaceous member of the Mariana Limestone formation underlies an area of several square miles in the southern part of the plateau. This formation extends below sea level in the narrow waist of the Island and rests on a steep surface of volcanic rock dipping northward near the southwestern border of the outcrop running from Pago Bay to Adelup Point. The Argillaceous Limestone has moderate to high permeability.

The Barrigada Limestone in the nonargillaceous formations of the Mariana formations are virtually pure limestone and are overlain by a thin friable red soil containing a large percentage of alumina and iron oxide. The Agana Argillaceous member of the Mariana formation generally contains about 6 percent disseminated clay and locally up to 50 percent clay in cavities and fissures. Much of the Argillaceous limestone is covered by several feet of clay soil.

The geologic formations south of an imaginary boundary line between Pago Bay and Adelup Point consist of a complex of pyro-clastic rock and lava flows, clastic sediments derived from the volcanic rock, and small amounts of intermittent limestone which make up the Alutom, Umatac, and Bonya formations. Overlying parts of the complex are Alifan Limestone formations forming caps on peaks and ridges, and the Mariana Limestone forming marginal aprons along the coast.

The permeability of the volcanic rock and clastic sediments is low, with the upper few feet having slightly higher permeability than the underlying material. The limestone overlying the volcanic and clastic rock has high permeability.

TABLE 3-2
GEOLOGIC FORMATIONS OF GUAM

GEOLOGIC AGE	FORMATION	GENERAL CHARACTER AND DISTRIBUTION	WATER-BEARING PROPERTIES
Pleistocene and Recent	Beach deposits	Unconsolidated calcareous sand and gravel; consolidated beachrock in intertidal zone. Occurs irregularly along the shore, particularly in beaches in embayments.	Sand and gravel have moderate to high permeability and, below sea level, are saturated, mostly with brackish water but locally with small quantities of fresh water.
	Alluvium	Poorly sorted clay, silt, sand and small amounts of gravel occur chiefly in the bottoms of valleys, and muck and clay in marshy estuarine deposits along the west coast. Maximum thickness is about 100 ft.	Most of the material is saturated with water a few feet below the ground surface, but because of low permeability it does not release water readily. Water is fresh except at the shore.
Pliocene and Pleistocene	Mariana Limestone	A complex of reef and lagoonal limestone consisting of a forereef facies, a reef facies, a detrital facies, a molluscan facies, and the Agana Argillaceous Member. Underlies most of the north half of Guam; forms a broad marginal apron along the east coast between Pago Bay and Inarajan; and forms Orote Peninsula. Agana Argillaceous Member underlies the narrow waist of the island and is dominant in the apron along the east coast. Maximum thickness is greater than 500 ft.	Permeability of nonargillaceous limestone is generally very high but irregular. Where the rock extends below sea level, it commonly contains relatively fresh basal ground water, but numerous solution channels and fissures may promote sea-water intrusion in some places, especially in coastal areas. Permeability of the argillaceous member is moderate to high.
Late Miocene and Pliocene	Alifan Limestone	Generally massive poorly- to well-consolidated detrital limestone, recrystallized in some places. Forms caps on Barrigada Hill, Nimitz Hill, and the high ridge between Mount Alifan and Mount Lamlam, and crops out in small patches along the coast in the Apra Harbor area. Includes Talisay member, at base made up of volcanic conglomerate, bedded marine clay, marl, and clayey limestone. Maximum thickness of formation is about 200 ft.	Permeability is moderate to high. Contains perched ground water in some places in southern Guam where it lies on less permeable volcanic rock. Is the source of several perennial springs. Talisay Member has low permeability, but clayey limestone yields water at small and mostly intermittent springs.
Late Miocene and Pliocene	Janum Formation	Well-bedded tuffaceous limestone. Small lenticular deposits crop out in several localities along the northeast coast between Lujuna Point and Anao Point. Maximum thickness is about 70 ft.	Permeability low to moderately high, but does not contain water.
	Barrigada Limestone	Pure detrital limestone, fine grained and homogeneous, massive, and well lithified to friable. Underlies most of north half of Guam and crops out over a broad ring-shaped area in north-central part. Width of the outcrop averages about 1 mile. A southern extension of the outcrop encircles Barrigada Hill. Thickness probably is greater than 540 ft.	Permeability of the rock is high. Wherever it extends below sea level, it contains fresh basal ground water as much as 7 ft. above sea level. This rock supplies numerous wells.
	Bonya Limestone	Friable to compact clayey medium- to thick-bedded jointed and fractured detrital limestone. Exposed principally in small outliers in the Fena-Talofofo valley, in small patches on southeast side of Ugum River, in the Togcha River valley, and near Mount Santa Rosa. Maximum thickness is about 120 ft.	Generally high permeability, but because of its small extent it contains very little ground water.
Early Miocene	Umatac Formation	Predominantly a volcanic formation made up of the following member: Dandan Flow Member (basalt lava flows); Bohanos Pyroclastic Member (breccia conglomerate, sandstone, and shale); Maemong Limestone Member (limestone and calcareous tuff); and Facpi Volcanic Member (basalt lava flows, shale, sandstone). Underlies most of Guam lying south of a line between Talofofo Bay and Agat Bay. Total stratigraphic thickness is greater than 2,000 ft. Extends below sea level throughout area.	Largely saturated with water below depths of a few tens of feet beneath the surface, but the rocks are poor water-bearing materials because of low permeability. A surficial mantle of granular weathered material commonly contains thin bodies of perched water that discharge at seeps.
Late Eocene and Oligocene	Alutom formation	Fine to coarse grained well-bedded tuffaceous shale and sandstone, lenses of tuffaceous limestone, and interbedded lava flows. Includes the Mahlac Member consisting of thin-bedded to laminated friable calcareous shale. The rocks cover a large area in central Guam from the vicinity of Asan and Piti villages to Mount Jumullong Manglo and the northern environs of the Fena basin. Underlies younger rock in north half of Guam and crops out at Mount Santa Rosa and Mataguac Hill. Stratigraphic thickness greater than 2,000 ft. Extends below sea level throughout area.	Permeability is moderate in a few places but mostly is low. Saturated with water at variable depths below the surface, but yields water slowly to wells. Surficial mantle of weathered material contains small perched supplies in many places.

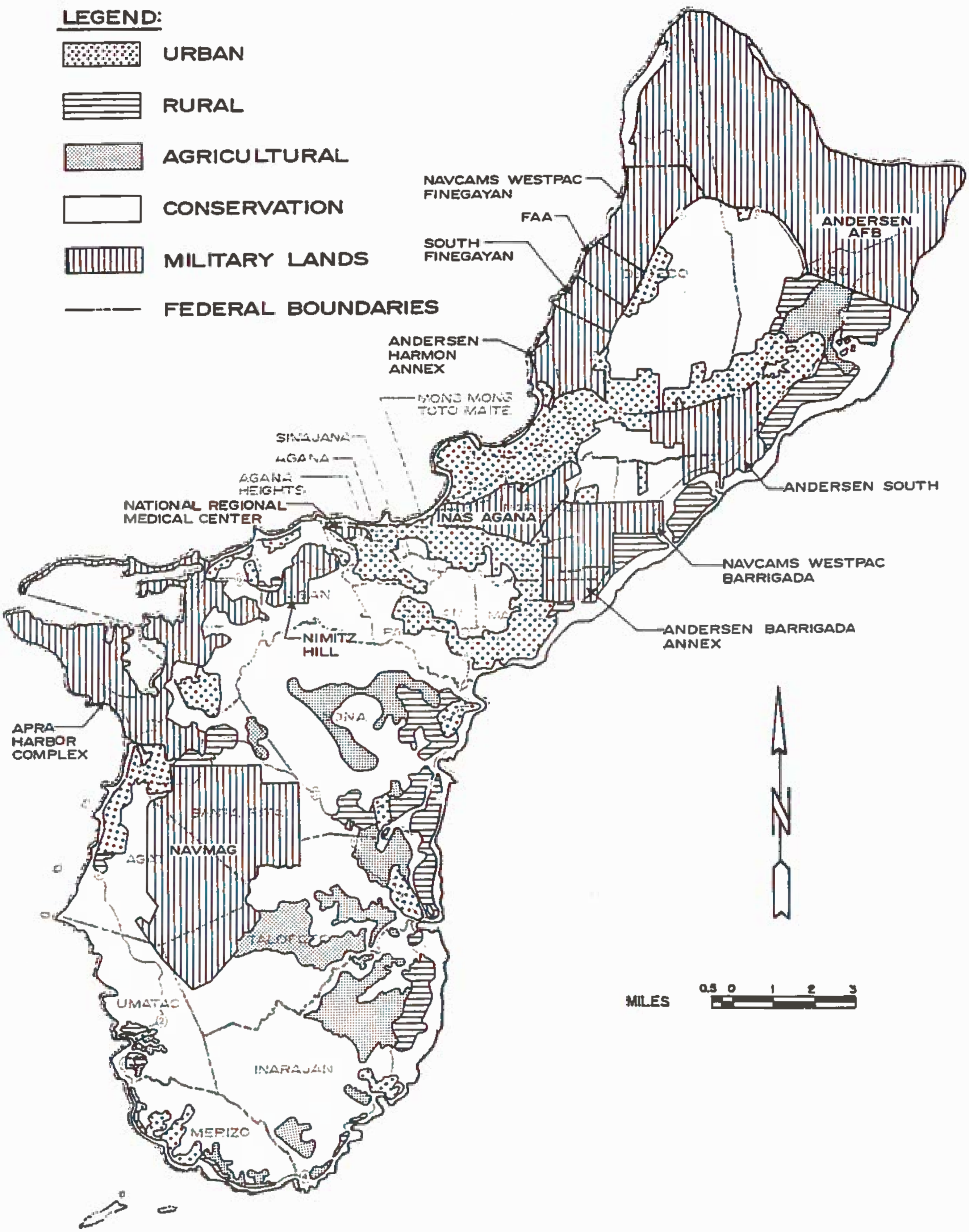
Source: Hydrology of Guam, U.S. Geological Survey, Professional Paper 403-H, 1965.

Unconsolidated deposits of alluvial clay having some silt, sand, and gravel underlie the floors of large valleys and form irregular narrow bands in coastal low lands along with Island's southwestern coast. These deposits generally have low permeability.

Land Use

As mandated by Public Law 12-200, in 1978 the Bureau of Planning prepared the *Land Use Plan Guam, 1977-2000*, as a component of an overall comprehensive development plan for Guam. A new *Land Use Plan* is currently being prepared, but at the time of this report is incomplete. In the existing *Land Use Plan*, Guam's major land areas were identified and evaluated for development potential, existing characteristics and environmental restrictions or ecological complexity. Based on this evaluation, four civilian land use districts were defined; namely, urban, rural, agricultural, and conservation. A map indicating the boundaries of each of the four general types of districts is presented as Figure 3-7. Excerpts from the *Land Use Plan* which characterize and define each of the four types of districts are as follows:

> *URBAN DISTRICT. Those areas characterized by intensive, high density use including residential, commercial, and industrial uses as well as public facilities and designated park areas. Boundaries of urban districts included lands now in urban use and a sufficient reserve area for foreseeable urban growth.*
>
> *Within urban and other districts, there will be designated Areas of Particular Concern (APC) which would generally include areas where natural resource value (including areas suitable for intensive development, such as ports, power facilities, etc.) or where hazards play an important role in determining the suitability of land for particular uses. Designated urban districts are those where the Government of Guam is now providing, or has projected, expansion of infrastructure (roads, power, water, sewer and other services) which would enable an area to support high-density development.*
>
> *RURAL DISTRICT. Those areas of probable future expansion of urban districts and primarily characterized by mixed, low-density residential lots and agricultural use. Maximum density (other than certain specific areas existing with a higher density) should not exceed one dwelling per one-half acre, where an urban level of services, structures, streets, and concentration of people are absent.*



SOURCE: LAND USE PLAN GUAM 1977-2000, BUREAU OF PLANNING

FIGURE 3-7

LAND USE MAP

Within designated rural districts, the Government of Guam is not committed to providing such urban-level services as sewers, road improvements for all lots, or water and power other than at a basic level until such a time as the designation is changed to urban. If urban development is proposed and accepted as compatible to the rural district by various overseeing agencies and commissions, the developer should be charged with the responsibility of providing all infrastructure if the rural district is retained.

AGRICULTURAL DISTRICT. Those areas characterized by topography, relationship to water resources, soils, existing or potential capacity of intensive cultivation. Agricultural activities include four basic elements: field farming, livestock and poultry production, aquaculture, and forestry. Hydroponics is a form of agriculture; however, self-contained environmental controls can permit its use within an urban or rural district. Included in the definition of agricultural land use are services and facilities and uses related to the above elements, but not limited to farm residences, storage facilities, animal shelters, and road-side markets for the sale of agricultural products. Open-space areas and small-scale recreational facilities are clearly compatible with agricultural land use.

The primary development guideline for agricultural areas involves the discouragement of urban level density within an agricultural district. A necessary amount of infrastructure and residences must accompany agricultural land use. However, excessive development of roads and residences, particularly when land-grading or soil removal is in effect, begins to degrade and dissect large tracts of land and agricultural acreage begins to assume rural or urban characteristics.

The delineation of agricultural districts has specifically been limited to land areas that are fairly level and contain adequate soil conditions. Soil data are concerned with depth, texture, drainage, stoniness, and fertility. The proximity to watershed areas (irrigation sources) enhances agricultural growth potential within individual district areas. Agricultural land, however, is kept at a buffer distance from major surface drainage rivers or aquifer recharge areas due to the potential adverse effects of pesticides, fertilizers, and slaughterhouse leachates on water quality.

CONSERVATION DISTRICT. Those areas necessary for protecting water-sheds and water resources, preserving scenic and historic areas; providing parklands, wilderness and beaches; conserving indigenous plants, fish and wildlife; preventing floods and soil erosion; and enhancement of forestry development potential. These are usually more specifically classified as various areas of particular concern and permitted uses would include those existing uses within these designated areas. Such uses may include limited agriculture, associated structures, park development, non-intensive recreation areas, open space, aquaculture, or other uses not determined to produce irreversible adverse impacts. The scenic vistas and detailed beauty of conservation districts are resources of immeasurable value. Undeveloped areas provide a place for nature observation, scientific study, and preservation of the overall aesthetic appearance of Guam. Conservation districts not only enhance the quality of life for the island resident, but entice the economically important tourist.

Growth Trends Analysis

Need for Analysis. The above district delineations and definitions were derived from a wide range of data including environmental research, public investment and aerial photography. The *Land Use Plan* was intended to be used as a decision making tool for Guam's future development including planning of water facilities expansion. However, the *Land Use Plan* has not been closely followed by permitting agencies or planning commissions since its completion. Although land use, in general, still follows the patterns originally prescribed by the Bureau of Planning (BOP), it is beginning to change significantly with the rapid pace of resort development on Guam. This is particularly true of the eastern and southern agricultural areas of the island where large destination resorts are being planned and constructed.

Given these significant shifts in land use patterns, and the fact that the update of the original *Land Use Plan* is just now being undertaken, a growth trends analysis was conducted for the purpose of updating the *Guam Water Facilities Master Plan (GWFMP)*. This growth trend analysis is discussed in the following paragraphs.

For the purposes of the *Water Facilities Master Plan*, the ultimate objective in analyzing future growth trends is to project future water demands and the possible distribution of these demands. To meet this objective, future population levels and their distribution must be projected. A critical factor in such projections is the establishment and implementation of a definitive land use plan for the planning period.

Because the update of Guam's *Land Use Plan* is yet to be completed, the growth trends analysis that was performed for this Water Master Plan was conducted considering the existing population and land use trends. However, the projection of future population and land use trends is not as easily determined. Various assumptions needed to be made and these had to be combined with factors that may inhibit growth. On this basis, several scenarios of future population levels and distribution were derived.

It should be noted that upon completion of the update of Guam's *Land Use Plan*, it will be necessary to re-evaluate this Water Facilities Master Plan and it may be necessary to revise specific elements of the plan to reflect the differences in projections of Guam's future population and land use patterns.

Assumptions. Since there are numerous variables that can affect the course of future events, particularly the establishment and implementation of a definitive land use plan, reasonable assumptions about future conditions had to be made in order to prepare projections useable in developing a water master plan. The following assumptions were made in preparing this update of the *GWFMP*.

1. *Continued Growth of Tourism.* At present Guam's tourism market is strong but inextricably tied to Japan. As of October 1989, visitors from Japan accounted for 85 percent of the 552,714 tourists to Guam. Ownership of resort facilities are also almost exclusively Japanese. Consequently, the viability of Guam's tourism industry is highly dependent on the economic well-being of Japan and its people. For the purpose of this study, the continued growth and viability of Guam's tourism industry was assumed.

2. *Continuation of Current Government Policy.* The attitude heretofore exhibited by the Government of Guam which has encouraged development of Guam's economy and its tourism industry is assumed to continue to the planning horizon. The record of development variances and qualifying certificates issued to projects indicates the

government's encouragement of resort and tourism growth. However, it now appears that a moderate shift in attitude is occurring which will favor management of the growth being experienced in Guam. It is anticipated that the updated Guam *Land Use Plan* currently being prepared will express this shift in attitude. However, until the Plan's completion, it must be assumed that the official policy will remain "pro-development" as in the past.

Federal government policies on land ownership shall also be assumed to continue unchanged. A significant amount of federally held lands are in prime development and water resource areas. This study assumes that lands currently occupied by the federal government will not be significantly reduced. However, it should be noted that recent statements regarding sovereignty and the transfer of lands in Barrigada may portend future changes to this assumption. There have also been lands under federal government control which have been declared as surplus lands and which are slated for return to either the Government of Guam or the original land owners.

3. *Military Population.* Military population, including dependents of military personnel, is assumed to be constant. Although significant changes in the military population or water demand could occur, should bases in the Republic of the Philippines be relocated, for example, there is no way to reliably predict this occurrence. Recent statements by both the U.S. Navy and the U.S. Air Force on Guam claim that they are unable to predict any long term expansion or reduction in their presence on Guam and that the expectation is to maintain the status quo.

4. *"Mega-Resort" Development in the South.* Large, self-contained, destination resorts, designed for residence and recreation, have been proposed by Japanese developers for the southern portion of Guam. Although there is considerable land area available in the south it is currently zoned agricultural and potential developments have met with vocal opposition from some southern residents. Although it appears likely that such developments may eventually occur in the south, it is almost impossible to reliably predict when, where, and how big these will be. Consequently, the study has projected only those developments that are under construction or are known to be going in by virtue of approved zoning variances. The advent of such developments

in the south would significantly alter the demand and distribution scenarios put forth in this version of the *GWFMP*.

Land Use Trends. Throughout the last half of this century, land use on Guam has been most influenced by military presence on the island. However, in the past few years, the accelerated pace of tourism and resort demand has altered the historical patterns of use. Not surprisingly, in the growth trends analysis prepared for this plan, two key determinants of future land use--resort and residential needs--were identified.

1. *Resort Land Use.* The existence of natural resources which make Guam attractive for resort development are abundant. The entire island, each district with its own particular land forms and natural advantages, is conducive to resort development.

   The proximity of Guam to Japan is another driving resource. With Japan's strong position in the world's economy, the opportunity for Japanese to venture to U.S. territory just 2-1/2 hours from Tokyo, can provide Guam a potentially long-term market of tourists. Even presuming a levelling off or drop in Japan's economic position, Guam could possibly remain a closer and less expensive place to visit than, say, Hawaii, its greatest competitor for the Japanese tourist.

   As has been experienced in Hawaii, a trend towards "mega-resorts" has begun to appear on Guam. Essentially self-contained "destination resorts," such developments are less dependent on traditional ocean and beach resources for siting. Instead, their feasibility depends more on the potential for developing on-site amenities such as golf courses. As a result, they can develop on large tracts of interior land and thus put all of Guam in a potentially developable status. Consequently, the entire island of Guam, not just areas with access to the ocean, must be considered as a potential land resource for resort development.

2. *Residential Land Use.* Residential land uses, while in competition for many of the same natural resources and conditions sought by resort development, are more likely to locate in areas of convenience. Proximity to employment, existing infrastructure, circulation and ease of access significantly influence the location and direction of residential development. Since existing residential areas already have many of these

qualities, they can be ideal sites for additional residential development, providing sufficient space for the expansion is available.

While vacant lands will likely be developed first, as the growth of development continues some older areas may be redeveloped. The replacement of many single family residences in Tumon, Tamuning, and Harmon with condominiums and apartments is an example of this trend. Consequently, the potential for redevelopment of existing residential areas must be included in considering the distribution of future land use.

For the purpose of discussing land use trends in this study, the island is divided into three regions--north, central and south. Figure 3-8 illustrates the predicted direction and preference of projected growth. A summary of the conclusions regarding land use trends in these regions follows.

North

The northern region of Guam consists of the Municipalities of Dededo, Tamuning and Yigo. This region is envisioned to be the most heavily populated and the first to be urbanized. The first order of development pressure is projected to extend progressively outward from the Tumon-Agana centroid along Marine Drive.

Dededo. Dededo is foreseen as a residential community of local population servicing the employment centers of downtown Agana and resorts at Tumon Bay. Expansion of residential development within Dededo is imminent, with development and redevelopment beginning with properties closest to the highways. A mix of low to medium density projects is expected with pressure for development of single family residences moving further north.

Commercial land use is expected immediately adjacent to the major roadways. The Micronesian Mall is expected to serve the regional shopping needs of the anticipated population. Smaller neighborhood shopping complexes will probably avoid competing with the Mall by the leasing of their shops to service and convenience businesses.

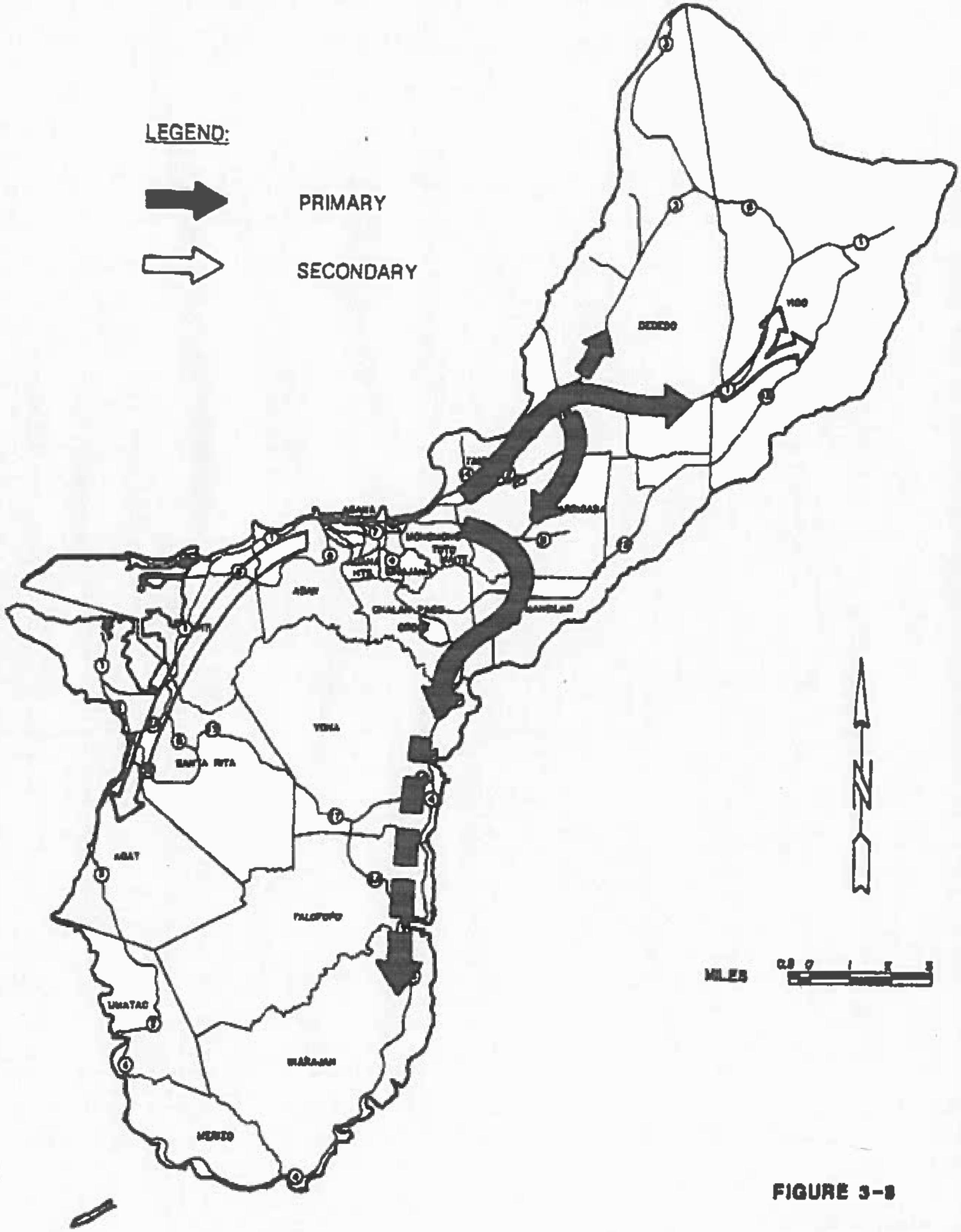


FIGURE 3-8

ANTICIPATED MAIN DEVELOPMENT CORRIDORS

Tamuning. Land use in Tamuning will be dominated by resort activity at Tumon Bay where much of the present boom is now occurring. The present pace of development should continue into the near future with over 11,400 currently proposed hotel rooms coming on line within the 1993-1995 time frame in this area alone. Land use along the shores of Tumon Bay will be traditional resort hotels interspersed with some commercial and shopping developments. Economic pressures to put property to the highest and best use will continue to entice the redevelopment of lesser producing properties. Ultimately, Tumon is expected to achieve development densities and characteristics similar to those of Waikiki in Hawaii.

In the area between San Vitores Boulevard and the cliffline along Marine Drive, high density residential use, such as high rise condominiums and apartments, can be expected. Higher-priced single family residential use is projected to continue in the areas close to the Guam Memorial Hospital.

Both sides of Marine Drive are prime apartment areas with easy access to the high employment centers. It is also an ideal location for development of medium priced housing. A mixture of commercial, existing industrial, and residential in-fill are expected to result in medium density development for this area. Active redevelopment of properties into higher use should also be expected.

Yigo. Yigo is also expected to receive some of the growth pressures of the north. More remote than Dededo and Tamuning, Yigo should continue to receive single family development and more pressure for golf course developments. As densities in Dededo and Tamuning begin to increase, overflow should move into Yigo. A greater proportion of this increase is expected in the years beyond 2000.

Central

The Central region includes the municipalities of Agana, Agana Heights, Sinajana, Chalan Pago-Ordot, Barrigada, Mangilao, Mongmong-Toto-Maite, Piti and Asan.

The majority of the region's activity is expected to occur in Barrigada, Chalan Pago-Ordot, along the coast of Mangilao, and, to a limited extent, Mongmong-Toto-Maite.

Barrigada is expected to receive a high degree of development of single family and lower density, multi-family housing as an overflow of Tamuning and Dededo. However, assuming no release of military lands to civilian authority, this development is expected to end rather abruptly as its available lands are exhausted.

South

The southern region is defined as the municipalities of Agat, Santa Rita, Umatac, Merizo, Inarajan, Talofofo and Yona.

Yona is currently experiencing one of the first "mega-resort" developments, Manengon Hills. Continued development is projected for Yona and its evolution as a southern commercial hub with a shopping center would not be surprising. The development in Yona would have a secondary effect of stimulating growth in Chalan Pago and Mangilao due to their advantage in location between Yona and the more populated districts of Barrigada and Tamuning.

Larger, "mega-resorts" appear to be in the offing for Inarajan and Agat. These resorts are expected to be self-contained residential and recreational entities that would also generate moderate to low levels of adjacent residential development off-site.

Tourism

Until 1961, when President Kennedy removed the security clearance requirement for visitors to the Island, Guam's tourist industry was practically non-existent. In 1962 and 1963 Typhoon Karen and Typhoon Olive devastated most of the island and virtually destroyed physical facilities built to accommodate the newly developed tourist industry. It wasn't until 1967, nearly five years after the typhoons, that Guam was once again prepared to enter the tourist market. The first direct scheduled flight from Japan to Guam was initiated in May of 1967.

During the late 1960's, Guam's tourist industry was severely hindered by the lack of accommodations. This situation was remedied in the early 1970's by the construction of several large hotels in the Tumon Bay area (see Table 3-3). The increase in hotel rooms combined with the increase in direct, scheduled airline flights resulted in tremendous visitor growth. By 1974, the number of tourists increased to 260,568, representing an average growth rate of 67 percent per year since 1969.

TABLE 3-3
TOTAL NUMBER OF HOTEL ROOMS

	Year	Number of Rooms	Percent Change Over Previous Year
	1968	270	--
	1969	520	92.6
	1970	680	30.8
	1971	1,020	50.0
	1972	1,240	21.6
	1973	2,090	68.5
	1974	2,250	7.7
	1975	2,560	13.8
	1976	2,350	-8.2
	1977	2,081	-11.4
	1978	2,080	0.0
	1979	2,336	12.3
	1980	2,345	0.4
	1981	2,345	0.0
	1982	2,416	3.0
	1983	2,819	16.7
	1984	2,964	5.1
	1985	2,991	0.9
	1986	3,248	8.6
	1987	3,864	19.0
	1988	3,939	1.9
	1989	4,133	4.9
	1990	4,288	11.4
Planned	1991	10,610	147.4
Planned	1992	16,932	59.6
Planned	1993	23,254	37.3

Source: *Statistical Abstract*, Vol. 8, Guam 1977, *1989 Guam Annual Economic Review*, and *Summary of General Tourism Statistical and Other Information*, July 1990, Department of Commerce, Government of Guam; Territorial Land Use Commission, Bureau of Planning.

In 1975, the industry suffered another setback as the flow of visitors declined. Many factors contributed to the decrease in visitor traffic, including the 1975-1976 worldwide recession, increasing competition for Japanese tourists from other areas, lack of public transportation facilities, and an increase in the local crime rate. Perhaps the major limiting factor was Guam's lack of adequate tourist activities and attractions or destination points.

Recently, however, Guam has seen a resurgence of its visitor and tourist industry. As shown in Table 3-4, the number of annual visitors to Guam has grown to a total of 780,400 for the year 1990, an increase of about 220 percent over the year 1977 and about 74 percent over the year 1987.

Perhaps the single greatest factor in the rejuvenation of Guam's tourism industry has been the strengthening of the Japanese economy. As indicated in Table 3-5, the overwhelming majority of Guam's visitors and tourists have been from Japan. Consequently, the tourism industry on Guam is almost totally dependent on the Japanese market and the strength of the industry is essentially tied both to the well-being of the Japanese economy and the willingness of the Japanese government to allow its citizens to invest in and transport expenditures to other countries.

Other factors which enhance Guam's potential as a tourist destination, described in the Bureau of Planning report, *Growth Policy of Guam,* 1977, and cited in the original *Water Facilities Master Plan,* bear repeating here.

- Guam's proximity to Japan and its strategic location in the Pacific will make the island a unique place which no other country can match as a tourist attraction and as a business/financial center.

- Guam has opportunities for expanding air routes.

- Guam's political and social conditions are favorable factors for foreign investment. Guam has a history of political stability.

- Guam possesses outstanding natural beauty.

TABLE 3-4
VISITOR ARRIVALS

Year	Number of Arrivals	Percent Change Over Previous Year
1969	58,265	--
1970	73,723	26.5
1971	119,124	61.6
1972	185,400	55.6
1973	241,140	30.1
1974	260,570	8.1
1975	239,700	-8.0
1976	205,100	-14.4
1977	243,330	18.6
1978	238,820	-1.9
1979	272,680	14.2
1980	300,770	10.3
1981	321,770	7.0
1982	326,390	1.4
1983	350,540	7.4
1984	368,660	5.2
1985	378,150	2.6
1986	407,100	7.7
1987	447,500	9.9
1988	576,170	28.8
1989	668,748	16.1
1990	780,400	16.7

Source: *Statistical Abstract*, Vol. 8, Guam 1977 and *1989 Guam Economic Review*, Department of Commerce, Government of Guam; Land Use Commission; Bureau of Planning; Guam Visitor's Bureau

TABLE 3-5
DISTRIBUTION OF VISITORS BY COUNTRY OF ORIGIN

Percent of Total Visitor Arrivals

Year	Japan	U.S.A.	Pacific Islands	Other
1969	50	32	--	18
1970	60	24	--	16
1971	71	17	--	12
1972	75	16	--	9
1973	70	15	--	15
1974	66	11	--	23
1975	67	9	--	24
1976	69	9	--	17
1977	63	12	--	25
1978	70	14	7	9
1979	72	13	9	6
1980	76	12	7	5
1981	81	8	7	4
1982	84	8	5	3
1983	85	6	6	3
1984	84	7	6	3
1985	83	7	7	3
1986	84	7	6	3
1987	86	7	5	2
1988	86	6	6	2
1989	84	6	6	4

Source : *Statistical Abstract*, Vol .8 ,Guam 1977 and *1989 Guam Annual Economic Review*, Department of Commerce, Government of Guam .

- Guam is an Island attraction with its unique heritage, language and culture.

As Table 3-6 indicates, the current trend in increased visitor arrivals has pushed existing hotel facilities almost to their limits. With hotel occupancy rates averaging about 86 percent over the last five years, the construction of hotel rooms is barely keeping up with demand and continues to be one of the limiting factors to the industry's growth. The number of existing hotel rooms on Guam had increased to a total of 4,288 in 1990, representing an average annual increase of approximately 6.5 percent since 1977. However, most of this growth has taken place since 1986, which reflects an average annual growth rate of about 9.3 percent per year.

Just as significant an indication of the anticipated rate of growth in tourism is given by the number of proposed hotel rooms. An additional 18,966 units were identified by the growth trends analysis as being planned for completion in the period 1993-1995, as shown in Table 3-7.

It should be noted that these numbers only represent those developments that have applied to the Territorial Land Use Commission (TLUC) for conditional use permits or variances. It does not include developments that fall within the requirements of their particular zone and have no need of TLUC action. While the Department of Public Works (DPW) lists building permits by type of construction--e.g. Residential, Hotel, Condominium, Commercial, etc.--it has not indicated, in the past, the total number of units per construction type. However, even a conservative estimate, based solely on those rooms under construction, approved by Territorial Planning Commission (TPC) and requiring TLUC action (Table 3-8), indicates that the number of hotel rooms may increase by about 211 percent over the next 5 years.

It is difficult to project future tourist growth trends. Nevertheless, it is necessary to estimate a range for future tourism as the industry has direct and indirect impacts on water system master planning. In making these projections it is important to acknowledge that Guam currently enjoys an extremely favorable position in the eyes of the Japanese. The consequence to Guam if the Japanese attitude were to change would be severe. As it is not feasible to accurately predict any changes in this attitude, the Water Facilities Master Plan assumes that no change in Japan's positive attitude towards Guam occurs during the 20 year planning period.

TABLE 3-6
MONTHLY HOTEL OCCUPANCY RATES

CY 1981-CY 1989
(Percent)

MONTH	1981	1982	1983	1984	1985	1986	1987	1988*	1989*
January	78	79	83	85	79	74	93	89	98
February	92	95	101	94	94	97	99	97	102
March	94	94	100	94	90	94	97	91	87
April	70	76	74	82	77	87	78	64	73
May	70	72	73	73	73	76	78	69	79
June	71	70	89	84	86	97	94	86	96
July	81	80	80	86	78	91	105	94	99
August	95	85	92	90	86	98	97	96	99
September	89	93	105	93	91	93	92	95	92
October	71	71	82	75	73	74	61	70	84
November	82	90	85	80	80	83	68	78	86
December	67	71	81	73	74	78	71	81	84
Annual Average	80	81	87	84	82	87	86	84	90

*Note: 1988 and 1989 figures reflect the following hotels:

Hilton International Guam Hotel
Pacific Star Hotel
Guam Okura Hotel
Guam Dai-Ichi Hotel
Fujita Guam Tumon Beach Hotel
Pacific Islands Club Hotel
Sotetsu Tropicana Hotel
Sun Route Hotel
Cliff Hotel
Guam Plaza Hotel
Joinus Hotel
Guam Reef Hotel

Source: Guam Economic Development Authority, Guam Visitor' Bureau, Guam Hotel/Motel and Restaurant Association

TABLE 3-7
PLANNED HOTEL ROOMS

	No. of Rooms	Total
Dededo		1,977
Grandview Corp.	462	
Uranoa	1,000	
Hatsuho Int.	65	
Goodwind Dev. Corp.	450	
Tamuning		11,419
Tumon		
Continental/Marriott	500	
Fujita	656	
Guam AB Inc.	400	
Guam Beach	276	
Guam Hakubotan	581	
Guam Plaza	140	
Guam Reef	172	
Guam Suehiro	212	
Haseko-Hasegawa	500	
Hafa Adai Properties	123	
Hillside Corporation	126	
Hilton	121	
Holiday Inn Guam	300	
Hyatt Regency	448	
Japan Pacific Development	140	
Leo Palace	382	
Macau-Hong Kong Dev. Inc.	400	
Nikko	500	
Nansay	1,400	
Pan Pacific	400	
Pacific Is. Club	820	
Rihga Royal	451	
Tumon Holiday Plaza	130	
Tokyu-Micronesian Dev. Corp	400	
Yamanoi	61	
P. & A. Sach Dev. Inc.	113	
Tumon Royal	300	
United Overseas Inv.	242	

TABLE 3-7(cont)
PLANNED HOTEL ROOMS

	No. of Rooms	Total
Tumon (continued)		
Matsuzato Int. Inc.	157	
Milo Corp.	32	
Palace Hotel	405	
Paul's Hotel	135	
Royal Hotel	90	
San Byung Han Motel	38	
Sunset View	300	
Agana		440
Int. Design Consortium Inc.	440	
Mangilao		590
Hanil Resorts Corp.	590	
CP - Ordot		100
United Pacific Investment	100	
Barrigada		1,200
Sohbu Marbo Cave Resort	1,200	
Agat		1,600
Nexus Resort	1,600	
Yona		1,090
Ylig Shores Inc.	890	
Sumitomo/Miyama Hills	200	
Inarajan		550
Inarajan Bay Hotel	100	
Dandan Country Club	450	
Summary:		
North	13,396	
Central	2,330	
South	3,240	
Projected Additional	692	
TOTAL PROPOSED ROOM	18,966	

TABLE 3-8
GUAM'S APPROVED, ANNOUNCED AND SPECULATIVE NEW HOTEL/MOTEL DEVELOPMENTS

Location	Type	Name of Company/Developer/Project	Projected # of Rooms/ Units	Status	Forecasted Completion Date
Tumon-Gun Beach	T	Hotel Nikko Guam/TNN Guam Inc./ Taniguchi Ruth & Assoc.	500	UC	Mar. 1991
Tumon	T	Tumon Holiday Plaza	130	UC	July 1990
Tumon	T	Regency Hotel	123	UC	1990
Tumon	T	Pacific Islands Club (Phase III)	313	UC	Sept. 1991
Tumon	T	Guam Reef Hotel	160	UC	Oct. 1990
Tumon	T	Hillside Corp. III	63	UC	1990
Tamuning	T	Palace Hotel	405	UC	Nov. 1990
Tamuning, Oka Point	T	Onward Agana Beach Hotel	300	UC	Aug. 1990
Tumon	T	Yamano Guam (67 Condo, 61 rm Htl)	61	UC	1990
Btwn Okura & Reef Hotels	T	Hotel Leo Palace	382	UC	Dec. 1992
Toto/Across NAS	NT	Guam International Hotel	64	TP	1990
Subtotal			2,437		
Dededo/Harmon	T	Goodwind Development Corp./Grandview Hotel	450	TP	OH
Dededo	NT	Hatsuho Intl., Inc.	15	CA	?
Harmon, Dededo	NT	M/M Chang Motel	16	TP	?
Harmon	T	Nansay Guam, Inc. c/o Duenas & Swavely	1000	CA	?
Tumon Cliffside	T	Holiday Inn Guam	291	TP	Nov. 1991
Tumon	T	#Fujita Guam Tumon Beach Hotel	650	TP	1992/1993
Tumon	T	Hilton International Guam Hotel	121	TP	Aug. 1991
Upper Tumon	NT	P. & A. Sachdev/Cornerstone	113	TP	?
Upper Tumon	T	Matsuzato Guam Resort Complex (+719 condos)	157	TP	Dec. 1992
Tumon	T	United Overseas Investment	85	TP	?
Tumon	T	Terraza Hotel	10	TP	1990
Tumon	T	Hyatt Regency Hotel	448	TP	Dec. 1992
Tamuning	T	Chiyoda Guam Corp. Hotel c/o Richard Rosario	250	CA	?
Inarajan	T	DanDan Est. & Country Club (+720 TH & Condo)	200	TP	1996
Inarajan	NT	Inarajan Shores	24	TP	?
Merizo	NT	Achange Bay Marina Bungalows	6	TP	1990
Agana	NT	Ely Del Carmen Motel	60	TP	?
Agana	T	Agana Bay Marina Hotel	440	TP	1992
Yona	T	Sumitomo/Miyama Hills Hotel	200	TP	1995
Barrigada	T	Marbo Cave Resort (+600 Condos)	1200	TP	Dec. 1994
Subtotal			2,813		?

TABLE 3-9
PROJECTED HOTEL UNITS UNDER CURRENT GROWTH RATES

LOCATION	EXISTING 1990	PROJECTED INCREASE IN HOTEL UNITS							TOTAL YR 2010
		ADD. YR 1993	TOTAL YR 1993	ADD. YR 2000	DISTRIB. OF INCREASE	TOTAL YR 2000	ADD. YR 2010	DISTRIB. OF INCREASE	
NORTH									
DEDEDO	3	1,977	1,980	1,050	5%	3,030	600	3%	3,630
TAMUNING	3,715	11,419	15,134	11,970	57%	27,100	6,800	34%	33,900
YIGO	0	0	0	210	1%	210	600	3%	810
CENTRAL									
AGANA	145	440	585	420	2%	1,010	0	0	1,010
AGANA HEIGHTS	0	0	0	0	0	0	400	2%	400
ASAN	0	0	0	0	0	0	0	0	0
BARRIGADA	0	1,200	1,200	420	2%	1,620	200	1%	1,820
CHALAN PAGO-ORDOT	0	100	100	420	2%	520	200	1%	720
MANGILAO	0	590	590	420	2%	1,010	800	4%	1,810
MONGMONG-TOTO-MAITE	227	0	227	420	2%	650	200	1%	850
PITI	0	0	0	0	0	0	0	0	0
SINAJANA	0	0	0	0	0	0	0	0	0
SOUTH									
AGAT	70	1,600	1,670	630	3%	2,300	400	2%	2,700
INARAJAN	0	550	550	1,680	8%	2,230	3,000	15%	5,230
MERIZO	128	0	128	0	0	130	800	4%	930
SANTA RITA	0	0	0	0	0	0	0	0	0
TALOFOFO	0	0	0	1,680	8%	1,680	3,000	15%	4,680
UMATAC	0	0	0	0	0	0	0	0	0
YONA	0	1,090	1,090	1,680	8%	2,770	3,000	15%	5,770
TOTAL	**4,288**	**18,966**	**23,254**	**21,000**	**100%**	**44,260**	**20,000**	**100%**	**64,260**

NOTE: Totals for projections beyond year 1993 have been rounded off to the nearest ten.

TABLE 3-10
PROJECTED HOTEL UNITS UNDER SLOWED GROWTH RATES

LOCATION	EXISTING YR 1990	PROJECTED INCREASE IN HOTEL UNITS						TOTAL YR 2010
		ADD YR 1993	ADD YR 1994-2000	DISTRIB. OF INCREASE	TOTAL YR 2000	ADD YR 2010	DISTRIB. OF INCREASE	
NORTH								
DEDEDO	3	1,977	530	5%	2,510	450	3%	2,960
TAMUNING	3,715	11,419	5,990	57%	21,120	5,100	34%	26,220
YIGO	0	0	110	1%	100	450	3%	550
CENTRAL								
AGANA	145	440	210	2%	800	0	0	800
AGANA HEIGHTS	0	0	0	0	0	300	2%	300
ASAN	0	0	0	0	0	0	0	0
BARRIGADA	0	1,200	210	2%	1,410	150	1%	1,560
CHALAN PAGO-ORDOT	0	100	210	2%	310	150	1%	460
MANGILAO	0	590	210	2%	800	600	4%	1,400
MONGMONG-TOTO-MAITE	227	0	210	2%	440	150	1%	590
PITI	0	0	0	0	0	0	0	0
SINAJANA	0	0	0	0	0	0	0	0
SOUTH								
AGAT	70	1,600	310	3%	1,980	300	2%	2,280
INARAJAN	0	550	840	8%	1,390	2,250	15%	3,640
MERIZO	128	0	0	0	130	600	4%	730
SANTA RITA	0	0	0	0	0	0	0	0
TALOFOFO	0	0	840	8%	840	2,250	15%	3,090
UMATAC	0	0	0	0	0	0	0	0
YONA	0	1,090	840	8%	1,930	2,250	15%	4,180
TOTAL	4,288	18,966	10,510	100%	33,760	15,000	100%	48,760

NOTE: Totals for projections beyond year 1993 have been rounded off to the nearest ten.

Several factors are expected to contribute to this slowdown in development, and are discussed in detail in the following sections. The single most prominent inhibiting factor is a shortage of labor to service the expanded tourist industry. Guam's ability to house the employee and residential population generated by hotel development is predicted to be another potential inhibitor. The ability of Guam's infrastructure system to provide utilities such as water, sewage and power to such a rapidly increasing population over such a relatively short period of time may also contribute to a slowdown in growth. Community resistance to additional development may occur as the negative impacts of past and current development becomes obvious, inhibiting further growth.

For the period 1993-2000, in the high growth scenario, the projected construction of hotel units would slow from the present rate of 6,000 units per year to 3,000 units per year. This growth scenario would yield an additional 21,000 hotel rooms for a total of approximately 44,260 hotel rooms on Guam by the end of the year 2000.

For the years beyond the current boom--2000-2010--the assumed rate of development is further lowered to 2,000 units per year. This period would yield an additional 20,000 hotel rooms for a total of about 64,000 hotel rooms by the end of 2010.

A further assumption in the high growth rate shown in Table 3-9 is that Tumon Bay will eventually be fully developed to the same density as Waikiki in Hawaii. The rationale for this assumption is that the Tumon area is strikingly similar in size to Waikiki and, with one of the few sizable, picturesque lagoons on Guam near an urban environment, Tumon Bay has the proven draw for hotel development. Circulation in Tumon, with its one large avenue, is more efficient than in Waikiki which suffers from an older road system that was laid out for residential use. In addition, this study estimates Tumon at around 170 acres of prime hotel zone while Waikiki has about 140 acres of similar prime resort area. As the new expansion of the Fujita Hotel demonstrates, sufficient demand exists to warrant replacement of large tracts of existing commercial and residential structures with more dense, high-rise hotels.

Using Waikiki as the model, floor area ratios (FAR) of Waikiki were tested and applied to project densities for Tumon. The FAR is the ratio of building floor area to lot size. Typical FAR calculations for Waikiki are in the 4.5 range. The growth trend analysis projects that

Tumon will be at this general level at full build-out, or roughly 400 hotel rooms per acre. Thus, Tumon would have approximately 34,000 hotel rooms by the end of year 2010.

Table 3-10 represents a slower projected hotel growth scenario resulting from the effects of various growth-inhibiting factors. These factors are expected to become more apparent as Guam proceeds along its current development path and are given a brief treatment here. It should be emphasized that these factors are perceived as only inhibiting and not preventing development.

1. *TLUC Growth Management.* A shift in government attitude regarding the development of Guam's economy and its tourism industry has occurred recently. Where previously a policy of encouraged resort and tourism growth has existed, it is expected that a moderate degree of control will be exercised in the future. This shift in attitude should result in a slowing down of current growth trends.

2. *Labor.* Labor supply is potentially the single most significant inhibitor of rapid growth in the tourist industry on Guam. Labor estimates for the year 1989 show the total number of civilians employed was 39,230. At this level the unemployment rate was only 2.1% (820 persons). Applying a modest factor of 2 hotel induced jobs per hotel room (existing levels are 4 jobs per room) reveals that the additional 18,966 rooms anticipated for 1993 will require approximately 37,932 employees or 97% of the total existing labor force on Guam. Obviously the existing labor force will not be able to double itself by natural increase in three years. The results of this shortage would be a wide-scale deficiency in hotel and hotel related services, a general slow down in units coming on line or, most likely, a combination of both.

   By the year 2000, even at the reduced hotel construction level projected for the 1994-2000 period in Table 3-10, over 33,000 hotel rooms could be in place, with direct and indirect labor requirements almost triple the current labor force in a span of only ten years.

   One solution to this potential labor shortage would be the importation of immigrant labor under H-2 visa provisions, most likely from the Philippines, Korea or China. However, obtaining clearances for such visas can be difficult and takes considerable time. At present, the U.S. Immigration and Naturalization Service (INS) does not allow such a temporary worker category for hotel workers. Micronesians are currently being actively recruited, but the number is not expected to be sufficient to fill the demand. Likewise, the mainland U.S., Hawaii and other Pacific Island territories are not expected to be sufficient sources of labor.

Consequently, the shortage of qualified hotel workers is expected to become the first and most enduring of inhibitors to affect the rate of hotel development.

3. *Housing*. In 1980, Guam had a total of about 28,000 housing units. Historically, housing delivery averages 300 units annually. At this level, a total of approximately 31,000 housing units (not including attrition or demolition) should be available in 1990 Guam for an estimated 27,535 resident households. Hypothetically, by 1993, with population expanding to meet the hotel induced employment demand, and assuming a ratio of 0.5 households per hotel employee, an estimated total of 60,000 households will be required. At current delivery rates, a housing shortfall of about 29,000 housing units will occur. Conversely, if all hotel units currently proposed are built, approximately 10,000 housing units would need to be built annually over the next three years to satisfy demand increases created by hotel employees. It is unlikely that this rate of production will occur and consequently the supply of labor required to sustain resorts and hotels will be severely impacted. Similarly, as rents, real estate and home purchase prices are driven higher by this shortage, and entering the home ownership market becomes more difficult, the more mobile local residents will move away from Guam adding to the labor supply shortage.

4. *Community Awareness and Resistance.* As witnessed by the recent opposition to the Taotao Resort in Inarajan and the Achang Bay Marina development in Merizo, awareness of the negative impacts of rapid development and resistance to such development is increasing on Guam. Reactions to the negative impacts of development will be a function of the degree of economic and other positive benefits local residents perceive themselves deriving from hotel and resort development. Variations in the degree of this resistance will occur on an issue-oriented basis. But in the long term, the attitudes of the local population will influence the government's attitude toward approvals within

the development process. Traditionally, the course of events has been one of gradually escalating resistance to the proliferation of resorts.

5. *Infrastructure.* The ability of Guam's infrastructure to provide water and power service and adequately collect and dispose of wastewater in the years 2000 to 2010 are also potential inhibitors of the higher levels of growth predicted in Table 3-9.

   As an example, the finite supply of relatively inexpensive and easily obtainable water in Guam's northern groundwater lens will support only a limited amount of demand. As this supply is exceeded, more expensive methods of water development must be turned to. At the point that water becomes more expensive, the burden of such costs becomes an additional inhibitor to growth.

The preceding discussion illustrates the rationale for modifying the development trends projected in Table 3-9. The point is that some time soon, one or more of the various inhibitory factors described above will cause a deterioration and slowing of the entire development process. Table 3-10 represents the growth trends analysis's prediction of hotel development under these conditions.

Under the slower growth projections, hotel units are predicted to increase at a steady rate of 1,500 units per year between 1993-2010. This results in approximately 33,760 and 48,760 total hotel units, respectively, for the years 2000 and 2010.

At the time this report was being prepared, the Government of Guam was considering limiting the total number of hotel rooms on Guam to 30,000. Since no official government policy to this effect has yet been implemented, and given the recent history of the government's encouragement of development, the values presented in Table 3-10 have been adopted for use in this plan. However, should the Government impose such a ceiling to development, the planning and water consumption projections proposed in this report would have to be revised accordingly.

Population

To provide a basis for predicting future water requirements, a population projection must be made or obtained from a planning source. As described earlier, the population projections used in the update of the Water Facilities Master Plan were derived in the growth trends analysis conducted for this report.

As in the original Water Facilities Master Plan, this report looks at population in three general categories: military; civilian and tourist.

Tourist population, as it affects water master planning, is accounted for through reference to hotel rooms. Throughout the report it is assumed that each hotel room represents an average of two tourists. Projections of the direct impacts of tourist population on the water facilities of Guam can be determined by referring to Tables 3-9 and 3-10.

Current military population on Guam is approximately 26,000. As stated earlier, representatives of both the Air Force and the U.S. Navy have indicated that, since the redeployment of large numbers of personnel can happen suddenly, it is almost impossible to predict any long range variations in the military population of Guam. While the recent removal of the B-52 wing from Andersen Air Force Base is expected to decrease the Air Force population by approximately 1,400 (including dependents), it is also expected that other Air Force elements may be relocated to Andersen from the Philippines. For the purposes of this study, the military population is assumed to be constant through the planning period.

Civilian population is perceived, in this report, as having two layers. The base population, referred to as the "natural" population of Guam, is essentially the civilian, residential population on Guam today. "Natural" increases to this population are considered to be those that would occur irregardless of immigration trends and the impacts of hotel and resort development.

Superimposed on this "natural" base and its increase are more elusive increases induced by external forces such as hotel development, military build-ups or cut backs, and immigration policies. This report feels that, for the planning period, the most significant increases will come from hotel/resort induced employment. That is, employees who are brought or attracted to Guam for employment in hotels, or in hotel related services, and their dependents.

During the period from World War II to the year 1960, Guam's civilian population increased at an annual rate of approximately 1.2 percent. In 1962, when President Kennedy lifted the security clearance requirements and allowed unrestricted movement to and from Guam, the annual rate of population growth increased. The rate of growth in 1975 was 3 percent. This rate slowed somewhat between 1975 and 1980 to approximately 2 percent.

Table 3-11 shows the base population and its distribution for the years 1980 and 1990. Also shown are the gross projections of total population for the years 1990, 2000 and 2010. At the time of the growth trends analysis for this report, the 1990 census for Guam was not yet complete. Therefore, census information for 1980 only is presented in Table 3-11. The projections for 1990 and 2000 population totals were based on projections prepared by the Government of Guam's Department of Commerce. The 2010 population was projected using district increase rates derived from the 1980 - 1990 data. Distributions of the projected base populations by election district shown in Table 3-11 and Figure 3-9 were also derived from the 1980 census data.

Projecting the increases in population due to hotel development was accomplished by applying multipliers for direct and indirect employment to the projected number of hotel rooms. An allowance for employee dependents was included in these multipliers. The rates applied in this study varied with the type and location of the accommodation as shown in Table 3-12. The multipliers are based on similar development experience in Hawaii.

Since the projections of hotel induced population increases are based on numbers of hotel rooms, the same assumptions and factors previously applied to hotel and resort development will also apply directly to the hotel-related population trends. Table 3-13 presents projected populations for a range of growth rates which include the hotel room growth scenarios previously described. Of the hotel growth trends considered in the growth trends analysis, the growth slowdown scenario depicted in Tables 3-10 and 3-14 is felt to be the more realistic. Consequently, these tables are used as the basis for projecting hotel and hotel-related water demand in Chapter V. Figure 3-10 depicts the projected distribution of the civilian population for the year 2010 based on Table 3-14.

TABLE 3-11
GUAM NATURAL POPULATION

LOCATION	1980	1980 DIST	PROJECTED 1990 POP	INC RATE 1980-1990
NORTH				
DEDEDO	20,090	0.23	25,300	0.26
TAMUNING	13,510	0.16	17,600	0.30
YIGO	5,280	0.06	6,600	0.25
CENTRAL				
AGANA	900	0.01	1,100	0.23
AGANA HEIGHTS	2,970	0.03	3,300	0.11
ASAN	1,620	0.02	2,200	0.36
BARRIGADA	6,040	0.07	7,700	0.28
CHALAN PAGO-ORDOT	3,120	0.04	4,400	0.41
MANGILAO	5,980	0.06	6,600	0.10
MONGMONG-TOTO-MAITE	4,840	0.06	6,600	0.37
PITI	1,510	0.02	2,200	0.45
SINAJANA	2,490	0.03	3,300	0.33
SOUTH				
AGAT	4,000	0.05	5,500	0.38
INARAJAN	2,060	0.02	2,200	0.07
MERIZO	1,660	0.02	2,200	0.32
SANTA RITA	3,400	0.04	4,400	0.30
TALOFOFO	2,010	0.02	2,200	0.10
UMATAC	730	0.01	1,100	0.50
YONA	4,230	0.05	5,500	0.30
TOTAL GUAM	**86,400**	**1.00**	**110,000**	**0.27**

GROSS PROJECTION OF NATURAL POPULATION TOTALS

YEAR	1990	2000	2010
Population	110,000	140,300	182,000

NOTE: Village population projections have been rounded off to the nearest hundred.

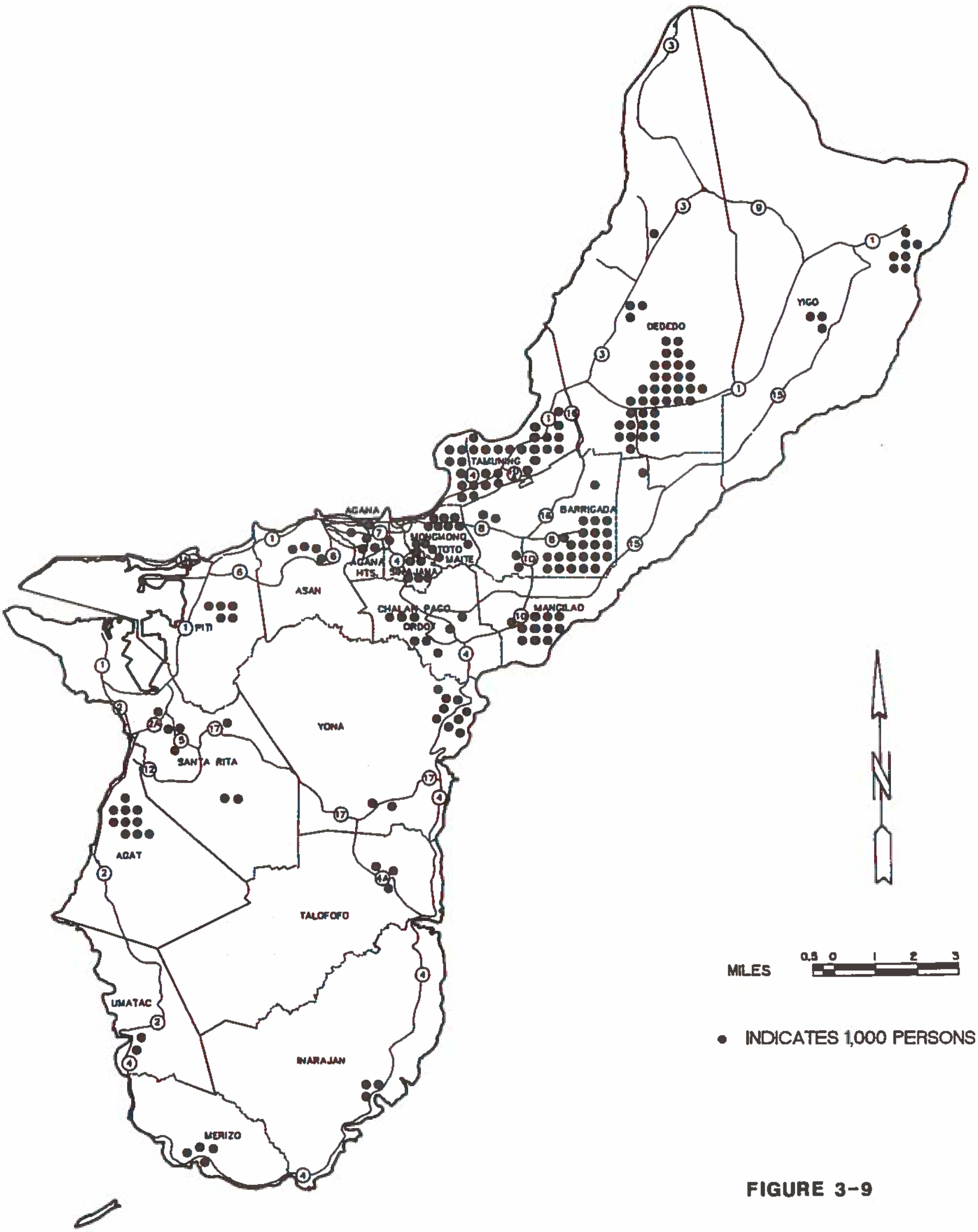


FIGURE 3-9

PROJECTED BASE POPULATION GUAM,

YEAR 2010

TABLE 3-12
MULTIPLIERS FOR DIRECT AND INDIRECT EMPLOYMENT

Accommodation Type	Direct Employment	Indirect Employment	Employee Dependant
HOTEL			
Tumon, North and Central Guam	0.75	1.0	0.5
Resort; Southern Guam	2.0	1.0	0.5
OTHER RESORT TYPE			
Condo/Townhouse	0.5	0.5	0.5

To evaluate future water supply facilities, the non-military lands that currently require or will potentially require water service were subdivided into four regional service areas. The boundaries of the designated water service areas conform to the Bureau of Planning's *Land Use Plan* and PUAG's existing water service areas. Each of the four regional areas was then divided into smaller sub-regions as shown on Figure 3-11. The regionalized areas are utilized throughout the report to evaluate existing water system operations and to project future water requirements and needed capital improvements. Table 3-14 is a breakdown of the civilian population projections, not including tourists, by increments to the year 2010.

As will be noted in Chapters V and VI, the need for future expansion of the existing water facilities on Guam will largely be a function of population growth when and as it occurs. Thus, the actual date or point in time at which the population reaches a given level is not as important as is the magnitude of the growth. Hence, the water system improvements presented in this report are not dependent upon the rate of growth suggested by projections such as those presented in Table 3-14. Such projections are only approximations of when a given magnitude of population will be reached.

TABLE 3-13
POPULATION RANGES BY DISTRICT

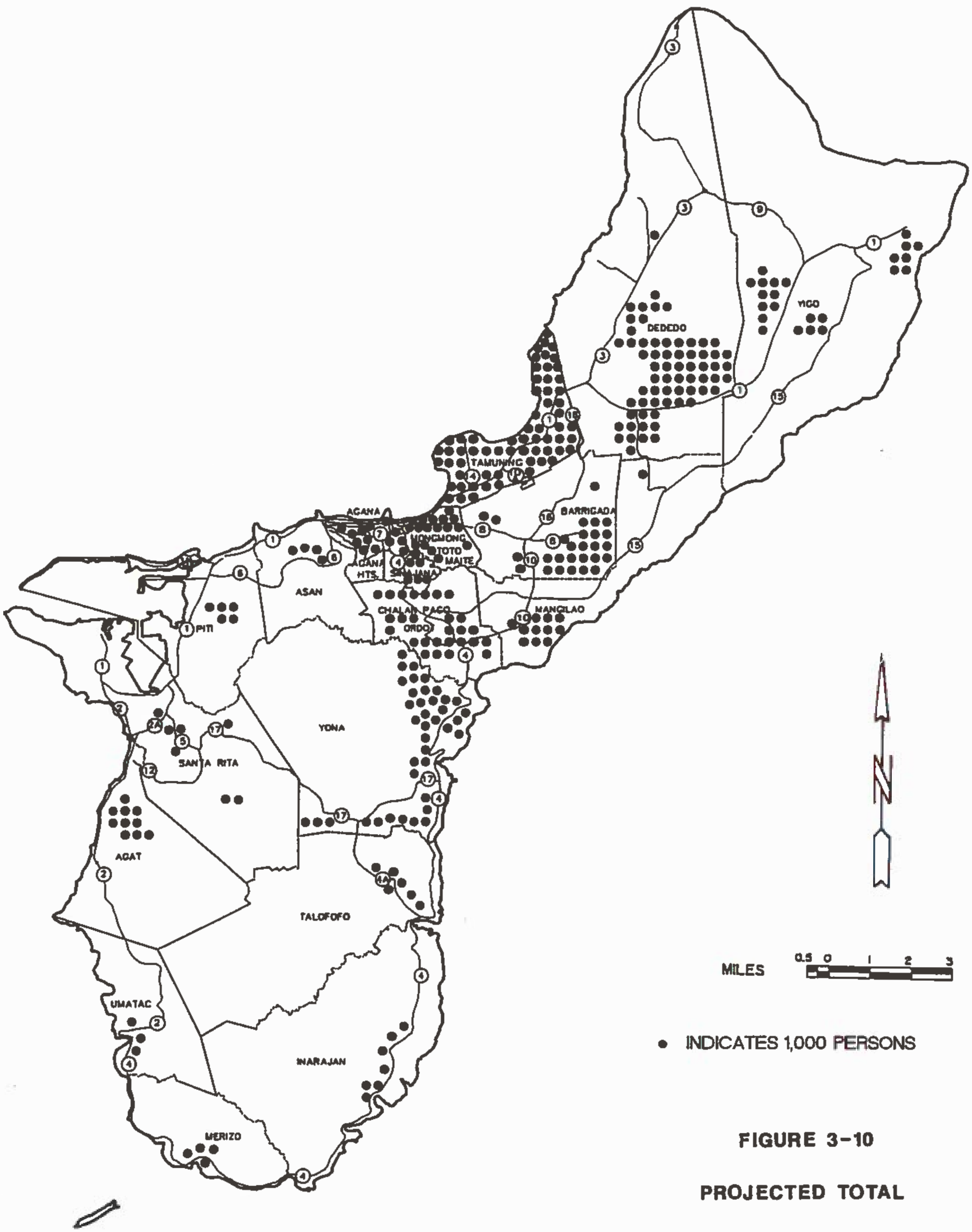
	TOTAL RES POPULATION		NATURAL POP		EMP POP INCREASE		TOTAL RANGE LOW THRU HIGH, GUAM 2010 POPULATION EXCLUDING MILITARY AND TOURISTS			
	YR 2000 LOW	YR 2000 HIGH	YR 2010 LOW	YR 2010 HIGH	YR 2010 LOW	YR 2010 HIGH	LOW			HIGH
DEDEDO	49,100	84,700	54,500	90,100	6,700	20,100	61,200	74,600	96,800	110,100
TAMUNING	46,800	91,200	52,600	97,000	7,200	21,500	59,700	74,000	104,100	118,500
YIGO	12,600	21,400	24,500	33,400	4,800	14,300	29,300	38,900	38,200	47,700
AGANA	1,700	2,600	3,200	4,100	1,900	5,700	5,200	9,000	6,000	9,800
AGANA HEIGHTS	4,500	6,300	5,300	7,000	1,000	2,900	6,200	8,000	8,000	9,900
ASAN	3,400	5,200	3,800	5,600	500	1,400	4,300	5,200	6,000	7,000
BARRIGADA	25,600	52,200	26,000	52,600	500	1,400	26,400	27,400	53,100	54,000
CHALAN PAGO-ORDOT	16,300	34,100	20,200	38,000	4,800	14,300	24,900	34,500	42,700	52,300
MANGILAO	7,800	9,600	9,000	10,700	1,400	4,300	10,400	13,200	12,200	15,000
MONGMONG-TOTO-MAITE	7,800	9,600	10,900	12,600	3,800	11,500	14,700	22,300	16,500	24,100
PITI	3,400	5,200	3,800	5,600	500	1,400	4,300	5,200	6,000	7,000
SINAJANA	4,500	6,300	4,900	6,700	500	1,400	5,400	6,300	7,100	8,000
AGAT	7,300	9,100	8,500	10,200	1,400	4,300	9,900	12,800	11,700	14,500
INARAJAN	3,400	5,200	4,900	6,700	1,900	5,700	6,800	10,700	8,600	12,400
MERIZO	3,400	5,200	3,800	5,600	500	1,400	4,300	5,200	6,000	7,000
SANTA RITA	5,600	7,400	6,000	7,800	500	1,400	6,500	7,400	8,200	9,200
TALOFOFO	3,400	5,200	4,600	6,300	1,400	4,300	6,000	8,800	7,800	10,600
UMATAC	1,700	2,600	2,100	3,000	500	1,400	2,600	3,500	3,400	4,400
YONA	11,000	44,100	27,300	50,400	8,100	24,400	35,400	51,700	58,500	74,800
	219,300	407,200	275,800	453,400	47,900	143,100	323,500	418,700	500,900	596,300

NOTE: Village population projections have been rounded off to the nearest hundred.

TABLE 3-14
TOTAL POPULATION BY DISTRICT

LOCATION	PROJ. 1990 POP	NATURAL INC. PROJ. 2000 POP	YR 2000 EMP CAUSED POP DISTRIB	TOTAL YR 2000 POP	NATURAL INC PROJ 2010 POP	YEAR 2010 EMP CAUSED POP	TOTAL YR 2010 POP
NORTH							
DEDEDO	25,300	31,400	20,000	51,500	37,200	27,600	64,800
TAMUNING	17,600	24,600	24,100	48,700	30,800	32,100	62,900
YIGO	6,600	8,100	5,000	13,100	12,300	10,400	22,700
CENTRAL							
AGANA	1,100	1,200	1,000	2,300	2,900	3,200	6,100
AGANA HEIGHTS	3,300	3,600	1,000	4,600	4,400	2,100	6,500
ASAN	2,200	2,500	1,000	3,500	2,900	1,600	4,500
BARRIGADA	7,700	12,200	15,100	27,300	12,700	15,500	28,200
CHALAN PAGO-ORDOT	4,400	7,400	10,000	17,400	11,600	15,400	27,000
MANGILAO	6,600	6,900	1,000	7,900	8,200	2,600	10,800
MONGMONG-TOTO-MAITE	6,600	6,900	1,000	7,900	10,200	5,300	15,500
PITI	2,200	2,500	1,000	3,500	2,900	1,600	4,500
SINAJANA	3,300	3,600	1,000	4,600	4,000	1,600	5,600
SOUTH							
AGAT	5,500	6,400	1,000	7,400	7,700	2,600	10,300
INARAJAN	2,200	2,500	1,000	3,500	4,200	3,100	7,300
MERIZO	2,200	2,500	1,000	3,500	2,900	1,600	4,500
SANTA RITA	4,400	4,700	1,000	5,700	5,100	1,600	6,700
TALOFOFO	2,200	2,500	1,000	3,500	3,800	2,600	6,400
UMATAC	1,100	1,200	1,000	2,300	1,700	1,500	3,200
YONA	5,500	9,400	13,000	22,500	16,500	22,200	38,700
TOTAL GUAM	110,000	140,100	100,200	240,700	182,000	154,200	336,200

NOTE: Village population projections have been rounded off to the nearest hundred.



• INDICATES 1,000 PERSONS

FIGURE 3-10

PROJECTED TOTAL

CIVILIAN POPULATION UNDER

SLOW GROWTH RATE GUAM, YEAR 2010

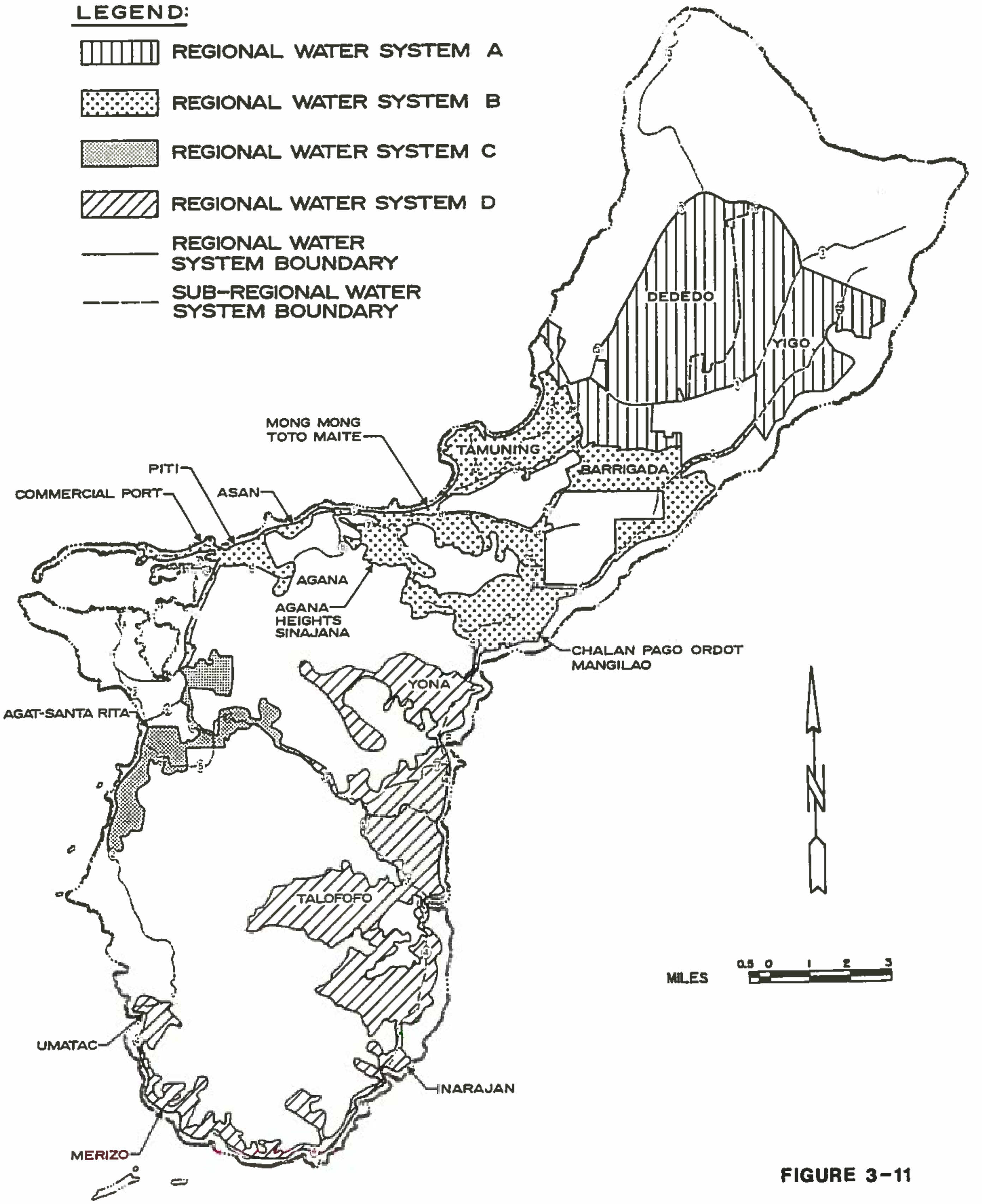


FIGURE 3-11

REGIONAL WATER SYSTEM BOUNDARIES

IV

EXISTING WATER FACILITIES

CHAPTER IV
EXISTING WATER FACILITIES

General

The evaluation of a water system requires a thorough understanding of each component, including water supply, treatment, storage and distribution. Each plays a key role in assuring that a safe water is delivered to consumers in adequate quantities under all conditions. This chapter describes each component of PUAG's water system and how each was evaluated. Also included is a description of the military water systems as they relate to supplying water to PUAG customers throughout the Island.

For ease of evaluation and understanding by the reader, the non-military lands that currently or will potentially require water service were divided into four regional water service areas. These water service areas conform to the areas shown in Figure 3-11 presented earlier in the report. To aid in familiarizing the reader with PUAG's Island-wide facilities, Figure 4-1, at the end of the chapter, has been printed on a foldout sheet that allows easy reference to the various island-wide facilities while reading the text. The reader may also refer to Figures 4-2A, 4-2B, and 4-2C, entitled "Hydraulic Profile of Existing PUAG Facilities", which are also located at the end of the chapter.

The information contained in this plan is based on information provided by PUAG and on the island-wide PUAG Water System Sanitary Survey Report (WSSSR) prepared by GEPA in 1988. Actual field investigations were not a part of this study's scope.

This chapter is divided into several sections, the first of which details the methods and procedures used to inventory and evaluate existing facilities. To simplify this process, PUAG facilities are categorized as either water supply or water distribution facilities. The water supply facilities section discusses groundwater development followed by a description of surface water supplies and springs. Water distribution facilities are discussed by location within regional water service areas. The "Water System Evaluation - Summary of Findings" section suggests possible methods to improve current operations and eliminate maintenance deficiencies. The final section of the chapter discusses the need for additional sanitary surveys. A priority list for future sanitary surveys is included to identify those water systems needing study.

Data Collection

Meetings were held with PUAG representatives to discuss the scope of work, limits of the field survey and proposed survey methods. During the meetings, the following data were requested from PUAG for use in the facility investigations:

- Mapping
  a) System maps
  b) Construction maps and "as-builts"
  c) System schematics
- Military supply connection locations and descriptions
- Physical/chemical water analyses
- Description of health problems encountered
- Description of operating difficulties
- Production/usage records
- Water service meter inventory and description of meter reading program
- System maintenance procedures and records
- Emergency procedures
- Valve and hydrant testing program

During the facilities evaluation, additional information was provided by PUAG as required. In addition, interviews were held with PUAG personnel to discuss the current status of the water facilities. Historical operating data were also utilized in assessing the facilities operations.

PUAG System Maps indicating the location of all PUAG facilities were utilized as base maps for planning PUAG's existing and future water system improvements. The System Maps consist of 72 mylar photomosaic contour maps showing all island-wide PUAG water lines as of 1978.

Water Supply Facilities

Chapter V provides background on Guam's historical water supply development and production from groundwater, surface and spring supplies. Chapter IV provides descriptions of the water supply facilities and an evaluation of the facilities operation.

Groundwater Supplies - The northern (groundwater) aquifer, or lens, is Guam's primary source of potable water. As a step to minimize the potential for degradation of the northern groundwater, a notice was published in the Federal Register on April 26, 1978, in which the Environmental Protection Agency (EPA) designated the northern groundwater system of Guam as a sole source aquifer. The impacts of this designation are discussed in Chapter VIII.

The northern groundwater lens is currently being developed by wells which are normally drilled to depths of 300 feet or more.

There are 117 production wells on Guam with an average withdrawal rate of 28 MGD. 101 of the production wells are located in the north. PUAG has a total of 86 producing wells and 10 not in operation. An additional 21 wells belong either to the Air Force (9 wells), the Navy (3 wells) or private entities. Not all of the wells are continuously active, since some are shut down for maintenance at any given time. No wells were identified as under construction in the WSSSR. However, PUAG records indicate wells under construction in the Nimitz Hill and Anigua zones to provide total production of 966 gpm and 150 gpm respectively.

The PUAG wells are identified by a geographical classification system, the Air Force and the Navy wells by numbers assigned to them by the appropriate command, and the private wells are designated by owner. All of the groundwater supply sites in Guam are shown on Figure 4-3. The PUAG "A" series wells are located in the Agana region and extend from the Adelup-Pago contact northward to Barrigada. The "M" series wells extend from the Naval Communications Station in Barrigada to Dededo-Yigo. The "D" series runs north from the village of Dededo along Y-Sengsong Road. The "Y" series is limited to the Yigo area. The "F", "H" and "AG" series are located in the Finegayan, Harmon Village (Cliffline), and Machananao (Agafa Gumas) areas, respectively. In the south, the wells are designated as "Mj" at Malojloj and "T" at Talofofo. In the well classification system a single capital letter with a number (e.g., Y-1) or a capital letter followed by a lower case letter and a number (e.g., Mj-1) refers to general geographic location and order of drilling. The lower case letter

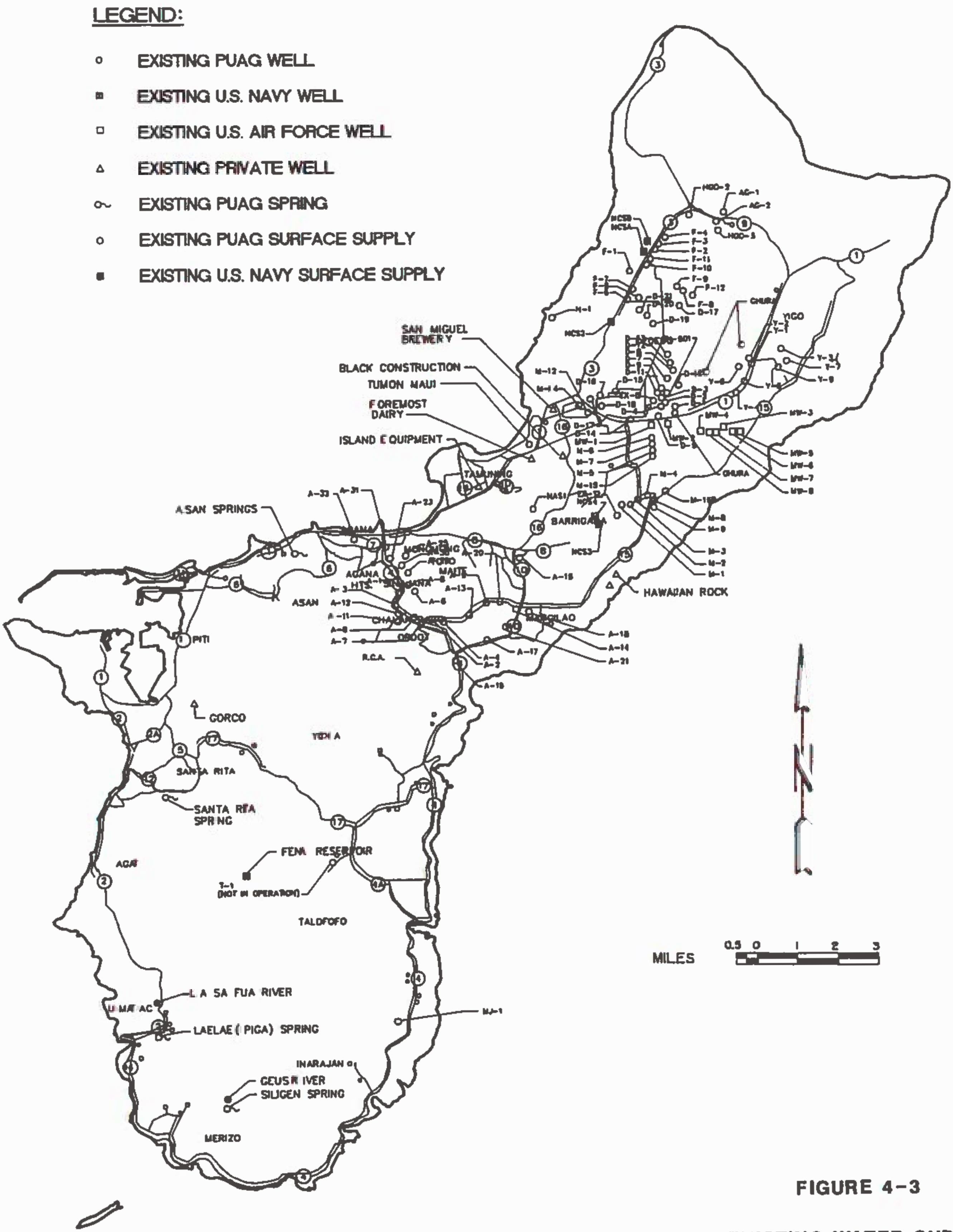


FIGURE 4-3

EXISTING WATER SUPPLY

DEVELOPMENT SITES

is added to define a geographical area different from the area which initially preempted the capital letter - e.g., well M-1 in Mangilao is differentiated from well Mj-1 which is located in Malojloj. A summary of all PUAG wells in current operation is shown in Table 4-1.

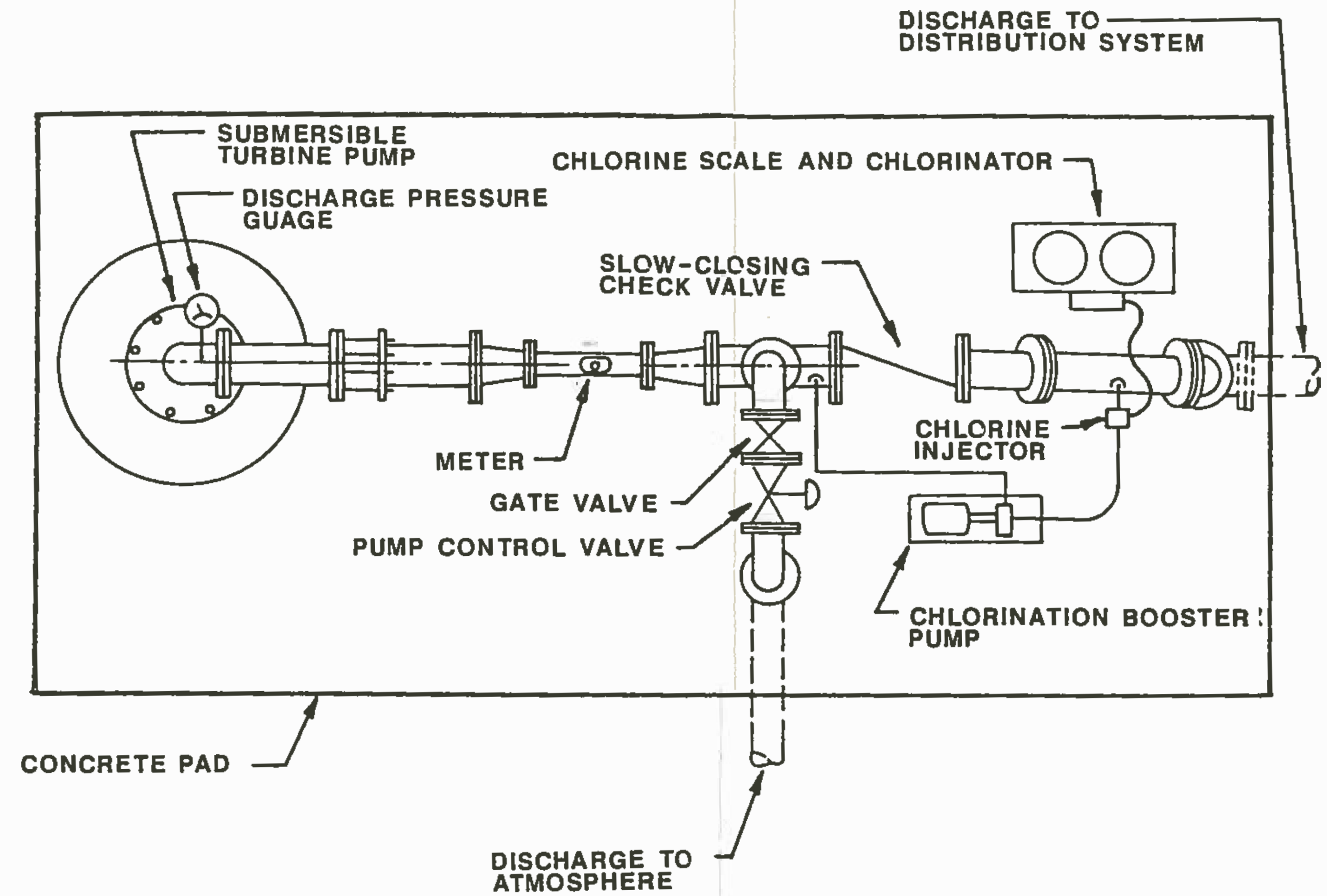
A summary of the physical and operating characteristics for each of PUAG's wells is presented in Appendix D.

All discharge piping and controls are essentially the same except for differences in configuration required to adapt each well to a particular site. The well pumps and motors are standardized with replacement units carried in inventory so that immediate repairs can be made in case of a pump or motor failure. Each well station is provided with a meter, a slow closing check valve and a pump control valve. The wells are designed with a pump control valve located on the "discharge to atmosphere" piping. The function of the pump control valve is to close slowly when the well pump is started and to open slowly when the well pump is shut down to prevent surge or "water hammer". Many of these valves have been inoperative for some time, the controls having been removed. This has not created an operational problem in the existing system, as the wells are normally run 24-hours per day. PUAG is currently in the process of replacing the valves with a remote-controlled telemetry system which will automatically switch the pumps on and off, while monitoring the production and discharge pressure of each pump.

There are currently 11 wells which have totally inoperable emergency generators. Ten other wells have emergency generators which require only minor repairs in order to function effectively. In some cases, the only repair needed is replacement of batteries. Photographs of two typical well stations and a sketch indicating discharge piping arrangements are shown on Figure 4-4.

WELL AG-1

WELL F-5



TYPICAL WELL STATION PIPING

FIGURE 4-4

TYPICAL WELL STATION FACILITY

TABLE 4-1
SUMMARY OF PUAG WELLS

Series	General Location	Wells In Operation	Wells Not In Operation	Wells Under Construction	Total Number of Wells
A	Agana	27	5	0	32
AL	AsAlonso	0	2	0	2
AG HGC-2	Machananao	3	0	0	3
D	Dededo	21	0	0	21
EX	Mangilao	2	0	0	2
F	Finegayan	12	0	0	12
GH	Dededo	1	0	0	1
H	Harmon	1	0	0	1
M	Mangilao	15	3	0	18
MJ	Malojloj	2	0	0	2
T	Talofofo	0	1	0	1
Y	Yigo	7	1	0	8
YL	Ylig	0	2	0	2
TOTAL		91	14	0	105

Source: GEPA: *Groundwater Management Report*, FY 89
PUAG: Total Production and Purchases of Water for FY 89

In the past, corrosion of equipment at well stations has been a major problem. To combat the effects of corrosion, exposed piping must be painted with a rust inhibiting coating on a regularly scheduled basis. As of November 1989, PUAG assumed responsibility for maintenance of production wells, which had previously been contracted to a private operation and maintenance firm. PUAG plans to contract these functions out again but with a more specific scope of work and accountable payment scheme.

The effects of a marine environment on exposed piping can be seen in Figure 4-5.

Figure 4-6 is a photograph of a typical pump control valve installation. As indicated previously, the pump control valves which were originally designed for surge suppression have

FIGURE 4-5
EFFECTS OF MARINE ENVIRONMENT
ON EXPOSED PIPING

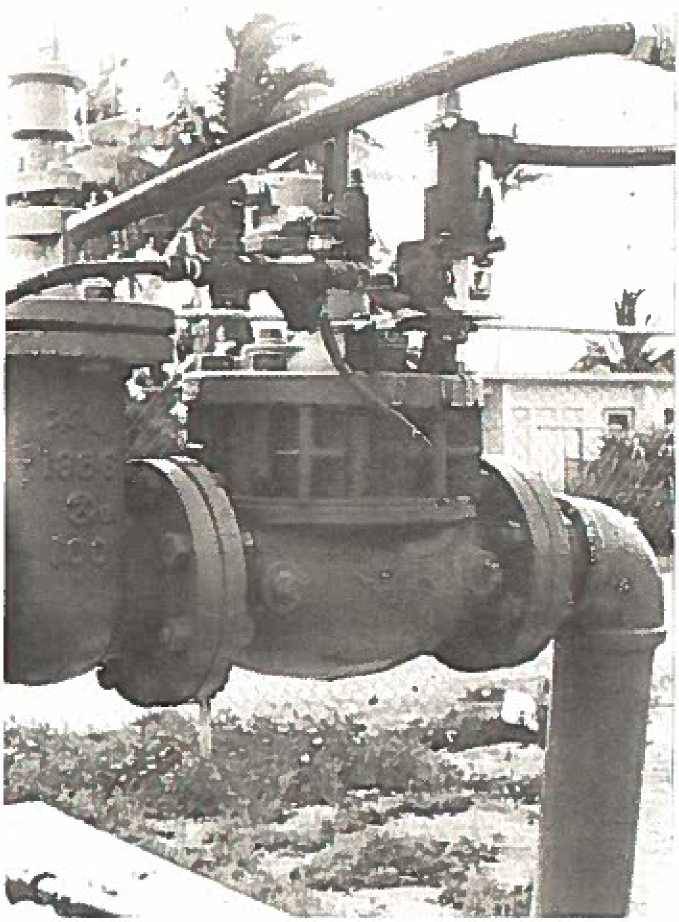


FIGURE 4-6
PUMP CONTROL VALVE

been inoperative since before the original Master Plan. All of the solenoid switch leads to these valves have been disconnected and the manual shutoff valve upstream of each pump control valve has been closed. When it is necessary to shut a pump off, no precaution is taken to open the gate valve on the "discharge to atmosphere piping" to reduce the effects of water surges and likelihood of damage to the water distribution system. Many of the well pumps operate at pressures in excess of 100 psi, which could result in damage to pipelines during shutdown if surging is not controlled. In the northern area of Guam, surges could cause a pipeline break resulting in large water losses. To compound this problem, water main leak detection is extremely difficult in the northern area of Guam due to the porosity of the limestone formations. It is recommended that complete rehabilitation of all well pump control valves be undertaken and proper care be exercised to ensure their proper operation in the future. It is also recommended that stainless steel bolts and hydraulic tubing be specified for all installations.

The chlorination equipment at the wells is currently neither housed nor shielded from direct sunlight and thus constitutes an unnecessary safety hazard. Chlorine gas can cause varying degrees of irritation to the skin, mucous membranes, and respiratory system.

Chlorine concentrations of 40-60 parts per million (ppm) for 30-60 minutes are dangerous and concentrations of 1000 ppm kill most animals in a very short time. Unprotected chlorine gas cylinders are subject to the effects of direct sunlight and vandalism, including rifle fire which can penetrate the chlorine cylinder wall or chlorinator unit. Because of the high coefficient of thermal expansion of liquid chlorine, a full container whose contents are heated above 70°C (140°F) can burst. A fusible plug on 150-lb. cylinders is designed to release the contents of the cylinder gradually if the temperature exceeds 70°C but there is always a chance of failure. Approximately 40 structures to house both the chlorination and the fluoridation cylinders stored at the well stations are currently under design and construction by PUAG. Additional improvements include housing the pump controls and chlorine alarms inside the buildings. The telemetry system, once on line, will also be located inside.

In the past, all of PUAG's wells were operated manually; that is, the wells were started and stopped by manually turning the pumps' power supply on and off. Normally, pressure controls were provided to shut off a pump when the distribution storage reservoir, to which the well was pumping, was full.

PUAG is currently installing telemetering equipment at wells, reservoirs and booster pump stations. The reservoir and booster pump station telemetering contract specifies a Supervisory Control and Data Acquisition (SCADA) Telemetry System. The SCADA system receives data from remote points in the system via radio signals and records the results at a central point (control center). The initial system provides the following:

Water Reservoirs; 21 sites:

- Level signal
- Power fail alarm

Booster Pump Stations; 2 sites:

- Chlorine alarm
- Low suction pressure alarm
- Discharge pressure signal
- Flow signal
- Power fail alarm
- Emergency power generator running
- Wet well level signal

The wells are also currently being connected to a telemetry system. At a minimum, the system should provide the following information at each production well:

- Pump status - on/off/fail
- Flow rate
- Discharge pressure

Until the telemetry systems are completely implemented, manual control of production pumps will continue. In the meantime, continuous operation of pumps will result in water wastage from overflowing reservoirs and insufficient data on the operating characteristics of the system.

Existing operations and maintenance procedures for PUAG wells are listed in Table 4-2.

GEPA conducts an annual inspection of the PUAG well system to determine if public health problems exist and to establish compliance with the Water Resources Conservation Act, Chapter II, Title LXI, of the Government Code of Guam, and pertinent provisions of the Guam Primary Safe Drinking Water Regulations. The results of the GEPA inspections are summarized in Groundwater Management Program Annual Reports and in Table 4-3.

PUAG is currently in the process of replacing defective meters. It is recommended that PUAG maintain an inventory of well meters and/or spare parts so that well meters can be replaced or repaired immediately upon detection of a malfunction. No meter should be left inoperative for more than five days. As shown by the data in Table 4-3 there is latitude for improvement in operation and maintenance of these facilities.

Although water quality in wells is generally good, the WSSSR noted that recent problems have emerged at several locations. Wells A-16, A-20, A-24, A-27 and M-11 were abandoned due to high chloride concentration and M-10 due to oil contamination.

In the same vein of chloride intrusion prevention, the 1982 GEPA report entitled *Northern Guam Lens Study* (NGLS) made recommendations for well development policies in the northern lens aquifer in order to achieve a sustainable yield of about 60 MGD. The recommendations are divided into two parts, those for basal aquifers and for parabasal aquifers. In the basal aquifers, the fresh water floats on top of the saline salt water. In the parabasal aquifers, the fresh water overlies volcanic mass formations.

The NGLS recommendations for production well design are summarized as follows:

For basal aquifers development:

A. In management zones where fresh water heads are less than 4 feet, wells should be limited to 200 gallons per minute (gpm) capacity. The well bottom elevation should not exceed 40 feet below mean sea level (MSL) and preferably be not more than 25 feet below MSL.

TABLE 4-2
EXISTING OPERATION AND MAINTENANCE PROCEDURES FOR PUAG WELLS

Maintenance Task Description	Frequency
Measure voltage, amperage and resistance to check motor performance.	Monthly
Check that motor will not operate more or less than 10% from rated voltage.	As required
Check that motor will not operate less than specified flow of liquid so as not to damage the starter winding or motor and thrust assembly.	As required
Check-up water level.	Monthly
Water well rejuvenation. Acid treatment and cleaning to maintain well yield as required.	As required
Check that pump head (first elbow) is sealed to prevent water contamination.	Monthly
Check-up air release connection and pressure gauges, install one if there is none and replace if it is defective.	As required
Check-up for leaks and corrosion on piping, coupling, reducer, tee, valves and bends.	Monthly
Report to PUAG Laboratory and GEPA any well that is being pulled out so as to analyze the water chloride and coliform count prior to completion.	As required
Check proper operation of no slam check valve and pump control valve with solenoid.	Monthly
Record water meter and pressure reading for pump performance; replace as required if malfunction occurs.	Monthly
Maintain and repair pump control panel by cleaning the magnetic contactor with lint free cloth.	As required
Check electrical wiring to chlorination equipment.	Daily
Record power meter reading for motor's performance on power consumption. Refer to GEPA as required if malfunction occurs.	As required
Maintain fence and secure gate.	Monthly
Maintain ground inside and outside fence enclosures up to 10 feet from fence line.	Monthly
Deep wells without telemetry shall be inspected to make sure they are operating properly.	Daily

TABLE 4-3
GEPA 1989 WELL INSPECTION REPORT SUMMARY

Item	Number of Wells
Defective Water Meter	15
Defective or Missing Pressure Gauge	16
Unsecured, Broken or Disrepaired Gate, Fence	14
Defective Chlorinators or Scales	9
Elevation Marker Missing	0
Corrosion Present	0
Medium Leak	2
Unsecured Booster Pump	1
Fluoride Leak	1
Empty Cl_2 Bottle	7
No Well Number Tag	6
Cl_2 Leak	0
Defective Booster Pump, Motor	7

Source: Summary of Well Inspections, *Groundwater Management Program, Annual Report* 1985-1989, GEPA.

B. In management zones with fresh water heads greater than 4 feet, wells should be limited to 350 gpm capacity and the well bottom elevation should not exceed 50 feet below MSL, and preferably not more than 35 feet below MSL.

For the development of parabasal aquifers, wells should be designed for the maximum that the aquifer can deliver without exceeding the sustainable yield of the management zone and without exceeding 750 gpm. However, because of low permeabilities in many parts of the Northern Lens, the following well designs are provided as guidelines for groundwater development.

A. In the southern part of the Agana Sub-basin, low permeabilities will probably limit well capacities to 200 gpm, and perhaps under special conditions 350 gpm. Wells in this area should probably be drilled no deeper than 50 feet below MSL.

B. In the upper part of the Yigo Sub-basin, wells will probably yield 750 gpm. Wells in this area should probably not be drilled any deeper than 50 to 60 feet below MSL.

C. Wells in all other parabasal zones should have a capacity of about 500 gpm with well bottom elevations not exceeding 50 feet below MSL.

Wells should not be placed any closer than 500 feet from the salt water toe in clean limestone, and 1000 feet from the toe in argillaceous limestone.

Wells should be placed at least 300 feet apart in both the basal and parabasal aquifers.

Although many existing wells penetrate much lower than the recommended depth, PUAG is implementing the recommendations for all new wells. Furthermore, in response to recommended pumping limits, wells A-23 and A-25 pump system head curves have been changed to decrease withdrawal rate.

During the 1970's and 1980's, deeper wells were drilled such as D-11 at minus 37 feet, D-12 at minus 42 feet, D-13 at minus 53 feet, and D-14 at minus 63 feet. The NGLS has indicated that these are dangerous depths for wells in a basal lens and should be avoided. The "M" Series wells have been drilled to minus 50 feet, because of experience with limestone of low permeability at M-1, but several recently constructed wells are much deeper, including M-6 at minus 80 feet, M-7 at minus 78 feet, and M-11 at minus 60 feet. The ability to continuously pump high quality water from the wells at a rate of 200 gpm is questionable. Despite the progress toward implementation of the NGLS recommendations, salt water upconing may be a problem because of pre-existing situations. Increased chloride levels have been noted in the Mangilao area wells, which required reduction in pumping rates.

The recommendations of the NGLS have provided a basis for proper well design criteria and optimum groundwater management practices. Well design is also subject to the rules and procedures prescribed in the 1985 GEPA *Water Resource Development and Operating Regulations*. PUAG should closely monitor the fluctuations in thickness and horizontal extent of the basal lens under various demand and recharge conditions. The data gathered by such monitoring will prove invaluable in responding to changes in both demand and supply.

In Chapter IX a program for the construction of additional wells is discussed. Assumptions as to well locations and capacities have necessarily relied to a great extent on the recommendations in the NGLS. However, it is not reasonable to assume that all future wells will necessarily be located in the precise areas where they are presently proposed or that they will all be designed to produce approximately 200 gpm in accordance with current design practices.

The point has been reached where it is not prudent to construct new wells in some portions of the lens; however, greater production may be obtained from other zones. Further analysis of well production data is required to better identify the productive potential of the Northern Lens and design restrictions proposed in the NGLS will likely change in the future as the study is updated.

In addition to water development procedures presented in GEPA's *Water Resource Development and Operating Regulations*, well design and construction standards are also included in Appendix C of the NGLS. These volumes detail recommended requirements for production wells, and address the following aspects of PUAG well construction:

Materials furnished by driller

- Well casing and screen materials, construction diameter. Acceptable screens are either (1) wire wrap screen or (2) shutter or louver slot screen.
- Sounding tube specifications are schedule 80 threaded PVC.
- Cement specified is ASTM Designation C150 or API Class G.
- Drilling fluid requirements
- Gravel pack specifications for the annular space between the borehold and the casing/screen assembly. The possibility of dispensing with a gravel pack is noted.

Well Construction (In chronological order)

- Pilot boring procedures
- Test pumping requirements
- Reaming the pilot boring
- Installation of temporary conduction casing
- Installation of well casing and screen requirements

- Alignment of well
- Installation of sounding tube
- Installation of gravel pack (if required)
- Installation of grout seal

Video survey of well

The following items are checked to insure that proper construction techniques have been followed:

1. Conditions of casing and screen
2. Proper and complete welds
3. Screen placed at proper interval

Figures in the document define the required well construction dimensions.

Other portions of Appendix C of the NGLS cover the following areas of production well projects.

1. Well development and testing
2. Pump and motor selection
3. Well completion and start-up

Surface Supplies and Springs

In addition to utilizing the northern aquifer, PUAG produces water from surface and spring sources and purchases water from the Navy and Air Force. The surface and spring supply facilities utilized by PUAG are listed in Table 4-4 and shown on Figure 4-1. Regional Water Service Area "A" does not contain any spring or surface supply sources as all water requirements are met through well production and from water purchased from the Air Force.

Regional Water Service Area "B" - Regional Water Service Area "B" receives spring water from two sources, Agana Springs and Asan Springs. The Asan Springs facility is located in the upper reaches of the village of Asan, and is shown on Figure 4-7. No "as built" drawings were available to indicate the layout of the facility. It is believed that the original installation, constructed by the U. S. Navy in 1929, included only an uncovered storage basin, a perforated conduit penetrating into the hillside with a gravity discharge, and an overflow

TABLE 4-4
SURFACE AND SPRING SUPPLY FACILITIES

Regional Water Service Area	Name of Facility	Estimated[1] Capacity (gpm)
A	None	-
B	Asan Springs	297
C	Santa Rita Springs	149
D	Geus River Dam	39
	Siligin Spring	10
	Laelae (Piga) Spring	34

(1) Indicates estimated average production only. Accurate records on historical production are not available.

Source: PUAG, *Total Production and Purchases of Water for FY89.*

spillway. The basin, which is divided into two compartments, is approximately 10 feet deep and has a total storage capacity of approximately 30,000 gallons. Since 1929, the storage basin has been covered with a concrete roof to provide protection against potential pollution from outside sources.

Two vertical turbine booster pumps, shown on Figure 4-8, are designed to operate one at a time and to pump with sufficient head to supply Piti Reservoir. One pump is equipped with a 15 HP motor and has a nominal capacity of 260 gpm. The second pump is equipped with a 20 HP motor and has a capacity of 350 gpm. Pump operation is controlled manually, and the pumps are alternated on a monthly basis. Chlorine for disinfection is the only form of water treatment required. The chlorine is injected at the pump discharge piping using a solution feed gas chlorinator.

The Asan Springs Facility has not been comprehensively improved in recent years beyond the integration of a cathodic protection system. However, several problems noted in the previous water master plan have been corrected. This work included repairs to pump controls, motors and pumps to prevent overfilling of the Piti Reservoir and backfeeding from the "on line" pump to Asan Springs storage basin.

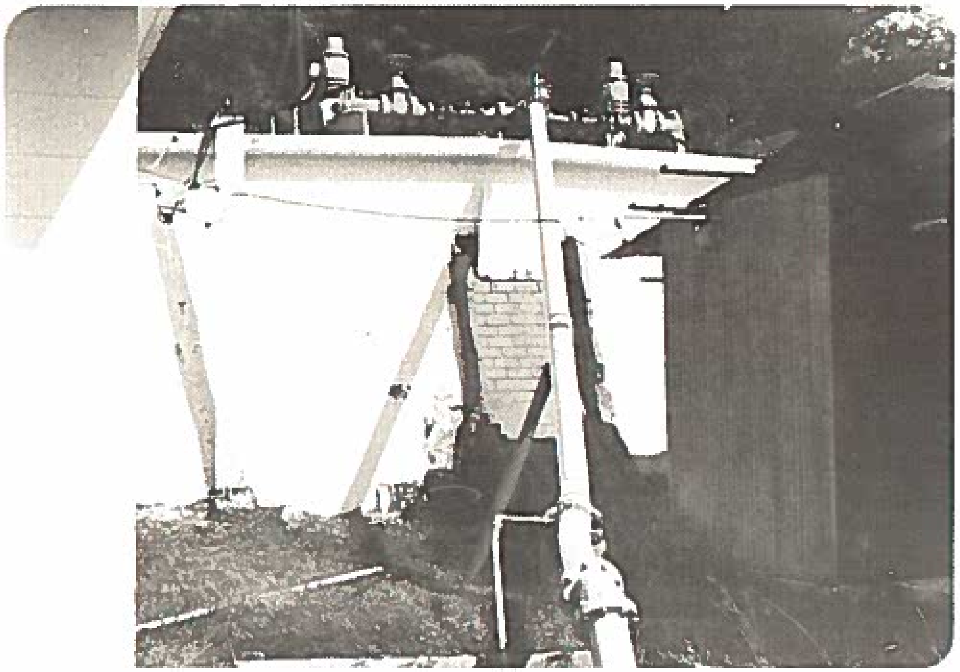


FIGURE 4-7
ASAN SPRINGS STORAGE BASINS

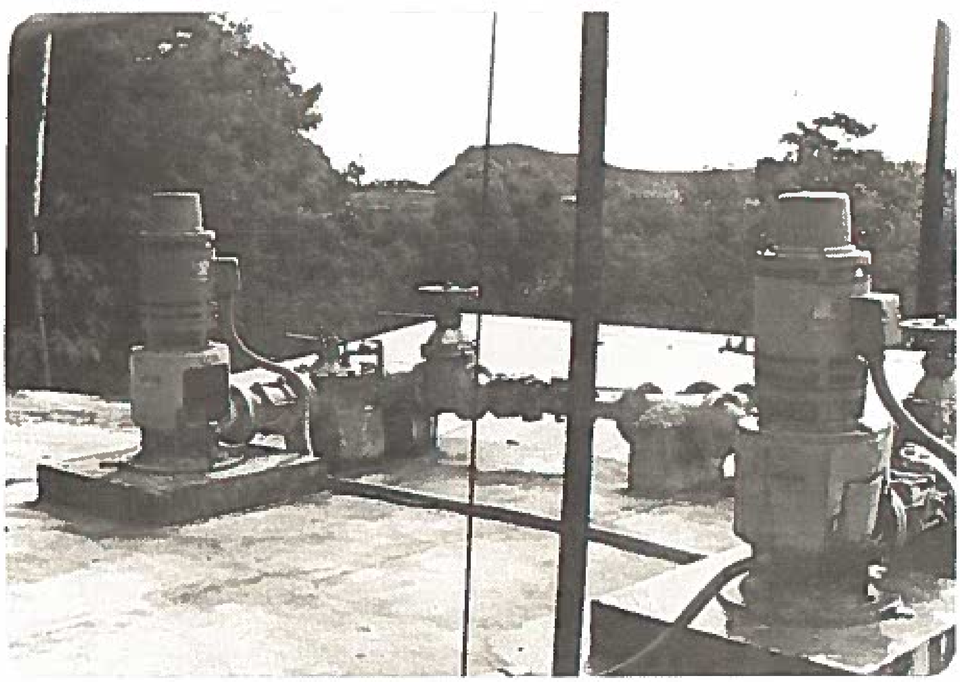


FIGURE 4-8
ASAN SPRINGS BOOSTER PUMPS

The WSSSR noted some significant deficiencies at the Asan Springs facility as follows:

1. Only the 260 gpm pump is operable. It is badly corroded and wiring is exposed to the elements.
2. The chlorinator is in an enclosed building but there is no door lock.
3. There is no padlock on the cyclone fence pedestrian gate.
4. The storage basin and the surrounding chlorinator building is overgrown with vegetation creating a hazard for operation and maintenance staff.
5. The right of way for the access road is in dispute with an adjacent private land owner and is completely impassable to vehicles. Therefore, all materials, including heavy tools and chlorine cylinders, must be carried by staff.

In summary, the Asan Springs facility is quite old but remains a viable water supply facility. It is recommended that the spring be utilized to its maximum production potential as it provides a good quality and relatively inexpensive source of potable water. Steps must be taken to remedy the previously mentioned problems noted by GEPA in the WSSSR.

The Agana Springs Facility has been improved within the last decade and has been connected to Regional Water Service Area "B". The facility has been provided with cathodic protection as part of the improvements. The facility consists of two wells, A-29 and A-30, which supply 300 and 700 gpm respectively. The production pumps run continuously to supply the Chaot Reservoir.

Regional Water Service Area "C" - This water service area, encompassing the Agat-Santa Rita area, receives potable water from two sources, the Santa Rita Springs and the U. S. Navy.

The Santa Rita Springs reservoir was originally developed by the U. S. Navy in 1929 and is similar in construction to the Asan Springs Facility. A perforated pipe extends into the hillside and discharges spring water into one of the two storage basins having a combined capacity of 105,000 gallons. As the water enters the storage basin, it is chlorinated by means of the standard chlorination system used by PUAG, consisting of a solution feed vacuum-type chlorinator with scales. The water from the storage basins flows by gravity into the distribution system serving the old Agat and Hyundai subdivision area. During the period of the year when the spring production exceeds system demands, water is discharged through the outlet pipes and over the basin weirs. The average water production rate is about 150 gpm. The facility was recently improved to provide concrete covers for the storage basins, shown in Figure 4-9. Other storage and distribution system improvements include the construction of a 1.0 MG steel reservoir above the Santa Rita village and the installation of a booster pump station at Santa Rita Springs consisting of two 40 HP pumps with capacities of 650 gpm. Old 3- and 4-inch diameter RCP lines in Agat have been replaced. The Route 5 booster pump station (a Navy connection) has been abandoned, and two new booster pump stations with pipelines connecting Sinifa Reservoir to the system have been constructed.

Regional Water Service Area "D" - Historically, the southern villages of Guam have relied on local surface and spring water sources. Inadequate water treatment at the majority of these local sources results in water of a quality below current standards set by the E.P.A. Safe Drinking Water Act. The local water supply for the village of Merizo is augmented by imported northern groundwater, while Yona, Inarajan, and Talofofo are totally dependent on imported water.

The Ylig Water Treatment Plant, installed by the U.S. Navy during World War II, has deteriorated beyond repair. The original Master Plan had recommended it's replacement as soon as funding permitted because of the plant's importance in supplying water demands for the area. Since that time the plant has been removed from service with no replacement.

The present sources of water supply for the village of Merizo are the Geus River and Siligin Springs, which are utilized on an intermittent basis only. The springs are located about 3,000 feet upstream from the Geus River Dam in a watershed area that is thick with vegetation. The water flowing from one spring is collected in a 6 foot by 8 foot concrete structure which also receives water from a second spring via an 8-inch diameter cast iron pipe. According to U.S. Geological Survey (USGS) records, these springs flow continuously year-round. The water from the two springs joins the Geus River Dam supply just downstream from the dam. Together the Siligin Springs and the Geus River supply an estimated 100 to 150 gpm which flows by gravity approximately 1,200 feet westerly to the Pigua Booster Pump Station. Additional treatment, recommended in the original Master Plan, is provided in the form of pressure sand filters. The water is then chlorinated and pumped to Merizo Reservoir. The pump station and reservoir will be discussed later in the chapter.

The Geus River water supply is impounded behind an old concrete dam and diversion structure shown on Figure 4-10. The volume of water impounded is approximately 100,000 gallons. The stored water must pass through a sand filter located in the dam structure before entering the transmission main to the Pigua Booster Pump Station.

Water obtained from these sources is of high turbidity, especially during the wet season, and has on several occasions failed to meet the Maximum Contaminant Level (MCL) standard for total coliform count. The Geus River system is occasionally shut down when the river water becomes highly turbid, especially during the wet season, and periodically runs dry during the dry season. For this reason, it has never been a dependable source of water supply for the southern villages.

In the WSSSR, Guam EPA recommended the permanent abandonment of the Geus Dam source. It would then be necessary to locate another source of water supply for the southern villages.

The Umatac community water system is supplied by Laelae Springs, also known as the Pigua Spring. The spring is located approximately one mile east of Route 4 off Mandino Street and produces approximately 65 gpm. Although no drawings are available, it is believed that the spring water is collected using two perforated pipes that penetrate the hillside. The water drains from the perforated pipes into an uncovered two cell storage tank approximately 6-feet by 8 feet in size. From the storage basin the water flows by gravity through a 6-inch diameter pipe into a 30,000 gallon steel reservoir and is piped through a 4-inch galvanized iron pipe to a chlorination building located approximately 1,000 feet east of Route 4. After the water is chlorinated it flows by gravity into the distribution system. A second previous water source for the Umatac Region, the La Sa Fua River intake, has been abandoned.

Currently under construction is a river intake structure and treatment plant designed to supply approximately 2 MGD to the communities in the Malojloj-Inarajan area. The water source site is located along the Ugum River approximately 1.2 miles northeast of Talofofo Bay. The collected water from the river will drain into a concrete wet well from which it will be transferred by two 150 HP submersible pumps to the treatment and storage facilities. Treatment will consist of chemical addition for flocculation, followed by gravity sedimentation and rapid sand filtration. The water will flow by gravity through the treatment plant and into

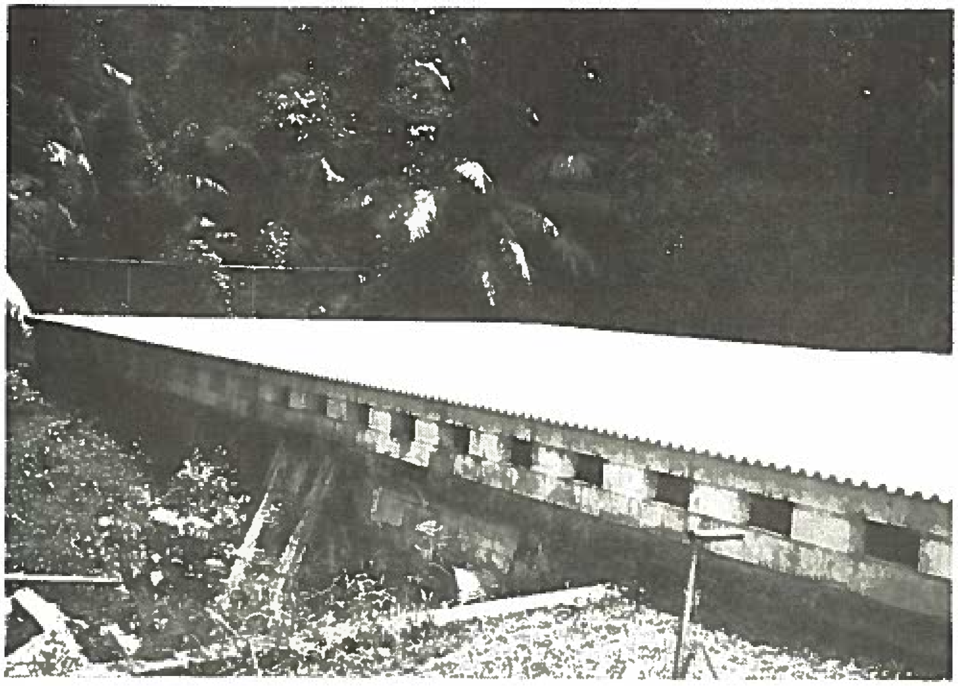


FIGURE 4-9

SANTA RITA SPRINGS STORAGE BASINS

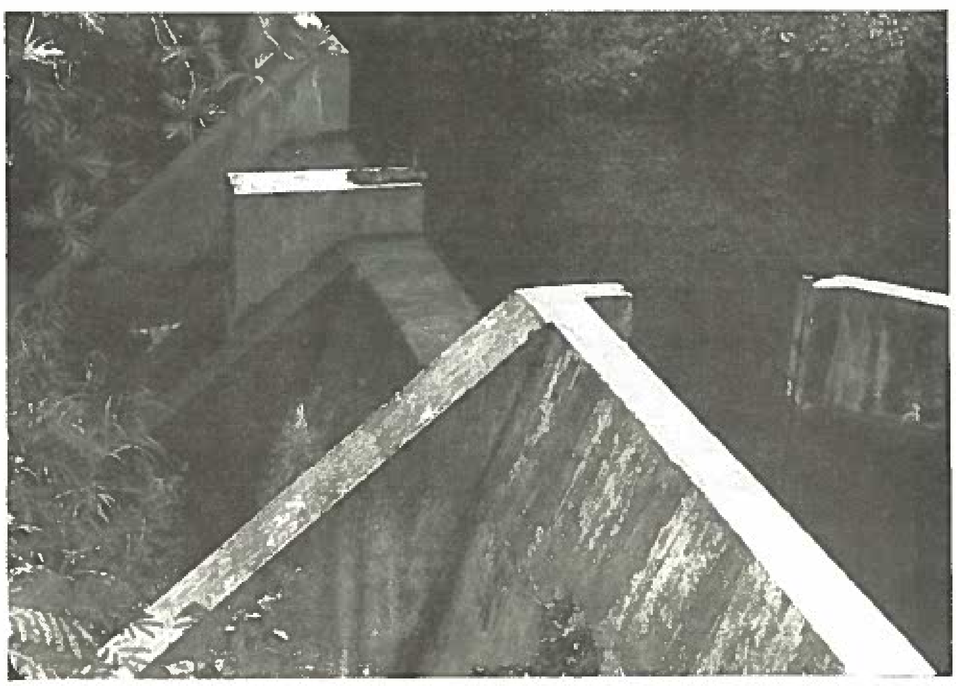


FIGURE 4-10

GEUS RIVER DAM

reservoir tanks for storage. Booster pumps located on Route 4 will then lift the water to Malojloj and Windward Hills reservoirs for distribution.

Military Supply Sources - Guam's second and third largest water producers are the U. S. Navy and U. S. Air Force, respectively. The Navy's main water supply is Fena Reservoir, although they do operate three wells near NCS-Finegayen and obtain water supplies from Bona Spring and Almagosa Spring on the southern end of the island. The Air Force, with nine deep wells and one infiltration tunnel, relies on the northern groundwater lens as its sole source of water supply.

Fena Reservoir was constructed by the Navy in 1951 to supply its existing and future military operations on Guam. The reservoir, located in the Naval Magazine, has a six-square mile watershed and a capacity of approximately 2.3 billion gallons (7,050 acre-feet). Fena Dam is approximately 85 feet high and 1,050 feet in length. The Almagosa Spring and the Bona Spring are also located within the Naval Magazine and supplement the impounded supply. Water is pumped three miles from the Fena Reservoir to the Fena Water Treatment Plant by four 3,500 gpm, 300 HP pumps located at the reservoir. While water from the Almagosa Spring flows by gravity to the treatment plant, the Bona Spring is located at an elevation such that water from this source must be pumped to the treatment plant.

Raw water from the two springs and the reservoir are combined and pre-chlorinated in the raw water pit. A schematic flow diagram of the treatment plant is shown on Figure 4-11. The treatment plant can process a maximum flow of 13.5 MGD.

The water flows from the raw water pit into a baffle chamber where alum and lime are added for coagulation to improve the solids removal process. From the baffle chamber, the water flows into the pretreatment tank, shown on Figure 4-12, which consists of a flash mixer cell located in the center of a 125-foot diameter sedimentation tank. The settled solids (sludge) are discharged to a washwater tank while the clarified water flows to one of six dual media filters for removal of remaining turbidity. After filtration, the water is chlorinated for disinfection and is discharged into a one million gallon clearwell. The six filters are periodically backwashed to clean the filter beds. The spent washwater from backwashing is discharged into the washwater tank where the solids are settled and discharged under NPDES permit by

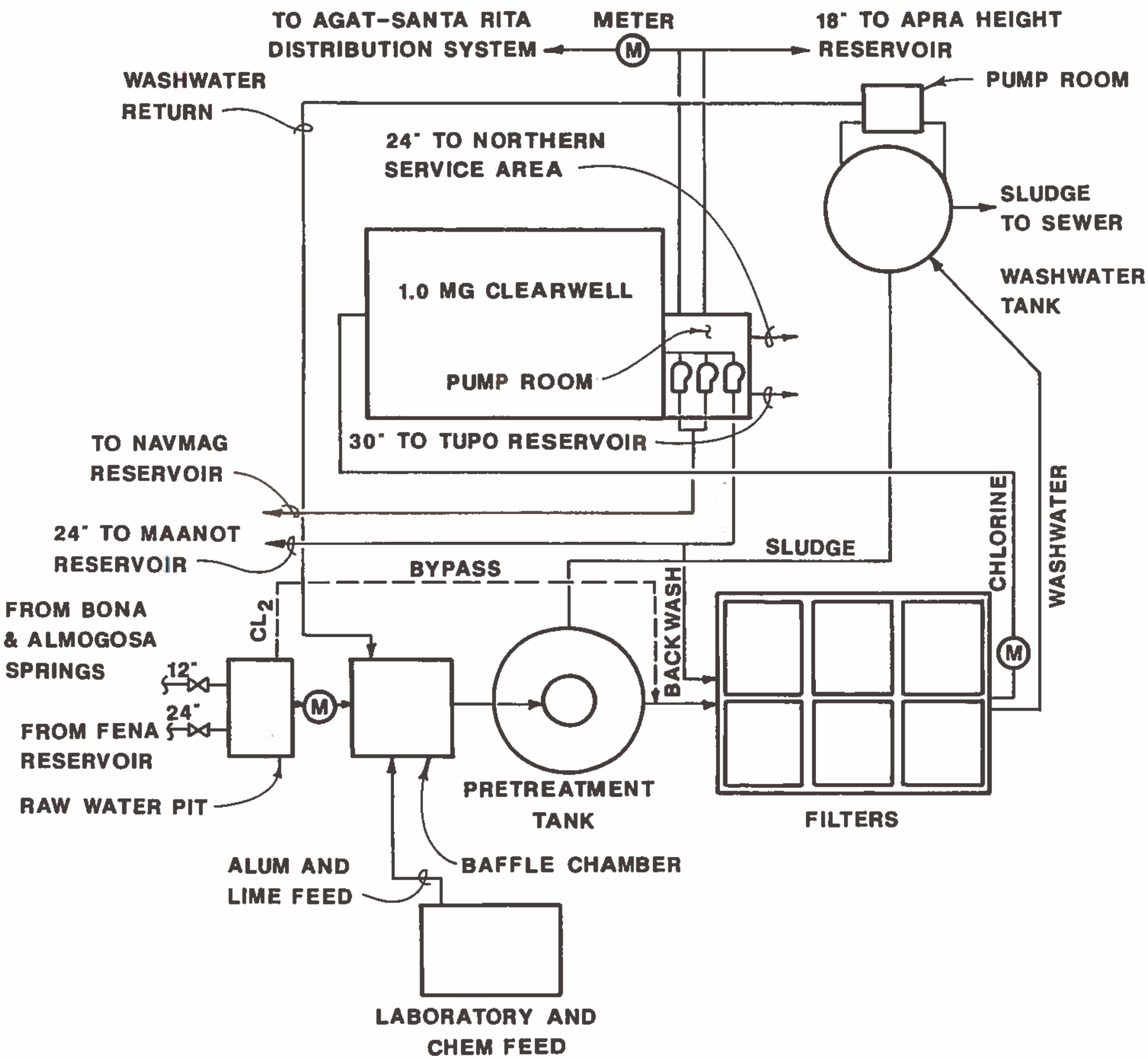


FIGURE 4-11

FENA WATER TREATMENT PLANT

SCHEMATIC DIAGRAM

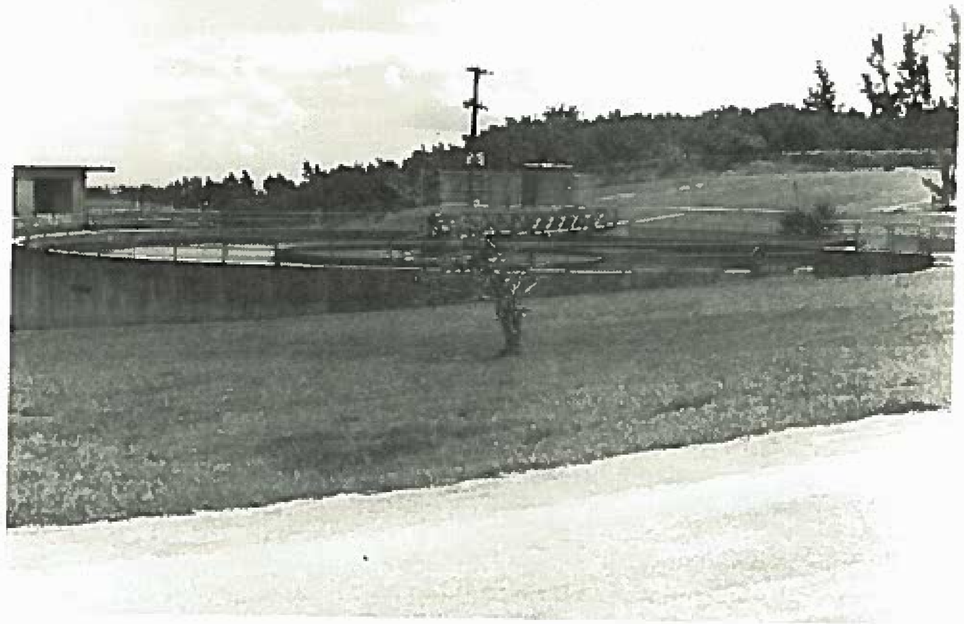


FIGURE 4-12
FENA WATER TREATMENT PLANT
PRETREATMENT TANK

outfall to local creeks and rivers, their ultimate destination Apra Harbor. The decanted washwater is returned to the baffle chamber for reprocessing with the incoming raw water.

The clearwell, shown on Figure 4-13, is used as an equalization reservoir for finished waste distribution to the Navy's NavMag, Maanot, Apra Heights and Tupo Reservoirs which have capacities of 0.75 MG, 0.5 MG, 5.0 MG and 5.9 MG, respectively.

The use of a drying bed currently under construction at the Fena Water Treatment Plant will minimize the pollution of creeks and rivers now caused by the discharge of solid waste via the outfall.

In late 1988, Guam EPA, in conjunction with the U.S.Navy PWC, conducted an extensive field sanitary survey of the U.S. Navy water system on Guam. This survey included inspection of the entire system to assess the environmental impact of the facilities, to identify operation and maintenance problems, and to determine the existing condition and location of the water production, treatment, storage, transmission and distribution facilities. The GEPA concluded

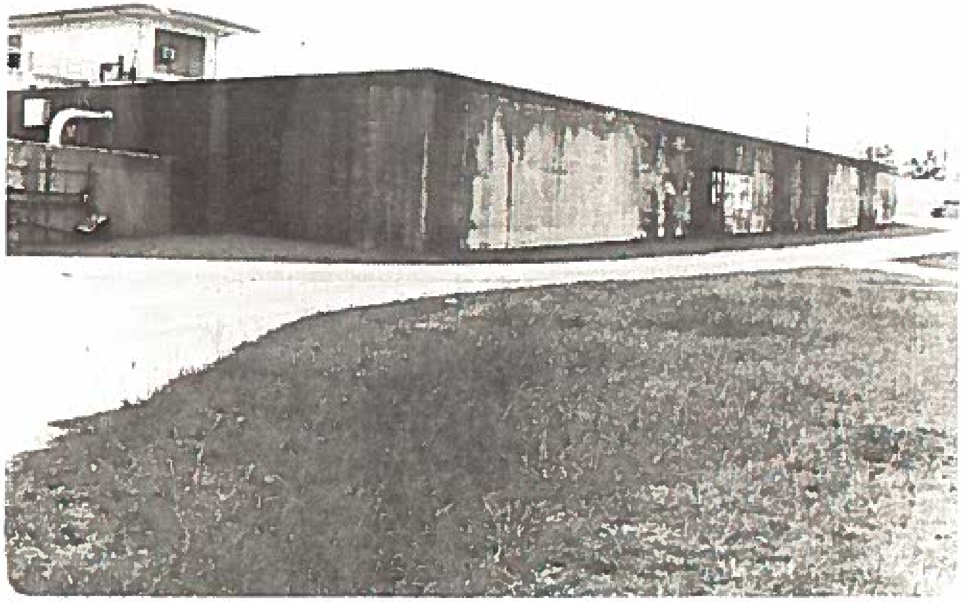


FIGURE 4-13
FENA WATER TREATMENT PLANT CLEARWELL

that the Fena Water Treatment Plant and its associated facilities are structurally in sound condition. However, it did recommend the replacement of many of the instruments, controls, chemical feeders, and associated components, some of which have been in continuous use since their original installation in 1953.

In an agreement between the U. S. Government and the Government of Guam, dated July 1, 1956, the Navy is committed to provide a portion of its water supply for use by the Government of Guam.

An excerpt from the Agreement reads as follows:

> "The Navy assumes no responsibility for increasing the quantity of water available for use or distribution by the Government of Guam beyond existing commitments aggregating 4.25 million gallons per day, of which 0.75 million gallons per day are to be delivered to the Government of Guam systems served from the portion of the Navy system south of the junction of Routes 1 and 2A, 2.50 million gallons per day north of the junction of Routes 1 and 2A, and 1.00 million gallons per day from the Navy's

Agana Springs system. The Navy may, if re-requested, furnish additional water to the Government of Guam subject to the availability of such water after the needs of the military services have been fulfilled".

Since the execution of the agreement, the Agana Springs system has been abandoned by the Navy and rehabilitated by PUAG. Although the agreement indicates a geographical allocation of water, the Navy has permitted additional diversions south of the junction of Routes 1 and 2A in the Agat-Santa Rita water area provided that the overall Government of Guam water use is maintained below the present (i.e., without Agana Springs) 3.25 million gallon per day allocation. The Navy has requested that PUAG make every effort to disconnect and abandon Navy supply locations as soon as possible. Typically, during the months of April through June, the Navy has difficulty meeting their own water demands plus their commitment to PUAG. According to the U.S. Navy Water System Sanitary Survey of FY 1989, Naval water usage averages 285 gallons per capita per day (gpcd), a figure almost double the 150 gpcd usage usually expected in large American industrial cities. As explained in detail in Chapter 5, the average current per capita use for the civilian population on Guam is 124 gpcd. The high water demand generated by the military population results in water shortages for Agat-Santa Rita consumers, requiring water rationing and other emergency measures. The U.S. Navy has drilled five production wells located in the central and northern parts of the island primarily intended to supplement the water demand, especially during the dry season.

Anderson Air Force Base (AAFB) is located on a relatively flat limestone plateau on the northern end of Guam, surrounded by steep limestone cliffs. No surface streams exist here; storm water on AAFB is channeled relatively short distances into natural or man-made depressions in which underground injection wells have been drilled. These injection wells allow infiltration of surface waters into the Northern Lens, which is the island's major aquifer and is described in detail in Chapter 8. More than 100 of these injection wells have been installed on AAFB.

The base has nine production wells, and one well for irrigating the golf course. The water from the nine wells is pumped into a reservoir for treatment before feeding into the distribution system.

The 2.0 MG concrete Santa Rosa Storage Tank supplies the water requirements of AAFB by a 6,500 foot length of 16-inch diameter gravity line. The Santa Rosa tank is supplied from the Marbo Booster Station #3, which in turn is supplied by the 0.42 MG concrete Marbo Storage Tank #4. Marbo Booster Station #3 and water production wells 5 through 9 supply Marbo Tank #4. The 0.25 MG Marbo Tank #2, which feeds Marbo Booster Station #2, is supplied by production wells 1, 2, 3 and the Tumon Maui Well. On the line between production well 5 and Marbo Tank #4 is a chlorination, fluoridation and polyphosphate water treatment plant. Pipes on this system consist of unlined cast iron pipe, asbestos cement pipe and PVC pipe.

A 0.075 MG elevated steel water tank, located at the former Northwest Housing Area, is gravity fed from Santa Rosa Storage Tank. The elevated tank feeds the 0.15 MG steel water tank at Detachment 5 and the Navy 0.15 MG steel tank for Ritidian by gravity.

The 1.0 MG concrete Tarague Reservoir, located on the north side of the base, has been abandoned due to high chloride content in the supply well. AAFB has no plans to return the well to use.

The existing water supply and distribution system relies on a 12-mile length of line from the Tumon Maui Well, located in upper Tumon. The water, which supplies approximately 35 percent of the total water production for the base, is collected in an infiltration tunnel and is pumped through a transmission main to Marbo Tank #2, a 250,000 gallon concrete reservoir, located in Dededo. The water supply is limited by the pumping capacity of the booster stations. Booster Station #3, feeding the Santa Rosa 2.0 MG Storage Tank, can feed approximately 3.0 MGD (in 20 hours of pumping) into the tank, while a combination of pumps could provide (in 20 hours) as much as 4.2 MGD, which is considered maximum pumpage of the existing system. The Air Force has recently negotiated an agreement with PUAG to exchange the Tumon Maui Well for equivalent PUAG water from northern lens wells located closer to Anderson Air Force Base. However, the Air Force may terminate the agreement at any time that security requires it.

In addition to the Tumon Maui Well, the Air Force maintains five deep wells in the Air Force Marbo Annex area and three deep wells along Marine Drive.

The U.S. Air Force supplied PUAG with approximately 0.2 MGD through seven connections during FY 1989. PUAG is currently investigating each military water supply connection to determine the feasibility of abandonment. However, the elimination of supply connections that are remote from the main PUAG system will require extensive capital investments. The agency has no plans to completely eliminate water supply connections from either military sector for at least the next ten years.

Precise consumption and unaccounted-for water data is not available due to a lack of metering devices within the system. Metering is currently used only for production wells and for the sale of water supplies to GovGuam.

The locations of all major military water supply, transmission and storage facilities that traverse non-military lands are shown on Figure 4-14. Figure 4-14 also shows the location of military connections to PUAG water supply. Table 4-5 lists the monthly water deliveries in 1989 for each of the supply connections. The information presented in Table 4-5 shows that the Navy supplied an average of 4.6 MGD through 56 supply connections. The Air Force supplied negligible amounts of water through 7 connections.

Water Distribution Facilities

After the development and treatment of a water supply, the distribution system must deliver the water to the users. To be considered adequate, the distribution system must be capable of furnishing an ample supply of water of satisfactory sanitary and aesthetic quality whenever and wherever it is required in the water service area. Distribution system components include booster pumps, pipelines, control valves, hydrants, storage reservoirs, service connections, and meters.

The distribution system must provide adequate pressure for normal residential, commercial, and industrial uses and for fire protection purposes. It is often necessary to pump the supply to a higher elevation to provide adequate service.

Distribution storage is utilized to equalize and reduce peak loads, including fire demands, which are placed on the production and transmission elements of the system and to provide standby supplies during emergencies such as typhoons. A list of all PUAG distribution system reservoirs is found in Table 4-6.

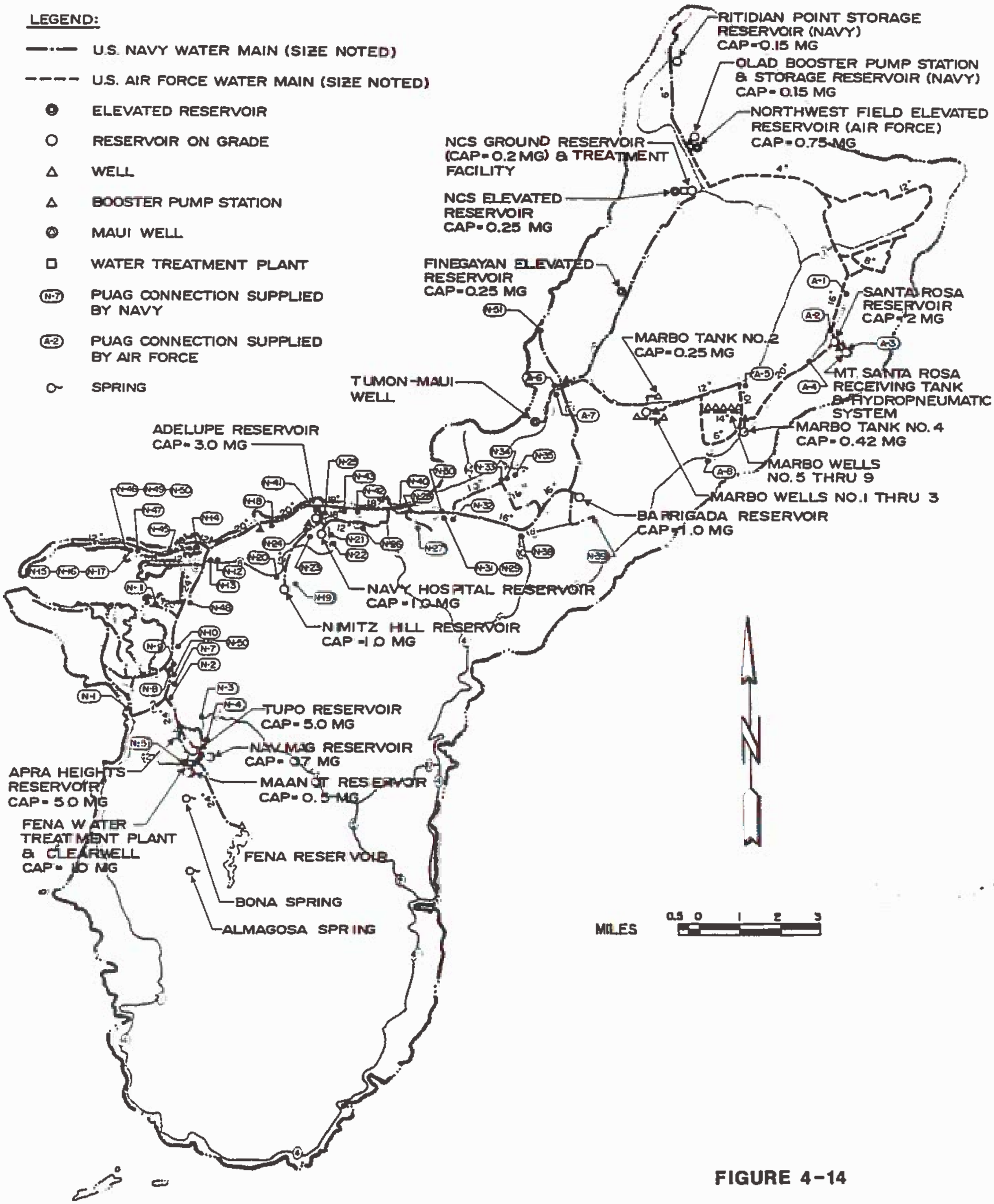


FIGURE 4-14

EXISTING MAJOR

MILITARY WATER SYSTEM FACILITIES

& PUAG SUPPLY CONNECTIONS

TABLE 4-5

MILITARY SUPPLY CONNECTIONS TO PUAG FACILITIES(1)

No.	Location	Monthly Water Deliveries (1000 gal/mo) Average	Maximum
	NAVY SUPPLY CONNECTIONS		
N-1	Rizal Beach	9	38
N-2	Gov. Guam Rt. #5	5	10
N-3	Route #17 Inter-Island	0	0
N-4	Sinifa	17,566	19,612
N-5	Santa Rita/Agat	52,597	59,409
N-7	Route #2 PUAG	111	377
N-8	Orchid #1	316	640
N-9	GovGuam Fugawari Beer Garden	32	99
N-10	Palai Housing	320	385
N-11	Gov Guam School Bus Pool	30	91
N-12	New Piti School	131	284
N-13	Piti Warehouse(3)	191	362
N-14	GPA Cabras Island	5,165	5,637
N-15	Standard Oil Company	0	0
N-16	Standard Oil #1	0	0
N-17	Standard Oil #2	0	0
N-18	Piti Village(2)	4,697	8,233
N-19	Johnston's Residence	202	243
N-20	Larson Rd. Nimitz Hill	4,814	5,650
N-21	Maina Housing	112	134
N-22	Maina Housing (Upper)	382	560
N-23	Pan American Housing	2,614	3,570
N-24	Maina Housing (Lower)	183	246
N-25	Hansen Rts. #6 & #7	1,054	1,885
N-26	Naval Hospital Housing Area(2)	23,702	29,850
N-27	MongMong	662	1,425
N-28	Maite Village	7,566	8,676
N-29	Maite Old, Trust Territory	0	0
N-30	NAS Agana D.P.I.(3)	0	0
N-31	Old Trust Territory	0	0
N-32	Old MCD-3 Area NCS	117	7,000

No.	Location	Monthly Water Deliveries (1000 gal/mo) Average	Maximum
	NAVY SUPPLY CONNECTIONS		
N-33	Air Terminal - NAS	15	26
N-38	Barrigada Village #1(2)	0	0
N-39	Halmi Res., Barrigada(2)	0	0
N-40	Agana Junction(2)	0	0
N-41	Adelup Point	966	1,099
N-42	Agana City #1(3)	0	0
N-43	Agana City #2(3)	0	0
N-46	ESSO	0	0
N-47	New Commercial Port	0	0
N-48	Laquas Bridge Piti	0	0
N-49	Mobile Petroleum	26	31
N-98	GORCO Fuel Tank	1,139	1,408
N-159	Route 3	548	645
N-172	Black Construction	0	0
N-201	Asan Village	7,399	10,022
N-241	Harmon Team Center	8	26
N-229	OSI Port A & B	91	281
N-234	Figarul #2	0	0
N-235	GovGuam Cabras #1	0	0
N-236	GovGuam Cabras #2	5,778	7,182
N-238	GovGuam Old In	735	1,445
N-284	Yacht Club OSI	14	66
N-285	Rt. #3 NCS GovGuam	0	0
N-152	Tamuning Ex B	-7.4	-21
	Sub-Total	139,290	176,626
	AIR FORCE SUPPLY CONNECTIONS(4)		
	Sub-Total	5,990	6,417
	TOTAL	**145,280**	**183,043**

(1) Shows water deliveries from Oct. 1988 through Sept 1989
(2) Emergency use only
(3) Permanently closed
(4) No individual connections shown on PUAG records

TABLE 4-6
DISTRIBUTION SYSTEM STORAGE
PUAG RESERVOIRS[1]

Location	Capacity (mg)	Height (ft)	Overflow Elevation (ft)	Floor Elevation (ft)
Regional Water Service Area "A"				
Barrigada Reservoir #1	1.00	40	497.8	457.8
Barrigada Reservoir #2	2.00	39	N/A	N/A
Agafa Gumas Elevated Reservoir	Abandoned			
Yigo Reservoir	0.50	40	658	618
Ysengsong (Astumbo)	1.00	39	N/A	N/A
Gavinero	1.00	39	N/A	N/A
Regional Water Service Area "B"				
Agana Heights Reservoir	1.00	40	236	196
Upper Barrigada Reservoir	1.00	40	497.8	457.8
Chaot Reservoir	1.00	32	381.6	349.5
Mangilao Reservoir	1.00	40	381.6	341.6
Piti Reservoir	1.00	40	236	196
Tumon Reservoir	1.00	40	236	196
Tumon Loop Reservoir[2]	1.00	40	252.6	212.6
Dededo Ground Reservoir	0.50	18	386	368
Dededo Elevated Reservoir	Abandoned			
Regional Water Service Area "C"				
Sinifa Reservoir[2]	1.00	40	725	685
Santa Rita	1.00	40	392	352
Regional Water Service Area "D"				
Yona Reservoir	Abandoned			
Windward Hills Reservoir No. 1	0.10	24	450	426
Windward Hills Reservoir No. 2	1.00	40	444	404
Brigade Reservoir	Abandoned			
Merizo Reservoir	1.00	40	334	294
Malojloj Reservoir	Abandoned			
Malojloj Reservoir No. 2	1.00	40	410	370
Inarajan Reservoir	0.20	24	297.5	273.5
Umatac Village Reservoir	0.40	16	N/A	N/A
Laelae Springs	0.50	40	360	320
Umatac Subdivision Reservoir	0.50	40	360	320
Agat-Umatac	0.60	24		
Pulantat(Yona)	1.00	65	420	355
Malojloj-Ugum River[3]	1.00	40	N/A	N/A

(1) Reservoirs with capacities less than 40,000 gallons not included.
(2) Reservoirs presently not connected to PUAG water system.
(3) Reservoirs currently under construction.

The following sections describe PUAG's existing water distribution facilities and their operating characteristics. Each water system is discussed sequentially according to location by regional water service areas. The reader should refer to Figures 4-1 and 4-2 while reading the following descriptive material.

Regional Water Service Area "A" - Regional Water Service Area "A" includes the Yigo, Machananao (Agafa Gumas), Dededo and Harmon Village (Cliffline) water systems. The Yigo and Harmon Village Water Systems are both autonomous with the exception of three, 2-inch diameter pipelines which interconnect the Yigo and Dededo water systems. The Agafa Gumas and Dededo water systems are interconnected near Route 3, where an 8-inch line from the "F" series wells intersects a 6-inch line running from the "AG" series wells further north.

The Yigo system is described and evaluated in the WSSSR prepared by GEPA. The following is based on the WSSSR and current information supplied by PUAG.

The Yigo water distribution system is comprised of two zones or subsystems. The main zone serves the majority of the Yigo area, including Ypapao Estates, Perez Acres, Yigo Village, Marianas Terrace, Takano Subdivision, customers adjacent to Route 1 (Marine Drive), and those low density residential and agricultural areas located west of Route 1. A 12-inch diameter asbestos cement transmission main extends along Route 1 from Ypapao Estates to Gayinero Drive where a 16-inch main is currently under construction to augment the existing 8-inch main that extends northerly along the east side of Route 1 to Yigo Reservoir. From the intersection of Route 1 and Gayinero Drive, an 8-inch diameter asbestos cement water main extends along the south side of Gayinero Drive to the Marianas Terrace and Takano Subdivisions. The 8-inch water main continues through Takano Subdivision and terminates at the corner of Carnation Avenue and Route 15, Mangilao. The 8 "Y" series wells are the main sources of water supply in this area and the 0.5 MG reservoir located at Yigo serves as the control and storage facility.

The Air Force maintains four water supply connections utilizing PUAG-owned meters to serve PUAG customers in areas not contiguous with the main zone. Figure 4-15 is a schematic diagram of the Air Force-PUAG water system facilities. As shown on Figure 4-15, the Andersen Elementary School meter is located adjacent to the Route 15 entrance to Andersen

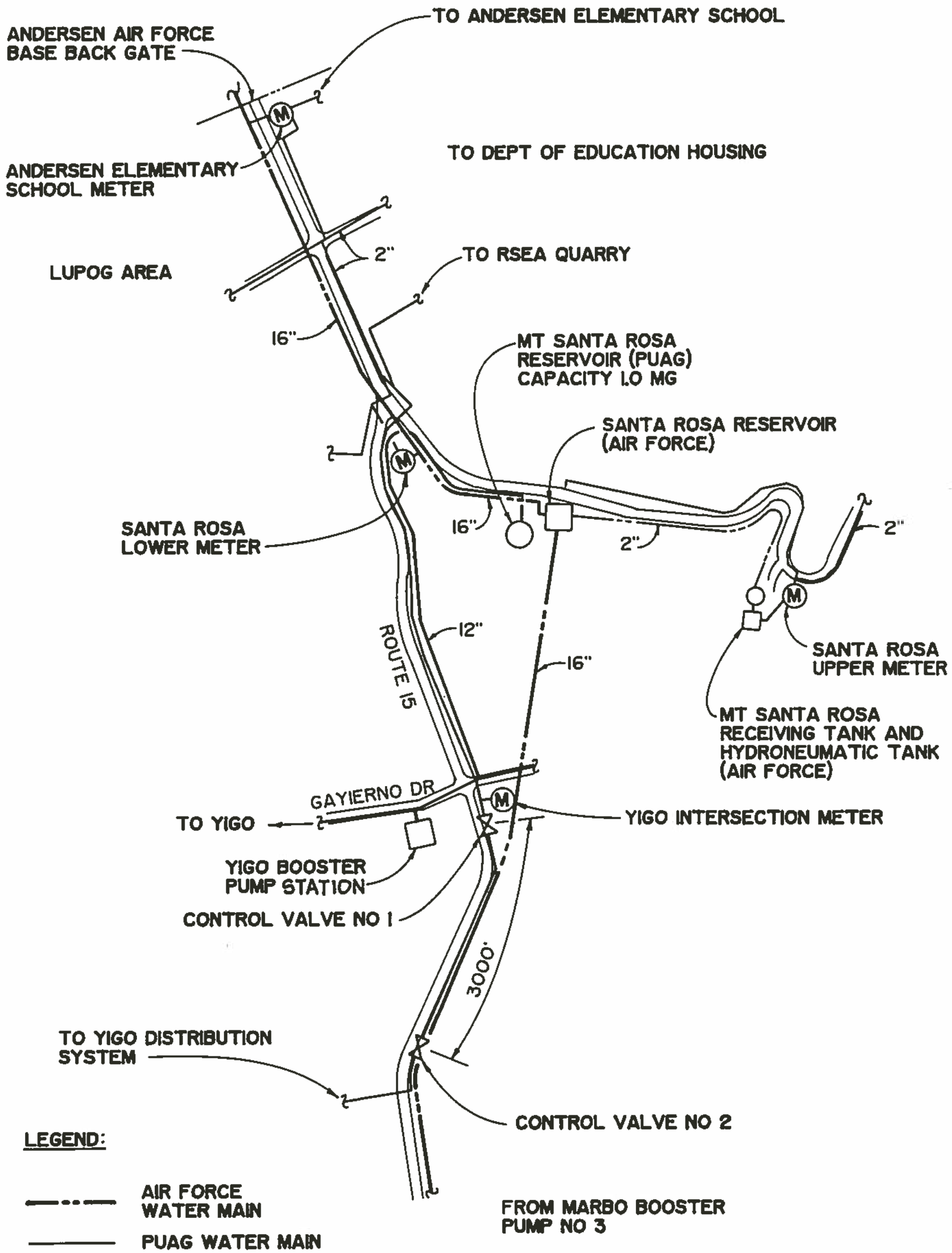


FIGURE 4-15

AIR FORCE-PUAG WATER SYSTEM

IN MOUNT SANTA ROSA AREA

AFB. The meter serves Andersen Elementary School plus five customers (formerly Department of Education housing) located adjacent to the school.

The Santa Rosa-Lower Meter serves approximately 50 customers in the Lupog area while the Santa Rosa-Upper Meter serves approximately 25 residences in the Mount Santa Rosa area.

The Yigo Intersection Meter serves between 50 and 70 residential customers depending upon the operation of Control Valves No. 1 and 2 (see Figure 4-15). According to PUAG operations personnel, Control Valve No. 1 is normally left in the closed position which results in the PUAG customers north of Gayinero Drive being served from the main Yigo distribution system. If the water level in Yigo Reservoir drops, the pressure to several of the PUAG customers located along Route 15 south of Gayinero Drive decreases to an unacceptable level. In this situation, Control Valve No. 1 is opened and Control Valve No. 2 is closed.

The Yigo Intersection Meter is presently inoperative as the meter face is missing, and therefore, monthly water deliveries must be estimated.

Under a joint-use agreement between the Government of Guam and the Air Force, a 75 gpm submersible pump, mounted in Santa Rosa Reservoir, is used to deliver water through a 2-inch water main to a 10,000 gallon tank located on top of Mt. Santa Rosa. The submersible pump is owned by the government of Guam but is operated by the Air Force. In the event of a pump failure, the Air Force notifies GovGuam to make the necessary repairs. A small hydropneumatic tank owned and operated by the Air Force is located at the top of Mt. Santa Rosa to serve the adjacent military operations and civilian population. The Air Force also maintains one connection to the PUAG Yigo water system at the intersection of Marine Drive and the Marbo entrance to the Air Force facilities. The 4-inch metered connection is used only in emergency situations when PUAG is in need of a backup water supply. The meter and two isolating gate valves are housed in a locked underground vault. In addition to the Air Force connections, PUAG has constructed its own booster pump station in Gayinero. The Gayinero Pump Station equipment includes two 450 gpm pumps with 10 HP motors, which boost water through a 12-inch main along Route 15 to PUAG's 1 MG steel reservoir on Mt. Santa Rosa for distribution through the existing lines.

Those customers residing in the low density area to the west of Route 1 are served by a random network of pipelines with diameters of 2 inches and less. The system obviously affords no fire protection to customers in this area.

Yigo Reservoir, shown on Figure 4-16, is a 40-foot high by 46-foot diameter, 0.5 million gallon, welded steel tank. The reservoir was constructed in 1966 and has since been repainted. The reservoir site should be fenced to reduce the possibility of vandalism.

The reservoir is provided with overflow, drain, and common inlet-outlet piping. The inlet-outlet piping arrangement includes an altitude valve, check valve, and isolating gate valves. The valves and piping are located in a concrete pit which was originally covered with grating which has since been stolen by vandals. The function of the altitude valve is to prevent flow into the reservoir when high level is reached. The function of the check valve is to allow flow in one direction only through the bypass piping (i.e., from the reservoir to the distribution system). The altitude valve has been repaired since the original Master Plan. However, the check valve is still wedged open to permit flow in either direction. For that reason, the water level never reaches the top of the reservoir, and the altitude valve is never utilized. The SCADA system previously described provides the reservoir with level sensing and recording instrumentation and solar power supply. At some future date, a transmitter for control of one or more of the Yigo wells will be provided so that the reservoir level can be controlled and overflowing prevented without the use of the altitude valve.

The common overflow and drain pipe has been plugged with concrete as an expedient method of preventing leakage from a malfunctioning drain valve. The original Master Plan recommended that the next time the reservoir was dewatered for cleaning, the drain valve should be repaired or replaced and the concrete plug removed. These repairs have never been performed, as the reservoir has never been dewatered for cleaning. At present any overflow is still via the access hatch on the reservoir roof.

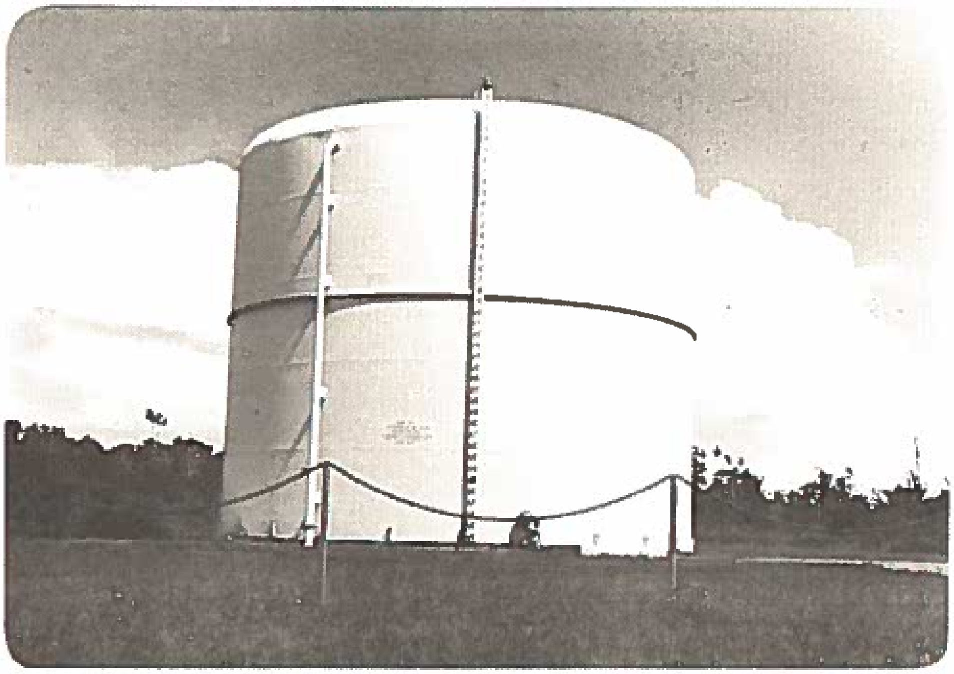


FIGURE 4-16
YIGO RESERVOIR

The WSSSR made the following observations on the Yigo distribution system.

- Those areas serviced by 2-inch water mains do not have adequate fire protection. Some of the 2-inch mains are located above ground. Unless located in BOP designated conservation areas, all water mains should be located underground and of sufficient size to meet fire fighting requirements.

- Only two water system leaks were located by observing surfacing water and subsequently determining its origin. The two locations were at BengBing Street and Quail Court in Ypapao Estates and in Yigo Village along Mataguac Avenue.

- Only one pump serves the upper Mount Santa Rosa area. Without a standby pump, those customers served from the Santa Rosa Upper Meter will be without water in the event of pump or motor failure until the necessary repairs can be made.

- In the event of a power failure, the customers served from the Santa Rosa Upper Meter will be without water as the Air Force hydropneumatic system and the Santa Rosa Reservoir booster pump are not provided with standby power.

- The PUAG meters at the Air Force supply points are subject to vandalism as evidenced by the condition of the Yigo Intersection Meter. All supply meters should be located underground in locked meter vaults.

- Leak detection surveys indicated extensive water losses in the Yigo area. One major leak was identified and subsequently repaired by PUAG. Survey findings indicate that extensive leakage is still occurring. A probable source of the leakage is in an old 4-inch galvanized water main along Route 1 and Gayinero Road. The 4-inch main should be abandoned as soon as funding permits.

Plans for construction of a system to boost water from Yigo to the Mount Santa Rosa Reservoir through expanded transmission lines and to supply water to Andersen Elementary School are presently under design.

The Machananao (Agafa Gumas) water system is located just south of Route 9 at the northern end of the island. The old Agafa Gumas Reservoir has been abandoned. The water supply is now pumped from 11 "F" series wells and wells AG-1 and AG-2 through a 6-inch, an 8-inch and a 12-inch asbestos concrete pipe to the new 1.0 MG Astumbo Reservoir, shown in Figure 4-17. The reservoir serves the Machananao Community, the New Santa Ana Subdivision, residences located on the east side of Route 3, GHURA 503 and 505, Perez Gardens, NCS Villages, Dededo Village and all residential and agricultural development along Y-Sengsong Road between the intersection of Route 3 and the vicinity of Astumbo Reservoir.

The distribution pipelines in the Machnanao area are old and in some locations undersized. Some of the mains are located on private property and should be relocated to public rights-of-way.

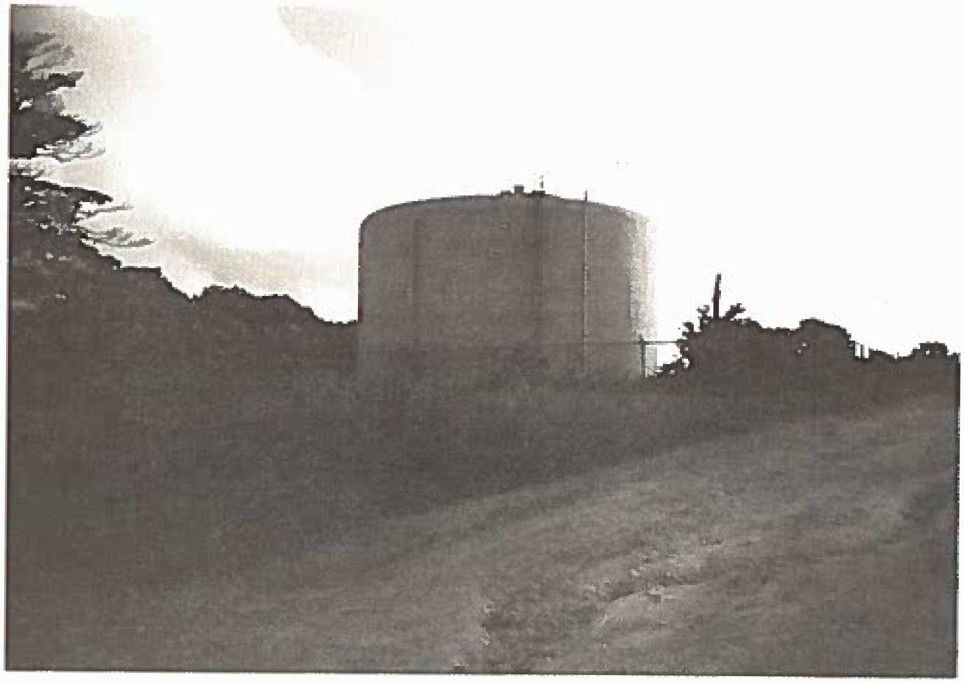


FIGURE 4-17
ASTUMBO RESERVOIR

The system is interconnected with the Dededo water system by a 12-inch transmission line with a pressure sustaining valve located at Y-Sengsong Road. Therefore it is desirable to keep the manually controlled wells AG-1 and AG-2 operating on a continuous basis to allow water production in excess of Machananao's demands to flow into Dededo and thus maximize utilization of the existing wells.

Improvements proposed by the WSSSR to the Yigo/Dededo Water Source and Storage System include the design and construction of six production wells, a 5.0 MG reservoir and 45,000 l.f. of 24-inch water transmission line.

The Dededo area is one of the Island's prime groundwater development sites as evidenced by the existing 15 "D" series wells, 12 "F" series wells, and 5 "M" series wells. In addition to the new Astumbo Reservoir, hydraulic control (i.e., pressure) in the Dededo system is also supplied by the Barrigada Reservoirs, located at Latte Heights and shown in Figure 4-18. A second reservoir of 2.0 MG capacity was constructed in 1988 adjacent to the original

Barrigada reservoir. The new reservoir has provided badly needed storage capacity to the south Dededo system.

The Dededo Elevated Reservoir has been abandoned.

The Wusstig Booster Pump Station located on the eastern side of Wusstig Road just north of the two GHURA developments pumps water to the upper Wusstig area.

The Y-Sengsong booster pump station located along Y-Sengsong Road to the north of Dededo near Well F-8 has been abandoned and replaced by pump station F-12.

The construction of a new 16-inch transmission line from Route 4 to Route 17 and a 16-inch transmission line from Route 10 to Route 4 via Mai-mai Road has been completed. A 16-inch transmission line with two 250 gpm booster pumps which was not being utilized due to low pressure at the existing 1.0 MG Barrigada reservoir is now operational since the completion of the new 2.0 MG storage tank. This existing 16-inch line along Carnation Avenue can be utilized to divert water to Route 15 and then to southern Guam.

All of the "F" series and "D" series wells, excepting D-1 through D-6, supply the Dededo community water system. Wells D-1 through D-6 are located in Dededo but supply the 0.5 MG Dededo Ground Reservoir, shown on Figure 4-19, which serves as distribution storage for the Tumon-Tamuning community located in Regional Water Service Area "B".

Most of the Dededo community consists of planned residential developments which, with a few exceptions, have resulted in a well-gridded water distribution system. Thus, the piping is generally up to modern water service standards. The major areas or subdivisions currently served by the Dededo water service area are Dededo Village, Liguan Terrace, Gugagon, and Y-Sengsong.

The water source of the Harmon Village (Cliffline) area consists of 6 production wells of the "D" series in addition to wells H-1 and H-2. The main control and storage is the Dededo concrete reservoir (0.5 MG capacity) located at Dededo. The system serves Harmon Loop Harmon Village, and portions of the Tamuning and Tumon areas.

FIGURE 4-18
BARRIGADA RESERVOIR

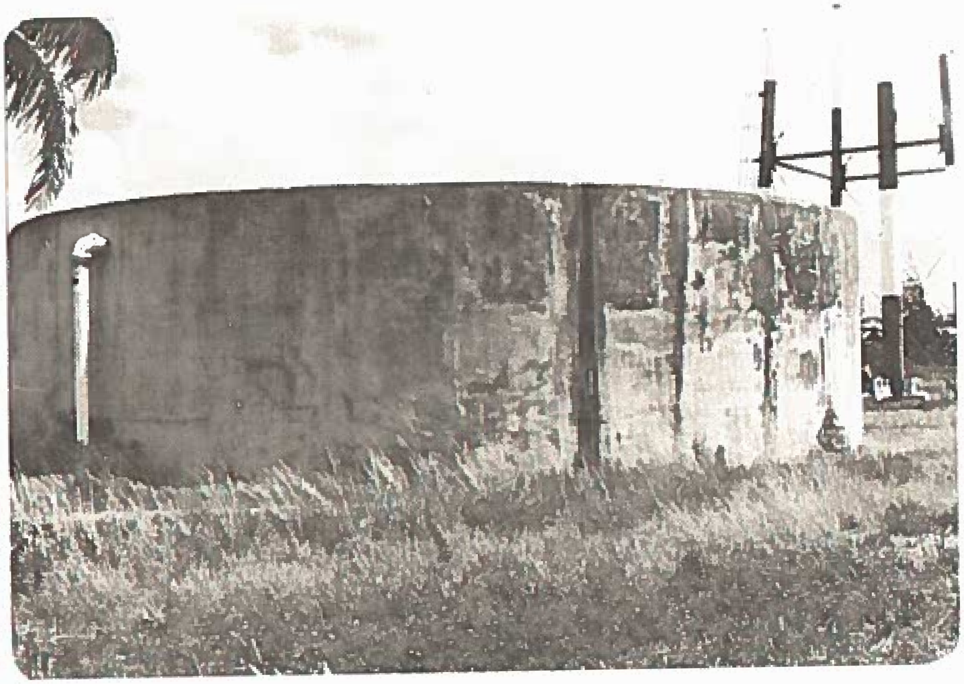


FIGURE 4-19
DEDEDO GROUND RESERVOIR

Regional Water Service Area "B" - Serving the villages of Asan, Piti, Agana Heights, Sinajana, Chalan Pago-Ordot, Mongmong-Toto-Maite, Mangilao, Barrigada and Tamuning, Regional Water Service Area "B" supplies the vast majority of Guam's population. With the exception of the Asan-Piti area, the water systems serving all the villages are integrated and operate as one system utilizing several pressure zones.

As mentioned in the preceding section, the water system serving Tamuning is interconnected with the Dededo Ground Reservoir which in turn is filled from several of the "D" series wells. A large percentage of Tamuning's water is supplied from this source; the remainder from the "A" series and "M" series wells, via Agana Heights Reservoir as shown on Figure 4-2. A 14-inch diameter water main conveys water from the Dededo Ground Reservoir to the 1.0 MG Tumon Reservoir located on Route 10A near the Guam International Airport. The Tumon and Tumon Loop Reservoirs are the storage facilities serving the Tamuning-Tumon area, although during peak demand the Agana Heights Reservoir also serves the Tamuning-Tumon area as it is located at the same elevation as the Tumon Reservoir. The Tumon Reservoir is in good condition, but is unfenced, and therefore subject to vandalism. Water level in the reservoir is controlled by a float valve which closes the inlet valve when the reported maximum operating level is reached. However, it has been reported that the inlet valve shuts off flow before the maximum reservoir level has been reached.

The 1.0 MG Tumon Loop Reservoir was constructed in 1976 for the purpose of providing storage to serve the lower Tumon area with its many hotels. It is supplied by an 8-inch main from Dededo and provides flow through a 12-inch main along San Vitores Road. PUAG operations reports that the reservoir is not being used at the present time, and believes that the reservoir is possibly being bypassed due to a 12-inch line constructed between the inflow and outflow piping by the Department of Public Works (DPW). Further investigation is recommended to determine the exact cause of the problem. A float valve is to be installed in the near future, and if the bypassing problem were to be corrected at that time, the reservoir could then be returned to operation. The water system in the lower Tumon area along San Vitores Road is currently being fed from two connections. One connection is at a pressure regulator located west of the intersection of San Vitores Road and Marine Drive. This regulator is fed from the Barrigada Reservoir. This water is delivered to the lower Tumon area through 8-inch and 12-inch diameter water mains traversing Liguan Terrace. The second connection is located at the intersection of San Vitores Road and Tumon Loop adjacent to JFK

High School. This connection is supplied by a 14-inch main from Dededo Reservoir. Thus, the Tumon area is supplied from two different pressure zones requiring a pressure regulator on the higher pressure supply side. The water mains along San Vitores Road in lower Tumon vary in size from 4 inches to 12 inches in diameter. Supplied by Tumon Loop Reservoir is a new 12-inch water main, recently installed by DPW. It runs along San Vitores Road but currently only provides service to new fire hydrants as few service laterals were provided. PUAG has completed the design to install additional laterals to the new 12-inch main and the work is in progress. When completed, the Tumon distribution system will be more reliable and will improve the ability to deliver fire flow in the system. The Tumon Loop Reservoir should be incorporated into the system to improve fire protection in the resort hotel area. Water level in the reservoir is controlled by a float valve which closes the inlet valve when the maximum operating level is reached.

As indicated on Figure 4-2, the Tamuning area is served by a 12-inch main from the Tumon Reservoir and a 12-inch main located along JFK Road which is supplied by the 14-inch transmission main from the Dededo Ground Reservoir. In effect, the Tamuning area is served by two different pressure zones. Pressure regulating valves (PRVs), are located along both JFK and San Vitores Roads in order to equalize the pressure. Another solution is to serve the Tamuning area from a single pressure zone with hydraulic control from a reservoir near the airport, at the same elevation as Dededo with a backup connection to the Dededo zone through a pressure regulator.

The Tamuning distribution system is a random mixture of recently constructed and older water mains. Many of the old mains are located on private property, sometimes running under buildings. Many were constructed to serve dwellings and commercial buildings that are no longer in existence. PUAG records do not indicate whether these lines were left in service or abandoned. The potential for water losses from older metallic mains is obviously high.

The Tamuning system is interconnected with the Agana area water system via a 16-inch water main along Marine Drive. Tumon Reservoir and Agana Heights Reservoir are located at the same elevation. Thus the Tamuning system and the Agana system fall in a common pressure zone.

As discussed earlier, the Barrigada Reservoirs are utilized to serve the Dededo Area. These reservoirs also function as a supply for a more elevated pressure zone serving the Latte Heights area. The Barrigada Booster Pump Station, shown on Figure 4-20, pumps water from Barrigada Reservoirs to the 1.0 MG Barrigada Heights Reservoir. Equipment at the pump station includes two identical vertical turbine pumps with globe-type check valves and a pressure relief valve discharging to the suction piping. Design capacity of the 50 HP pumps is 500 gpm. The pumps operate only in the manual mode as level control equipment servicing the booster pump station and Barrigada Heights Reservoir is inoperable. According to PUAG personnel, the level control system has never functioned. The Barrigada Booster Pump Station is not often used since there are two wells, M-17A and B, which can supply the Barrigada Heights Reservoir and Barrigada Reservoirs.

The 1.0 MG steel Barrigada Heights Reservoir currently serves Barrigada Heights from it's location just south of the village. The Barrigada Heights subdivision is served by a network of 6-, 8- and 10-inch asbestos-cement (A.C.) mains fed by gravity from a 12-inch main connection to the Barrigada Heights reservoir. A 10-inch A.C. main extends from Lirio Avenue at the northwest corner of the subdivision to Route 16. The overflow elevation of the Barrigada Heights reservoir is 705 feet MSL; the finished floor elevation is 665 feet MSL. The highest point of service in the subdivision is at elevation 625 feet MSL. A 4,500 lf length of 6-inch line has been installed along Bello Road to alleviate low water pressure in the area and provide fire protection. The point of connection to the existing line is between Barrigada Reservoir and Barrigada Heights Reservoir.

The Barrigada Heights distribution system is constructed of relatively new asbestos cement lines. GEPA field investigations indicated that the network is in good condition.

The Barrigada Heights reservoir is also able to serve Guam International Airport via a 12-inch main constructed in 1986. Mains were installed about 15 feet deep resulting in maintenance difficulties for PUAG staff. It is recommended that additional blowoffs be provided to ensure proper maintenance. In addition, the mains were installed without fire hydrants. It is recommended that hydrants be provided to conform with PUAG design criteria.

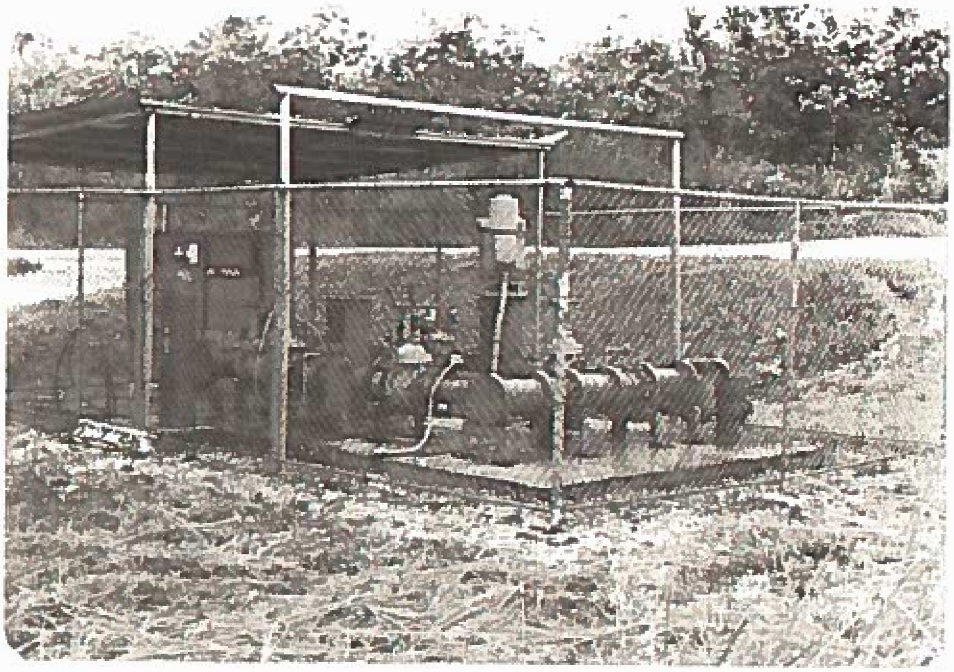


FIGURE 4-20
BARRIGADA BOOSTER PUMP STATION

The Barrigada Reservoirs serve the Latte Heights area through an 8-inch diameter water main. The average elevation in the Latte Heights area is about 400 feet MSL, resulting in a static water pressure of about 40 psi if the Barrigada Reservoirs are full. Thus the water pressure in the Latte Heights area is marginal. The 8-inch diameter water main continues south through Latte Heights to Route 15 where the water main increases in size to 12 inches in diameter. Several "M" series wells are located along the 12-inch line and deliver water to either Barrigada Reservoir or Mangilao Reservoir or both depending upon water demands. The elevation at the location where the 8-inch water main meets Route 15, is approximately 441 feet, resulting in a static water pressure of approximately 24 psi when Barrigada Reservoir is full. The operating water pressure in the Latte Heights - Route 15 area is less than that recommended in Chapter VI, "Design Criteria."

The 12-inch water main continues south along Route 15 to the Mangilao distribution system. At the point of connection, a pressure-reducing, pressure-sustaining valve reduces the upstream pressure controlled by Barrigada Reservoir to Mangilao system pressure which is regulated by the 1.0 MG Mangilao Reservoir. The pressure sustaining feature of the valve is to allow excess water from the Barrigada Reservoir to flow to Mangilao but not to the extent that it will deplete the Dededo water supply. The Latte Heights Booster Pump Station consists of three 550 gpm pumps which boost the water from Barrigada Reservoir to the 12-inch main on Route 15 that supplies Mangilao Reservoir. It draws water through a 16-inch diameter main that follows Carnation Road and connects to the 12-inch inlet/outlet main from Barrigada Reservoirs. The pump station's discharge line is also 16 inches in diameter and follows Carnation Road east to connect to the old Carnation Road 12-inch main shortly before it joins the Route 15 main to Mangilao. However, PUAG reports that due to operations problems, the station is not used. PUAG operations have reported that there is inadequate pressure on the suction side of the pump station to safely run it. One PUAG inspection indicated that the low suction side-pressure was due to a closed valve on the inlet piping that should have been open. Further investigation of this problem should be conducted to resolve the difficulties and formalize the proper operation of the station.

The Mangilao, Agana, Chalan Pago-Ordot, Sinajana, Agana Heights, and Barrigada municipalities are supplied from the "A" series wells and lie within a single pressure zone controlled by the 1.0 MG Chaot and Mangilao Reservoirs, both having the same overflow level elevation. The "A" series wells are intended to be automatically operated in response to water levels in the Mangilao and Chaot Reservoirs. Apparently the controls and/or pumps are not working properly because the reservoirs never fill completely and therefore the pumps run continuously. The cause of this condition should be further investigated and rectified by control system maintenance or improvements to the pumping system.

The Mangilao-Chaot system feeds the Regional Water Service Area "D" through one 12-inch and one 16-inch water main along Route 4 south of Route 10. This interconnection will be discussed later in the chapter. The Mangilao-Chaot system also serves the Agana and Tamuning areas through the Agana Heights Reservoir, shown on Figure 4-21.

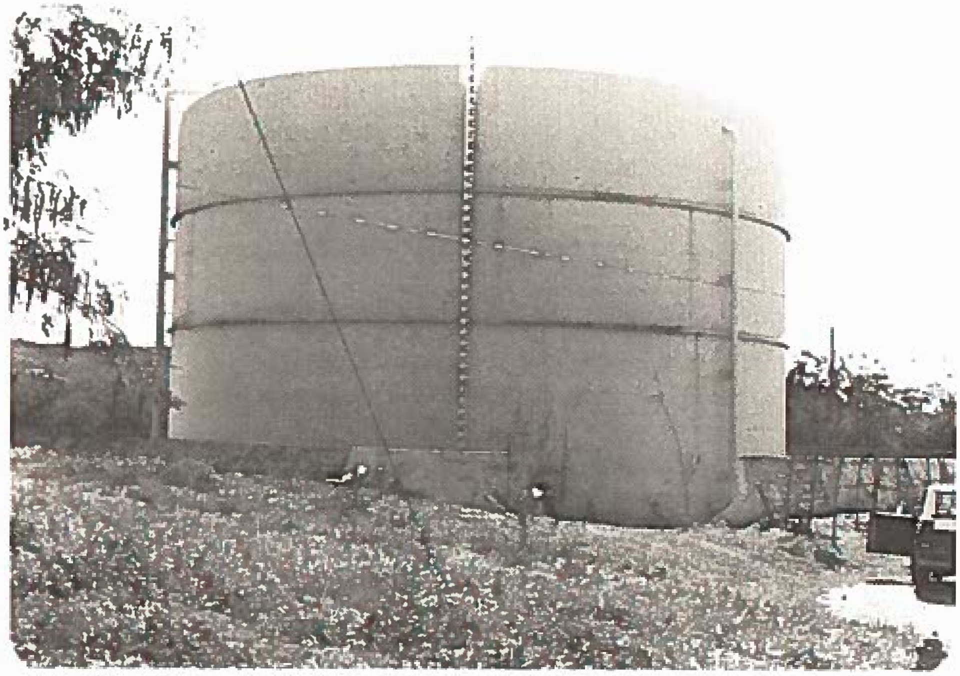


FIGURE 4-21
AGANA HEIGHTS RESERVOIR

The Agana Heights Reservoir is a steel tank constructed in the old uncovered concrete basin that served this area previously. The 1.0 MG tank is reported to be in fair condition. According to PUAG personnel the reservoir is equipped with a float control valve to prevent overflow. Water from the Chaot-Mangilao system enters the reservoir through an 8-inch diameter inlet. The separate 12-inch diameter outlet discharges water from the reservoir to serve the Agana-Tamuning area.

Previous problems with the reservoir, including a blocked overflow and a leaking fill pipe, have been repaired by PUAG staff.

The Mongmong-Toto-Maite area is served in part by the U.S. Navy distribution system using five connections. The five metered locations are shown on Figure 4-14 as locations N-27 through N-31. Metered water deliveries for each are shown in Table 4-5. Currently plans are being formulated by PUAG to disconnect the water service area from the Navy supply.

The Asan-Piti water system is isolated from other PUAG water in Service Area "B". As previously described, the major water source for these two villages is Asan Spring. The Asan Spring source is pumped to Piti Reservoir, a 1.0 MG steel tank, through a 12-inch line. A second source of water, a U.S. Navy connection, is utilized only for emergency purposes. The Navy connection is shown as N-18 on Figure 4-14.

The Village of Asan water distribution system is undergoing rehabilitation as part of a GHURA urban renewal project and is in relatively good condition in those areas where the urban renewal has been completed.

The Piti water distribution system is generally well-gridded with few deficiencies other than the typical water system maintenance problems.

Along and adjacent to Route 6 in the Nimitz Hill area, PUAG serves customers using water supplied by the U.S. Navy from two connections, N-19 and N-20 (see Figure 4-14). A few privately owned dwellings located south of Larson Road along Turner Road are served by the small Nimitz Hill Booster Pump Station which takes suction from connection N-19. The pump station consists of a single 52 gpm centrifugal pump which works directly from the main. A vertical hydropneumatic tank formerly used at this location has been removed from service due to a "flooding" problem which caused the pump to cycle for 3 seconds at approximate 45 seconds intervals to meet small demand bursts, causing excess wear and deterioration of the motor. Direct operation is now used. The existing Nimitz Hill BPS is to be replaced by a new pump station currently under design which will include two 100 gpm pumps.

Other PUAG customers located in the Nimitz Hill area reside in the Nimitz Hill Estates and in Nimitz Hill towers off Route 6 east of the Piti community, and in a small residential area north of Larson Road on the west side of Route 6. These customers are served from a PUAG distribution system, but the actual water supply is from Navy connection N-20 located at the intersection of Larson and Turner Roads. A 6-inch PUAG main extends from the connection point along Larson Road to Route 6 and extends north to a small number of homes and also south to Nimitz Hill Estates and Nimitz Hill Towers. An old 2-inch water line parallels the 6-inch main from Larson Road southerly along Route 6 for a distance of approximately 3,200-feet. The 2-inch water line should be abandoned. The major problem associated with serving these two areas is the lack of fire protection afforded other than that provided by the U.S. Navy.

Regional Water Service Area "C" - Regional Water Service Area "C" encompasses the Agat-Santa Rita water systems.

The water distribution system is comprised of two zones or sub-systems. One zone serves Santa Rita Village and New Agat Village with the clearwell at the Navy's Fena Water Treatment Plant serving as both the water source and as distribution storage. A 10-inch diameter cast iron transmission main extends from the Navy's Fena Water Treatment Plant to Route 12 where its size increases to 12 inches in diameter and continues westerly along the south side of Route 12 (Bishop Olano Drive) to Santa Rita Village. The Santa Rita Village distribution system consists of 4-inch and 6-inch cast iron and asbestos cement water mains. The normal water surface elevation of the clearwell is approximately 360 feet which provides static pressures in Santa Rita Village ranging from a low of approximately 25 psi to a high of 105 psi depending upon location. The majority of customers are provided service pressures in the 40-80 psi range.

The 12-inch transmission main continues westerly along Route 12 and southerly along Pale Duenas Street where it leaves the traveled roadway and traverses westerly and southerly through an undeveloped area to New Agat Village. Just above New Agat Village a pressure regulating station reduces the up-stream pressure from the 80 to 100 psi range to approximately 45 psi. The distribution system consists of a well-gridded pattern of 4-, 6-, and 8-inch cast iron water mains which feed a 12-inch asbestos cement water main that extends southerly from New Agat Village, along Route 2, for a distance of approximately 5,100 feet. At this point the 12-inch main again reduces to an 8-inch diameter cast-iron main and continues for another 3,900 feet. There are several 2-inch and smaller water mains which connect to the Route 2 main and serve scattered dwellings.

The second zone in the distribution system is fed from Santa Rita Springs and serves Old Agat, the Santa Rosa (Hyundai) Subdivision and those dwellings located south of Santa Rita along Route 12 and Pale Ferdinan Way from Route 12 to Truman Elementary School. An 8-inch water main extends from Santa Rita Springs northerly along Pale Duenas and westerly along Route 12 to Pale Ferdinan Way. The 8-inch line continues westerly along Route 12 to serve the Old Agat area and north-easterly along Pale Ferdinan Way to Santa Rosa Avenue to serve the Santa Rosa Subdivision. The Old Agat distribution system consists of 2-, 3-, 4-, and 8-inch water mains. The majority of the water mains are asbestos cement but some mains are cast iron or galvanized steel. A portion of the water main along Route 2 is located west of the roadway along the beach and was constructed under houses in several locations. A 2-inch pipeline connects the Old Agat and New Agat Village distribution system.

The normal water surface elevation of the storage basins at Santa Rita Springs which serves this zone is approximately 290 feet, which provides static pressures in the range of 80 to 100 psi in the Santa Rosa subdivision and static pressures of 110 to 125 psi in Old Agat. Pressures under average to peak demand conditions would be somewhat lower. Pressure regulators are provided on customer services.

As mentioned earlier, the two zones of the distribution system are interconnected to allow use of water purchased from the Navy Old Agat and Santa Rosa subdivision areas when the Santa Rita Springs production is less than demand. To serve Old Agat and Santa Rosa, the flow from the Navy source must be manually controlled by throttling two gate valves located at the intersection of Route 12 and Pale Duenas Street.

In addition to the two main zones previously described, there are two small subsystems serving the Route 5 and Route 17 service areas. The Route 5 system is served from a 6-inch metered tap to the Navy's 14-inch transmission main located along Route 5. After the meter, the PUAG 6-inch water main continues north and east along Route 5 to Pale Ferdinan Way, terminating at the Truman Elementary School. The 6-inch main connects to the 8-inch main serving the Santa Rosa Sub-division. The Naval Magazine (Nav Mag) Booster Pump Station, owned by PUAG, is adjacent to the 6-inch Navy meter. The station serves customers located at higher elevations along Route 5 near the station.

The Route 5 subsystem thus includes two pressure zones: a lower zone providing a cross-feed to the Santa Rita Springs zone regulated from the Navy's Maanot Reservoir (water surface elevation 409 feet); and a higher, pumped zone serving customers as high as 425 feet. The second small subsystem serves customers located along Route 17, also known as the Cross Island Road. Water is purchased from the Navy at the Apra Heights Reservoir where it is metered. The Apra Heights Booster Station boosts the water along a 6-inch main to Route

5 to an 8-inch main that runs north and east approximately 3,750 feet overland to the Sinifa Booster Pump Station on Route 17. The Sinifa Pump Station utilizes two 85 gpm pumps with 10 HP motors to move the water east along Route 17 through a 12-inch main to the 1.0 MG Sinifa Reservoir with a floor elevation of 685 feet and an overflow elevation of 725 feet. Sinifa Reservoir also receives water from the 12-inch diameter main from the Windward Hills Booster Pump Station. Water is released from the Sinifa Reservoir through a 12-inch main that connects to the 8-inch main from Apra Heights Pump Station at the Sinifa Booster Pump Station.

The Santa Ana Booster Pump Station currently pumps water to the end of the Agat distribution lines at Facpi Point.

The original Water Master Plan included an inspection report on the distribution system. The original report is amended based on information provided by PUAG and GEPA's WSSSR. The amended inspection report is as follows:

- Many water meters were lacking meter boxes, leaving them vulnerable to damage from roadway traffic or vandalism.
- Several meters were located in areas subject to flooding, were buried, or were covered with thick vegetation.
- Twelve (12) production well meters were either inoperable or defective.
- Approximately 70 percent of existing fire hydrants lacked protective guard rails.
- The general condition of fire hydrants indicated minimal maintenance, as evidenced by leaking valves, rusty bolts, and hydrant valves that were difficult to open.
- Many fire hydrants lacked gate valves on the service line; on others, the valve boxes had been covered by dirt or paved over.
- Some fire hydrants had been shut off at the main due to leaking valves.
- Several fire hydrants located on newly improved roadways were not at the correct grade, rendering them inoperable.
- Many valve box covers were missing; consequently, the boxes were filled with rocks, dirt and debris, rendering the valves inoperable.

- Several gate valves were located in concrete blow-off vaults without surface valve boxes to allow operation of the valve from the street level.

- A survey of 25 percent of the PUAG water system resulted in the location of 90 leaks with a total estimated flow of 2,019 gallons per minute, or almost 3.0 MGD.

- Of the 88 wells operated by PUAG islandwide, only 17 have emergency generators, none of which are operable due to mechanical defects or lack of batteries.

- Typical 2-inch water mains, commonly used on the Northern end of the island, were constructed of galvanized iron pipe which is susceptible to corrosion.

As noted previously, the Santa Rita Springs Basins have been covered in accordance with recommendations in the original *Water Facilities Master Plan*. Other recommended improvements to the system that have been implemented by PUAG include the following:

- New 1.0 MG steel reservoir above the Santa Rita Village.
- A new booster pump station at Santa Rita Springs.
- 3- and 4-inch mains along the beach in Agat have been replaced to provide adequate service.
- Two booster pump stations and connections to Navy systems have been abandoned.
- Two new booster pump stations and water mains have been constructed to connect Sinifa Reservoir to the system.
- Leaks in the Santa Rosa (Hyundai) Subdivision from corroded pipes have been repaired.

Regional Water Service Area "D" - The Island's southern villages, including Yona, Talofofo, Inarajan, Merizo and Umatac, are served by a combination of local surface and spring supplies, two small wells, and groundwater transported from Service Area "B". The water systems serving all of the villages are interconnected as shown on Figure 4-2.

Yona, the most northerly of the five villages, receives its water supply from the 12- and 16-inch water transmission mains from the Chaot-Mangilao pressure zone (Service Area "B"). Yona's water distribution system is located on both sides of Route 4. The distribution system is served by Pulantat Reservoir which in turn is supplied by the three 1,000 gpm pumps at Pago Bay Booster Pump Station. The Pulantat Reservoir is a 1.0 MG steel structure with overflow at elevation 420 feet and footing elevation 325 feet. A 12-inch main connects the reservoir to the Yona distribution system. Pulantat has replaced the Yona elevated reservoir, which has been removed from service. The Pago Bay Booster Pump Station is currently in operation 24 hours a day in an attempt to provide adequate pressure in the area east of Route 4.

An 8-inch main branches from the 12-inch main at the intersection of Route 4 and Route 17, following Route 17 to the Brigade Booster Pump Station No. 3. The 16-inch main from Pago Bay also continues along the same route to Brigade Pump Station No. 3. This pump station provides the additional pressure needed to fill Windward Reservoirs No. 1 and No. 2 through the 8-inch and 16-inch mains following Route 17. The pump station is equipped with three pumps with capacities of 500 gpm each and 50 HP motors. Planned repairs on the Brigade Booster Pump Station have been halted, as it is anticipated that the pump station will seldom be required due to the new booster pump station on Route 17.

Windward Hills Reservoirs No. 1 and No. 2, with capacities of 0.1 MG and 1.0 MG, respectively, serve the Baza Gardens and Talofofo areas. The newer tank, No. 2, was constructed in 1974. Both tanks are reported to be in good structural condition and are shown in Figure 4-22. The Windward Hills Booster Pump Station, located near the Takayama Golf Course, is rated at 400 gpm and consists of three 60 HP pumps which move water from the Windward Hills Reservoirs to Sinifa Reservoir through the 12-inch main along Route 17. The pump station has three 60 HP pumps rated at 400 gpm each.

The Talofofo community water distribution system is well gridded with adequately sized water mains. A few houses immediately north of the community will be served by an 8-inch diameter main currently under construction which will connect the Notre Dame Line with the 12-inch line on Route 4.

The Windward Hills-Talofofo system is currently connected to the 12-inch water main that parallels Route 4 at two locations. The two connections are both via 2-inch mains that, in effect, function as pressure regulators. The locations of the connections are due east of the Talofofo community at Route 4 and at the intersection of Route 4 and Route 4A.

FIGURE 4-22
WINDWARD HILLS RESERVOIR

The new Malojloj Booster Pump Station, shown on Figure 4-23, was recently built to boost water to the 1.0 MG Malojloj Reservoir. The existing Malojloj Booster Pump Station, built by DPW, is rated at 230 gpm and is soon to be taken off line. The new station, which is expected to be completed soon, will provide two 540 gpm pumps and one 200 gpm pump. The design capacity of the new station is 740 gpm with one of the large pumps out of service.

Well M-1 discharges into the 8-inch diameter water main along Route 4.

Malojloj Reservoir discharges into an 8-inch and a 12-inch water main which parallel Route 4 and supply water to Malojloj and Inarajan. A PRV is utilized along the 8-inch water main in order to lower the water pressure in the Inarajan community. The Inarajan Booster Pump Station is a package, constant-pressure system which utilizes three 20 HP 150 gpm pumps to supply water through an 8-inch main to Inarajan High School and a small number of dwellings to the north of Route 4. The station lifts the water to a 0.2 MG steel reservoir

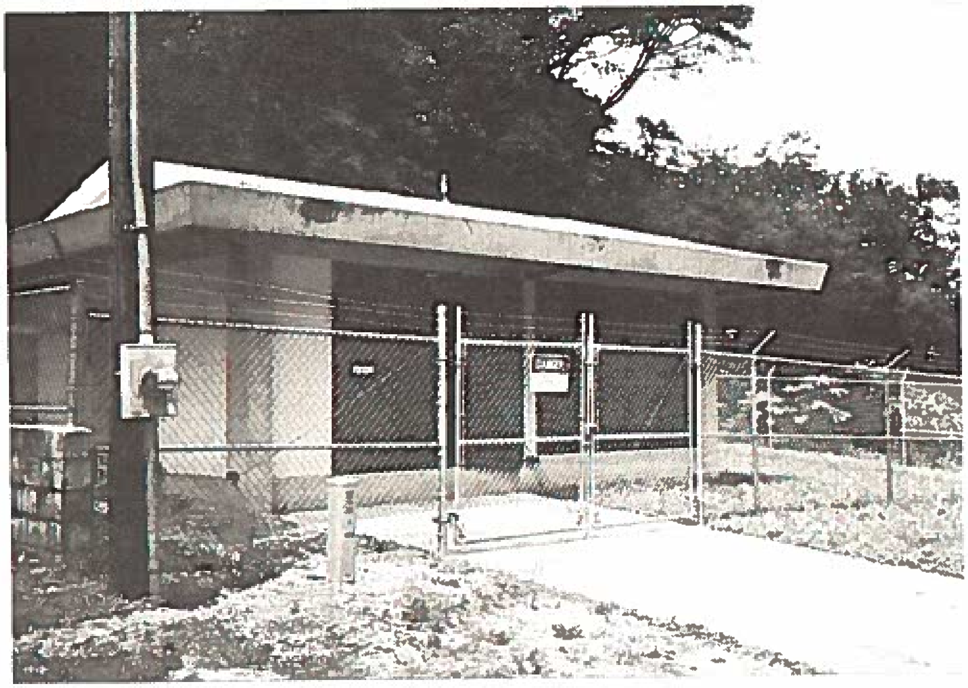


FIGURE 4-23
MALOJLOJ BOOSTER PUMP STATION

located northwest of the high school, which provides fire protection and emergency storage capabilities to the high school and residences.

The main connecting the Inarajan area to the Pigua Booster Pump Station in central Merizo is 12 inches in diameter. The Pigua Booster Pump Station, shown on Figure 4-24, is about ten years old. The station receives its supply from both the Inarajan-Merizo transmission main and the Geus River-Siligen Spring and boosts the water to Merizo Reservoir. The Pigua Booster Pump Station is equipped with two vertical centrifugal pumps, each rated at 300 gpm, with a 40 HP motor and a single 550 gpm 25 HP unit. Of the three pumps, the 550 gpm pump is currently not operational. As the water supply to the Pigua Booster Pump Station varies with the season, only one of the small pumps is used on an intermittent basis. According to PUAG, if the two 300 gpm pumps are operated simultaneously at design speeds, they create a negative pressure in the suction piping, thus entraining air. This entrainment of air will cause cavitation and drastically shorten the useful life of the pumps. The water from the Geus River and Siligen Spring is chlorinated at the pump station and is then discharged through an 8-inch diameter main into Merizo Reservoir.

The Pigua/Merizo Reservoir, located above Merizo Elementary School, is a 1.0 MG steel tank. The SCADA System will monitor and record water level and alarm power failure.

A 6-inch water main connects the Merizo system to the Umatac system. Umatac Booster Pump Station #2, located on the west side of Route 2 at the north end of town, moves water from the 6-inch transmission main to Umatac Village Reservoir.

The Umatac Booster Pump Station #3, shown in Figure 4-25, is located along Route 4 at the south edge of the Umatac community, and is used only intermittently, as it's water source is seasonal. Two steel reservoirs now serve Umatac. A 200,000 gallon reservoir, Umatac Village Reservoir, is located on the right side of Route 2 adjacent to a 10,000 gallon storage tank traveling north out of Umatac.

The second reservoir, Umatac Subdivision Reservoir, has a 0.5 MG capacity and is located east of the Umatac Subdivision, south of Umatac on the east side of Route 4.

The Laelae Booster Pump Station, also called Umatac BPS #1, is rated at 22 gpm but is currently not in use.

In spite of improvements in the form of a new 6-inch transmission main and two reservoirs, the Umatac area water system is still in poor condition and is unable to satisfactorily meet the community's water requirements. The distribution system consists largely of undersized mains that provide little fire protection.

Water System Evaluation - Summary of Findings

The preceding sections of Chapter IV described PUAG's existing facilities, commented on each system's operational characteristics, and indicated various deficiencies that require attention. The nature of many of the deficiencies will necessitate capital improvements for correction, but in many cases simple operational and/or preventative maintenance practices will provide all or part of the solution. In other instances, the problems suggest that a modification to management practices is warranted.

FIGURE 4-24
PIGUA BOOSTER PUMP STATION

FIGURE 4-25
UMATAC BOOSTER PUMP STATION

The following paragraphs categorically summarize the types of problems encountered during the facilities evaluation. Many of the problems listed below are the basis for developing the capital improvement program. The reader is reminded that this chapter does not evaluate the adequacy of PUAG's facilities in meeting the projected water demands for the next twenty years. Instead, this chapter evaluates the performance of existing facilities under current operating and water demand conditions. Results of a hydraulic analysis of PUAG's facilities is presented in Chapter IX, "Water System Improvements," which describes additional improvements that are needed based on hydraulic criteria.

Management Deficiencies

The following problems should be addressed:

- The System Maps prepared for the original 1979 *Water Facility Master Plan* reflected inaccurate water system facility information which was to be corrected. In addition, the maps should be updated to include improvements to the system since 1979. Limited action has been taken to remedy this problem in the interim. PUAG should continue to move away from reliance on the memory of key personnel toward the more reliable and permanent method of mapping the existing system.

  Keeping distribution system records up-to-date is often considered secondary to other engineering work. It should be expected of the engineer, just as it is expected of the accountant, that he keep an accurate record of his work. Accurate System Maps will aid PUAG in the initial development of a recordkeeping program. It is recommended that one PUAG engineering staff member be assigned to develop a current set of maps and then maintain the recordkeeping system on a full time basis. Periodically, the responsibility should be transferred to increase personnel's awareness of the system. All water system improvement contract drawings should be routed through the recordkeeping system and added to the System Maps with an identification number - e.g. work order number-that can be used to determine where the detailed construction information is filed. An excellent guide for developing recordkeeping practices can be found in the AWWA publication, Water

Distribution Training Course. One individual should be responsible for checking and supervising all recordkeeping work.

- The PUAG Design Standards should be improved in accordance with AWWA standards.

  It is recommended that the current PUAG Standards for water be revised to include the AWWA standards and the lead solder ban for copper water service pipe. Furthermore, standard details showing plan and elevation views of all appurtenances should be developed.

- Currently, approximately 16 percent of PUAG operators are certified operators as required by the Safe Drinking Water Act.

  Job descriptions should be reclassified to require certification within six months of employment for new employees and as soon as practical for existing uncertified employees. Training session opportunities have been provided for operators since 1989 and this practice should be continued on a regular basis.

- Currently PUAG water systems personnel are responsible for groundskeeping tasks at water facilities, which have nothing to do with water production and reduce time available for system operation and maintenance.

  Separate groundskeeping functions at water facilities from the Source and Supply Section. Assign groundskeeping function to support services or contract to a private entity.

- Improved recordkeeping on production and demand would assist the PUAG Engineering Division in evaluating the benefits of system improvements. It is anticipated that recordkeeping improvements will follow telemetering of production and storage components of the system. Recommended improvements to water meters should improve consumption records.

Comprehensive record-keeping should be required and should include the accurate metering of water production and consumption. Information on all system repairs should also be documented.

Operation Deficiencies

The following is a partial list of the operational problems encountered during evaluation of PUAG water system facilities:

- Corrosion of exposed water system components is a never ending maintenance problem on Guam. This is especially true for exposed piping at the well stations.

  Exposed piping at wells and booster pump stations must be painted on a more frequent basis than is the current practice. A schedule for protective painting of PUAG facilities has been implemented but is insufficient to fully meet the protection requirements of a preventative maintenance program. In the future, stainless steel bolts and tubing should be specified for use on expensive flow control valves and consideration should be given to the use of quality plastics where appropriate.

- All of PUAG's wells are presently operated by turning the pumps' power supply on and off manually. The pump control valves originally designed for surge suppression are inoperative, substantially increasing the chances of water main breaks. Although a telemetry system is currently being installed which would record tank levels, it may be some time before automatic production pump controls are provided for wells. Whether controlled manually or automatically, the pump control valves are an essential component of the system.

  It is recommended that complete rehabilitation of all the well pump control valves be undertaken and proper care be exercised to ensure their future operation.

- Some of the well station water production meters are inoperative. The GEPA Water System Sanitary Survey Report indicated that the problem is improved over past years. As of November 1989, PUAG assumed control of all maintenance tasks at production wells.

It is recommended that PUAG maintain an inventory of spare meters and key parts, where appropriate, for all well meters so meters can be replaced immediately upon detection of a problem. After replacing the meter, PUAG can make the needed repairs to the defective meter before it is placed back into service. No meter should be left inoperative for more than one day.

- As evidenced by the GEPA Water System Sanitary Survey Report, and information provided by PUAG staff field inspections during the study, the well stations receive little maintenance other then the bare minimum required to keep the wells in operation.

  It is recommended that PUAG return to using a private contractor for well maintenance and operation. The new contract should clearly delineate all the duties required of the Contractor. Routine payments should be tied to submittal of complete and accurate maintenance and operation reports by the contractor.

- Not all existing chlorination facilities are enclosed within protective buildings and are subject to intense heat and possible vandalism.

  All new chlorination facilities, whether located at treatment facilities, wells, or pumping stations, should include a small concrete block building to house equipment and cylinders. This policy should be extended to existing well stations as funding permits.

- PUAG reservoirs are generally in need of repainting as evidenced by rusting and the effects of vandalism.

  All of the PUAG steel reservoirs should be inspected by a representative of a reputable tank contractor for corrosion damage and overall condition. Thereafter the tanks should be regularly inspected and, as required, painted to AWWA specifications. All reservoir sites should be fenced and locked. Water *tanks should be cleaned each time an inspection is made. Inspections should be scheduled at maximum intervals of five years.*

- Reservoir level monitoring equipment has been provided for all PUAG reservoirs as part of the Motorola telemetering project scheduled for completion on September 30, 1990. The monitoring equipment encountered some signal interference problems caused by other local systems using the same frequency. The signal is being changed to a different frequency, which should eliminate interference problems. In October 1990 Andersen AFB will begin converting to a telemetering system which will use equipment identical to the PUAG system.

  Well pump on/off control based on reservoir level should be included in the telemetry system at the earliest possible date.

- The Yigo Reservoir pilot valve actuating the altitude valve is not operating properly. In response, the drain valve for the reservoir has been wedged open, wasting water to prevent reservoir overflow.

  The pilot valve should be replaced and the altitude valve tested to determine whether the problem is solved. If the problem persists, other appropriate action should be taken to restore normal reservoir operation.

- The old 4-inch water main in Yigo along Marine Drive and Gayinero Road is a source of water loss.

  The 4-inch water main should be abandoned and existing services reconnected to the new 8- and 12-inch water mains.

- Fire hydrants receive little maintenance and are often defective. The responsibility for the inspection of fire hydrants has been placed under the control of each local fire department. However, PUAG is responsible for any deficiencies revealed by inspections of fire hydrants including leaks, breakdown and replacement.

The hydrants should be inspected on a frequency of not less than four times per year on a quarterly basis. Some defects are reported to have been corrected by PUAG, but approximately 40 percent of the improvements on the island remain to be completed. It is also recommended that PUAG number all fire hydrants island-wide for ease of identification and for maintenance purposes.

- The various water systems have considerable footage of pipelines 2 inches in diameter and smaller.

  All pipelines smaller than 2 inches in diameter that are located in public right-of-ways and are not within Conservation Lands should be replaced with adequately sized water mains.

- Some water mains are located on private property and under buildings. PUAG records do not indicate which of these lines were left in service or abandoned.

  Sanitary surveys should be conducted for the various village water systems not yet surveyed as part of this study. The survey should include the identification of water mains that are no longer in use and should be abandoned. Proper abandonment procedures should be developed and implemented.

- Individual water service meters are a major source of unaccounted-for water due to underregistering meters. Many meters are exposed without meter boxes and thus are inadequately protected from inadvertent damage and vandalism. Some meters are buried and cannot be read.

  The majority of problems associated with the meters were identified in the various sanitary surveys conducted since the original Water System Master Plan. All service meters should be calibrated every five years. In addition, the computerized meter records should be reviewed by the PUAG engineering staff every six months to identify unusually high- and low-reading meters. Meters with extremely high usage may be an indication of water leakage in the customer's water system. A regularly scheduled program for meter *maintenance and recalibration is required to minimize leakage and underrecording of services.*

- In many cases, residential meters serve more than one dwelling, thus resulting in a loss of revenue and low pressure to one or more of the dwellings.

  All meters should be verified as to the number of dwellings served. No residential meter should serve more than one dwelling.

- PUAG residential water meters have been purchased by bidding with the contract awarded to the lowest bidder. The result is that no standard water meter manufacturer exists, and PUAG must maintain a large inventory of parts. Also, staff must understand repairs and calibration for several types of meters.

  If allowed by law, PUAG should select a single source for water meters and purchase all future and replacement meters from that manufacturer. Such a policy would greatly reduce current inventory problems and simplify operation and maintenance of meters.

- The well stations are not provided with standby power facilities and consequently, upon power outages, community water supplies are quickly depleted.

  It is recommended that approximately 25 percent of the existing wells be provided with permanent standby power generators. The generators should be located in optimum locations so that generators can be used to serve up to three well stations. Those wells not provided with permanent generators should be equipped with standby power hook-ups to allow mobilization of portable generators to areas of power outage.

- PUAG has implemented a leak detection survey and crews are currently repairing leaks discovered in the initial survey.

It is recommended that the leak detection survey be extended to include the remainder of the island and subsequent repair work be carried out expeditiously.

- Production well water quality analyses performed for GEPA have shown that some Series "A" well water exhibits relatively high concentrations of nitrates and chlorides.

  It is recommended that a comprehensive study of Series "A" wells be conducted to determine the source of the elevated levels of nitrate and chloride and to recommend action to remedy the situation.

- A number of non-looped, dead-end mains exist in the distribution system. Non-looped mains are undesirable because of reduced delivery capacity and because relatively stagnant conditions may cause sediment deposition.

  Where dead end mains exist, flushing should be provided at least twice a month.

The problems pinpointed above do not necessarily reflect all of the observed deficiencies. Many of the problems encountered are more appropriately addressed elsewhere in the report under chapters which discuss future water supply and distribution system improvements. In general, most of the operating problems noted above could be prevented in the future by strengthening design, construction and operating standards.

Future Sanitary Survey Requirements

In spite of nomenclature connotations, a sanitary survey is not a study of sewerage facilities but rather a detailed field study and evaluation of potable water system facilities. The two are somewhat related in that a sanitary survey investigates the possible sources of water contamination due to direct or indirect cross-connections to sewerage facilities. The basic scope of a sanitary survey must include the study and evaluation of the water system's influencing environment, historical water supply and water demand relationships, water quality and physical and operating characteristics.

The first sanitary survey conducted on Guam was for the Merizo water system. The survey was conducted by GEPA's staff and has been used as a basis for developing a framework for subsequent sanitary surveys. As part of the original master plan, two additional sanitary surveys were completed covering the Agat-Santa Rita and Yigo water systems. These surveys are quite comprehensive and may also be used as a guide for conducting further surveys. GEPA completed a sanitary survey in 1988 to comprehensively evaluate PUAG's Island-wide water system and recommend physical and management improvements. The GEPA survey was based on review of PUAG data and records, field investigations, and interviews with staff. The survey report is a major information source on the current status of the system for the *Water Facilities Master Plan Update*. A properly conducted and complete survey is valuable since only an in-depth study can define specific operating conditions and potential problems. Water systems are constantly modified as water service areas expand, new buildings and commercial areas are constructed and others are abandoned, and water mains and mechanical equipment become old and worn. Because of these changes it is necessary to periodically review water system operations. It is more productive if the sanitary survey is conducted by a consultant or other party not in the direct employ of the operating agency as this policy will maximize the objectivity of the survey.

The 1978 Agat-Santa Rita, the 1979 Yigo, and the FY 1988 and 1989 GEPA sanitary surveys identified problems that when corrected will reduce the operating budget by more than the actual costs of the surveys. Thus, sanitary surveys should not be postponed due to financial concerns as they are generally a cost-saving measure with immediate benefits. The current 53 million dollar bond, capital improvement program will implement some of the Agat-Santa Rita sanitary survey recommendations. Items completed since the original Agat-Santa Rita survey include replacing the old 3- and 4-inch mains in Agat along the beach.

A sanitary survey is not worth the investment if the recommendations are not implemented. Thus it is important that the operating agency, such as PUAG, carefully digest the findings and schedule required system improvements. It is equally important that an enforcement agency, such as GEPA, follow-up on the progress of the implementation of the recommended system improvements on a regular basis. If the findings and subsequent recommendations are not taken seriously, there is no value in conducting additional sanitary surveys. It is important to resurvey the water system after a period of time to identify any changes and conditions and to document improvements.

None of the sanitary surveys recommended in the previous water master plan have been implemented. The last municipal sanitary survey conducted was the Yigo Sanitary Survey completed in 1979. The inaction on additional surveys may have been due to slow progress in implementing the Agat-Santa Rita and Yigo recommendations or to low enforcement priority for the improvements. Nonetheless, many of the recommendations from the two sanitary surveys completed thus far have now been implemented, so the way may be clear for additional sanitary surveys. In addition, the GEPA Water System Sanitary Survey Report defined a basis for more detailed local surveys. GEPA has established a priority for implementing the recommendations contained in that document. It is strongly recommended that the program be revived and that the recommended sanitary surveys be implemented on a regularly scheduled basis.

Each sanitary survey is normally unique to the system surveyed as the nature of the problems may be quite different in any two systems.

As an example, the Yigo water system was characterized by large water losses and, therefore, much of the study was oriented towards leak detection. The Agat-Santa Rita survey utilized leak detection surveys but also emphasized locating and identifying existing facilities because the system was old and few construction drawings were available.

Based on the findings of the Agat-Santa Rita and Yigo Sanitary Surveys, future surveys should include more extensive field verification of facilities, especially in areas where "as-built" construction drawings are unavailable. It is recommended that future surveys include verification of water mains by actual excavations utilizing PUAG personnel and equipment. The excavation of facilities could provide useful information in evaluating the reliability of information shown on the System Maps and updating the information where appropriate.

The major objective or thrust of a sanitary survey is usually known at the start of the survey but should allow flexibility to pursue major problem areas as they arise during the course of study. Generally, the types of problems can be categorized as either water quality, excessive water losses or identification of facility locations. Eleven service areas have been listed in Table 4-7 as needing future sanitary surveys. Based on findings developed in the master plan, the areas have been given a priority indicating the importance and proposed sequencing of the sanitary surveys. The table also shows the major area(s) of concern for each sanitary survey;

TABLE 4-7
SANITARY SURVEY PRIORITY SCHEDULE

Priority	Community	Problems
1	Barrigada-MongMong-Toto-Maite	WQ, LF, LD
2	Umatac	WQ, LF
3	Mangilao-Chalan Pago-Ordot	WQ, LF, LD
4	Talofofo-Inarajan	WQ, LF
5	Agana-Agana Heights-Sinajana	WQ, LF, LD
6	Yona	WQ, LF
7	Tamuning-Tumon	LF, LD
8	Asan-Piti	WQ, LD
9	Agafa Gumas-Finegayan	LF, LD
10	Dededo-Latte Heights-Barrigada Hts.	LF, LD
11	Harmon Village (1)	LF

WQ = Water Quality
LF = Location of Facilities
LD = Leak Detection

(1) A sanitary survey for Harmon Village should be conducted before the system is connected to the Dededo system and therefore the priority may need to be revised.

e.g. water quality, location of facilities, or leak detection. Selection of areas receiving the highest priority are, of course, somewhat subjective and may be revised to reflect acute problems.

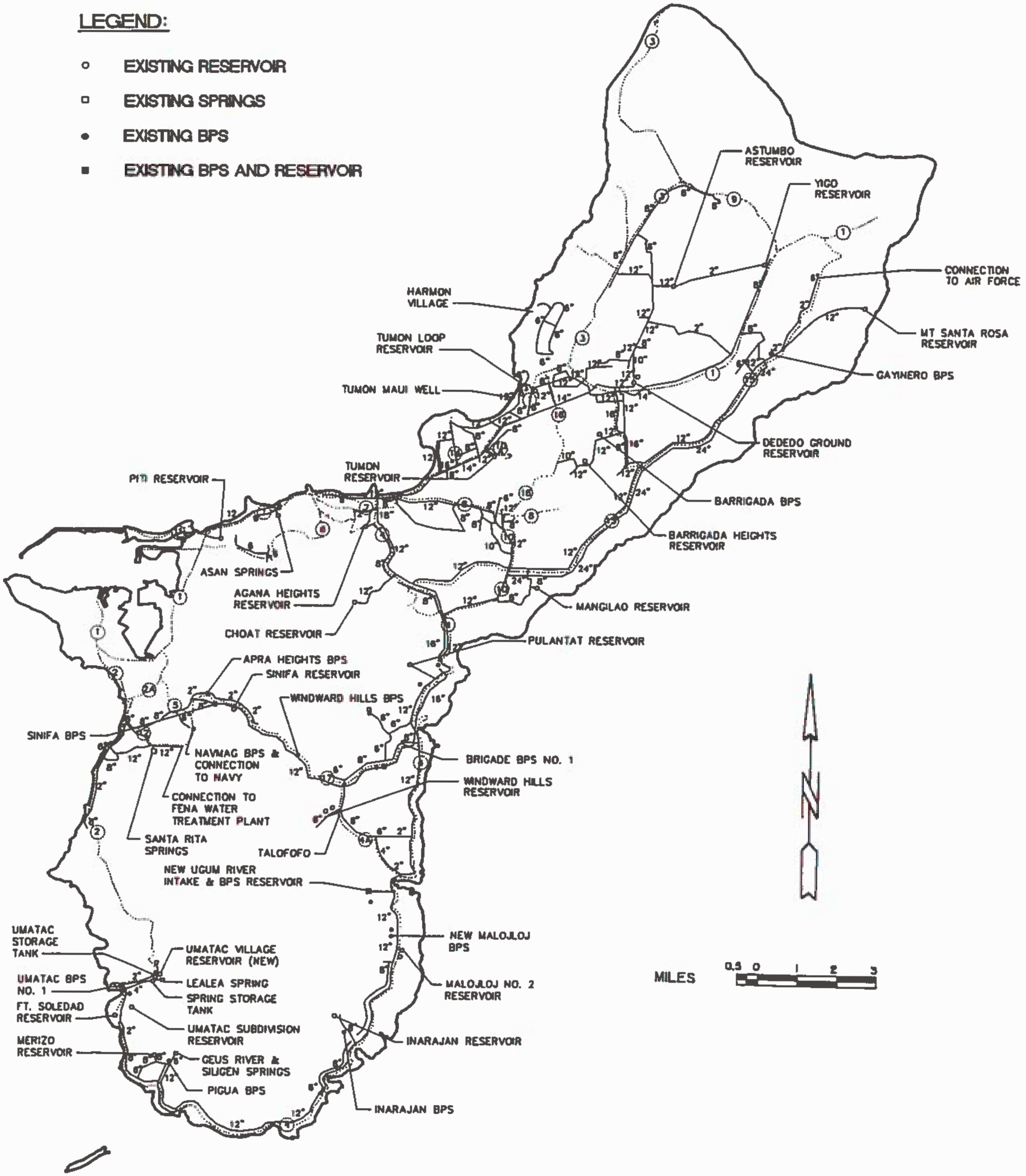
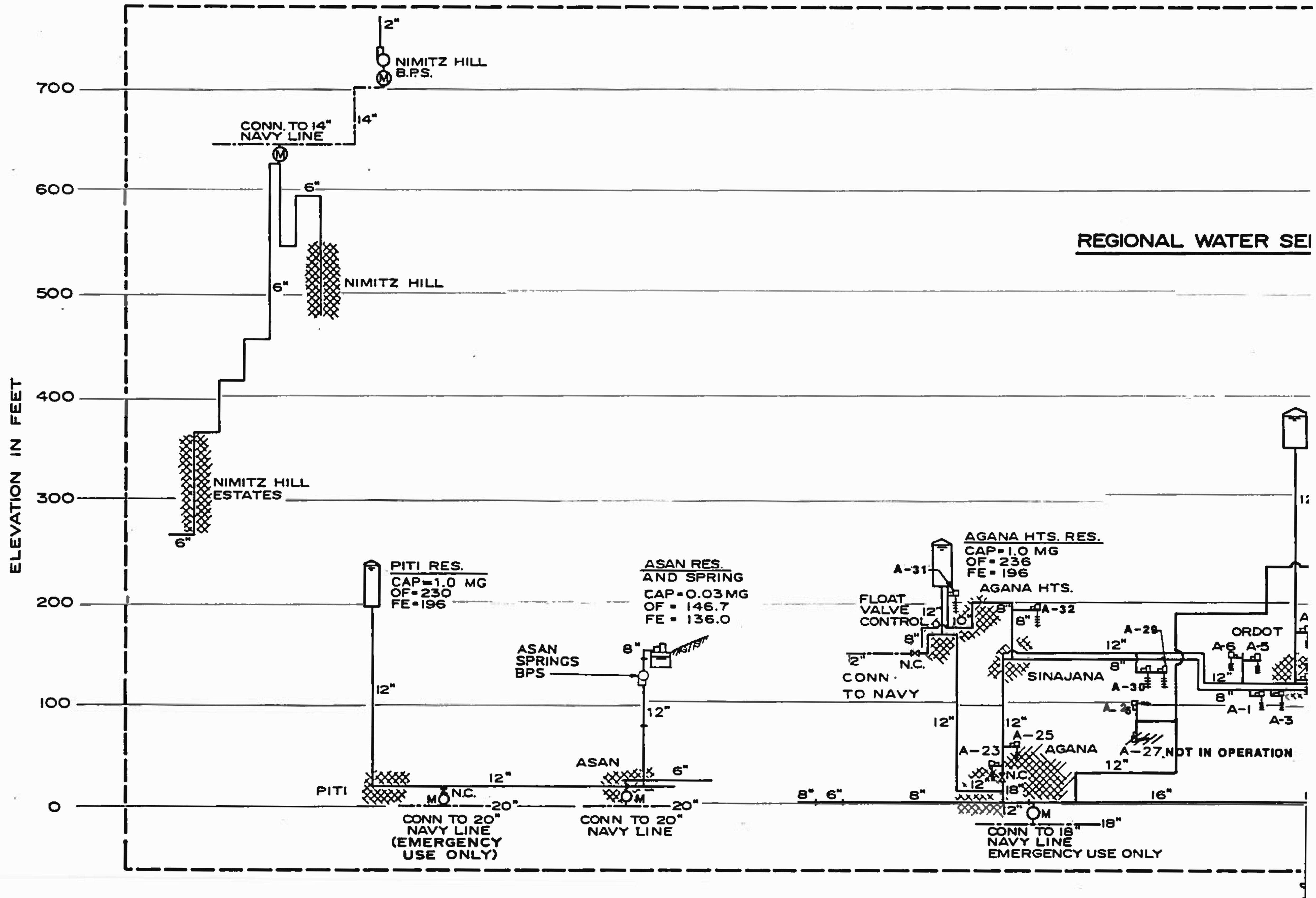


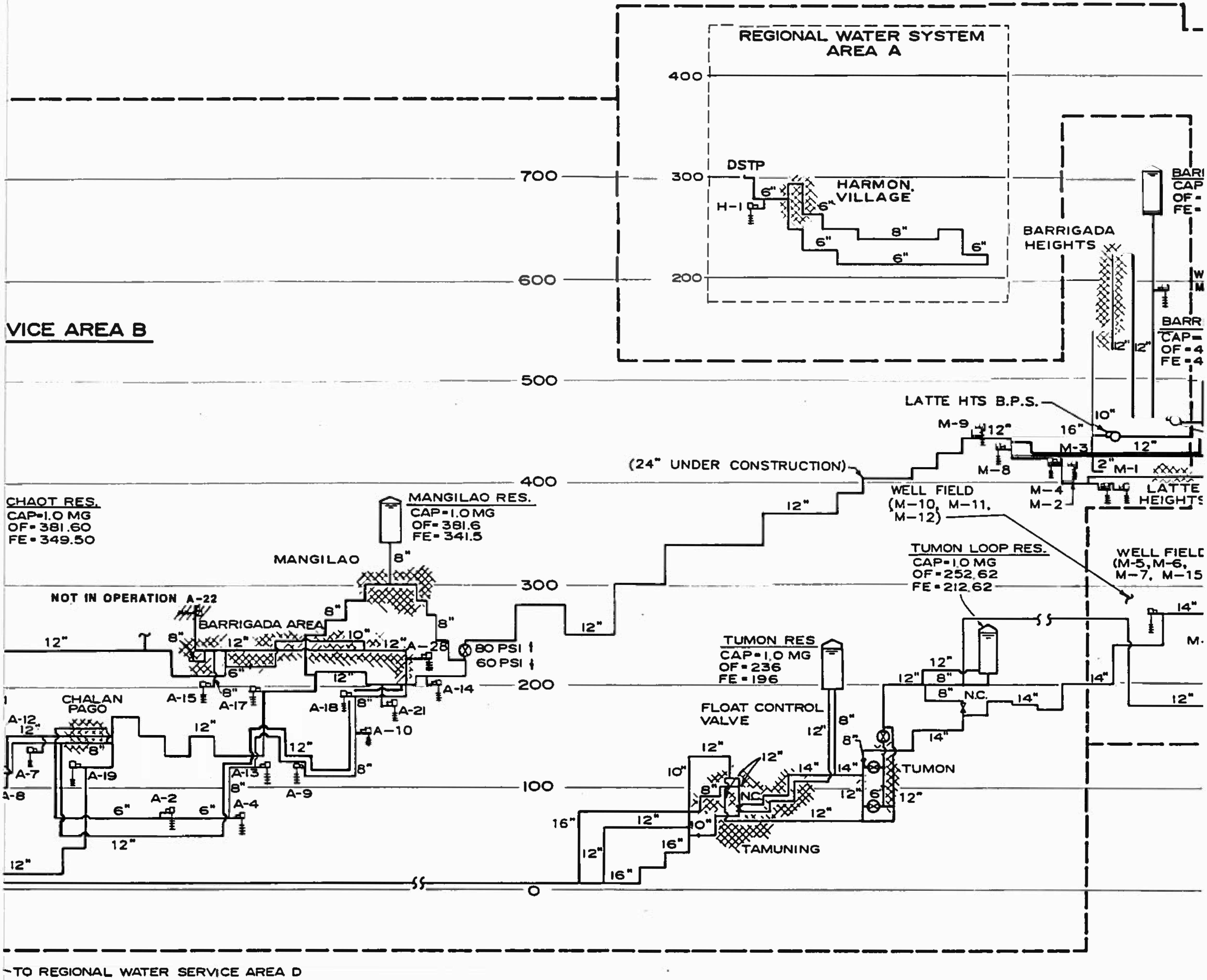
FIGURE 4-1

EXISTING PUAG ISLAND-WIDE

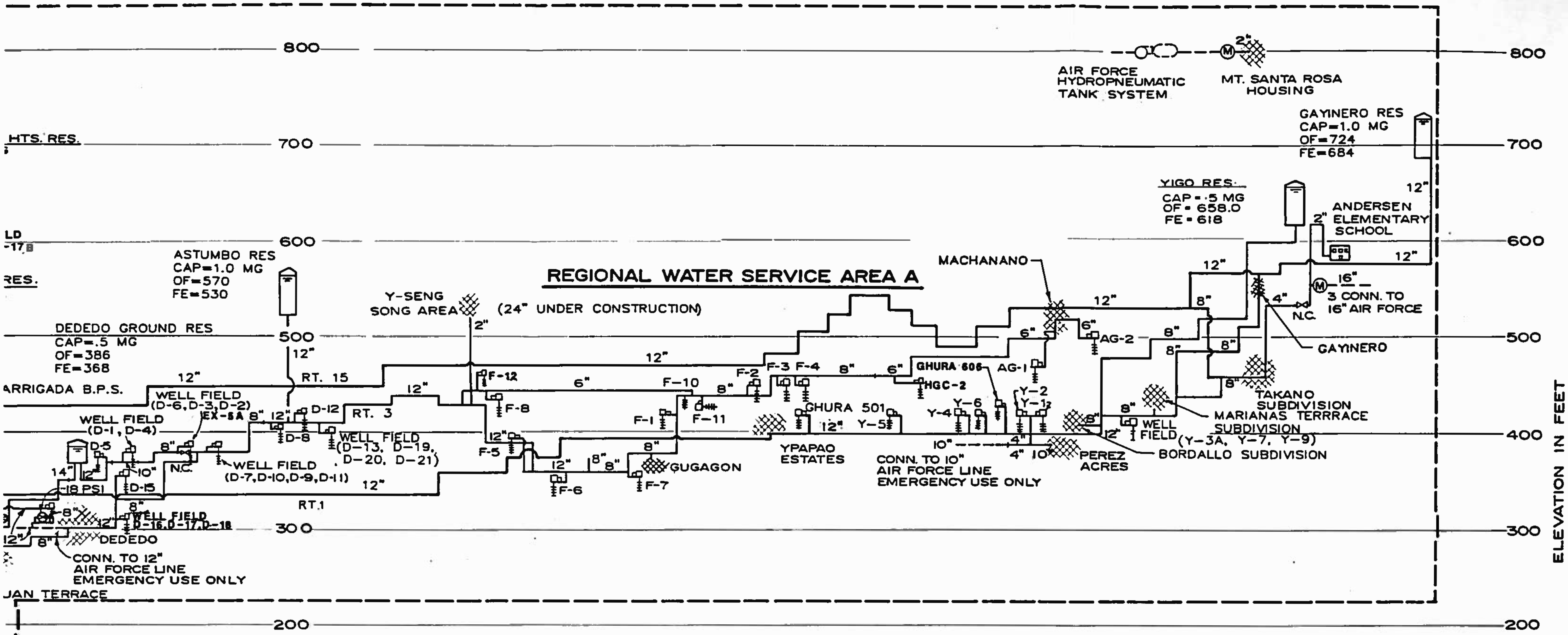
WATER DISTRIBUTION SYSTEM



REGIONAL WATER SEI
ELEVATION IN FEET
700
600
500
400
300
200
100
0
2"
NIMITZ HILL
B.P.S.
14"
CONN. TO 14"
NAVY LINE
6"
6"
NIMITZ HILL
NIMITZ HILL
ESTATES
6"
PITI RES.
CAP=1.0 MG
OF=230
FE=196
12"
PITI
12"
N.C.
20"
CONN TO 20"
NAVY LINE
(EMERGENCY
USE ONLY)
ASAN RES.
AND SPRING
CAP=0.03 MG
OF = 146.7
FE = 136.0
ASAN
SPRINGS
BPS
8"
12"
ASAN
6"
20"
CONN TO 20"
NAVY LINE
AGANA HTS. RES.
CAP=1.0 MG
OF=236
FE=196
AGANA HTS.
A-31
FLOAT
VALVE
CONTROL
A-32
CONN.
TO NAVY
N.C.
SINAJANA
A-29
A-30
A-25
A-23
AGANA
A-27 NOT IN OPERATION
ORDOT
A-6
A-5
A-1
A-3
8", 6"
8"
16"
18"
CONN TO 18"
NAVY LINE
EMERGENCY USE ONLY



REGIONAL WATER SYSTEM AREA A
DSTP
H-1
HARMON VILLAGE
BARRIGADA HEIGHTS
VICE AREA B
LATTE HTS B.P.S.
(24" UNDER CONSTRUCTION)
WELL FIELD (M-10, M-11, M-12)
LATTE HEIGHTS
CHAOT RES.
CAP=1.0 MG
OF=381.60
FE=349.50
MANGILAO RES.
CAP=1.0 MG
OF=381.6
FE=341.5
MANGILAO
NOT IN OPERATION A-22
BARRIGADA AREA
80 PSI
60 PSI
TUMON LOOP RES.
CAP=1.0 MG
OF=252.62
FE=212.62
WELL FIELD (M-5, M-6, M-7, M-15
TUMON RES
CAP=1.0 MG
OF=236
FE=196
FLOAT CONTROL VALVE
TUMON
TAMUNING
CHALAN PAGO
N.C.
700
600
500
400
300
200
100
0
TO REGIONAL WATER SERVICE AREA D



LEGEND

— — —	SERVICE AREAS
———	PUAG MAINS
- - - -	AIR FORCE MAINS
— · — ·	NAVY MAINS
BPS	BOOSTER PUMP STATION
NC	NORMALLY CLOSED
CAP	CAPACITY
OF	OVERFLOW
FE	FLOOR ELEVATION
RES	RESERVOIR

FIGURE 4-2A

HYDRAULIC PROFILE

OF EXISTING PUAG FACILITIES

REGIONAL WATER SERVICE AREA A & B

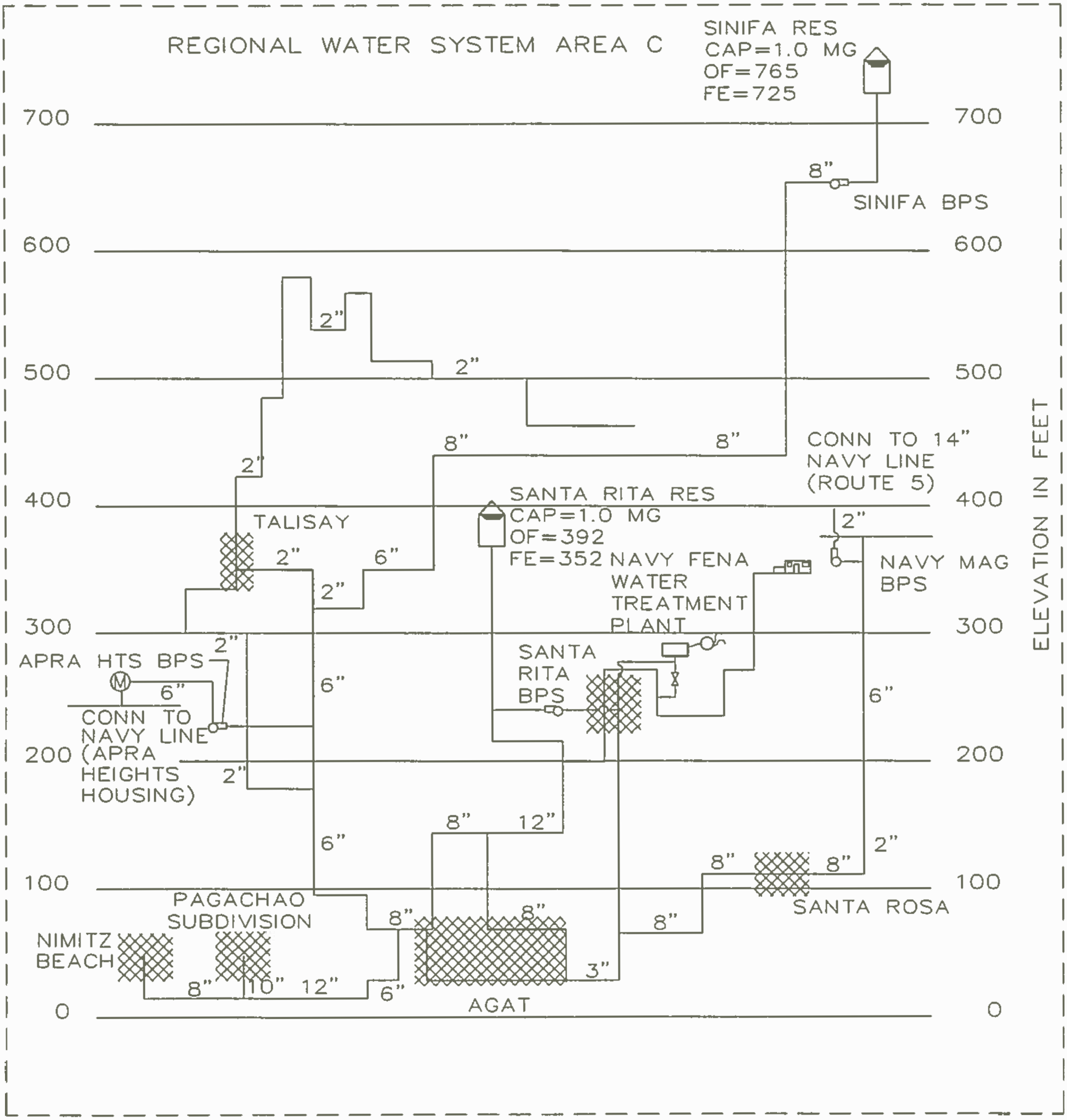
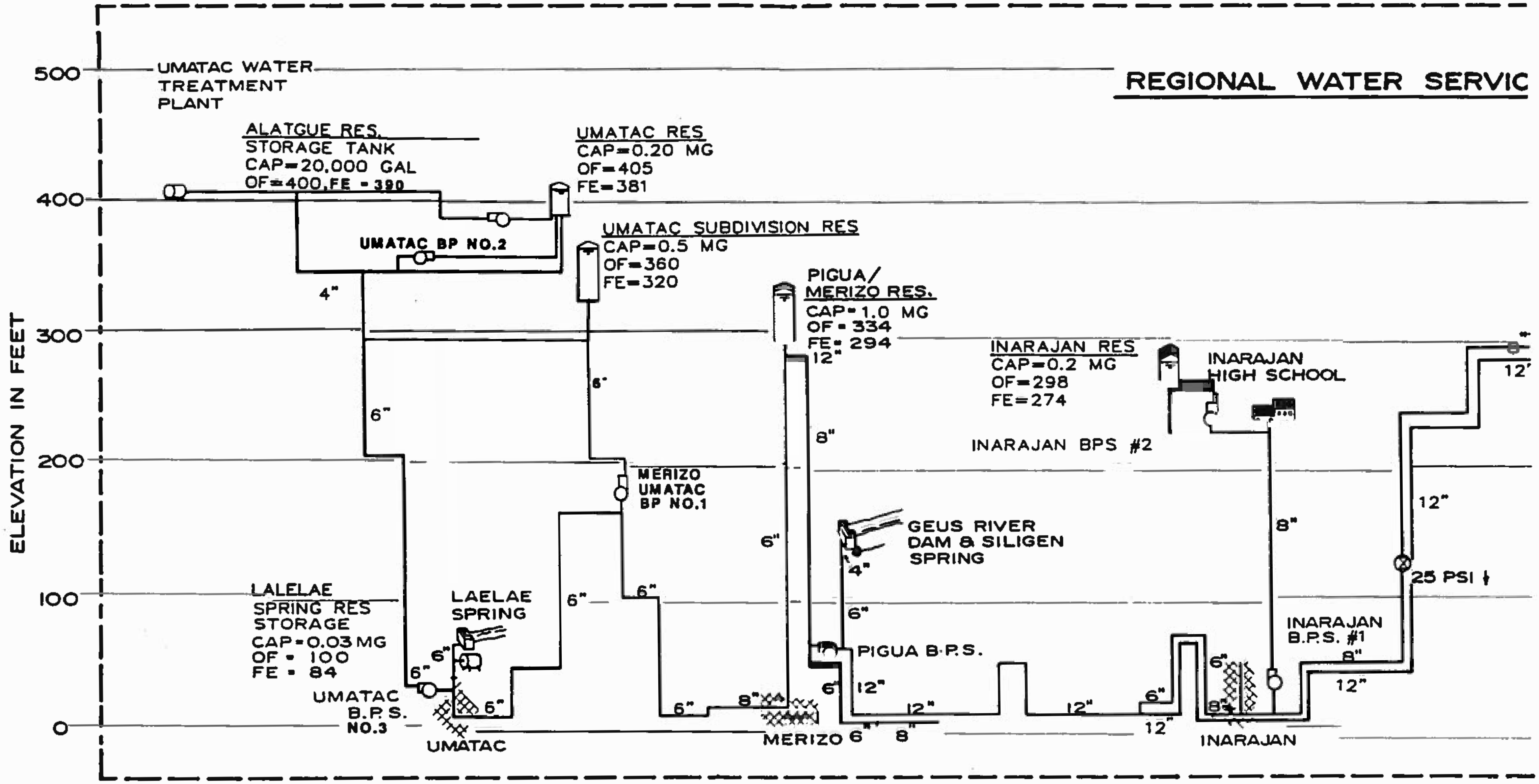


FIGURE 4-2B

HYDRAULIC PROFILE OF

EXISTING PUAG FACILITIES


REGIONAL WATER SERVIC
ELEVATION IN FEET
500
400
300
200
100
0
UMATAC WATER TREATMENT PLANT
ALATGUE RES. STORAGE TANK CAP=20,000 GAL OF=400, FE = 390
UMATAC RES CAP=0.20 MG OF=405 FE=381
UMATAC BP NO.2
UMATAC SUBDIVISION RES CAP=0.5 MG OF=360 FE=320
PIGUA/ MERIZO RES. CAP=1.0 MG OF=334 FE=294
INARAJAN RES CAP=0.2 MG OF=298 FE=274
INARAJAN HIGH SCHOOL
INARAJAN BPS #2
MERIZO UMATAC BP NO.1
GEUS RIVER DAM & SILIGEN SPRING
LALELAE SPRING RES STORAGE CAP=0.03 MG OF=100 FE=84
LAELAE SPRING
PIGUA B.P.S.
INARAJAN B.P.S. #1
25 PSI
UMATAC B.P.S. NO.3
UMATAC
MERIZO
INARAJAN
4"
6"
8"
12"

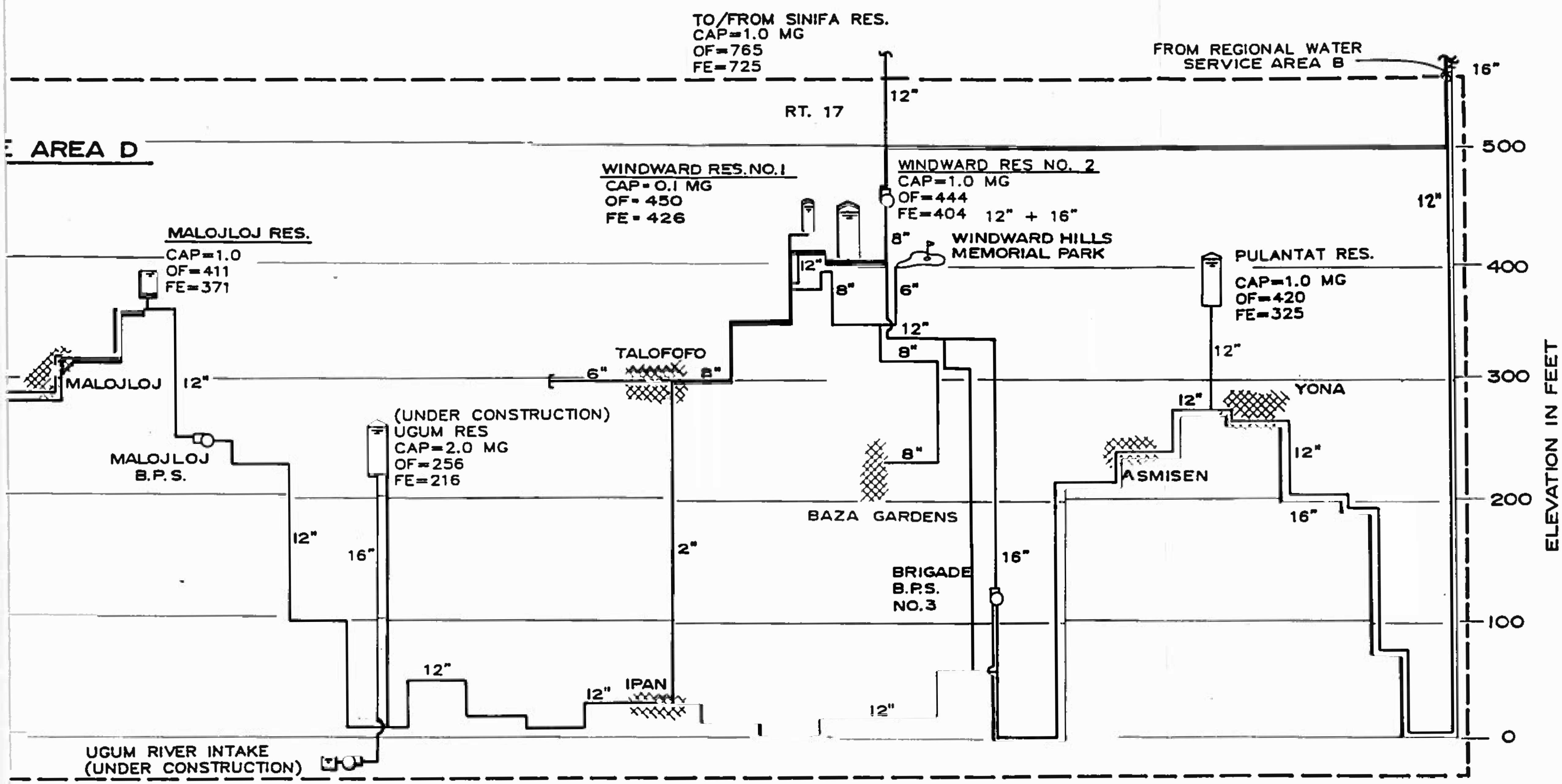


FIGURE 4-2C

HYDRAULIC PROFILE

OF EXISTING PUAG FACILITIES

REGIONAL WATER SERVICE AREA D

V

WATER REQUIREMENTS

CHAPTER V
WATER REQUIREMENTS

General

A public water system must be capable of furnishing water of acceptable sanitary and aesthetic quality at adequate and reasonably consistent pressures and quantities sufficient to meet normal patterns of demands for all categories of customers within the service area. "Water production" is the water entering the system from supply sources. Not all water entering a system is actually sold to consumers. The portion that is sold (i.e., metered) can be categorized by type of use and analyzed. The "Historical Water Production" section of this chapter deals with the established pattern of water use by customers.

The difference between production and demand is normally referred to as "unaccounted-for" water and includes leakage, metering inaccuracies, and unmetered public use of water. The "Per Capita Use" section of this chapter utilizes the historical production, demand, and "unaccounted-for" water data to develop a unit, or per person, demand figure that can be applied to population estimates in order to project Public Utility Agency of Guam (PUAG) water requirements for master planning purposes. The "Island-wide Future Water Requirements" section projects Guam's future overall water requirements including military and private needs. Finally, comments on the impacts of possible variations in per capita use rates are included in the "Variations in Water Demand Projections" section.

Historical Water Production

During the Spanish occupation, the Agana and Asan Springs were utilized as the two major fresh water sources. The Spanish left no sizeable water development construction but did have a good working knowledge of the Island's hydrology.

There are few records of water development by the U. S. Navy during their initial occupation of Guam. It is known, however, that the Navy relied heavily on the Agana and Asan Springs and also constructed several shallow wells and small surface water impoundments. In 1937, the Navy brought a drill rig to the Island and bored the first well near Barrigada. Several additional wells were drilled later confirming the existence of a substantial fresh water aquifer.

During the Japanese occupation from December, 1941, to July, 1944, little was done to update existing or construct new water supply facilities. The American liberation of Guam required immediate construction of new water system improvements as approximately 30,000 U.S. military personnel were then occupying the Island. Whereas the initial U. S. Military installations were generally concentrated in the Agana and Apra Harbor areas, the reoccupation left military installations scattered throughout the Island. To satisfy the sudden increase in water demands, several diversion structures were built on small streams. Wells were drilled near new military installations and two infiltration galleries were constructed. Although many of these early water supply facilities can still be found, few are still in use. Many of the wells drilled either failed during the drilling or failed because of salt water intrusion.

Historical records indicate that by 1947, approximately 7 million gallons per day (MGD) were being produced from the wells in the northern aquifer and from the Tumon infiltration gallery. In addition, Agana Springs produced up to 3 MGD while the total production from the southern Guam sources may have been as high as 5 MGD. Unfortunately, the majority of the Navy's water supplies were unreliable and the Navy elected to construct Fena Reservoir and Dam which has a watershed area of 5.8 square miles and a dependable yield of 15 MGD.

In 1963, Typhoon Karen swept over the Island crippling and/or destroying many of the water facilities that had been turned over to the Government of Guam by the Navy. Shortly after the effects of the typhoon were recognized, the Federal government granted substantial funding to GovGuam for rehabilitation of services, and in particular, water supply. Shortly thereafter numerous wells were constructed through extensive well-drilling programs. By the summer of 1974 a total of 57 wells were withdrawing about 15 MGD from Guam's northern aquifer.

Since that time, a marked change in the island's water demand has been caused by the dramatic boom in the tourist industry described in Chapter III. The sharp increase in the number of hotels and resorts created by this boom is also resulting in the development of large tracts of land into golf courses. The majority of this development can be found in the central part of the island, near Tumon Bay. Regular hotel use, in addition to hotel air conditioning and golf course irrigation, have significantly increased the demand for water. Several field studies have been conducted investigating hotel water use on Guam. The most recent of these, the *Tumon Bay Infrastructure Study* (1989), was sponsored by the TAWSA consortium of hotel owners and developers with the participation of and review by PUAG. Results of the study are discussed in the "Per Capita Use" section of this chapter.

Today, there are approximately 124 source diversions used by four different types of users or operating agencies: Government of Guam (PUAG); U.S. Air Force; U.S. Navy; and private wells. Of the total number of diversions, 117, or approximately 94 percent, are wells. In 1989 these wells produced a total of approximately 28 MGD, about 19 MGD of which was withdrawn from PUAG-operated wells. Table 5-1 indicates the yearly water production by source for each of the four different operating agencies from 1985 through 1989. Overall, little increase in total production has occurred during the five year period; approximately 65 percent of total production has been derived from wells, 4 percent from springs, and 31 percent from surface sources.

Table 5-2 summarizes the total water production by operating agency from 1986 through 1989. The Government of Guam produces the majority of the Island's water supply, at approximately 51 percent of the total. The U.S. Navy is the second largest producer with about 35 percent of the overall production. The U.S. Air Force comprises 11 percent of the Island's water production, while private suppliers produce approximately 3 percent of overall production. The historical water production picture is shown graphically on Figure 5-1.

PUAG's sources of water supply are tabulated in Table 5-3. Approximately 88 percent of the total supply is obtained from the central and northern geographical areas (i.e., Service Areas "A" and "B").

As described in Chapter IV, "Existing Water Facilities," PUAG obtains part of its water supply from both the Air Force and the Navy. Overall, the water purchased from the military accounts for slightly less than 20 percent of PUAG's total water supply.

TABLE 5-1
HISTORICAL WATER PRODUCTION BY SOURCE

	1985			1986			1987			1988			1989			Average	
Source/ Operating Agency	Water Total (MG)	Production Per Day (MGD)	Diver-sions	Water Total (MG)	Production Per Day (MGD)	Diver-sions	Water Total (MG)	Production Per Day (MGD)	Diver-sions	Water Total (MG)	Production Per Day (MGD)	Diver-sions	Water Total (MG)	Production Per Day (MGD)	Diver-sions	Water Production (MGD)	Percent of Total
Groundwater Production from Wells																	
Government of Guam	6825	18.7	81	7094	19.44	81	7004	19.19	80	7110	19.48	83	6874	18.83	86	19.13	49.6%
U.S. Air Force	1241	3.40	10	1405	3.85	10	1504	4.12	10	1573	4.31	10	1894	5.19	10	4.17	10.8%
U.S. Navy	106	0.29	3	80	0.22	3	164	0.45	3	200	0.55	3	256	0.70	3	0.44	1.1%
Private	197	0.54	7	120	0.33	7	153	0.42	7	507	1.39	8	1029	2.82	8	1.10	2.8%
Subtotal	8369	22.93	101	8699	23.83	101	8825	24.18	100	9390	25.73	104	10053	27.54	107	24.84	64.4%
Groundwater Production from Springs																	
Government of Guam	262	0.72	5	262	0.72	5	260	0.71	5	257	0.70	5	258	0.71	5	0.71	1.8%
U.S. Navy	365	1.00	2	365	1.00	2	365	1.00	1	365	1.00	2	365	1.00	2	1.00	2.6%
Subtotal	627	1.72	7	627	1.72	7	625	1.71	6	622	1.70	7	623	1.71	7	1.71	4.4%
Surface Water Production																	
Government of Guam	5	0.01	1	5	0.01	1	12	0.03	1	20	0.05	1	25	0.07	1	0.04	0.1%
U.S. Navy	4380	12.00	1	4380	12.00	1	3480	12.00	1	4380	12.00	1	4380	12.00	1	12.00	31.1%
Subtotal	4385	12.01	2	4385	12.01	2	4392	12.03	2	4400	12.05	2	4405	12.07	2	12.04	31.2%
Grand Total	**13381**	**36.66**	**110**	**13711**	**37.56**	**10**	**13842**	**37.92**	**108**	**14412**	**39.48**	**113**	**15081**	**41.32**	**116**	**38.59**	**100.0%**

Source: USGS
GEPA: Groundwater Management Report, FY85-89
PUAG: Total Production & Purchases of Water for FY85-89

Note: (1) Production based on PUAG estimates.
(2) Navy Surface & Spring Production based on USGS estimates.

TABLE 5-2
HISTORICAL WATER PRODUCTION BY OPERATING AGENCY

Production in MGD

AGENCY	1986	1987	1988	1989	AVERAGE	PERCENT
GOVERNMENT OF GUAM	20.17	19.93	20.23	19.61	19.99	51
U.S. AIR FORCE(1)	3.85	4.12	4.31	5.19	4.37	11
U.S. NAVY(1)	13.22	13.45	13.55	13.70	13.48	35
PRIVATE	0.33	0.42	1.39	2.82	1.24	3
TOTAL	37.57	37.92	39.48	41.32	39.07	100.0

(1) Includes production sold to PUAG

Source: PUAG, Total Production & Purchases of Water FY86-89
GEPA, Groundwater Management Report FY86-89

Note: Production is based on estimates by PUAG

A monthly record of PUAG water production for FY 1989 is shown in Table 5-4. Due to the unavailability of accurate spring and surface water production data, PUAG has estimated production for these two sources. It is interesting to note that the monthly production shows little seasonal variation in PUAG water production.

Water Demands

The Public Utility Agency of Guam categorizes users into five groups: residential; commercial; governmental; agricultural; and irrigation. The type of user classified under residential is self-explanatory. The commercial category is composed of the business and industrial sectors, including hotels, golf courses and resorts. The agricultural service classification is issued to a customer requesting meter service for livestock watering purposes. The irrigation service classification is for commercial crop production. The governmental classification includes public schools, commissioner's offices, fire departments, police stations, libraries, wastewater treatment plants, and other Government of Guam facilities.

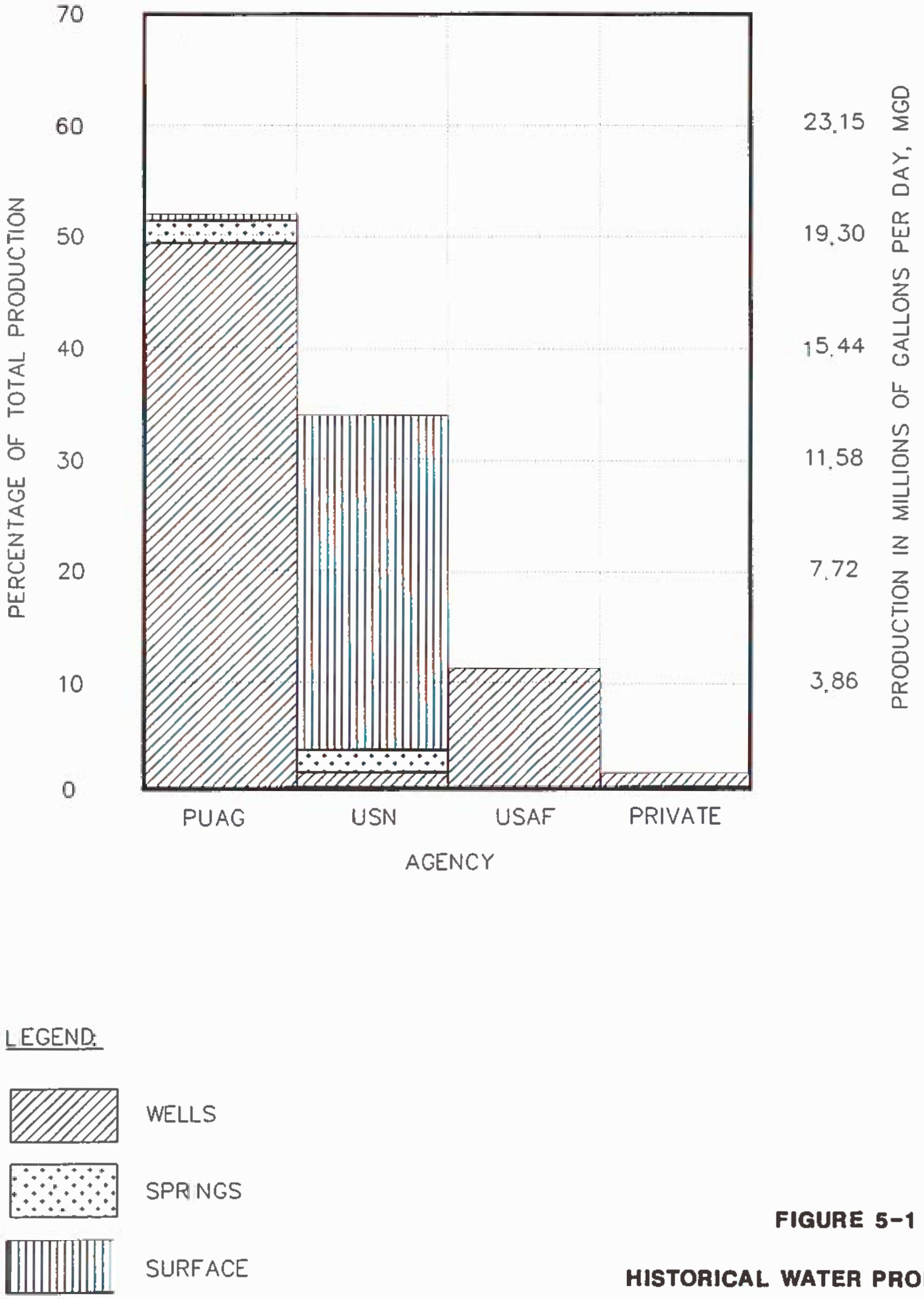


FIGURE 5-1

HISTORICAL WATER PRODUCTION BY

OPERATING AGENCY 1986-1989

TABLE 5-2
HISTORICAL WATER PRODUCTION BY OPERATING AGENCY

Production in MGD

AGENCY	1986	1987	1988	1989	AVERAGE	PERCENT
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U.S. AIR FORCE[1]	3.85	4.12	4.31	5.19	4.37	11
U.S. NAVY[1]	13.22	13.45	13.55	13.70	13.48	35
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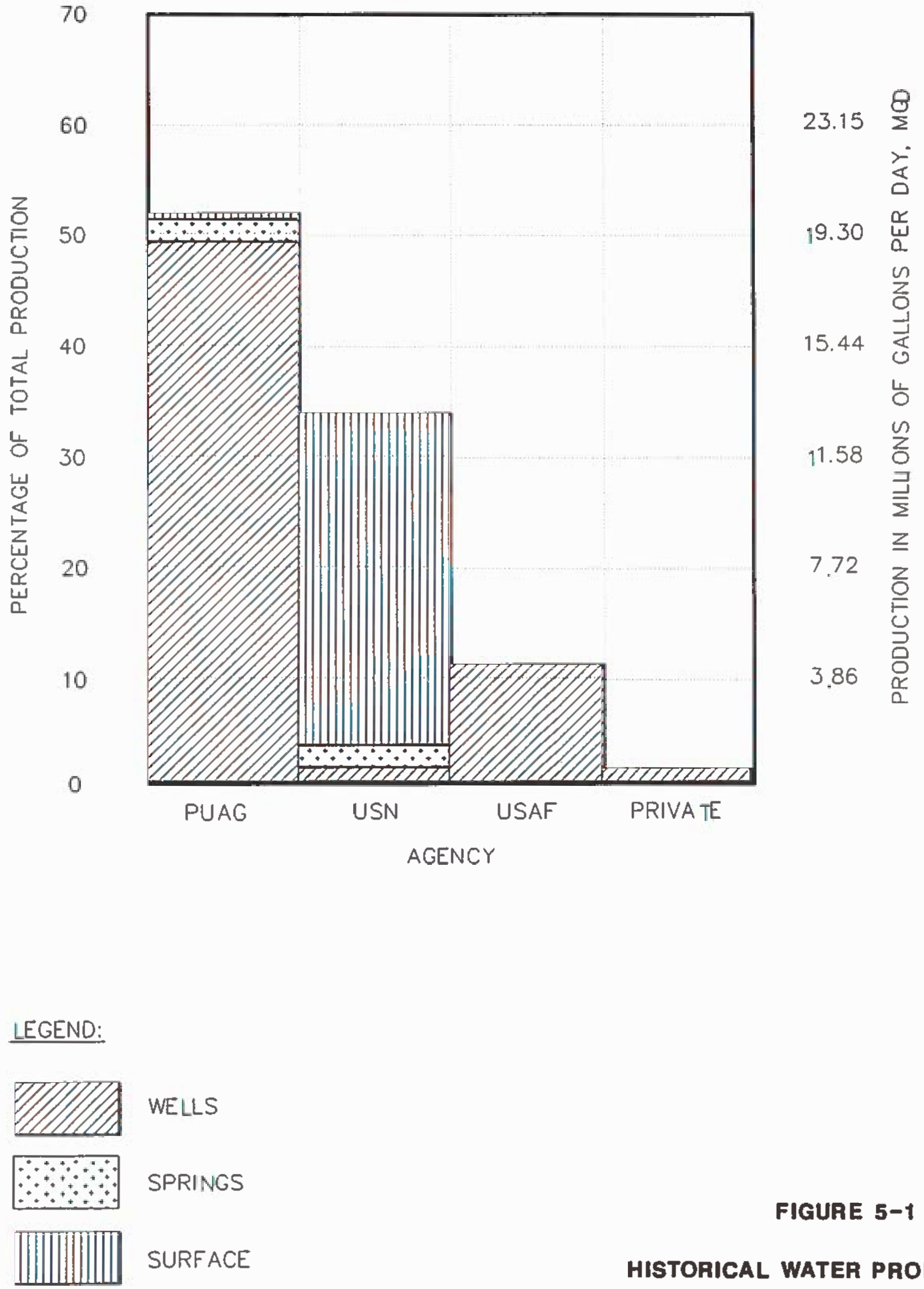


FIGURE 5-1

HISTORICAL WATER PRODUCTION BY

OPERATING AGENCY 1986-1989

TABLE 5-3
HISTORICAL PUAG WATER PRODUCTION AND PURCHASED MILITARY SUPPLIES BY WATER SERVICE AREA

	PUAG Production (MGD)					Purchased Military Supply					
Regional Water Service	Wells	Surface(1)	Spring(1)	Total	Percent	Navy	Air Force	Total	Percent	Total	Percent
Service Area "A"											
Dededo	8.52	0.00	0.00	8.52	34.8	0.00	0.00	0.00	0.0	8.52	34.8
Yigo	2.54	0.00	0.00	2.54	10.4	0.00	0.19	0.19	0.8	2.73	11.2
TOTAL	**11.06**	**0.00**	**0.00**	**11.06**	**45.2**	**0.00**	**0.19**	**0.19**	**0.8**	**11.25**	**46.0**
Service Area "B"											
Asan/Piti	0.00	0.00	0.43	0.43	1.8	1.00	0.00	1.00	4.1	1.43	5.8
Agana/Agana Hts/Sinjana	1.40	0.00	0.00	1.40	5.7	0.78	0.00	0.78	3.2	2.18	8.9
MongMong/Toto/Maite	0.00	0.00	0.00	0.00	0.0	0.29	0.00	0.29	1.2	0.29	1.2
Chalan Pago Ordot/Mangilao	6.02	0.00	0.00	6.02	24.6	0.00	0.00	0.00	0.0	6.02	24.6
Tamuning	0.00	0.00	0.00	0.00	0.0	0.00	0.19	0.19	0.8	0.19	0.8
Barrigada	0.17	0.00	0.00	0.17	0.7	0.02	0.00	0.02	0.1	0.19	0.8
TOTAL	**7.59**	**0.00**	**0.43**	**8.02**	**32.8**	**2.09**	**0.19**	**2.28**	**9.3**	**10.3**	**42.1**
Service Area "C"											
Agat/Santa Rita	0.00	0.00	0.22	0.22	0.9	2.41	0.00	2.41	9.8	2.63	10.7
Service Area "D"											
Yona	0.00	0.00	0.00	0.00	0.0	0.00	0.00	0.00	0.0	0.00	0.0
Talofofo	0.04	0.00	0.00	0.04	0.2	0.00	0.00	0.00	0.0	0.04	0.2
Inarajan	0.13	0.00	0.00	0.13	0.5	0.00	0.00	0.00	0.0	0.13	0.5
Merizo	0.00	0.07	0.00	0.07	0.3	0.00	0.00	0.00	0.0	0.07	0.3
Umatac	0.00	0.00	0.05	0.05	0.2	0.00	0.00	0.00	0.0	0.05	0.2
TOTAL	**0.17**	**0.07**	**0.05**	**0.29**	**1.2**	**0.00**	**0.00**	**0.00**	**0.0**	**0.29**	**1.2**
GRAND TOTAL	18.82	0.07	0.70	19.59	80.1	4.5	0.38	4.88	19.9	24.47	100.0

(1) PUAG surface and spring sources are generally unmetered. Data represents estimated production.

NOTE: Data obtained from PUAG records and military meter readings for calendar year 1989.

TABLE 5-4
PUAG MONTHLY WATER PRODUCTION

Month	Ground	(1) Spring	(1) Surface	Total	Navy	Air Force	Total	Total Water Prod.
	PUAG Sources (MG)				Purchased Supplies (MG)			
Oct 88	571.51	21.60	2.06	595.17	127.31	14.36	141.67	736.84
Nov 88	565.93	20.98	2.11	589.02	123.44	15.58	139.02	728.05
Dec 88	551.20	21.63	2.03	574.86	123.81	14.52	138.33	713.19
Jan 89	596.37	21.60	2.06	620.03	138.58	16.00	154.58	774.61
Feb 89	581.04	19.56	2.11	602.70	118.74	12.62	131.36	734.06
Mar 89	578.50	21.65	2.16	602.31	130.62	14.69	145.31	747.62
Apr 89	593.68	20.95	2.23	616.87	146.09	12.88	158.97	775.83
May 89	579.19	20.88	2.25	602.31	148.26	9.26	157.52	759.83
Jun 89	547.11	20.92	2.24	570.27	151.88	6.27	158.16	728.42
Jul 89	571.23	21.09	2.14	594.46	152.45	6.22	158.67	753.13
Aug 89	576.78	21.03	2.15	599.96	150.06	9.74	159.79	759.75
Sep 89	561.40	20.82	2.13	584.35	131.66	8.58	140.24	724.59
TOTAL	6873.95	252.70	25.66	7152.32	1642.88	140.73	1783.61	8935.92
AVERAGE	572.83	21.06	2.14	596.03	136.91	11.73	148.63	744.66

(1) PUAG surface and spring sources are generally unmetered. Data represents estimated production.

Source: PUAG records

Since October, 1977, PUAG has utilized a computer for storage of water service meter records for billing purposes. The computerized records not only expedite customer billings but aid in the retrieval of historical water use records for estimation of future water demands. Table 5-5 lists the monthly water demand for each user category for the period from October, 1988, through September, 1989, while Figure 5-2 shows each user category's percent of annual demands by month for the same time period.

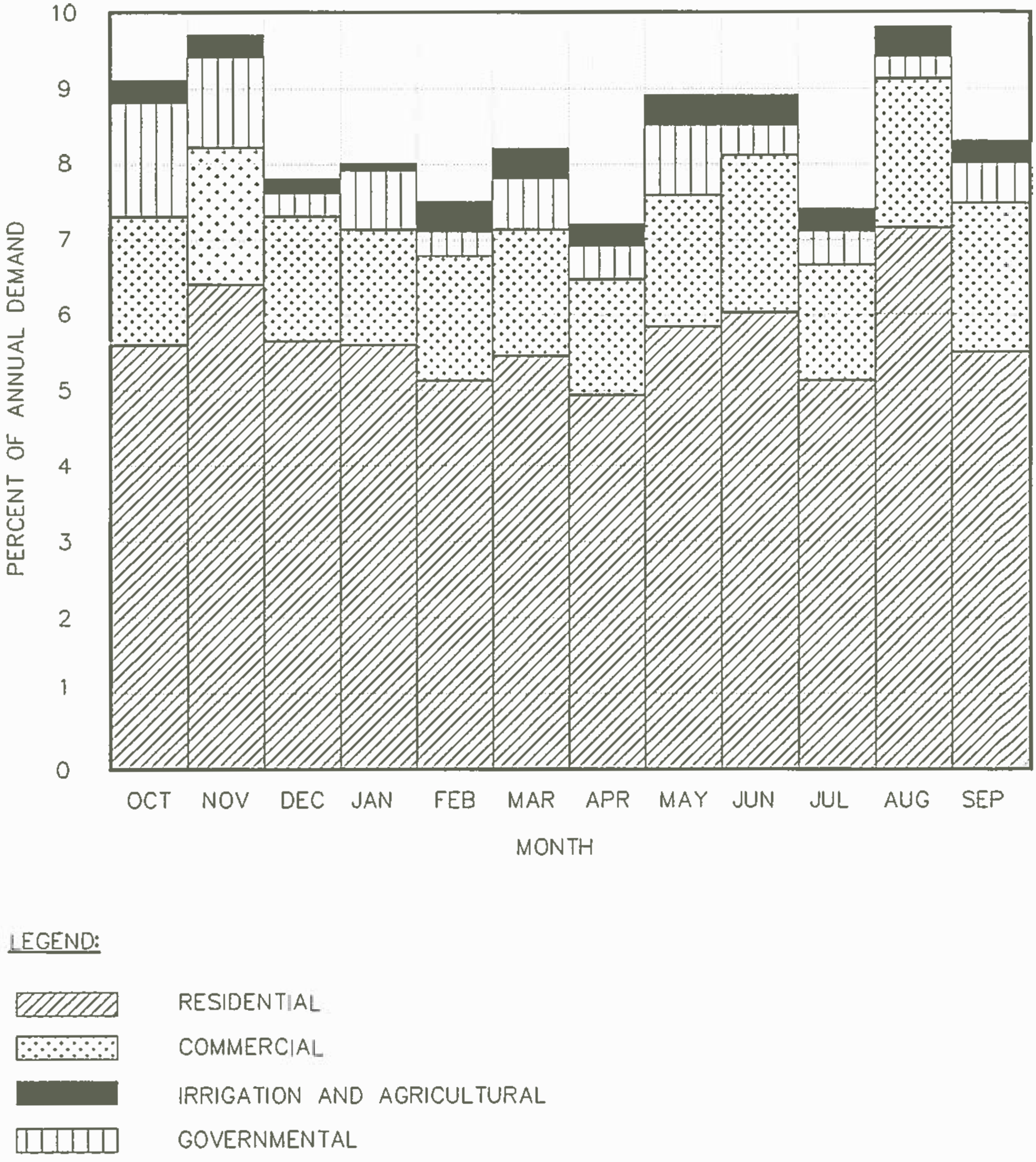
TABLE 5-5
ISLAND-WIDE CIVILIAN WATER USE CHARACTERISTICS

October 1988 Through September 1989

Month	Res	Comm	GovGuam	Agr	Irr	Total
Oct	300203	96619	80161	6716	6521	490220
Nov	341984	101414	60756	7165	9542	520861
Dec	307008	88087	3212	7441	2110	407858
Jan	299192	90526	17334	9126	6672	422850
Feb	274289	90638	18406	8201	7475	399009
Mar	291376	92964	31456	10810	11233	437839
Apr	249386	90749	19478	7277	8279	375169
May	311149	100974	40717	11498	12679	477017
Jun	320915	114187	19217	8632	9816	472767
Jul	274331	81344	25736	4783	5908	392102
Aug	379355	109415	23206	8351	6044	526371
Sep	292801	109779	23568	2110	3016	431274
TOTAL	**3,641,989**	**1,166,696**	**363,247**	**92,110**	**89,295**	**5,353,337**
PERCENT OF TOTAL	68.0	21.8	6.8	1.7	1.7	100
MONTHLY AVERAGE	303,499	97,225	30,271	7,676	7,441	446,111
DAILY AVERAGE	9,978	3,196	995	252	245	14,667
DAILY AVERAGE GPM	6,929	2,220	691	175	170	10,185

Source: PUAG Water Meter Records

NOTE: Unit = 1000 gallons except where otherwise noted



COMPILED FROM PUAG
WATER RECORDS FROM
OCTOBER 1988 THROUGH
SEPTEMBER 1989

FIGURE 5-2

WATER DEMANDS BY MONTH

The monthly water demand characteristics show that the highest user group is residential, comprising 68 percent of the overall total water demand for the Island. Second is the commercial classification which accounts for just under 22 percent of the total. The remaining three user types, governmental, agricultural, and irrigation taken together account for just over 10 percent of the total.

Several factors influence water demands in the various regions of Guam including localized climatic conditions, the character of the community or village served, the relative amount of commercial and agricultural development and the availability of an adequate water supply. Table 5-6 illustrates differences in total water usage and in water use by customer category between service areas. The regional service areas considered were those shown on Figure 3-11. The data in Table 5-6 are presented graphically in Figure 5-3. The central regional service area, designated "B", includes the majority of Guam's hotel and commercial enterprises and accounts for a large percentage of the Island's civilian population. Service Area "B" utilizes the majority of PUAG's water, accounting for 8.5 MGD or about 58 percent of the total metered water consumption on the Island. Service Area "A," including Yigo and Dededo, is second highest and is responsible for over 21 percent of PUAG's water use. Service Areas "C" and "D" taken together account for slightly over 20 percent of the total.

TABLE 5-6
WATER USE BY REGIONAL WATER SERVICE AREAS

October 1988 through September 1989

Average Daily Water Use (MGD)

Type of Customer	Service Area "A"	Service Area "B"	Service Area "C"	Service Area "D"	Total	Percent
Residential	2.81	4.84	1.07	1.26	9.98	68.0
Commercial	0.15	2.80	0.14	0.11	3.20	21.8
Governmental	0.04	0.80	0.08	0.08	1.00	6.8
Irrigation	0.08	0.06	0.02	0.09	0.25	1.7
Agricultural	0.09	0.04	0.04	0.07	0.24	1.7
TOTAL	3.17	8.54	1.35	1.61	14.67	100.0
PERCENT OF TOTAL	21.50	58.30	9.20	11.10	100.00	

Source: PUAG, Meter Consumption Records, FY88

Note: See Figure 3-11 for delineation of service areas.
Distribution between service areas is estimated from PUAG data.

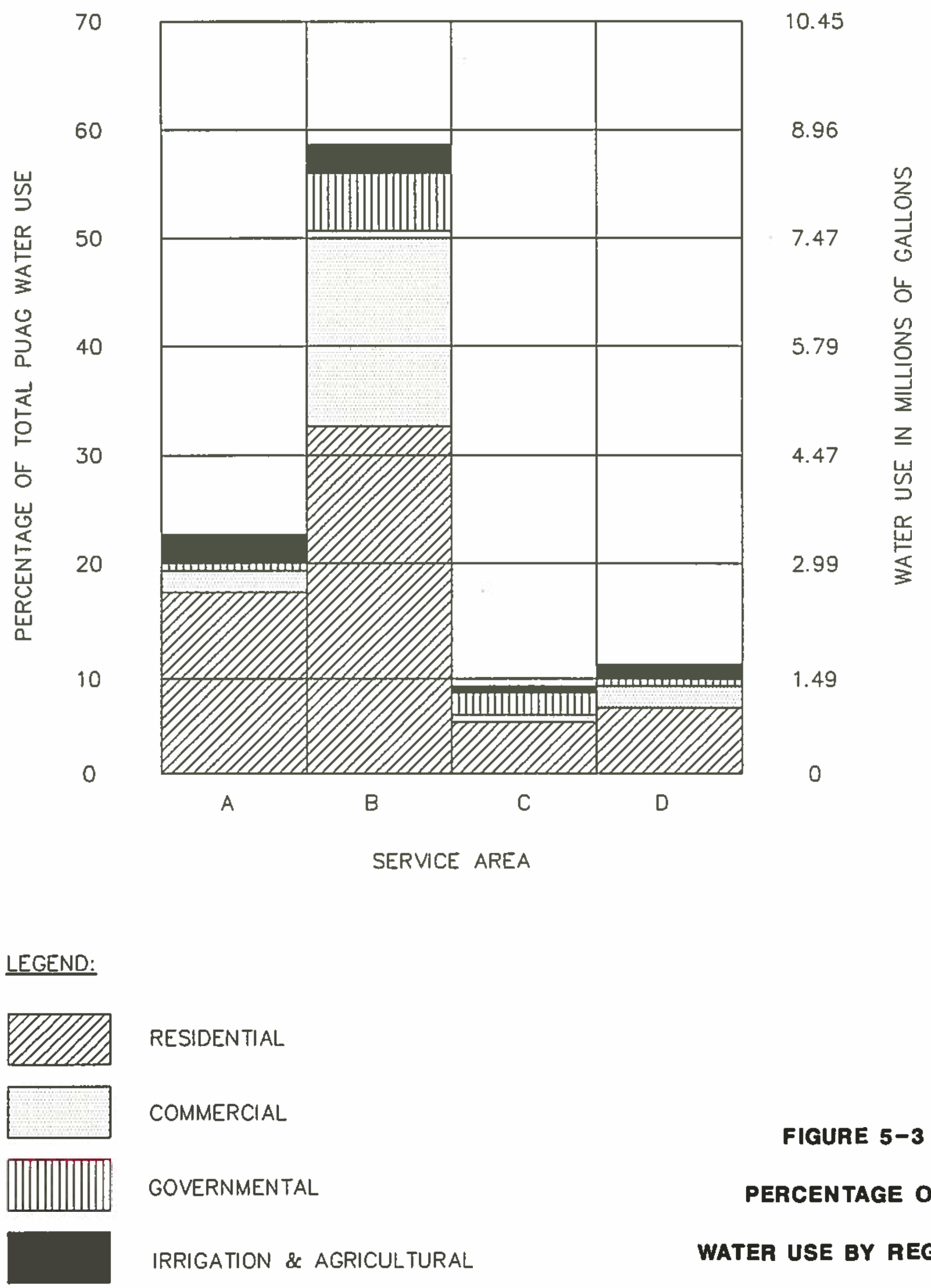


FIGURE 5-3

PERCENTAGE OF

WATER USE BY REGIONAL

WATER SERVICE AREA

Unaccounted-for Water

Unaccounted-for water is by definition the difference between water production and water sales. It is extremely important to minimize this non-revenue-producing "demand" to prevent unnecessary and premature depletion of the water supply, to reduce operating costs, and to reduce power demands. Additionally, from a capacity standpoint, such measures stretch the useful life of existing facilities and thus permit deferment of expenditures of capital for expansion of water supply and treatment facilities. There are many sources of unsold or unaccounted-for water including:

- Leaking water main piping and joints
- Leaking service piping and appurtenances
- Leaking fire hydrants
- Leaking valves
- Leaks in customer system
- Meter underregistration or malfunction
- Illegal connections and/or unmetered use
- Fire fighting requirements
- Pipeline flushing

According to the American Water Works Association (AWWA), the unaccounted-for water or unsold water component typically ranges from as little as 5 percent to as much as 35 percent depending upon characteristics of the particular water system. The AWWA also states "a fair average of unaccounted-for water might be 10 to 20 percent for fully metered systems having a good maintenance program and average conditions of service."

Based on data supplied by PUAG, water demand versus water production relationships were evaluated by comparing PUAG's total water production, including water purchased from the military, to PUAG's meter records. The comparison, presented in Table 5-7, indicates that unaccounted-for water for fiscal year 1989 averaged approximately 290 million gallons per month (equivalent to 9.5 MGD) and represented 39 percent of the total water production. This is consistent with PUAG data which indicates a yearly level of unaccounted-for water within the 40 to 50 percent range for the past decade, as shown in Table 5-8.

TABLE 5-7
METERED WATER DEMAND VERSUS WATER PRODUCTION

Month	Total Production	Metered Sales	Unsold Water	Percent Unsold Water
Oct 88	722.658	490.220	232.44	32.16
Nov 88	715.854	520.861	194.99	27.24
Dec 88	702.225	407.858	294.37	41.92
Jan 89	763.085	422.849	340.24	44.59
Feb 89	726.643	399.009	327.63	45.09
Mar 89	738.276	437.839	300.44	40.69
Apr 89	768.553	375.169	393.38	51.19
May 89	743.068	477.017	266.05	35.80
Jun 89	724.461	472.767	251.69	34.74
Jul 89	752.428	392.102	360.33	47.89
Aug 89	755.531	526.371	229.16	30.33
Sep 89	721.329	431.274	290.05	40.21
TOTAL	**8834.111**	**5353.336**	**3480.78**	**39.4**
AVERAGE	736.176	446.111	290.06	39.32

Source: PUAG, Total Production & Purchases of Water, FY 89
PUAG, Meter Consumption Records, FY 89

NOTE: (1) Production in millions of gallons
(2) Production is based on PUAG estimates

A leak-detection and meter repair program initiated in 1989 and completed in February, 1990, is expected to significantly reduce the amount of unaccounted-for water. PUAG estimates that approximately 6 MGD has been retrieved through the program. The results are not reflected in the latest PUAG records used for this report, as the project was completed only recently. However, PUAG data over the next several years should reflect these improvements in the water system. PUAG's objective for the leak detection program is to reduce unaccounted for water to approximately 15-20 percent.

The importance of routinely conducting leakage surveys and effective monitoring of unaccounted-for water cannot be overemphasized. Guam, because of its limited water resources, cannot afford unnecessary water losses or wasteful energy use to maintain such losses.

Per Capita Use

The average volume of water utilized by one person in one day is commonly referred to as the per capita use and is expressed in gallons per capita per day (gpcd). The per capita use can be based on the metered sales for the residential user group alone, a combination of user groups, or the sum of all the user groups. For the purpose of this plan, the per capita rate is based on the sum of all user groups, except hotels, applied to the total civilian, non-tourist population.

In Guam the per capita use varies throughout the Island, largely with the degree and type of supportive services within the community. As an example, Regional Service Area "B", where the majority of the Island's hotel and commercial activities are located, has a much higher per capita use than the northern or southern areas. To evaluate the variation in per capita use, consumption values were calculated for each of the four regional service areas. The estimated 1989 civilian, non-tourist population, interpolated from Table 3-11, and the Island-wide metered PUAG water use, as shown in Table 5-6, were utilized to calculate present per capita use for each service area. Results are shown in Table 5-9, and do not include unaccounted-for water or hotel use. As noted, Service Area "B" has the highest per capita water use, approximately 140 gpcd. The second and third highest are service Areas "C" and "D", with per capita use rates of about 135 and 120 gpcd, respectively. Service Area "A," which encompasses the Dededo and Yigo area, has the lowest of the four rates at approximately 100 gpcd. The Island-wide average is about 125 gpcd, an approximate 8 percent increase above the value of 115 projected for the year 1990 in the original master plan. One cause for the increase in the per capita use rate may be the implementation of capital improvements in the water system suggested in the original master plan, making more water available to a larger number of island residents. Another possibility is that as a result of a meter inspection program executed by PUAG, the water use is recorded more accurately than previously, resulting in less unmetered water use. The implementation of a better system of record-keeping may also have been a contributing factor.

TABLE 5-8
UNACCOUNTED-FOR-WATER

Year	% Unaccounted-for Water
1977	30
1980	56
1981	53
1982	45
1983	46
1984	49
1985	47
1986	46
1987	41
1988	39
1989	39
	Average = 45%

Source: PUAG, Metered Consumption Records, FY1980-1989

TABLE 5-9
EXISTING PUAG PER CAPITA USE

	Water Use[1] (MGD)	1989 Population	Per Capita[2] Use (gpcd)
Service Area "A"	3.17	31930	100
Service Area "B"	7.59	55098	140
Service Area "C"	1.33	9902	135
Service Area "D"	1.58	13207	120
TOTAL OR AVERAGE	13.67	110137	125

(1) Water use data for October 1987 through September 1988. Water use data does not include hotel water use or unaccounted-for-water.
(2) Per capita use is rounded to the nearest 5 gpcd.

Several factors affect the future per capita use rates, including water conservation practices, improved water system facilities, and increased standard of living. Increased public awareness of water conservation methods and realistic water service rates which reflect the true cost of water production can effectively reduce water wastage and, in turn, reduce the per capita use.

In recent years, throughout the United States, numerous communities have launched extensive water conservation programs. Many areas of the country and, in particular, California have been forced to adopt water conservation measures as a result of prolonged drought. Other communities choose to exercise water conservation programs in lieu of constructing costly water supply improvements.

One example of a community which has effectively utilized a water conservation program to reduce consumption during a period of drought is the East Bay Municipal Utility District (EBMUD) of California. EBMUD, located on the east side of San Francisco Bay, serves an area of over 300 square miles having a population of 1.2 million. By September 1987, storage levels in reservoirs providing the source of EBMUD's water had dropped to 30 percent below normal. A second dry year, in which precipitation amounted to only 56 percent of normal, further reduced total storage to 48 percent of normal levels.

In March 1987, EBMUD began efforts to limit water usage. A voluntary conservation program with a goal of 12 percent reduction in water use was adopted for the June-September period of that year. However, the result of the voluntary program was only a 3.5 percent reduction. Therefore, a more rigorous conservation program was enacted for the following year. To provide a financial incentive to all customers, an inclining-block rate schedule was established that progressively increased the cost of water above a base allotment of 200 gpd per household. The primary target group was single-family residential customers and irrigation customers, whose combined usage accounted for approximately 77 percent of the total peak summer consumption.

At the same time, an extensive advertising campaign was conducted to inform the public of the importance and methods of water conservation, and conservation education programs in local schools were expanded. A drought ordinance was passed, containing the following provisions:

1. Required hose shut-off nozzles for car washing purposes;
2. No placement of new turf on lawns, and only plants requiring minimal amounts of water to be planted;
3. Mandatory drought-compliance agreement for new service connections;
4. The water district would not be expanded beyond it's ultimate service boundary;
5. Establishment of a patrol to recognize violations;
6. Required installation of flow-restricting devices for repeat violators.

More than 50,000 conservation kits containing flow reducing devices such as low-flow shower heads were distributed free of charge. A subsequent survey of recipients indicated that 90 percent of the conservation devices had been installed.

The conservation measures enacted by EBMUD and it's clientele caused the actual consumption during the summers of 1988 and 1989 to be reduced by 30 percent and 25 percent respectively. This reduction exceeded the objective of 25 percent and 15 percent, enabling the reservoir storage levels to rise to more normal levels. The 15 percent drought emergency was called off in late summer, 1989.

One result of the drought crisis is that the majority of the customers found that reducing their daily water consumption could be done with surprisingly little sacrifice. Although long range impacts have yet to be determined, it is almost certain that one result of the drought will be a permanent reduction in per capita consumption in California.

More and more water utility agencies across the United States and world-wide are enacting water conservation legislation and formulating this type of program to extend the life of their potable water resources. In light of Guam's limited water supply, it is critical that the Government of Guam establish a water conservation program in the immediate future. There are numerous methods and approaches to water conservation, all of which have definite advantages and disadvantages. In order to enact a successful program, all the various economic and social factors must be carefully evaluated with extensive public involvement. In addition, the program must be equitable and strongly enforced.

Currently the rates paid to PUAG by water customers do not nearly reflect the actual cost of water production. One method of encouraging the public to conserve water resources would be to increase the rate gradually to cover that cost; for, as shown in the EBMUD example earlier, a higher price for water is a strong incentive for reduced consumption. The key factor is the term *gradually*, as the people of Guam are not accustomed to having to pay for the full cost of water service. As seen in 1987, when PUAG abruptly instituted rates reflecting the true cost of water service, a large and sudden jump in rates can create a very powerful negative public response. Translated into political action, this strong response may result in elimination of the rates and their conservationist effects.

Several other means of reducing water consumption on the Island of Guam concern the tourist industry and hotels in particular. Based on it's field investigations and PUAG records, the TAWSA's *Tumon Bay Infrastructure Study* (1989) determined a typical hotel consumption rate of approximately 450 gallons per room per day (gprd). In many hotels a significant fraction of this consumption is due to "water-cooled" air conditioning systems. A switch from the more commonly-used "water-cooled" air conditioning systems to the "air-cooled" type could reduce a hotel's water consumption by an estimated 33 percent, decreasing the hotel unit consumption rate from 450 to approximately 300 gprd. Another candidate for conservation, golf courses require about 0.13 million gallons of water per week per course to irrigate only the greens. The use of treated wastewater for this purpose would contribute to a reduction in the Island's water demand while providing an accepted method of treated wastewater disposal.

As will be discussed in Chapter IX, "Water System Improvements," several capital improvements are proposed for the future. Some of the improvements may result in increased consumption when the water supply improves. Such increases are often temporary in areas where system improvements have been made. In the past, it has been common practice to escalate per capita use values employed in making projections upward with time; however recent trends have been in the opposite direction, reflecting the national concern about conservation of natural resources and the country's very real energy problems. Therefore, for water master plan design purposes, it is anticipated that the base per capita use, not including hotel use or unaccounted-for water, will remain close to the following present rates:

Water Service Area "A"	100 gpcd
Water Service Area "B"	140 gpcd
Water Service Area "C"	135 gpcd
Water Service Area "D"	120 gpcd

Note: Rates are rounded to the nearest 5 gpcd.

The impacts of possible variations in the foregoing rates are discussed in subsequent sections of this report.

Future Civilian Water Requirements

The projected water requirements for general water use have been based on anticipated per capita use rates and then applied to the projected populations as presented in the *Growth Trends Analysis*, prepared for Barrett Consulting Group by Wil Chee Planning. The Island's future agricultural-irrigation requirements and water demands for the proposed Commercial Port expansion and Industrial Park complex have been included in the "General Civilian Demand" category, as the individual requirement for these two groups is not significant relative to the Island's overall water demand.

Hotel water requirements have the greatest single projected impact on islandwide water demand. Consequently hotel requirements have been evaluated separately. In addition, this category bears no direct relationship to the natural population trends of the island. The following sections provide discussion and rationale for the development of the water requirements for each of the four water use groups.

General Civilian Water Demands - As discussed earlier in the chapter, PUAG categorizes customers into five groups, namely, residential, commercial, governmental, agricultural, and irrigation. These five user groups comprise the General Civilian Water Demand category. A subcategory, hotel use, has evolved from the commercial category as the primary demand force affecting future water consumption. For purposes of future projections, hotel use will be considered in this report as a separate category within the General Civilian Water Demand. To estimate the future average daily water demands for the General Civilian user group, the anticipated per capita demands listed above were applied to the population projections shown in Table 3-14, while the typical hotel consumption rate of 450 gpd was applied to future hotel unit projections under the slowed growth rate scenario shown in Table 3-10.

Water demand variations employed in making projections were determined by the following ratios:

Demands	Ratio*
Average Day (in Maximum Month)	1.20
Maximum Day	1.50
Peak Hour	3.00

*Ratio is to average daily demand.

The ratio used for the average day in the maximum month is a close approximation of the average demand during the actual maximum month, August, that occurred during the 1988-1989 period. As is usually the case with small communities, no data was available for estimating maximum daily or peak hourly demands so ratios were developed from experience with other communities. The resulting General Civilian water demands projected by service areas from 1990 to the year 2010 are determined by combining the hotel and general population demands, as shown in Table 5-10.

As described in Chapter 3, the current high rate of hotel growth recently experienced on Guam is expected to begin slowing markedly. The slackening in rate is expected to be most pronounced with the completion of hotel units now in the design and permitting process which is anticipated to occur around the year 1993. Because the year 1993 represents a significant breakpoint in hotel growth rates (and consequently water consumption rates) it has been applied in Table 5-10, and subsequent tables and figures of this chapter, as a more useful benchmark year between 1990 and 2000 than the incrementally uniform year 1995. Water consumption values for the year 1995 in Table 5-10, and subsequent tables and figures, may be derived as a straight-line value between those for years 1993 and 2000.

As indicated earlier in the "Water Demands" Section, PUAG's current Island-wide "unaccounted-for" water amounted to approximately 39 percent of the total 1989 water demand. This is a substantial water loss considering that a 10 to 20 percent unaccounted-for water rate is typical for a system in good repair. PUAG estimates that through the recently completed leak detection and meter repair program, approximately 6 MGD has been recovered. However, additional reduction should be possible through the establishment of on-going leak detection/prevention and meter inspection programs. For the purpose of

TABLE 5-10
PROJECTED CIVILIAN WATER DEMANDS BY WATER SERVICE AREAS

	AREA A					AREA B					AREA C				
	1990	1993	2000	2005	2010	1990	1993	2000	2005	2010	1990	1993	2000	2005	2010
No. Hotel Rooms	3	1,980	2,610	3,060	3,510	4,087	17,836	24,880	28,140	31,330	70	1,670	1,980	2,130	2,280
Per Room Use (gprd)	450	450	450	450	450	450	450	450	450	450	450	450	450	450	450
Avg Annual Hotel Demand (MGD)	0.0	0.9	1.2	1.4	1.6	1.8	8.0	11.2	12.7	14.1	0.0	0.8	0.9	1.0	1.0
Population, General	31,900	39,000	64,600	76,000	87,500	55,000	99,600	127,800	149,800	171,600	9,900	12,300	13,100	15,500	17,000
Per Capita Use (gpcd)	100	100	100	100	100	140	140	140	140	140	135	135	135	135	135
Avg Annual General Demand (MGD)	3	4	6.5	7.6	8.8	7.7	14	17.9	21	24	1.3	1.7	1.8	2.1	2.3
Total Avg Annual Demand (MGD)	3	5	7.7	9.0	10.4	9.5	22	29.1	33.7	38.1	1.3	2.5	2.7	3.1	3.3
Percent Unaccounted-for Water	39	30	25	20	15	39	31	25	20	15	39	30	25	20	15
Unaccounted-for Water (MGD)	2	2	3	2	2	6	9	10	8	6	1	2	1	1	1
Avg Daily Production (MGD)	5	7	10	11	12	16	32	39	42	44	2	4	4	4	4
Avg Day in Maximum Month Production (MGD)	6	8	12	13	14	19	38	47	50	53	2	5	5	5	5
Maximum Daily Production (MGD)	8	10	15	16	18	24	48	58	63	67	3	6	6	6	6
Peak Hourly Demand (MGD)	15	21	30	33	36	48	96	117	125	133	6	12	12	12	12
Annual Production (MG)	1,800	2,600	3,600	4,000	4,400	5,800	11,700	14,200	15,300	16,100	730	1,500	1,500	1,500	1,500

	AREA D					TOTAL - ALL AREAS				
	1990	1993	2000	2005	2010	1990	1993	2000	2005	2010
No. Hotel Rooms	128	1,768	4,290	7,970	11,640	4,288	23,254	33,750	41,300	48,760
Per Room Use (gprd)	450	450	450	450	450	450	450	450	450	450
Avg Annual Hotel Demand (MGD)	0.1	0.8	1.9	3.6	5.2	1.9	10.5	15.2	18.6	21.9
Population, General	13,200	21,300	35,100	47,600	60,100	110,000	172,200	240,600	288,900	336,200
Per Capita Use (gpcd)	120	120	120	120	120	---	---	---	---	---
Avg Annual General Demand (MGD)	1.6	2.6	4.2	5.7	7.2	13.6	22.3	30.4	36.4	42.3
Total Avg Annual Demand (MGD)	1.7	3.4	6.1	9.3	12.4	15.5	32.8	45.6	55.1	64.2
Percent Unaccounted-for-Water	39	30	25	20	15	39	30	25	20	15
Unaccounted-for Water (MGD)	1	2	2	3	3	10	14	15	14	11
Avg Daily Production (MGD)	3	5	8	12	15	26	48	61	69	75
Avg Day in Maximum Month Production (MGD)	4	6	10	14	18	31	57	74	82	90
Maximum Daily Production (MGD)	4	7	12	18	22	39	71	91	103	113
Peak Hourly Demand (MGD)	9	15	24	36	45	78	144	183	206	225
Annual Production (MG)	1,100	1,800	2,900	4,400	5,500	9,400	17,600	22,200	25,200	27,500

Note: Unaccounted-for water and water production values have been rounded off to the nearest full MGD.

projecting future water production needs, unaccounted-for water is predicted to decrease to 15 percent by the year 2010. Figure 5-4 graphically illustrates the resulting increase in water production required if this goal is not accomplished.

Commercial Port/Industrial Park Water Demands - For some time the Government of Guam has been giving strong consideration to the expansion of the existing commercial port, and recently has begun action on that expansion. To better evaluate the feasibility of such a development, the Guam Economic Development Authority (GEDA) performed a study summarized in a report entitled *Program Development of Apra Harbor*, dated October 1977. To serve as a guide to port development, a GovGuam Task Force prepared an Economic and Land-Use Plan for Apra Harbor which was completed in August, 1979. More recently, the *New Master Plan for the Commercial Port of Guam*, dated June 1990, was prepared for the Port Authority of Guam (PAG) by TAMS Consultants, Inc. It's purpose was two-fold: to assist the PAG in dealing with the numerous responsibilities resulting from the increased use of the port over the past decade and to provide guidance for future expansion of the port.

According to the *New Master Plan for the Commercial Port of Guam*, the volume of goods passing through the port has nearly doubled in the last decade. In addition, the use of the port for passenger vessels and recreational crafts is increasing due to the boom in the tourist industry. This increase in activity is expected to continue into the future.

In an effort to accommodate the growing port needs, the Government has, in the period since 1979, acquired several tracts of land from the Navy for the use by the Port Authority of Guam. The tracts total over 400 acres, although one tract of approximately 200 acres is comprised largely of environmentally sensitive areas and shallow inlets that cannot be developed. The Government has already taken a first step in the proposed port growth with the recent expansion of the Container Yard from 15 to 26.5 acres. If the remainder of the land is to be developed to further expand the commercial port, an increase in water usage will result.

Apra Harbor is one of Guam's key natural resources and, if properly developed, could serve all types of vessels, including cargo ships and large oil tankers, and thus significantly contribute to the Island's economic growth. However, in the past, two major constraints had restricted the Government of Guam from expanding the current commercial port lands. The

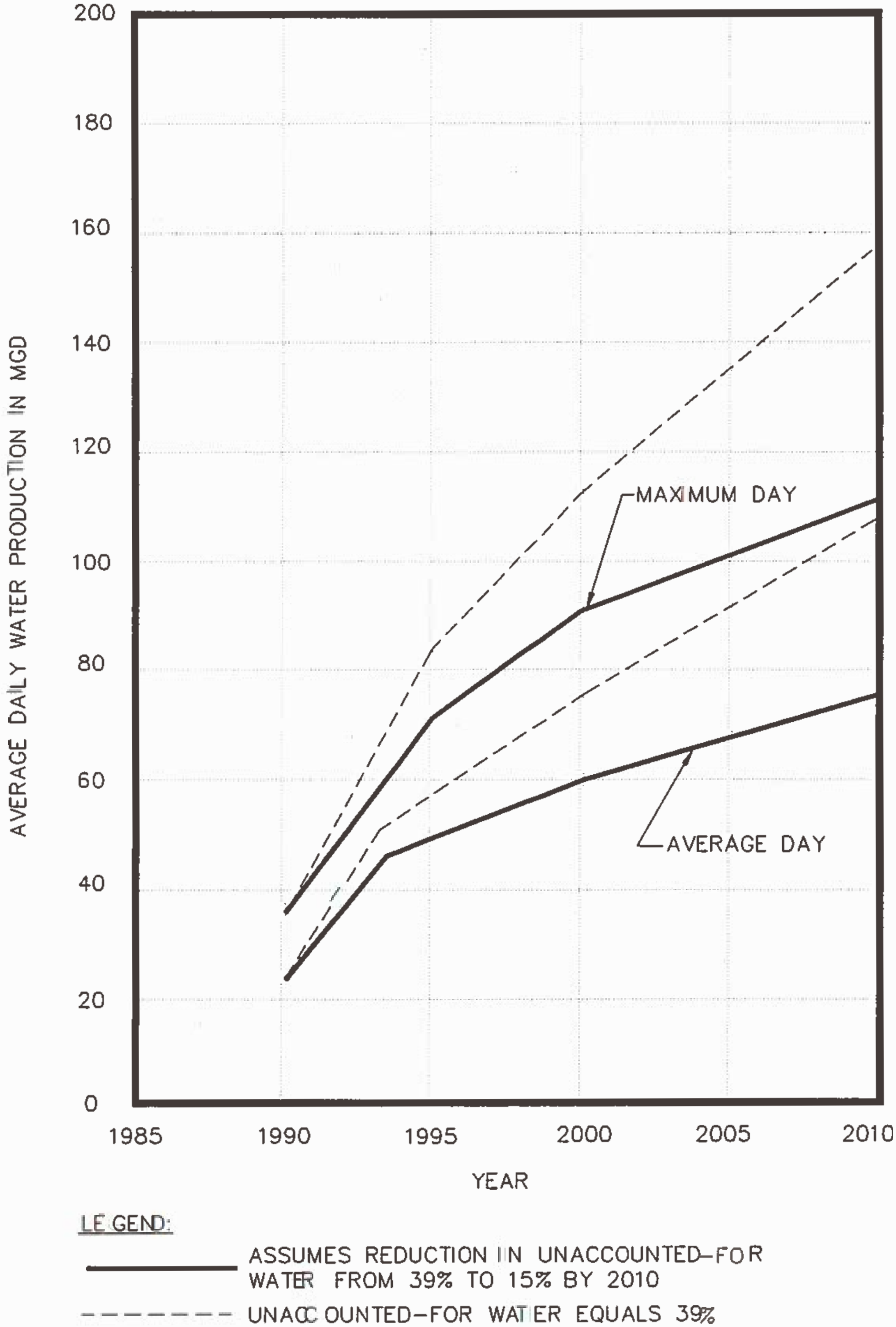


FIGURE 5-4

GENERAL CIVILIAN WATER DEMAND

first was the fact that the U.S. Navy owned the great majority of the land surrounding Apra Harbor, the exception being the Government of Guam's commercial port. The second has been the Navy's ammunition loading and unloading wharf along the breakwater at the western end of Cabras Island which posed potential dangers associated with the munitions handling operation.

The first constraint has been eliminated with the previously-mentioned acquisition of Navy land by the Government; the second by the relocation of the Navy's ammunition wharf to Orote Point.

According to the Port's 1990 Master Plan, port expansion plans include a multi-purpose commercial port/industrial park development with a commercial port, fishing port, passenger complex and industrial park activities. The land-use for the port area and the land areas for each use, proposed by the Port's 1990 Master Plan, are shown in Table 5-11.

It is difficult to accurately predict the future commercial port/industrial park water requirements without knowing the type and extent of industrial and commercial activities that will be located in the complex. Water use data for the current commercial port complex and projected workforce populations were utilized by the Port Authority of Guam in their *Commercial Port of Guam Master Plan* to estimate the future water needs.

The Port Master Plan estimates the current daytime population of the Port to be approximately 1,050. Expected continued growth of the Port and planned development of the Industrial Park could increase this value to 2,450 by the year 2010.

In developing projected water consumption figures, the *Commercial Port of Guam Master Plan* estimates an average daily use of 35 gpd per worker, and 5 gpd per cruise passenger. Industrial process water was determined by applying a figure of 75 gpd per industrial worker, and water deliveries to vessels were estimated to average 60,000 gpd by 2010. Projections of total daily consumption for the years 2000 and 2010 are 150,000 gpd and 265,000 gpd, respectively. These water demand figures are relatively small with respect to the total Island use, and therefore have not been considered as a separate demand but have been included in the General Civilian Demand category.

TABLE 5-11
PROJECTED LAND USE REQUIREMENTS
FOR COMMERCIAL PORT/INDUSTRIAL PARK COMPLEX

Land-Use Classification	Location	Estimated Land Area (Acres)
Commercial Port Facilities Examples: Container handling Administration buildings Docking space Cold storage Warehousing Fire station	Cabras Island	50.5
Water-Dependent Port-Related Industry Examples: Net repair Aquaculture ponds	Drydock Point	42
Port-Related Light Industry Examples: Warehousing	Cabras Island	65
Industrial Park Industry Examples: Fuel storage Warehousing Manufacturing	Marine Drive	25.5
Power Production Facilities Examples: Cabras Power Plant Piti Power Plant OTEC site	Cabras Island and Marine Drive	20
Waste-To-Energy Plant	Drydock Point	25
TOTAL		**228**

Note: Does not include land and water areas for recreation, conservation of wetlands and conservation of fishery resources (coral reefs and tidal flats).

Source: New Master Plan for the Commercial Port of Guam, June 1990

Hotel Water Demands - As mentioned previously, Guam's economy has witnessed a rapid growth in recent years due to the continued expansion of the tourist industry. This boom in tourism has resulted in a vast increase in the number of hotels and related population as discussed in Chapter III.

The typical water consumption rate for hotels on Guam has been calculated to be 450 gallons per room per day (gprd) by the *Tumon Bay Infrastructure Study*. As previously mentioned, one factor which contributes to this high demand is air conditioning. Most hotels use "water-cooled" air conditioning systems, which utilize water in a way that allows it to continuously evaporate during the process. The water demand of hotels using "air-cooled" systems, in which no water is able to evaporate, is typically reduced to approximately 300 gpd/unit, a reduction in usage of about 33 percent. If all hotels were to utilize the "air-cooled" system, the result could be a potential savings of as much as 10 MGD in the year 2010 for the projected number of hotel units.

Another water use related to the resort industry is the irrigation of golf courses. Currently there are five 18-hole courses available for play on the island, with another eleven either under construction or planned for the near future. One estimate of the irrigation water required for these golf courses can be made using the method shown in the Agriculture section of this chapter. Assuming only the course greens will be irrigated and an average green size of 5,000 square feet, the minimum water supply required is 18,000 gallons per day per course, or 0.29 million gallons per day total for the 16 courses island-wide.

One policy presently being developed to address this issue deals with requiring the golf courses to irrigate with only reclaimed, treated water from the wastewater treatment plants serving the resorts.

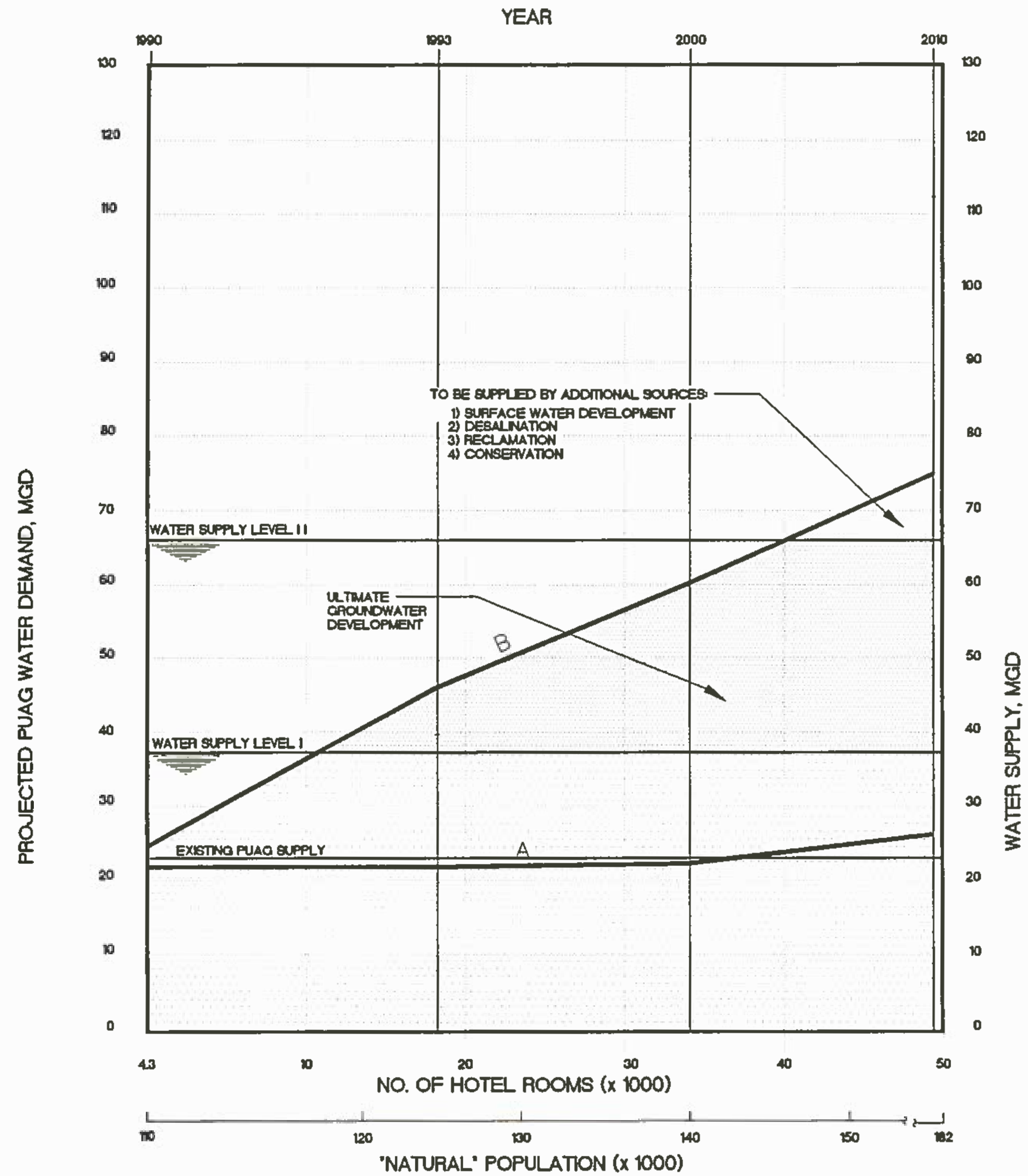
A related concern, which must be addressed by government regulatory agencies, involves the types and applications of fertilizers and pesticides used in agriculture and golf course maintenance. As discussed in Chapter VII, studies have shown that certain agricultural chemicals leach into the groundwater over a period of time, with the potential to contaminate the aquifer. If this leaching occurs to the sole source Northern Groundwater Lens, the outcome could be disastrous. Strict guidelines must be in place, with close monitoring for compliance and heavy penalties for abuse, if contamination is to be averted.

Figure 5-5 demonstrates the effect of tourist industry-related water demands on Guam's total water demand and the relationship of that total water demand to supply over the 20 year period from 1990 to 2010. The supply estimates are based on the most comprehensive estimates of available groundwater to date, those made in 1982 by the *Northern Guam Lens Study (NGLS)*. The sustainable yield of the entire northern aquifer is estimated at 60 MGD, although the sustainable yield can be exceeded for limited periods of time without damaging the aquifer. Therefore, it is assumed here that well production can be temporarily increased by the maximum day demand factor of 1.5 to meet maximum day demands.

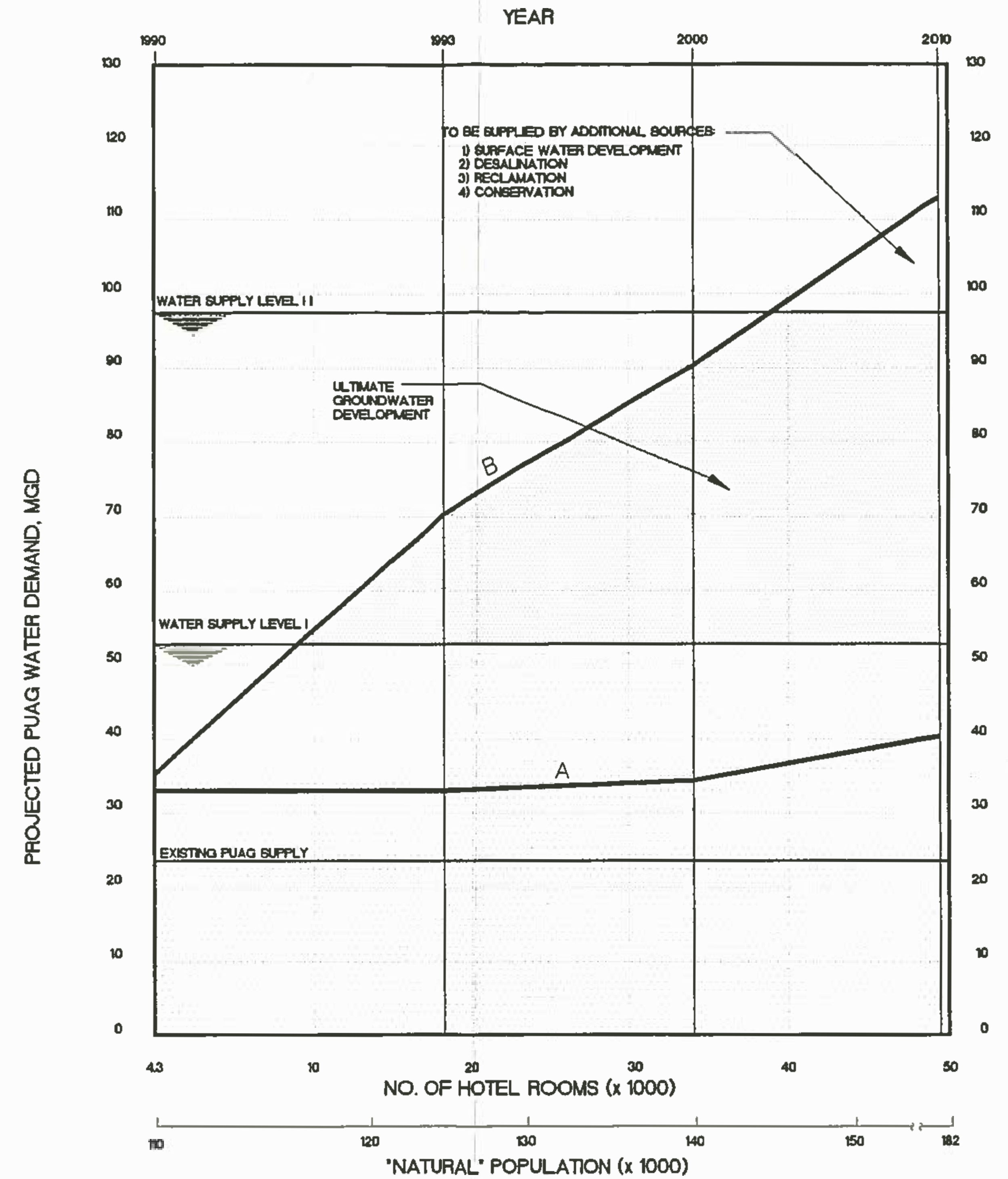
In both Figures 5-5A and 5-5B, Line A represents the demand projected for the natural growth of Guam's existing residential or non-tourist base population. Line B represents the demand of the projected base population plus demand due to hotels and hotel-induced residential population. Figure 5-5A compares the average day water supply with the average day water demand projected to the year 2010. The two horizontal lines on the graph represent two different supply scenarios for PUAG.

Water Supply Level I corresponds to 37 MGD and represents PUAG's existing water resources. These include existing purchases from the military, PUAG production and a conservative estimate, derived from the *NGLS*, of potential groundwater beneath civilian land. The area of the demand curve below Level I represents that portion of the demand that can be supplied by these existing sources.

Water Supply Level II, the 67 MGD supply scenario, assumes that an additional 30 MGD of sustainable groundwater yield can be obtained from the Northern Ground Water Lens, that the Ugum River intake provides 2 MGD upon completion, and that military purchases continue at the current level. This level represents maximum use of the entire sustainable yield of the Northern Ground Water Lens as estimated by the *NGLS*. However, as explained in Chapter VIII, the preliminary results of PUAG's recent ground water analysis program indicate that as much as 60 MGD sustainable yield may be available under civilian lands alone. The area of the demand curve between Levels I and II represents that portion of the demand that can be supplied by these sources.



a) AVERAGE DAY DEMAND



b) MAXIMUM DAY DEMAND

LEGEND

LINE A NATURAL GROWTH DEMAND WITH NO ADDITIONAL HOTELS
LINE B TOTAL DEMAND: NATURAL GROWTH PLUS HOTEL AND HOTEL-INDUCED POPULATION DEMAND.

NOTES:

1. WATER SUPPLY LEVEL I = TOTAL OF: EXISTING PUAG PRODUCTION; PURCHASES FROM MILITARY, POTENTIAL PRODUCTION FROM CIVILIAN GROUND WATER, AS DERIVED FROM THE NGLS; UGUM RIVER INTAKE.
2. WATER SUPPLY LEVEL II: ALL SOURCES FOR WSLI PLUS REMAINING GROUND WATER FROM NORTHERN LENS, AS DERIVED FROM THE NGLS.

MAXIMUM DAY DEMAND GRAPH ONLY.

MAXIMUM DAY SUPPLY LEVELS ASSUME THE GROUND WATER SUPPLY CAN BE STRESSED BY THE MAXIMUM DAY DEMAND FACTOR OF 1.5 ON A TEMPORARY BASIS.

FIGURE 5-5

WATER SUPPLY STATUS

In Figure 5-5A, Line A shows that during the 1990-2000 period the projected growth in average day demand due to natural increase in Guam's natural population is offset by the anticipated decrease brought about by a reduction in the unaccounted-for water rate resulting from leak detection surveys and repairs. After the year 2000 Line A begins to rise and reaches a rate of approximately 27 MGD in the year 2010. As indicated, this demand remains well below the total available supply of 37 MGD provided by groundwater sources currently accessible to PUAG plus the current allotment from the Fena Reservoir. As shown by Line B, when projected hotel and hotel-induced demands are added to those of the base population, the total average day supply of 37 MGD is exceeded before 1995. The deficit thus imposed may be met by development of additional groundwater sources until shortly after the year 2000. At that point, the total potential average day supply of 67 MGD, provided by all groundwater sources plus the Ugum intake and military purchases, would also be exceeded. A deficit of about 8 MGD would result by the year 2010. This deficit could be supplied by any one or a combination of several options, including conservation, reclamation, the development of additional surface water sources, and desalination. A discussion of these options as they pertain to the island of Guam is presented in Chapter VIII. The potential for the Northern lens to produce a sustainable yield greater than described in the *NGLS* is also discussed in Chapter VIII. The area of the demand curve above Level II represents that portion of the demand that must be supplied by one or more of these sources in addition to the maximum potential groundwater yield projected by the *NGLS*.

Figure 5-5B compares PUAG's existing and potential maximum day water supply with the maximum day water demand projected to the year 2010. The two horizontal lines indicate the same water supply scenarios for PUAG described for Figure 5-5A. However, it is assumed that with proper management, groundwater sustainable yields can be temporarily exceeded by a factor of 1.5 to meet maximum day demands.

Line A of Figure 5-5B shows that the projected growth in maximum day demand for Guam's existing non-tourist population reaches a level of approximately 40 MGD in the year 2010. As shown, this demand remains well below the total available supply of 52 MGD provided by groundwater resources currently accessible to PUAG plus the allotment from the Fena Reservoir. As shown by Line B, when projected hotel and hotel-induced demands are added to those of the base population, the total existing maximum day supply of 52 MGD is exceeded in the early 1990's. This deficit can be met by development of additional groundwater sources, in combination with the current water sources, until shortly after the year 2000. At that point, the total potential maximum day supply of 97 MGD as provided by all groundwater sources estimated by the *NGLS* plus the Ugum intake and military purchases would be exceeded. A deficit of about 16 MGD would result by the year 2010. As this deficit is beyond the maximum possible yield of the northern lens, it must be met through the same sources described for the average day scenario.

It must be stressed that this maximum day supply level provided by groundwater can be sustained for a limited time only without causing damage to the aquifer. If the maximum day supply must be provided on a long term basis, the deficiency must be provided by the other water sources described previously.

Agricultural Water Demands - An in-depth evaluation of potential agricultural water demands requires investigation of several factors including historical agricultural production, projected consumption of agricultural products, availability and location of agricultural lands, climatological conditions, type of crop production, and anticipated production characteristics including crop yield.

Prior to World War II, the Island of Guam was largely an agrarian society. The local production of food was sufficient and minimal importation of agricultural products was required. Agriculture was severely curtailed by World War II as Guam saw a dramatic change in its economy and lifestyle. Guam became militarily strategic with much of the agricultural lands converted into military bases. Many civilian jobs were created by the military presence. As a result of these sudden changes agricultural activities diminished and the Island quickly transformed from an agricultural to a military-based economy.

In the 1970's there was a renewed interest in redeveloping the agricultural industry with the hope that Guam could again return to self-sufficiency. This "return-to-the-land" movement brought about several studies to evaluate the feasibility of intensifying Guam's agricultural sector, including *Irrigation Feasibility Study for the Government of Guam, Guam Public Market Feasibility Study*, and the *Agricultural Development Plan for the Territory of Guam.*

During that period the Bureau of Planning (BOP) utilized available data to delineate the prime agricultural areas on Guam in their report entitled *Land Use Plan Guam, 1977-2000.*

Topography, soil data and climate were the criteria used by the BOP for designating lands well-suited to agriculture. Those lands that are level or gently sloping were considered well adapted for agriculture. Climate is important as rainfall is needed to support crop growth. Soil data is a basic element in the delineation of prime agricultural lands as the type of soil greatly influences both the variety of crop production and crop yields.

The work of the Bureau of Planning in the area of agriculture resulted in the establishment of Agricultural Districts as shown on Figure 5-6. An estimate of the land available for agricultural use in Guam is shown in Table 5-12. With the exception of some acreage in the Yigo area, all the Agricultural Districts are located in the southern villages of Guam. The main reason for the lack of designated agricultural lands in the north is the need to protect the northern groundwater aquifer from the polluting effects of fertilizers, herbicides and pesticides. The entire northern lens has been designated as a "sole source aquifer" by Federal EPA and the importance of protecting this valuable natural resource cannot be overemphasized.

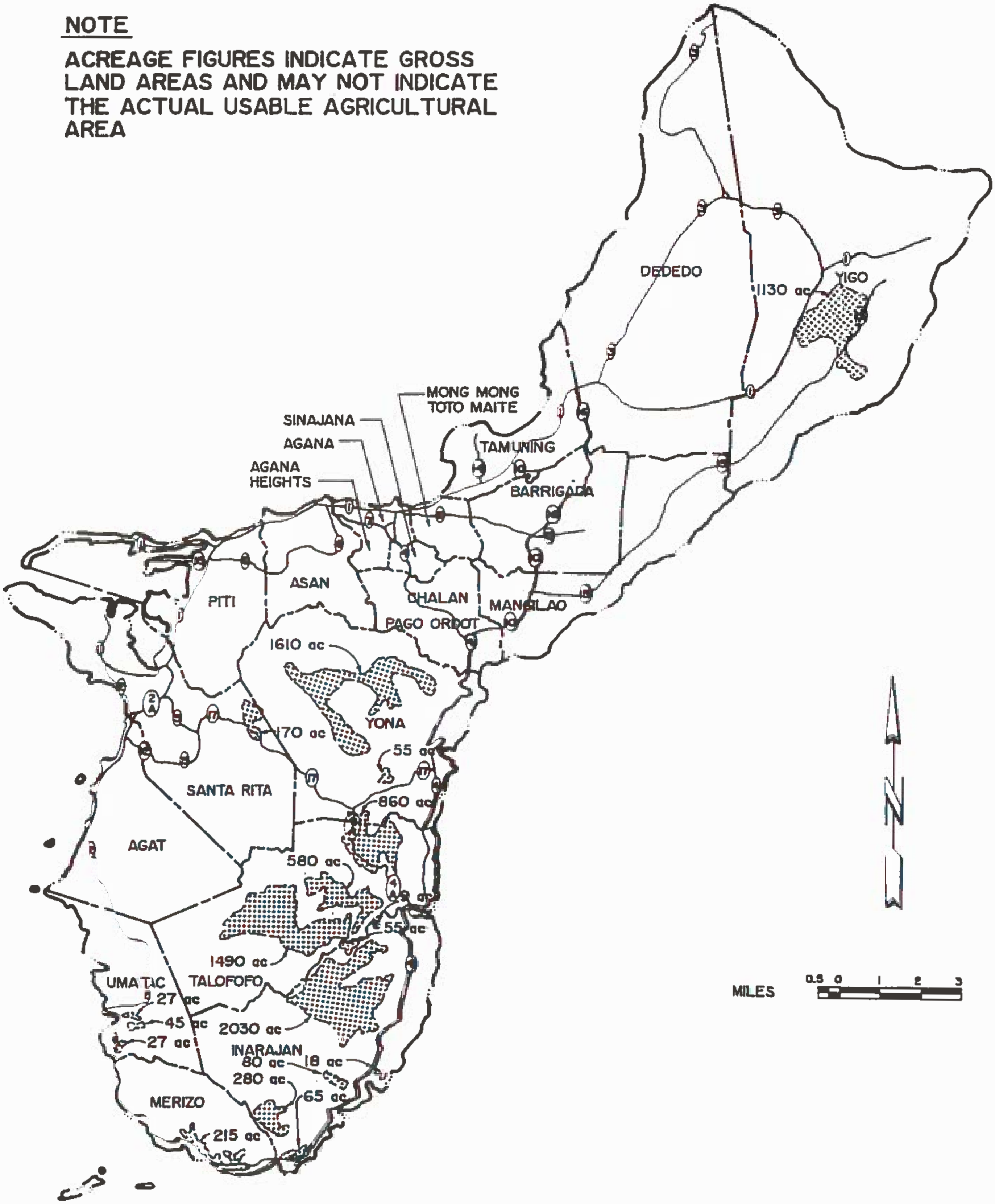
In their *Overall Economic Development Plan,* the Bureau of Planning outlined in some detail the procedures to be followed to develop additional irrigated lands on Guam. Constraints to be overcome in the areas of land development, operator/operations support, marketing, and distribution were carefully detailed. However, none of the programs recommended by the BOP in their report are currently being implemented.

Since the 1970's, the official focus of agricultural growth on Guam has shifted. Where previously, redevelopment of the agricultural industry to achieve self-sufficiency was a definite goal, today the government's objective appears to be that of "import-substitution". The purpose of this new plan is to reduce the Island's dependence on imports, reintroducing and expanding cultivation of native fruits and vegetables, and experimenting with new agricultural varieties.

The goal of "import-substitution", however, is not reflected in production, as evidenced by the fact that the Island now imports 90 percent of its food. Cultivated agricultural land is estimated by the Department of Agriculture and U.S. Soil Conservation Service (USCS) at between 500 and 800 acres. This is well below the projection of 1100 acres made by the original Water Facilities Master Plan for the year 1990 and comprises only about 10 percent of the total land suitable for agricultural use.

NOTE

ACREAGE FIGURES INDICATE GROSS LAND AREAS AND MAY NOT INDICATE THE ACTUAL USABLE AGRICULTURAL AREA



SCOURCE: LAND USE PLAN-GUAM, 1977-2000 BUREAU OF PLANNING, GOVERNMENT OF GUAM

FIGURE 5-6

AGRICULTURAL

LAND USE DISTRICTS

TABLE 5-12
LAND SUITABLE FOR AGRICULTURAL USE

	Land Area (acres)				
AREA	RIVER BOTTOMS	COASTAL UPLANDS	INLAND PLATEAUS AND HILLS	TOTAL	PERCENT OF TOTAL
Water Service Area "A"					
	-	1,100	-	1,100	19.4
SUB-TOTAL	-	1,110	-	1,100	19.4
Water Service Area "D"					
Yona	200	-	1,040	1,240	21.9
Talofofo	360	220	1,190	1,770	31.2
Inarajan	410	340	810	1,560	27.5
SUB-TOTAL	970	560	3,040	4,570	80.6
TOTAL	**970**	**1,660**	**3,040**	**5,670**	**100.0**

Note: The total agricultural land suitable for Merizo and Umatac is 320 acres and 250 acres, respectively, which is not included.

Source: Bureau of Planning, *Agricultural Growth Policy* and *Land Use Plan Guam, 1977-2000.*

Table 5-13 shows the decline in staple crop output from Guam's pre-World War II days when the Island was self-sufficient. Since World War II, the agricultural sector has not maintained growth equal to that of other economic sectors. As shown in Table 5-14, production of fruits and vegetables increased only 27 percent in the ten year period from 1979 to 1988, and has in fact fallen slightly from 1986 to 1988. Based on available data, it appears that no plans have been implemented by the government to expand existing agricultural lands or increase crop production.

Reports and planning documents of various GovGuam agencies have, in the past, identified at least three factors which needed to be addressed if the scale of commercial agriculture was to be significantly expanded on Guam. These factors included agricultural land development and management, farm labor development and management, and comprehensive marketing practices. To date, neither GovGuam nor any private organization has implemented a program that has significantly increased agricultural land use. Consequently, no effective action has

TABLE 5-13
HISTORICAL AGRICULTURAL PRODUCTION

CROP	Production (in thousands of pounds) 1929	1939	1949	1959	1964	1975	1986
Cassava	195.5	472.7	15.7	95.5	95.8	85.2	30.3
Sweet Potato	587.4	756.4	107.0	67.5	83.9	43.3	95.3
Taro	1,825.0	N/A	280.7	169.8	153.2	111.6	36.2
Yam	1,160.3	840.0	87.3	97.8	76.8	47.2	14.8

Source: *Guam Public Market Feasibility Study*, Department of Commerce, Government of Guam; and *U.S. Census of Agriculture*, various issues.

TABLE 5-14
PRODUCTION OF FRUITS AND VEGETABLES

Fiscal Year	Production (in pounds)
1979	6,186
1980	2,976
1981	6,208
1982	4,833
1983	6,616
1984	6,631
1985	6,762
1986	8,035
1987	7,595
1988	7,878

Source: Department of Agriculture, Government of Guam been taken with regard to addressing any of these factors since the original Master Plan, and the entire industry seems to have declined rather than progressed toward any goal.

A decrease in available arable land has been one contributor to the decline of agriculture. One factor in this decrease is the potential for the development of golf courses on agriculturally-zoned land. The water requirements necessary for irrigating these courses will also affect the farming industry.

The island-wide labor shortage also affects the agricultural sector. Guam is experiencing a period of intense growth related to the tourist industry, resulting in the creation of thousands of jobs. According to the Department of Commerce, this economic boom has virtually eliminated unemployment to the extent of causing a severe labor shortage. Historically, farm laborers are lower paid, unskilled workers. This class of workers on Guam has been absorbed by the hotel/restaurant and construction industries. Most farmers on Guam employ family members to help with crop production, as no other labor is available. This restriction has contributed to the small number of acres under cultivation and also the quantity and quality of produce available.

A third factor affecting the growth of Guam's agricultural industry is marketing practices. These practices have not changed significantly since World War II. There appear to be no immediate plans to educate the farmer or modernize the marketing process, although the Guam Legislature has recently passed a bill appropriating funds to revitalize the Agricultural Extension Agency on Guam.

Another factor that has restricted the redevelopment of agriculture on Guam is the devastating impact of typhoons and tropical storms as evidenced by the agricultural damages suffered in the Sixties during Typhoons Karen and Olive. Between 1910 and 1990, other typhoons of varying intensity have passed over or sufficiently near the Island of Guam to cause significant damage. With an average of one typhoon every other year, the selection of crops and the timing of their growth and harvesting must be carefully planned and executed in order to minimize the crop damage. Such strategies would be to encourage the production of crops with short growing seasons, planting from nursery stock rather than seed, and minimizing the use of certain orchard and other crops particularly vulnerable to wind damage since production for an entire year could be lost in a single storm.

Hydroponic farming, proposed as an alternate strategy by the original master plan, has, in the past decade, shown itself to be a more expensive, more water-intense process than previously believed. For example, all hydroponic farming projects implemented in the State of Hawaii to date have failed due to the high costs of special structures, equipment, and skilled technicians. With regard to water consumption, two types of hydroponic farming exist: closed and open. In the closed system water is recirculated continuously, allowing for a lower water use than that of traditional agriculture. But it is also a risky method in that if a bacteria or fungus should enter the system, an entire crop could be lost. In an open system the water is disposed of after one circulation through the system. This exerts a water demand greatly in excess of traditional agriculture. Since hydroponic farming is performed in a greenhouse, more protection from less severe storms may be offered. However, the greenhouse could not be expected to withstand a storm of the intensity of the typhoons which regularly devastate the island. In summation, in all three areas of consideration (cost, water demand and weather resistance), hydroponic farming is not considered a feasible option to revive the stagnant agricultural industry of the island.

In order to project irrigation water demands, a knowledge of the water required by the particular crops currently grown on Guam is necessary. Due largely to a lack of crop data, this information is not readily available. The irrigation water demand is therefore determined utilizing rainfall records and information obtained from the Department of Agriculture and U.S. Army Corps of Engineers.

The Department of Agriculture indicates that irrigated crops on Guam require an inch of water every three days to sustain healthy growth and high production. Approximately 65 percent of the total rainfall on Guam occurs during the period of July through November and 35 percent between December and June. While supplemental irrigation supplies are normally needed during the dry months, there are extended periods during the wet seasons when crops would suffer without supplemental water. Hence, a dependable irrigation water supply must be available on a year-round basis.

The Corps of Engineers has estimated that typical vegetable and fruit crops in Guam consume, through evapotranspiration, approximately 6.4 inches of water per month on the average. The Guam National Weather Bureau records show that the minimum monthly rainfall ever to occur on Guam was 0.5 inches. Ignoring the water that might be temporarily available from within the soil, it may be necessary to apply as much as 5.9 inches of water per month to irrigate crops under extreme conditions. This translates into an island-wide rate of 4.2 MGD for the 800 acres under cultivation, a relatively insignificant amount when compared with the overall water demand.

Based on current crop production, economic trends, official governmental policies, agricultural land management, farm labor development, and marketing practices, it is assumed that the amount of land under cultivation will remain constant from the present through the year 2010. Therefore, the projected 4.2 MGD irrigation demand should also remain constant and has been included in the General Civilian Demand category.

Fire Protection Demands - The method used in this report to determine flow rate and duration for fire protection purposes was the Insurance Services Office (ISO) method, as presented in the American Water Works Association's (AWWA) *Distribution System Requirements for Fire Protection, 1989.* The ISO has developed the *Grading Schedule for Municipal Fire Protection*, which is used to classify municipalities with reference to fire fighting capabilities and physical conditions. From a study of pertinent conditions and performance records, the ISO has developed fire fighting and water supply standards which are compared to the various features of the fire defense in the community being rated. For each deviation from the standards, deficiency points are assigned proportionate to the seriousness of deficiency. The total number of deficiency points charged against a municipality determines its relative classification. Although Guam has not been evaluated by the ISO to date, the schedule can be used as a guideline in evaluating existing facilities as well as in projecting the need for future fire protection facilities.

The ISO has established a formula for estimating the needed fire flow (NFF) for a given fire condition as follows:

$$NFF = C_i\,(O_i)\,(X+P)_i$$

where C_i = $18\ F\ A^{0.5}$

= the construction factor

F = coefficient related to the class of construction

A_i = the effective floor area

O_i = the occupancy factor

X_i = the exposure factor

P_i = the communications factor

The AWWA's manual also presents the required fire flow duration based on the magnitude of the fire flow. This fire flow versus duration is shown in Table 5-15.

TABLE 5-15
FIRE FLOW DURATION REQUIREMENTS

Fire Flow (gpm)	Duration (hours)
2500 and less	2
3000 to 3500	3
4000 to 12000	4

Note: The fire flow durations are based on the 16th edition of the National Fire Protection Association's *Fire Protection Handbook*.

Estimated fire flows based on the ISO method and on discussions with the Department of Public Safety (DPS) are tabulated by type of land use as shown in Table 5-16. The fire flow requirements tabulated by type of land use as shown in Table 5-16 cannot be realistically satisfied in most areas within the next few years. However, fire flows can be utilized for planning purposes in the sizing and locating of proposed water distribution and storage facilities. It should be noted that the fire flows presented are approximations for typical structures or clusters of structures in each land use category and should not be utilized for establishing fire flow requirements for specific buildings. Instead, fire flow requirements for specific locations should be established on a case-by-case basis.

Fire protection requirements for the year 2010 were estimated from the fire protection classifications in Table 5-16 and the Bureau of Planning *Land Use Plan*. The various classes of fire protection required for each service area are given in Table 5-17.

Required distribution storage capacity was evaluated as the average daily demand, or 24 hours worth of average daily flow (ADF), as recommended in the April 15, 1989 issue of *Public Works: City, County and State.* This volume of water was determined to be adequate for several reasons. A large majority of the new commercial buildings and subdivisions on the island are constructed of concrete which, being non-flammable, thereby reduce the potential for a large-scale fire problem. The major water crisis is therefore seen to present itself in the form of typhoons or tropical storms, which may cause power outages of 24 hours or more

TABLE 5-16
FIRE FLOW REQUIREMENTS BY TYPE OF LAND USE

Land Use	**Fire Flow Requirement (gpm)**
Rural Residential	500
Urban Residential (low density)	1000
Urban Residential (medium-high density)	1500
Commercial (low density)	2500
Commercial (high density)	3500
Public Institutions	2500
Resort	3500
Industrial (light)	3000
Industrial (heavy)	3500

Note: Land use classifications conform to those established in the *Land Use Plan*.

duration. Most existing hotels provide their own 24-hour storage supply. It is likely that future hotels will also provide storage sufficient to meet their own 24 hour demand. Approximately 40 percent of the average daily storage island-wide could be provided in this manner.

Application of the foregoing criteria to each water service area resulted in the fire flow demands and water storage requirements shown in Table 5-18.

Total Civilian Water Requirements - The total projected civilian water requirements were obtained by combining the projected water demands for general civilian use, agriculture, commercial port/industrial park, hotels, and hotel-induced population. The total civilian water requirement thus obtained is shown in Table 5-19 for the years 1990, 1993, 2000, 2005, and 2010. Figure 5-7 shows the variation in demand depending upon the extent to which the unaccounted-for water component is reduced.

TABLE 5-17
FIRE PROTECTION REQUIREMENTS BY SERVICE AREA

Location	Residential			Commercial		Public Bldgs.	Resort	Industrial		Maximum Fire Flow (gpm)
	Rural	Urban (L)(1)	Urban (H)(2)	(L)(1)	(H)(2)			(Light)	(Heavy)	
Regional Water Service Area "A"										
Yigo	X	X		X		X				2500
Dededo	X	X	X	X		X				2500
Regional Water Service Area "B"										
Asan/Piti	X	X	X	X		X				2500
Agana/Agana Hts./ Sinajana		X	X	X	X	X	X			3500
Mong Mong/Toto/Maite		X	X			X		X		3000
Chalan Pago Ordot/ Mangilao	X	X	X	X		X				2500
Tamuning		X	X	X	X	X	X	X		3500
Barrigada		X	X	X		X	X			2500
Commercial Port/ Industrial Park								X	X	3500
Regional Water Service Area "C"										
Agat/Santa Riga	X	X	X	X		X	X			2500
Regional Water Service Area "D"										
Yona	X	X	X	X		X	X			2500
Taofofo	X	X	X	X		X	X			2500
Inarajan	X	X		X		X	X			2500
Merizo	X	X		X		X				2500
Umatac	X	X	X	X		X				2500

(1) Low Density
(2) High Density

TABLE 5-18
FIRE FLOW AND STORAGE REQUIREMENTS BY SERVICE AREA

	Basic Fire Flow (gpm)	Fire Flow Duration (hours)	Fire Reserve (MG)	Minimum Distribution Storage (MG)
Service Area "A"				
1990	2500	2	0.30	5
1993	2500	2	0.30	7
2000	2500	2	0.30	10
2005	2500	2	0.30	11
2010	2500	2	0.30	12
Service Area "B"				
1990	3500	3	0.63	15
1993	3500	3	0.63	31
2000	3500	3	0.63	38
2005	3500	3	0.63	42
2010	3500	3	0.63	44
Service Area "C"				
1990	2500	2	0.30	2
1993	2500	2	0.30	3
2000	2500	2	0.30	4
2005	2500	2	0.30	4
2010	2500	2	0.30	4
Service Area "D"				
1990	2500	2	0.30	3
1993	2500	2	0.30	5
2000	2500	2	0.30	8
2005	2500	2	0.30	12
2010	2500	2	0.30	15

TABLE 5-19
WATER DEMANDS

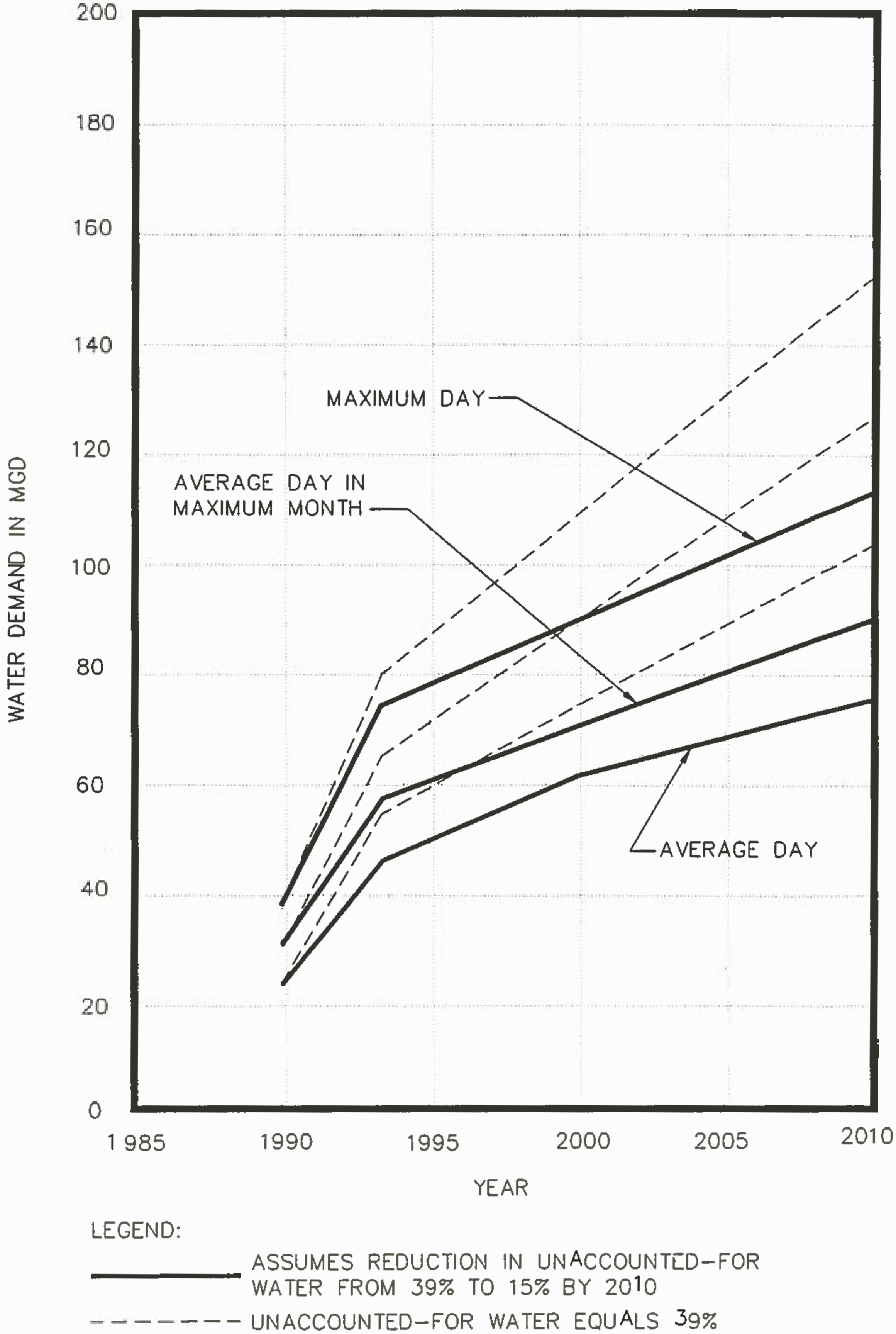
DEMAND	1990 WATER DEMANDS (MGD) REGIONAL WATER SERVICE AREA					1993 WATER DEMANDS (MGD) REGIONAL WATER SERVICE AREA					2000 WATER DEMANDS (MGD) REGIONAL WATER SERVICE AREA				
	A	B	C	D	TOTAL	A	B	C	D	TOTAL	A	B	C	D	TOTAL
Average Day															
General Civilian Use	5	12	2	3	22	6	19	3	4	32	9	23	2	6	40
Hotel Use	0	3	0	0	3	1	11	1	1	15	2	15	1	3	21
TOTAL	**5**	**15**	**2**	**3**	**25**	**7**	**31**	**4**	**5**	**47**	**11**	**38**	**3**	**9**	**61**
Average Day in Maximum Month[1]															
General Civilian Use	6	15	3	3	27	7	23	3	4	37	10	28	3	7	48
Hotel Use	0	3	0	0	3	2	14	1	1	18	2	18	1	3	24
TOTAL	**6**	**18**	**3**	**3**	**30**	**9**	**37**	**4**	**5**	**55**	**12**	**46**	**4**	**10**	**72**
Maximum Day[2]															
General Civilian Use	8	19	3	4	34	8	29	5	6	48	13	35	4	8	60
Hotel Use	0	4	0	0	4	2	17	2	2	23	2	22	2	4	30
TOTAL	**8**	**23**	**3**	**4**	**38**	**10**	**46**	**7**	**8**	**71**	**15**	**57**	**6**	**12**	**90**

DEMAND	2005 WATER DEMANDS (MGD) REGIONAL WATER SERVICE AREA					2010 WATER DEMANDS (MGD) REGIONAL WATER SERVICE AREA				
	A	B	C	D	TOTAL	A	B	C	D	TOTAL
Average Day										
General Civilian Use	9	26	3	7	45	10	28	3	8	49
Hotel Use	2	16	1	4	23	2	17	1	6	26
TOTAL	**11**	**42**	**4**	**11**	**68**	**12**	**45**	**4**	**14**	**75**
Average Day in Maximum Month[1]										
General Civilian Use	11	31	3	9	54	12	33	3	10	58
Hotel Use	2	19	1	5	27	2	20	1	7	30
TOTAL	**13**	**50**	**4**	**14**	**81**	**14**	**53**	**4**	**17**	**88**
Maximum Day[2]										
General Civilian Use	14	39	4	11	68	15	42	4	13	74
Hotel Use	3	24	2	7	36	3	25	2	9	39
TOTAL	**17**	**63**	**6**	**18**	**104**	**18**	**67**	**6**	**22**	**113**

(1) Indicates maximum month demand in average year. Assumes same demand factor as for general civilian demands (i.e., 1.2).

(2) Indicates historical maximum month demand. Assumes same demand factor as for general civilian demands (i.e., 1.5).

Water Demand Values have been rounded off to the nearest full MGD.



NOTE: INCLUDES COMMERCIAL PORT, HOTEL AND AGRICULTURAL DEMANDS

FIGURE 5-7

PROJECTED CIVILIAN WATER DEMANDS

Future Military Water Requirements

It is extremely difficult, if not impossible, to accurately forecast water demands for the military on Guam because of the uncertain and ever-changing nature of military operations. An example of an unanticipated water demand was the Vietnamese refugee operation of 1975 which taxed the Navy water system to the limit, resulting in curtailment of use during peak periods.

Guam is currently a possible site for the relocation of U.S. military bases now facing an uncertain future at their present locations in the Philippines. The restationing of these troops on the island would certainly increase the military water demand through an increase in the military population and operations.

The historical water production for the period of 1985 through 1989 for both the U.S. Navy and the U. S. Air Force is shown in Table 5-20. The Navy and Air Force's annual water production varied only 5.3 and 7.2 percent from the five year average, respectively. Unfortunately, as the military water systems are not fully metered, it is not possible to define that percentage of the total water production which represents true demand and that portion which is unaccounted-for water.

The Navy was requested to estimate future water demands as best possible at the time that the original Master Plan was prepared and to discuss the effects of unanticipated water demands such as mobilization or the construction of the ammunition wharf. The response was as follows:

> "Our (i.e., Navy) record indicates that the Navy water demand is about 3.3 billion gallons a year (9.04 MGD). The projected Navy demand for the year 2000 based on factors contained in the Naval Facilities Design Manual No. 5 (NAVFAC DM-5) is 5.0 billion gallons (13.7 MGD). Experience indicates that Navy operations, either anticipated or unanticipated, increase the Navy demand for water. The ammo wharf project will not significantly increase the Navy water demand."

The Navy's projected demand for the year 2000 (13.7 MGD) included water sold to PUAG.

TABLE 5-20
ANNUAL MILITARY WATER PRODUCTION

	Annual Production (MGD)		
Year	**US Navy [1]**	**US Air Force**	**Total**
1985	13.29	3.40	16.69
1986	13.22	3.85	17.07
1987	13.45	4.12	17.57
1988	13.55	4.31	17.86
1989	13.70	5.19	18.89
AVERAGE	13.44	4.17	17.62
PERCENT OF TOTAL	76%	24%	

(1) Includes production sold to PUAG

Source: GEPA, Groundwater Management Report, FY89

The Air Force responded at that time to the same question as follows:

> "We (i.e., Air Force) do not anticipate any significant increase in our water demand in the foreseeable future. Unless some unforeseen action causes an increase in the base population, we expect the base consumption will remain stable, and we hope our energy consumption program will decrease the amount of water used by Anderson."

Both Navy and Air Force rates have remained fairly constant since that time, with consumption at 9.19 MGD and 4.81 MGD for the Navy and the Air Force, respectively. Recent responses from both the U.S. Navy and Air Force with regard to updated demand projections are that demand is expected to remain "status quo". Therefore future projections are made under the assumption that this existing trend continues over the 20 year projection period, as shown in Table 5-21.

Future Private Water User Requirements

There have been approximately eight private water suppliers on Guam during the past decade. These entities, listed in Table 5-22, obtain their water from private wells. For the most part they are industries that utilize the wells for process water. Historical water production for the period from 1985 through 1989 is shown in Table 5-23. Private water production remained fairly constant over the first three years, then tripled between 1987 and 1988, and doubled from 1988 to 1989. The large increase in production during the period 1987 through 1989 is apparently due to the construction of a new well at the Hatsuho Resort and a new well owned by RCA. Another reason may be adjustments and repairs made on water meters during recent years that have led to better accounting of water production.

The current policy, effective 1990, is to allow the construction of new wells only on approval by GEPA and PUAG; therefore no major increase in the rate of private well production is expected and projections will assume a constant rate of 2.8 MGD.

Island-wide Future Water Requirements

In the preceding sections of this chapter water demands for the years 1990, 1993, 2000, 2005 and 2010 have been projected for the civilian (i.e., PUAG), military, and private use sectors. The required annual island-wide water production has for these years been estimated by totaling the projected average annual demands of the three suppliers as shown in Table 5-24 and Figure 5-8.

Variations in Water Demand Projections

As discussed earlier in the chapter, the general civilian water demands were projected on the basis that the current per capita use rates, as computed in Table 5-9, will remain constant. Many factors were considered in the making of this assumption. Those factors that will tend to restrict use are as follows:

- The implementation of a comprehensive water conservation program as recommended.

TABLE 5-21
PROJECTED MILITARY WATER DEMANDS

	Demands (MGD)		
Year	U.S. Navy[1]	U.S. Air Force[1]	Total
1990-2010	9.19	4.81	14.00

(1) Excludes water production from military facilities for PUAG demands. Assumes military consumption will remain constant from 1990-2010.

TABLE 5-22
PRIVATE WATER SUPPLIERS

Name	No. of Wells
Black Construction Corporation	1
Cocos Island Resort[1]	1
Foremost Foods, Inc	1
Hatsuho Golf Course	2
Hawaiian Rock Products	2
Island Equipment Company	1
RCA	1
Shell (GORCO)[1]	1

Source: Well Permit Applications, 1981-1990

(1) Not connected to PUAG system.

TABLE 5-23
SUMMARY OF PRIVATE WATER PRODUCTION

Year	Production (MGD)
1985	0.54
1986	0.33
1987	0.42
1988	1.39
1989	2.82
AVERAGE	1.10

Source: GEPA, Groundwater Management Program

TABLE 5-24
PROJECTED ISLAND-WIDE AVERAGE ANNUAL WATER DEMANDS

	Demands (MGD)				
Agency	1990	1993	2000	2005	2010
PUAG[1]	25	47	60	68	75
Military	14	14	14	14	14
Private	2	2	2	2	2
TOTAL	**41**	**63**	**76**	**84**	**91**

(1) Assumes reduction of unaccounted-for water from 40 percent in 1990 to 15 percent by 2010.

- The Northern groundwater lens is a limited water supply source. When the demand reaches the available capacity of the groundwater lens, a more costly alternative supply must be utilized. Increased water rates to offset the costs associated with utilization of a more costly water supply will tend to suppress use.
- Increased energy costs will require increased water rates and therefore tend to reduce, or at least suppress increases in usage. Scarcity of fuel may at times force conservation of energy, and thus water.

On the other hand, there are several factors which will stimulate water use, including:

- Improved water quality
- Higher operating pressure
- Improved economic status will encourage the use of water-consuming appliances such as washing machines, dishwashers, and garbage disposals.
- Available water will encourage water use for landscaping, car washing, gardening, and other outside uses.

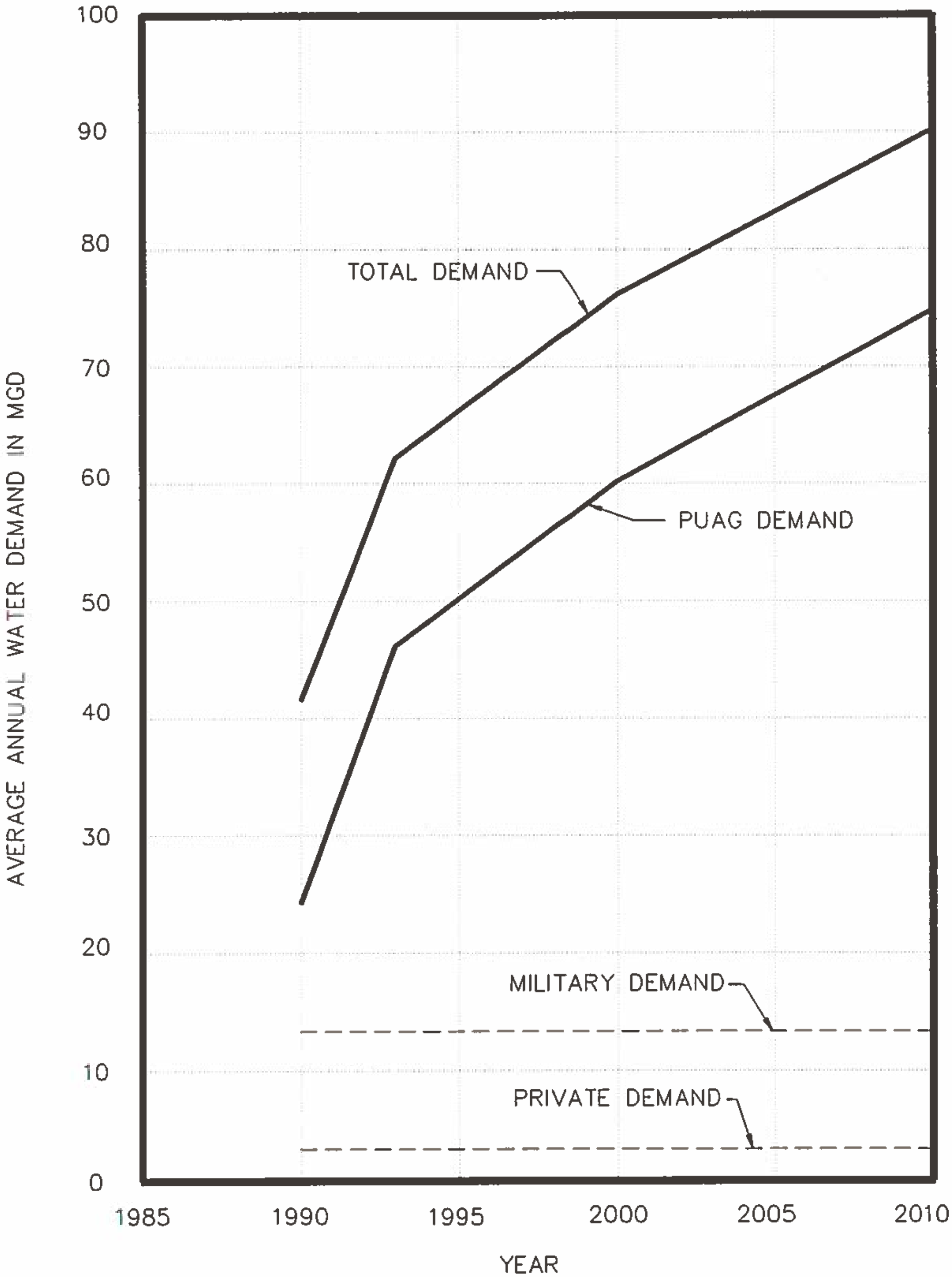
The "no increase in per capita use" assumption reflects the belief that conservation measures, a limited water supply, and energy considerations will offset the normal tendencies for increased usage. However, in order for the *Water Facilities Master Plan* to be an effective management tool, it must be sufficiently flexible to evaluate the consequences of water demands in excess of those projected, based on the foregoing assumption.

As indicated in Table 5-9, the current Island-wide average per capita use, excluding unaccounted-for water, is approximately 125 gpcd. Including allowances for 39 percent unaccounted-for water, the effective per capita use is approximately 205 gpcd.

To evaluate the effect of increased per capita use, Table 5-25 was prepared. This table shows that by the year 2010, assuming a 50 percent increase in per capita use and an unaccounted-for water rate of 15 percent, the effective per capita use would increase from the present 205 gpcd to 220 gpcd. Similarly, if the unaccounted-for water remained at the current 39 percent level, the per capita use would increase from the present 205 gpcd to 305 gpcd if a 50 percent increase in per capita use occurred.

The effects of increased per capita use rates on the total water demands for the civilian use sector are shown on Figure 5-9. Assuming Case I, that is, that the unaccounted for water is reduced from 40 percent to 15 percent by the year 2010, and assuming that the existing per capita use were to increase by 10 percent, the total water demand of 75 MGD for the year 2010 would occur in the year 2005, 5 years earlier than projected. If per capita use were to increase by 30 percent instead of 10 percent, the projected average water demand of 75 MGD would occur in 1998, 12 years prior to the projected date. Thus, additional water facilities would be needed sooner than expected.

The importance of periodic reevaluation of current water demands cannot be over-emphasized. The Government of Guam should evaluate the per capita use demands on a yearly basis as one means of self-monitoring the success of its water conservation practices. The Water Facilities Master Plan should be reviewed at least every five years and updated as required.



NOTE: ASSUMES REDUCTION IN PUAG UNACCOUNTED-FOR WATER FROM 39% IN 1990 TO 15% BY 2010

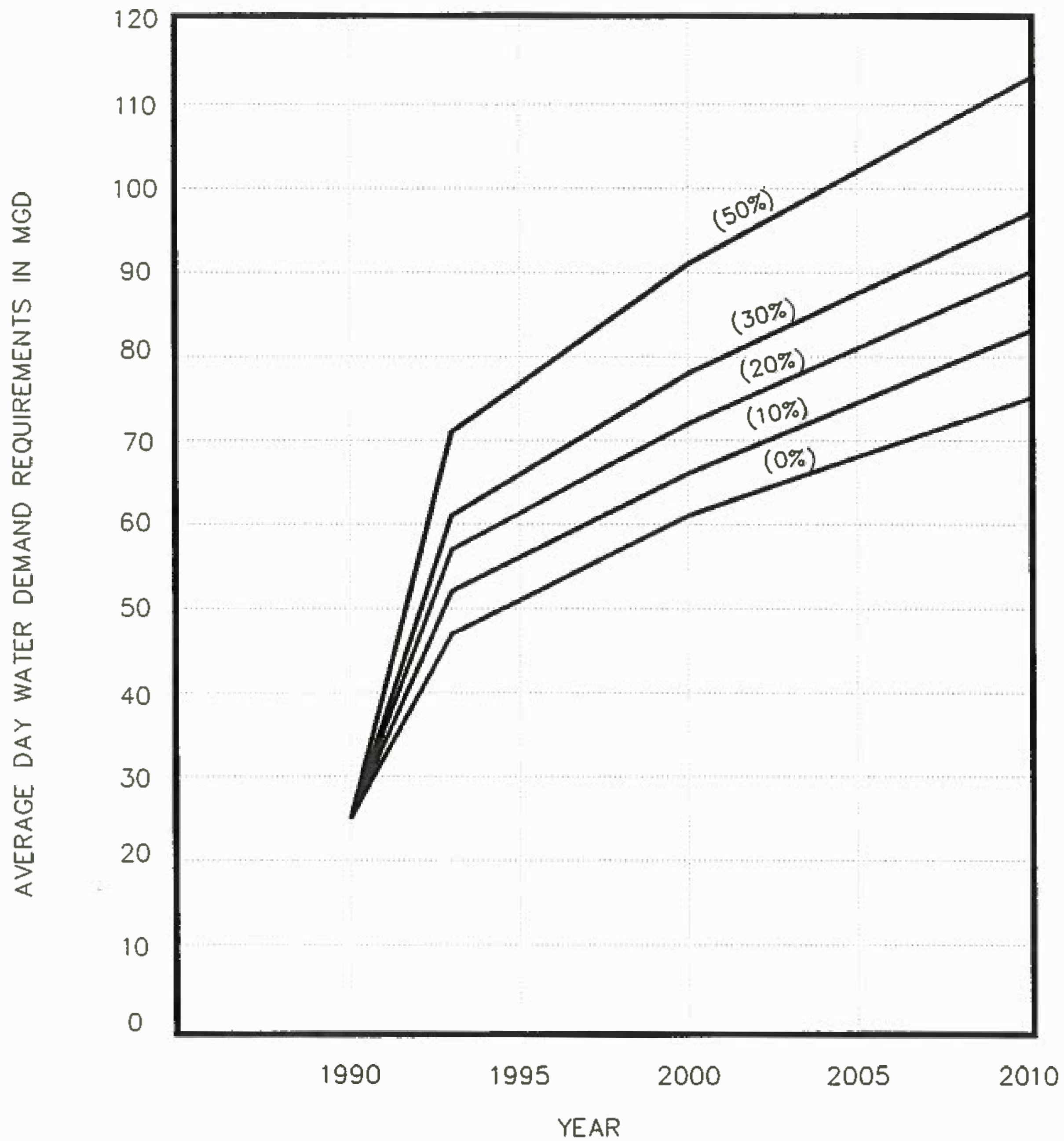
FIGURE 5-8

ISLAND-WIDE PRODUCTION REQUIREMENTS

TABLE 5-25
RELATIONSHIP OF UNACCOUNTED-FOR WATER
TO PER CAPITA USE RATES

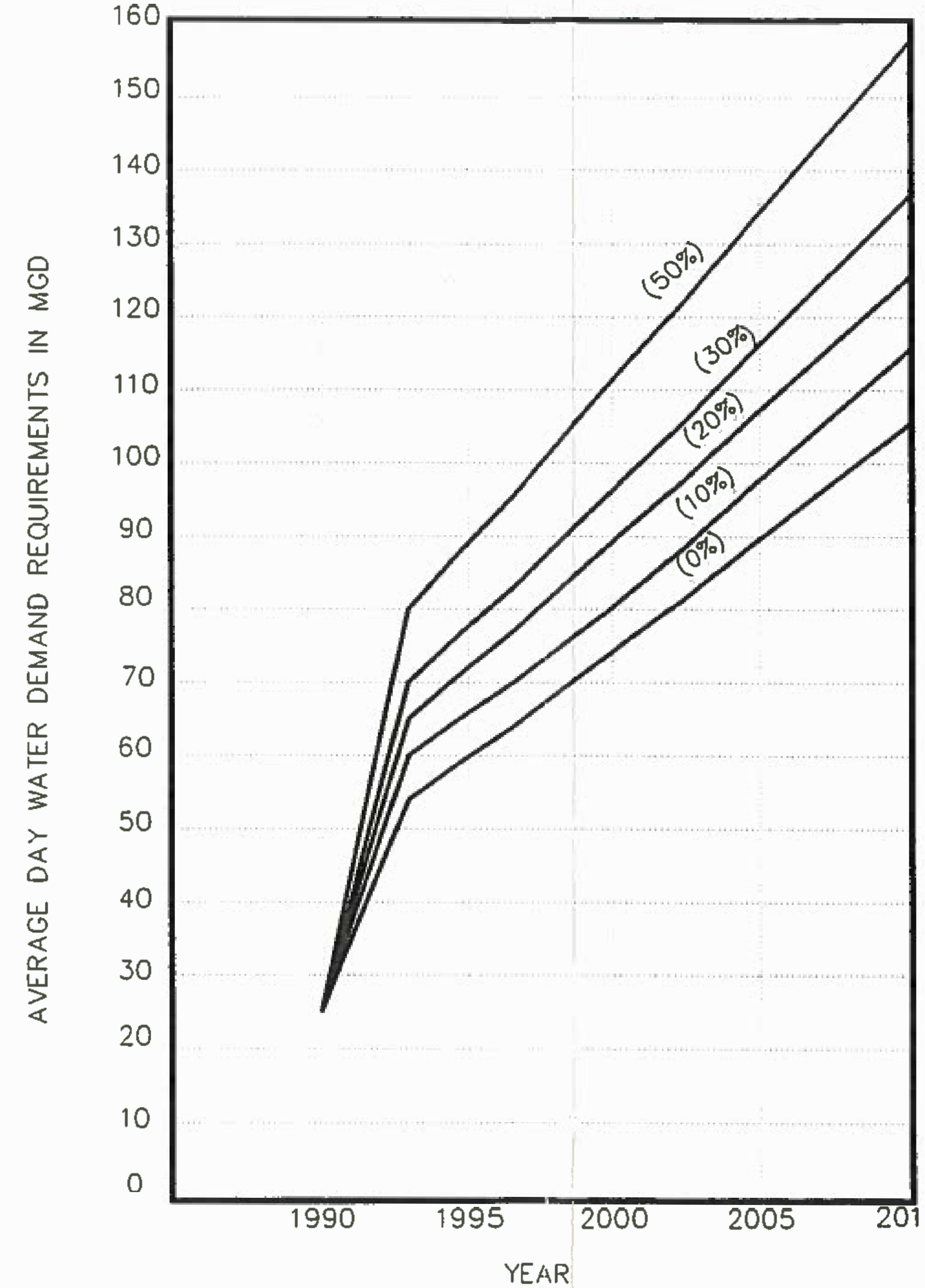
	Per Capita Use - Year 2010 (gpcd)		
Percent of Increase	0% Unacc-for Water	15% Unacc-for Water	39% Unacc-for Water
0	125	145	205
10	135	160	225
20	150	175	245
30	160	190	265
50	185	220	305

It should be emphasized that the most important factor in water demand projections from a facilities planning standpoint is not the magnitude of the water demand itself (within reasonable limits), but rather the time frame in which the water demand is reached. It is critical that the Government of Guam, either through its own agencies or through the use of an engineering consultant, continually evaluate their current water demands so that adjustments in the Capital Improvement Program can be made.



CASE I

ASSUMES REDUCTION IN UNACCOUNTED-FOR WATER FROM 39 PERCENT TO 15 PERCENT BY 2010



CASE II

ASSUMES UNACCOUNTED-FOR WATER REMAINS AT 39 PERCENT

LEGEND:

( ) INDICATES PERCENT OF INCREASE IN PER CAPITA USE BY THE YEAR 2010.

NOTE: INCLUDES COMMERCIAL HOTEL AND AGRICULTURAL DEMANDS.

FIGURE 5-9

EFFECT OF INCREASED PER CAPITA USE ON CIVILIAN WATER DEMANDS

VI

DESIGN CRITERIA

CHAPTER VI
DESIGN CRITERIA

General

Planning for new water facilities requires the development of basic criteria upon which the design of new supply, treatment, storage, and distribution elements will be based. These criteria should take into consideration basic water demands, projected rates of increase, period of design, financial capability of the utility agency, and various other related factors.

In general, the design criteria employed herein conform to current waterworks practice. Where applicable at the master planning level, the proposed PUAG design guidelines have been used. Table 6-1 (at the end of this Chapter) lists key design criteria used in developing water supply and treatment alternatives and for formulating distribution system improvements.

Design Period

The design period used for master planning of water system improvements is the next twenty year period (i.e., through the year 2010). Use of such criteria for locating and sizing supply, treatment and distribution system components does not necessarily imply that a component will be obsolete or so physically deteriorated that it will require replacement by the year 2010.

The design periods assumed for the individual components of a water system are based on such factors as ease of expansion, service life of the facilities, and ability to finance or fund the improvements.

Mechanical equipment in treatment plants and pumping stations normally has an economic life in the 10 to 20 year range. If consideration is given during design to future requirements, such equipment can be (a) conveniently replaced with larger units or (b) phased with the installation of additional equipment at the appropriate time.

Piping and the structural components of treatment plants and pump stations, and distribution storage facilities can serve 50 years or more with proper maintenance. These components may in some instances be constructed in 10 to 15 year staged increments. The feasibility of staged construction depends on many factors, including physical characteristics of the particular system, site conditions, the projected rate of increase in water demands, and the availability of funding.

Distribution mains have a relatively high initial cost and are not expandable. If additional capacity is required, a second pipeline must be constructed or additional pressure applied to the system which increases energy costs. However, an increase in size at the design stage prior to construction can be made at relatively little cost and assures the availability of adequate capacity in the future, particularly in borderline cases. For the Public Utility Agency of Guam (PUAG) all mains will be capable of meeting ultimate local development in the areas they serve. Transmission mains that will support the anticipated growth through the year 2010 have been included in the recommended capital improvement program.

System Pressures

Pressures within an existing system vary greatly and are dependent on numerous variables (for example: size of pipelines, topography, height of buildings, etc.). It is desirable that system design pressures for ordinary service be greater than 40 pounds per square inch (psi) and preferably be in the 50 to 80 psi range during the peak hourly demand throughout the distribution system. An additional factor which must be considered is the requirement of PUAG that a minimum residual pressure of 20 psi be maintained throughout the system during fire flow conditions.

In hilly or mountainous regions, such as those found in the southern areas of Guam, it is necessary to subdivide the water service area into pressure zones in order to prevent excessively high pressures at lower elevations in the system. High pressures require more expensive higher pressure-rated pipe, fittings, and valves and also complicated operating procedures. Pressures in excess of 80 psi should preferably be avoided but sometimes this cannot be done. If necessary, a reduction in pressure at the customer's service may be accomplished with individual household pressure regulators.

System Demands

The average volume of water utilized by one person in one day is commonly referred to as the per capita use and is expressed in gallons per capita per day (gpcd). Chapter V, "Water Requirements," provided the basis for establishing the per capita use throughout the Island.

Established fire flows based on the ISO schedule and on discussions with the Department of Public Safety (DPS) were established by type of land use. The fire flow requirements by land use and the required fire flow duration are summarized in Table 6-1.

Pipelines

A properly designed and operated water distribution system should be capable of supplying adequate quantities of water of reasonably consistent pressures to meet normal demand patterns. In particular, the distribution system must be capable of delivering the year 2000 maximum day demands plus any fire flows. For those transmission pipelines used to convey water to another service area, the pipelines must, in addition, be sufficiently sized to carry any inter-region water import/export requirements.

To reduce the effects of water surging and to minimize energy losses due to pipe friction, the water velocity should be limited to six feet per second during normal flow (non-fire flow) periods. During fire flow conditions a maximum velocity of ten feet per second can be maintained.

The most common formula used in the evaluation of pipeline hydraulics is the Hazen-Williams formula which states:

$$Q = 1.318\ C\ A\ R^{0.63} S^{0.54}$$

where Q = flow in cubic feet per second (cfs)
C = Hazen-Williams coefficient of roughness
A = cross-sectional area of the pipe in square feet
R = hydraulic radius in feet
and S = hydraulic slope in feet per foot of length

The hydraulic analysis, as described in Chapter IX, "Proposed Water System Improvements," utilizes the Hazen-Williams formula. The pipe friction coefficients "C" used in the analysis were 110 and 120 depending on the pipe diameter.

Distribution Storage

Sufficient distribution storage must be included in PUAG's water system to provide emergency fire reserves in each service area and to permit supply and treatment facilities to operate at a constant rate not to exceed the average demand during the maximum day (i.e., equalizing storage). Two criteria were established to determine the required storage capacity within each water service area. The total volume of distribution storage required was determined to be the larger of

- Twenty-four hours of the average day demand (year 2010) within each regional water service area.
- Fire flow volume required for the worst fire condition in the subregion plus 25 percent of the maximum day demand.

Often, a criteria of meeting the "maximum day demand" is used to establish water distribution storage. Using this criteria, over 110 million gallons of storage would be required on an Island-wide basis. This criteria is currently not economically feasible for Guam, particularly with the predominant source of supply being groundwater. Standby power provisions are being incorporated into the capital improvement program, thereby allowing water production to continue even if GPA power is interrupted. Thus, the natural storage of the groundwater aquifer will be used for storage, thereby allowing a reduction in design criteria. Based on this criteria, the quantitative storage requirements for each service area are presented in Chapter IX.

Supply

The basic criteria used in establishing Guam's water supply needs for the year 2010 assumes that the combined water supplies will be capable of producing sufficient water to meet the maximum day demand requirements. As discussed in Chapter VIII, "Water Supply and Treatment Alternatives," Guam currently has two major sources of water supply available: groundwater from the northern aquifer and southern surface supplies. As indicated in Chapter VIII, additional water sources will likely need to be developed, including additional groundwater and surface water supplies. In addition, it is likely that the Government of Guam will need to begin the use of desalinization treatment of brackish waters and wastewater reclamation in order to meet long-term water supply needs. The establishment of an intensive conservation program, in combination with any of these methods, can greatly contribute to reducing the overall demand, thereby decreasing the amount which must be supplied by these additional sources.

Water Treatment

Treatment process design criteria must be based on raw water quality and seasonal quality variations as well as on water demands. Treatment facilities for domestic use must produce a finished water meeting the Guam Primary Safe Drinking Water Regulations (GPSDWR).

As discussed in Chapter VIII, current technology and cost considerations limit Guam to two sources of water supply: groundwater in the north and surface water in the south. The northern groundwater supply has historically required chlorination for disinfection only when tests on samples collected from individual wells has shown excessive coliform counts. Chlorination of the wells can be best accomplished through the use of individual solution feed chlorinators with alarm systems and automatic well shutdown features.

The southern surface supplies require turbidity and color removal in addition to disinfection for domestic use. With the proper selection and application of chemicals, coagulation, flocculation, sedimentation, filtration and chlorination will produce a water meeting the Guam Safe Drinking Water Regulations. However, exact treatment requirements must be established on a case-by-case basis for each surface supply developed. As PUAG has little previous experience with water treatment, conservative design criteria should be adopted. Plant layout and piping should be such that expansion to double capacity could be achieved by merely adding additional process units.

TABLE 6-1
SUMMARY OF KEY DESIGN CRITERIA

I DESIGN PERIOD

Planning for future capital improvements	20 years
Useful life of mechanical equipment	10 to 20 years
Piping	50 years

II SYSTEM PRESSURES

Normal Service	40 to 80 psi (individual pressure regulators provided where pressure in main exceeds 80 psi)
Fire Flow Conditions	20 psi (minimum)

III SYSTEM DEMANDS

Average per capita use-Service Area "A"	100 gpcd
Average per capita use-Service Area "B"	140 gpcd
Average per capita use-Service Area "C"	135 gpcd
Average per capita use-Service Area "D"	120 gpcd
Hotel Room per unit use	450 gprd
Demand Ratio-Average day in maximum month	1.2 x average day
Demand Ratio-Maximum day	1.5 x average day
Demand Ratio-Maximum hour	3.0 x average day
Unaccounted-for Water	Varies from 15 to 40% (See Chapter V)
Fire Flow Required (rural)	500 gpm (2 hours)
Fire Flow-Residential (low density)	1,000 gpm (2 hours)
Fire Flow-Residential (medium to high density)	1,500 gpm (2 hours)
Fire Flow-Commercial (low density)	2,500 gpm (2 hours)
Fire Flow-Commercial (high density)	3,500 gpm (3 hours)
Fire Flow-Public including schools	2,500 gpm (2 hours)
Fire Flow-Resort	3,500 gpm (3 hours)
Fire Flow-Industrial	3,000-3,500 gpm (3 hours)

IV PIPELINES

Capacity - To meet year 2000 maximum day demands plus fire flow plus any inter-region water import/export requirements.

Velocity - Limited to a maximum of 6 feet per second (fps) and 10 fps for non-fire flow and fire flow conditions, respectively.

Pipe Friction (Hazen-Williams) Coefficients ("C")	= 110 (12" and smaller)
	= 120 (14" and larger)

TABLE 6-1 (cont.)
SUMMARY OF KEY DESIGN CRITERIA

V DISTRIBUTION STORAGE

Capacity - To meet year 2010 requirements in each subregion. The total volume of distribution storage provided shall be the larger of:

1) The average day demand (year 2010) within each regional water service area.

2) Fire flow volume required for the worst fire condition in the subregion plus 25 percent of the maximum day demand.

VI SUPPLY

Total Capacity - To meet Island-wide year 2010 maximum day demand requirements.

Wells - Design to conform to recommendations contained in Northern Guam Lens Study.

Surface Supplies - As described in U.S. Corps of Engineers feasibility study of the Ugum River Basin.

VII WATER TREATMENT

Source	Type of Treatment
Groundwater Supplies	Disinfection (as required)
Surface Water Supplies	Coagulation/Flocculation Sedimentation Filtration Disinfection

VII

WATER QUALITY

CHAPTER VII
WATER QUALITY

General

The Guam Safe Drinking Water Act (GSDWA) was adopted by the Government of Guam on December 27, 1977, as the territorial response to the Federal Safe Drinking Water Act (FSDWA). Section 57288 of the GSDWA authorizes the Guam EPA to prescribe such rules and regulations as may be necessary to implement its provisions. Pursuant thereto, the Guam EPA adopted the Guam Primary Safe Drinking Water Regulations (GPSDWR) on March 27, 1978.

The U.S. Environmental Protection Agency (EPA) concluded that the GSDWA and its companion GPSDWR were in compliance with the requirements of the FSDWA. On that basis, GovGuam, acting through Guam EPA, was granted primacy for the purpose of administering the Federal law on Guam on September 10, 1978.

The GSDWA and its companion GPSDWR are subject to regulations promulgated pursuant to the Federal law, including the Safe Drinking Water Act.

Safe Drinking Water Act

The Safe Drinking Water Act (SDWA) Amendments of 1986, signed into law by President Reagan in June 1986, are additions and changes to existing earlier legislation, the Safe Drinking Water Act of 1974. The 1974 Act required EPA to set limits for several chemical, physical, and biological parameters. Resulting regulations established maximum contaminant levels (MCLs) for ten inorganic chemicals, six organic chemicals, five radionuclides, turbidity, and coliforms. The 1986 amendments were formulated and passed by Congress as a result of growing concern over contamination of public drinking water supplies. These new amendments contain requirements that will impact every purveyor of water in the U.S.

Important key elements of the amendments are:

- Expanded list of regulated contaminants along with maximum contaminant levels (MCL) for 83 initial contaminants, as well as for an additional 25 contaminants every three years.

- Designation of best available technology for control of each of the regulated contaminants.

- Requirements for filtration of surface water supplies which do not meet specific criteria.

- Requirements for disinfection of all public water supplies - both groundwater and surface water.

- Monitoring requirements for contaminants that are not regulated.

- Prohibition of the use of lead solders, flux and pipe in public water systems.

- Requirements for development and maintenance of groundwater protection programs.

The Environmental Protection Agency (EPA), under the requirements of the 1986 Amendments to the SDWA, promulgated a National Primary Drinking Water Regulation (NPDWR) pertaining to public water systems using surface water sources. This regulation is referred to as the Surface Water Treatment Rule (SWTR). The final SWTR regulations were promulgated on June 19, 1989 and were published in the June 29, 1989 Federal Register (54 *FR* 27486). An extensive Guidance Manual has been prepared by EPA to aid in implementation of the requirements. Other regulations will be promulgated of which the following is a partial list:

Lead and copper
Organic and inorganic compounds
Disinfectants and disinfection by-products
Radionuclides
Groundwater disinfection

Each purveyor is required to conduct monitoring and testing, evaluate whether or not the system meets the criteria set forth in the regulations of the SWTR, and then design and construct any necessary system improvements. The compliance schedule set forth in the SWTR requires compliance for systems treating by disinfection without filtration by December 1991, and systems treating by filtration and disinfection by June 1993.

Surface Water Treatment Rule - The basis for the SWTR is the occurrence of waterborne disease outbreaks across the mainland U.S. from both *Giardia* and enteric viruses. *Giardia* and viruses have been identified in most all surface waters which have been tested. These two contaminants are potentially present in all surface water supplies. Since there is no economically and technically feasible method for monitoring and analysis, the EPA has established required treatment techniques in lieu of monitoring and analysis for comparison of a measured concentration against a MCL.

Significant field and research data has shown that a properly operated filtration plant with disinfection can be expected to provide the required inactivation of *Giardia* and viruses -- 99.9 percent and 99.99 percent, respectively. The purpose of the SWTR is to assure that all public water system using surface water sources provide a treatment level equal to that of a properly designed and operated filtration plant with disinfection. Therefore, in the case of *Giardia* and viruses (as well as turbidity, heterotrophic bacteria, and *Legionella*), filtration plus disinfection is the required treatment for surface water supplies.

The SWTR consists of requirements for public drinking water systems using surface water sources including: (1) criteria under which filtration would be required and procedures by which the States must determine which systems must either install filtration or upgrade existing filtration facilities; (2) requirements for disinfection as a treatment technique; (3) regulations for *Giardia lamblia*, enteric viruses, *Legionella*, heterotrophic plate count bacteria, coliforms, and turbidity; and (4) performance requirements in filtered water systems.

Water Quality Criteria for Domestic Use

Presented in Table 7-1 are maximum contaminant levels for inorganic and organic chemicals. The organics listed in Table 7-1 include all those parameters for the Primary Drinking Water Regulations.

Water Quality Criteria for Industrial Uses

While the total volume of industrial water demands on Guam is not anticipated to be great, some industrial processes are particularly sensitive to certain constituents found in typical water supplies. For example, a bottle washing operation requires soft water, even though harder waters may be utilized for boiler feed, cooling, or production purposes. Boiler feed waters ideally have a pH of around 8.0 for the lower pressure systems and in the range of 9.0-9.6 for higher pressure operations. Soft water is generally required for most boiler feed purposes, particularly for the higher pressure systems. Food processing operations are particularly sensitive to waters of high turbidity or with detectable amounts of color, taste and

TABLE 7-1
NATIONAL PRIMARY DRINKING WATER REGULATIONS
MAXIMUM CONTAMINANT LEVELS FOR ORGANIC & INORGANIC CHEMICALS

Contaminant	Maximum Contaminant Level mg/l
Inorganics	
Asbestos	7 million fibers/liter
Barium	5
Cadmium	0.005
Chromium	0.1
Mercury	0.002
Nitrate (as N)	10
Nitrite (as N)	1
Selenium	0.05
Silver	0.05
Volatile Organics (Solvents)	
cis-1,2-Dichloroethylene	0.07
1,2-Dichloropropane	0.005
Ethylbenzene	0.7
Monochlorobenzene	0.1
o-Dichlorobenzene	0.6
Styrene	0.005/0.1
Tetrachloroethylene	0.005
Toluene	2
trans-1,2-Dichloroethylene	0.1
Xylenes	10
Pesticides/Herbicides/PCBs	
Alachlor	0.002
Aldicarb	0.01
Aldicarb sulfoxide	0.01
Aldicarb sulfone	0.04
Atrazine	0.003
Carbofuran	0.04
Chlordane	0.002
Dibromochloropropane	0.0002
2,4-D	0.07
Ethylene dibromide	0.00005
Heptachlor	0.0004
Heptachlor epoxide	0.0002
Lindane	0.0002
Methoxychlor	0.4
PCBs	0.0005
Pentachlorophenol	0.2
Toxaphene	0.005
2,4,5-TP (Silvex)	0.05

odor. Iron and manganese can contribute to these problems. Tolerable threshold concentration for various constituents vary depending upon the food and the process. For all food processing operations, whether fresh or salt water is used, the water must meet exacting bacteriologic standards.

Presented in Tables 7-2, 7-3, and 7-4 are suggested water quality criteria applicable to the more restrictive industrial process requirements reasonably anticipated to occur on Guam. Table 7-2 presents suggested limits of tolerance for boiler feed waters applicable to the power industry or any other industry where boiler feed waters are employed. Table 7-3 presents suggested threshold tolerances for a few parameters of concern to the food processing industry, and would be applicable to both vegetable processing and fish canning. In addition, all food processing operations require waters which meet bacteriologic requirements of the GPSDWR. Special requirements for waters used for laundering are presented in Table 7-4.

Water Quality Criteria for Irrigation Water

Five parameters are primarily used for the classification of water supplies as to their suitability for irrigation purposes. These include: (1) percent sodium, (2) total dissolved mineral solids, (3) boron concentration, (4) chloride concentration, and (5) sulfate concentration.

The sensitivity of plants to the various constituents in the water supply can vary widely under actual field conditions depending on the climate, soils and the particular plant species. In many cases an inferior water supply may be used for irrigation purposes as long as the user accepts the consequent penalties in lowered crop quality and production. Hence, criteria for the classification of irrigation water supplies are usually expressed as a range of limiting concentrations with the lower limit reflecting the threshold value above which the impact of a particular constituent can be detected. A suggested list of criteria for the classification of surface and groundwaters on Guam for irrigation purposes is presented in Table 7-5.

TABLE 7-2
SUGGESTED LIMITS OF TOLERANCE FOR BOILER FEED WATERS

	Pressure (psi)			
Constituent	0-150	150-250	250-400	Over 400
Turbidity	20	10	5	1
Color	80	40	5	2
Oxygen Consumed	15	10	4	3
Dissolved Oxygen(2)(3)	2.0	0.2	0.0	0.0
Hydrogen Sulfide(1)	5	3	0	0
Total Hardness ($CaCO_3$)	80	40	10	2
Sulfate-carbonate Ratio (ASME) ($Na_2SO_4CO_3$)	1:1	2:1	3:1	3:1
Aluminum Oxide	5	0.5	0.05	0.01
Silica	40	20	5	1
Bicarbonate(2)	50	30	5	0
Carbonate	200	100	40	20
Hydroxide	50	40	30	15
Total Solids(4)	500-3000	500-2500	100-1500	50
pH value (minimum)	8.0	8.4	9.0	9.6

(1) Except when odor in live steam would be objectionable.
(2) Limits applicable only to feed water entering boiler, not to original water supply.
(3) Given as ml per liter. Multiply by 0.70 for mg/l.
(4) Depends on design of boiler.

Note: Units in mg/l except as otherwise noted.

Source: *Progress Report of the Committee on Water Quality Tolerances for Industrial Uses, NEWWA*; McKee & Wolf (1963).

TABLE 7-3
SUGGESTED THRESHOLD TOLERANCES FOR THE FOOD PROCESSING INDUSTRY

Constituent	Range of Recommended Threshold Values in mg/l
Turbidity	1.0
Color	5-10
Taste and odor	none
Iron	0.2
Manganese	0.2
Iron and Manganese	0.2
Alkalinity, as $CaCO_3$	30-250
Hardness, as $CaCO_3$	10-250
Total dissolved solids	684-710
Fluoride	1.0
Organic matter	infinitesimal
Chlorides	250

Source: McKee & Wolf (1963)

TABLE 7-4
RANGE OF RECOMMENDED THRESHOLD AND LIMITING CONCENTRATIONS FOR LAUNDERING PURPOSES

Constituent	Range of Recommended Threshold Values in mg/l
Hardness, as $CaCO_3$	0-50
Iron and manganese	0.2-1.0
Iron	0.2-1.0
Manganese	0.2
Alkalinity, as $CaCO_3$	60
pH	6.0-6.8

Source: McKee & Wolf (1963)

Water Quality Monitoring Program

Until a recent water quality monitoring program was instituted in response to recommendations of the Northern Guam Lens Study (NGLS), the available data was generally limited to the results of sampling and analyses conducted for specific projects or reports. The new water quality monitoring program analyzes each of the PUAG wells for pH, alkalinity, color, turbidity, taste, hardness, chlorides, and conductivity.

Most of the data utilized in this assessment were obtained from published and unpublished records of the USGS or from the 1976 report by John Mink, *Groundwater Resources of Guam: Occurrence and Development*, and the June, 1974, report by Kennedy Engineers entitled *Fena River Watershed and Reservoir Management Study.*

Quality of Surface and Spring Water Supplies

A summary of available analyses of surface and spring water sources on Guam is presented in Table 7-6 and the locations of sampling stations are shown on Figure 7-1.

With one or two minor exceptions, surface water qualities listed in Table 7-6 are satisfactory for all domestic and irrigation uses, as well as most industrial uses contemplated in this master plan. All of the waters identified in Table 7-6 appear to satisfy the mandatory requirements of the GPSDWR and they all generally contain constituents below the recommended limits in the U.S. Public Health Service Drinking Water Standards for other inorganic constituents. Minor elevations of iron and manganese are to be noted in Table 7-6 at Fena Reservoir, which the Corps of Engineers has suggested may be due to ammunition disposal practices of the Navy in the vicinity of the reservoir. However, the more recent analyses of surface waters in that area suggest that such waters are generally suitable for most beneficial purposes. A continuous monitoring program in the downstream areas would confirm the existence of the problem if one does exist.

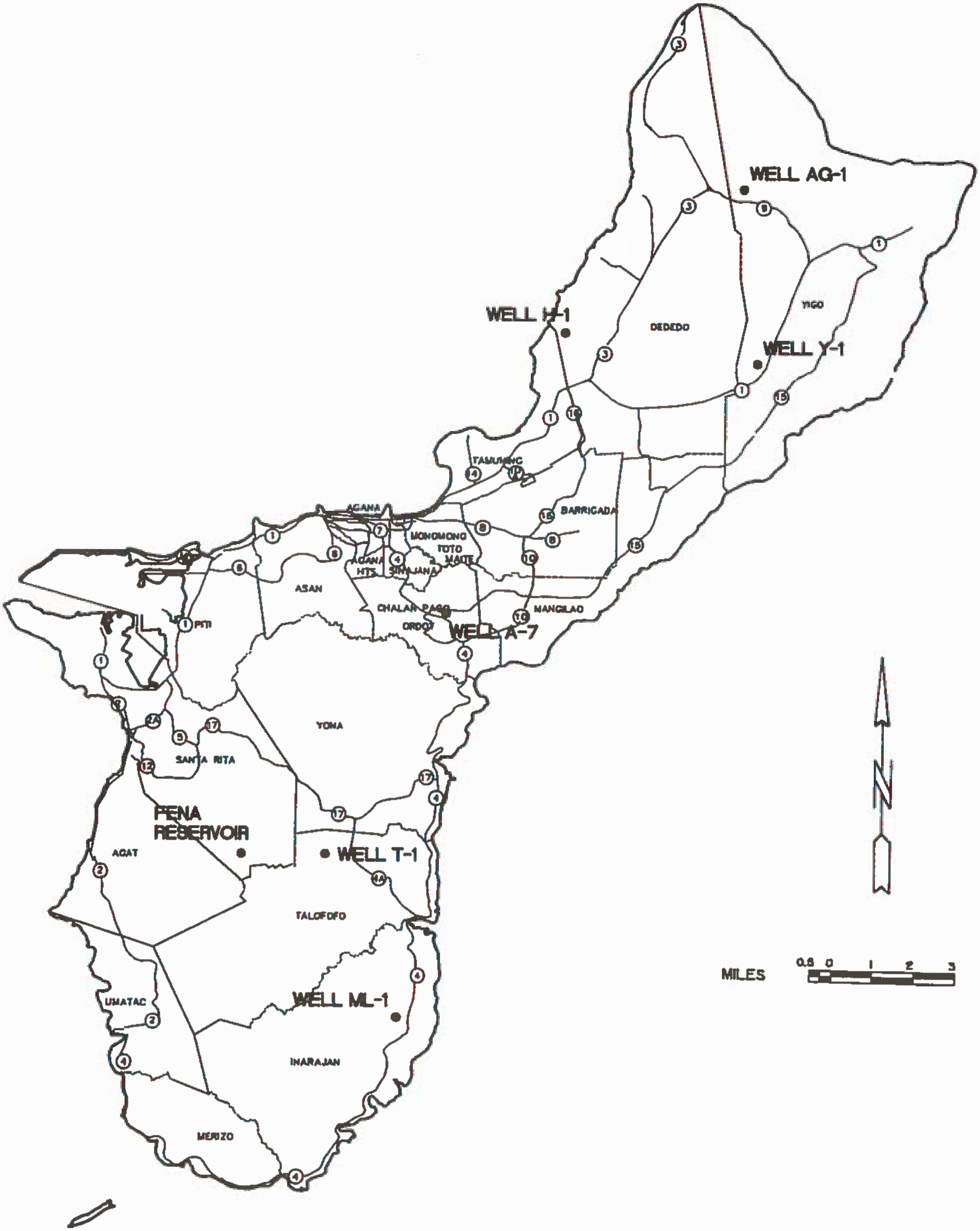


FIGURE 7-1

WATER QUALITY SAMPLE LOCATIONS

In Guam, the per capita use varies throughout the Island, largely with the degree and type of supportive services within the community. As an example, the central Guam area, Regional Services Area "B", where the majority of the Island's business activities are located, has a much higher per capita use than the northern or southern areas. The results of the per capita use analysis indicated that Service Area "B" has the highest per capita use (140 gpcd) as a result of intensified commercial business development in the Agana and Tamuning communities. Service Areas "C" and "D" have per capita use rates of 135 and 120 gpcd, respectively. Service Area "A", which encompasses the Dededo and Yigo area, has the lowest of the four rates at 100 gpcd. The Island-wide average is 125 gpcd. As would be expected, the per capita rates have increased slightly since the preparation of the 1979 Water Facilities Master Plan. These calculated per capita use rates, shown in Table 6-1, were used to project future water demands.

By utilizing the existing per capita use rates to project future water demands it is assumed that the per capita use rates will remain relatively unchanged. Chapter V indicates the various factors that influence the tendency to increase and decrease per capita use rates. Also provided in Chapter V is a discussion of the effects of increased per capita use rates on the future water demands.

Since the preparation of the 1979 Water Facility Master Plan, Guam has experienced a phenomenal growth in tourism. As discussed earlier in the report, this growth was not anticipated during the preparation of the 1979 Water Facilities Master Plan. At that time the water demand exerted by hotel developments was insignificant when compared to the total PUAG water demand. Today, the water demands attributed to hotel usage is a significant percentage of total demand and the percentage is expected to increase.

As indicated in Chapter V, the number of hotel rooms is expected to increase from approximately 4,100 in 1990 to over 48,000 by the year 2010. To account for the increasing water demand attributed to hotel rooms, a "per room use" demand of 450 gallons per day is being used.

Guam's future hotel water demands have been evaluated independently from those of the general civilian population as the two groups bear no direct relationship to each other.

Once the average daily water demand is established, demand ratios must be employed in making projections for the average day in maximum month demand, maximum daily demand, and the peak hourly demand.

The ratio used for the average day in the maximum month is a close approximation of the average demand during the actual maximum month, July, that occurred during the 1988-89 period of record. As is usually the case with small communities, no data was available for estimating the maximum daily or peak hourly demands so ratios were developed from experience with other communities. The water demand ratios used are shown in Table 6-1.

Unaccounted-for water is, by definition, the difference between water production and water sales. It is extremely important to minimize this non-revenue-producing "demand" to prevent unnecessary and premature depletion of the water supply, to reduce operating costs, and to stretch the useful life of existing facilities from a capacity standpoint. This will enable the deferment of capital expenditures for expansion of water supply and treatment facilities. Based on a comparison of PUAG's metered sales and production, as presented in Chapter V, an existing unaccounted-for water rate of approximately 30 to 40 percent was established. It was further assumed that with an effective preventative maintenance and leak detection program the unaccounted-for water losses would be reduced to approximately 15 percent by the year 2010.

It is extremely difficult to accurately forecast water demands for the military on Guam because of the ever-changing nature of military operations. Based on a review of historical military water demands and projections of future demands received from both the U.S. Navy and U.S. Air Force, future demands were estimated and are indicated in Chapter V.

Water supply requirements for fire protection purposes are established by the Insurance Services Office (ISO). The ISO has developed the *Grading Schedule for Municipal Fire Protection*, 1973, which is used to classify municipalities with reference to fire fighting capabilities and physical condition of existing facilities. An abbreviated version of the ISO's fire flow versus duration table was presented in Chapter V.

TABLE 7-6
SURFACE AND SPRING WATER QUALITY

Constituent	Units	Fena Reservoir	Almagosa River	Imong River	Maulap River	Agana Spring	Santa Rita Spring	Tarague Spring	Mataguac Spring	Janum Spring
Arsenic	mg/l	0.003	0.003	0.003	0.003	--	--	--	--	--
Chromium	mg/l	0.02	0.02	0.02	0.002	--	--	--	--	--
Copper	mg/l	0.02	0.02	0.02	0.002	--	--	--	--	--
Fluoride	mg/l	0.03	0.03	0.07	0.03	--	--	0.1	--	0.1
Lead	μg/l	20	20	20	20	--	--	--	--	--
Zinc	mg/l	0.05	0.10	0.40	0.20	--	--	--	--	--
Calcium	mg/l	24	40	34	43	101	64.1	74	36	4.2
Iron	mg/l	0.83	0.20	0.15	0.15	0.02	0.003	--	0.05	--
Magnesium	mg/l	4.8	5.8	5.3	7.7	6.6	3.42	14	5	8.7
Manganese	mg/l	0.06	0.02	0.02	0.02	--	0.007	--	--	--
Mercury	μg/l	0.2	0.2	0.2	0.02	--	--	--	--	--
Nitrate (as N)	mg/l	0.01	0.01	0.01	0.20	--	1.59	1.53	--	3.5
Phosphate (Total)	mg/l	0.30	0.013	0.010	0.014	--	--	0.1	0.6	0.01
Potassium	mg/l	2.5	2.2	3.2	4.0	2.4	--	3.7	--	1.3
Silica	mg/l	22	32	34	48	8.2	--	1.6	71	13
Sodium	mg/l	9.6	14	15	20.5	26	--	92	--	7.5
Sulfate	mg/l	0.5	0.6	0.6	0.6	11	--	25	3.4	3.0
Chloride	mg/l	7.5	9.0	9.0	9.0	36	--	155	19	9.9
Alkalinity (as $CaCO_3$)	mg/l	80	137	123	155	--	162	--	--	--
Conductivity	Mmhos	179	286	254	307	--	310	932	--	299
Hardness (as $CaCO_3$)	mg/l	80	124	96	140	--	174	--	--	--
pH	mg/l	7.7	7.9	7.7	7.8	7.4	7.3	8.2	7.5	8.0
Total Organic Carbon	mg/l	3.75	1	3	4	--	--	--	--	--
Total Dissolved Solids	mg/l	118	189	167	200	389	--	542	226	179
Color	mg/l	6	5	5	5	5	--	--	--	--
Phenols	mg/l	0.001	--	--	--	--	--	--	--	--
DDT	μg/l	0.05	--	--	--	--	--	--	--	--
Chlordane	μg/l	0.01	--	--	--	--	--	--	--	--
Aldrin	μg/l	0.01	--	--	--	--	--	--	--	--
Endrin	μg/l	0.01	--	--	--	--	--	--	--	--
2, 4, 5-D	μg/l	1.0	--	--	--	--	--	--	--	--

Note: Analyses for Fena Reservoir, Almagosa River, Imong River, Maulap River taken from Fena River Watershed and Reservoir Management Study, dated June, 1974. Analyses for Agana Spring, Tarague Spring, Mataguac Spring and Janum Spring taken from *Groundwater Resources of Guam: Occurrence and Development.* Agana Spring and Mataguac Spring samples analyzed during period of 1951-1957. Tarague Spring and Janum Spring samples analyzed in 1969.

All of the water supplies listed in Table 7-6 appear to be suitable for the production of agricultural crops appropriate for commercial irrigation applications on Guam. Although the available analyses have not reported boron concentrations, there is no evidence that boron concentrations on Guam are sufficiently elevated to cause problems for the sensitive plants. The collection and analyses of samples of a representative group of streams and springs for their boron concentrations would provide positive verification of any problem.

Quality of Groundwater Supplies

In response to the groundwater monitoring recommendation, the GEPA initiated a monitoring program, the results of which are tabulated and summarized in annual reports. The following is a summary of the findings of the *Groundwater Management Program Annual Report - 1988*:

> All production wells were monitored quarterly for nitrates and chlorides. Organic and inorganic analyses were performed on a representative cross-section of wells on a quarterly basis. Grab samples were collected from selected ponding/percolation basins, both natural and man-made, and analyzed for organic and inorganic constituents identified in the Safe Drinking Water Act (SDWA).
>
> 1. Chlorides - There were five (5) wells (A-13, A-14, A-17, A-18 and A-19), which produced water where the chlorides exceeded the 250 mg/l recommended maximum concentration. The chloride concentration of groundwater produced from the northern lens has shown a slight increase in salinity in response to the lesser amounts of rainfall and increased pumpage at various locations. As the chloride content in Groundwater Zone 33 is increasing, some of the wells in this zone may have to be shut down to reduce the increasing chloride content.
>
> 2. Nitrates - The nitrate analysis showed all wells have some nitrates present but none are presently approaching the Maximum Contaminant Level (MCL). Presently nitrate concentrations are less than 50 percent of the maximum contaminant level of 10 mg/l and therefore pose no health risks. Several studies have indicated that the major source of these nitrates is native vegetation.
>
> 3. Organic and inorganic water quality was routinely monitored. The results of the organic analysis consistently showed mostly levels below the detectable limits of the tests. Detection limits are set at a minimum of one tenth of the MCL down to one thousandth of the MCL. The inorganic analysis also show that all sources are below the SDWA MCL's.
>
> 4. The monitoring of wells A-17, A-19 and A-21 for selenium which was identified as being high in the NGLS continued. The results show that the concentration is now significantly below the 10 μg/l MCL concentration.

In conjunction with the preparation of the *Northern Guam Lens Study*, Guam's northern groundwater resource was sampled and analyzed for those priority pollutants identified by the U.S. Environmental Protection Agency (EPA) (See Table 7-7). Of all the priority pollutant constituents for which analyses were conducted, only eleven constituents had concentrations above the detection limits, and, of these, only one constituent (selenium) in one well (A-17) was above the EPA recommended drinking water limit.

Arsenic, iron, lead, manganese, selenium, and zinc were the only inorganic chemicals detected during the priority analyses. Iron and manganese concentrations in all samples were well below the EPA recommended secondary drinking water limit of 300 and 50 micrograms/liter (μg/l), respectively. These constituents are almost certainly of natural geologic origin. Zinc and lead concentrations were also well below recommended drinking water limits of 5,000 and 50 μg/l, respectively. These constituents may result from pipe corrosion, although they could also be of natural origin. Arsenic concentrations were well below the recommended drinking water limit of 50 μg/l. Though arsenic could be of natural origin, it is also associated with industrial waste discharges from electronics and plating industries. However, no such industries are known to exist near Wells A-15 and A-17.

In summary, the northern lens groundwater was found to be particularly pollutant free and of excellent quality. However, the study recommended that a groundwater monitoring program be established and that the selenium concentrations in the groundwater be monitored.

The principal chemical constituents of the groundwaters of Guam, in terms of significance related to origin and movement of the groundwaters, are: calcium (Ca), chloride (Cl), silicate (SiO_2), nitrate (NO_3), magnesium (Mg) and total hardness, with the relative concentrations of each reflecting the origin of the water. Perhaps the two most important factors are chloride, which reflect salt water intrusion, and total hardness, which is due to the presence of limestone.

TABLE 7-7
LIST OF PRIORITY POLLUTANTS

Volatile Organic Compounds

Acrolein
Acrylonitrile
Benzene
Bromomethane
Bromodichloromethane
Bromoform
Carbon Tetrachloride
Chlorobenzene
Chloromethane
2-Chloroethylvinyl ether
Chloroform
Chloromethane
Dibromochloromethane
Dichloroethylene
1.1-Dichloroethane
1.2-Dichloroethane
1.1-Dichloroethene
trans-1.2-Dichloroethane
1.2-Dichloropropane
cis-1.3-Dichloropropene
trans-1.3-Dichloropropene
Ethylbenzene
Methylene chloride
1.1.2.2-Tetrachloroethane
Tetrachlorethene
1.1.1-Trichloroethane
1.1.2-Trichloroethane
Trichloroethene
Trichlorofluoromethane
Toluene
Total Tricholomethane
Vinyl chloride

Base/Neutral Organic Compounds

Acenaphthene
Acenaphthylene
Anthracene
Benzo(a)anthracene
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Benzo(a)pyrene
Benzo(g,h,i)perylene
Chrysene
Dibenzo(a,h)anthracene
Fluoranthane
Fluorene
Indeno(1,2,3-cd)pyrene
Naphthalene
Phenanthrene
Pyrene

Acid Organic Compounds

4-Chloro-3-methylphenol
2-Chlorophenol
2.4-Dichlorophenol
2.4-Dimethylphenol
2.4-Dinitrophenol
2-Methyl-4.6-dinitrophenol
2-Nitrophenol
4-Nitrophenol
Pentachlorophenol
Phenol
2.4.6-Triclorophenol

Ethers and Esters

Bis(2-chloroethyl)ether
Bis(2-chloroethoxy)methane
Bis(2-ethylhexyl)phthalate
Bis(chloroisopropyl)ether
4-Bromophenyl phenyl ether
Butyl benzyl Phthalate
4-Chlorophenyl phenyl ether
Diethylphthalate
Dimethylphthalate
Dioctylphthalate
Di-n-butylphthalate
Isophorone

Pesticide Compounds

Aldrin
a-BHC
B-BHC
d-BHC
Y-BHC
Chlordane
2.4.5-TP Silvex
4.4-DDD
4.4-DDT
Dieldrin
Endosulfan I
Endosulfan II
Endosulfan Sulfate
Endrin
Endrin aldehyde
Heptachlor
Heptachlor Epoxide
Lindane
Methoxychlor
Toxaphene
PCB-1015
PCB-1221
PCB-1232
PCB-1242
PCB-1248
PCB-1254
PCB-1260

Nitrogen Containing Compounds

Benzidine
2.4-Dinitrotoulene
2.6-Dinitrotoluene
1.2-Dephenylhydrazine
Nitrobenzene
N-Nitrosodimethylamine
N-Nitrosodi-n-propylamine
N-Nitrosodiphenylamine

Chlorinated Hydrocarbons

2-Chloronaphthalene
1.3-Dichlorobenzine
1.4-Dichlorobenzene
1.2-Dichlorobenzene
3.3-Dichlorobenzidine
Hexachlorobenzene
Hexachlorobutadiene
Hexachloroethane
Hexachlorocyclopentadiene
2.3.7.8-Tetrachlorodibenzo-p-dioxin
1.2.4-Trichlorobenzene

Elements

Antimony
Arsenic
Barium
Beryllium
Cadmium
Chloride
Chromium
Copper
Fluoride
Iron
Lead
Manganese
Mercury
Nickel
Nitrogen (NO_2)
Selenium
Silver
Thallium
Zinc

Miscellaneous

Asbestos
Cyanides
Phenols
Sulfate
Foaming agents
Oil and grease

Chloride concentrations generally indicate the success of a well in a fresh water lens which is underlain by or immediately adjacent to salt water. Elevated chlorides indicate upconing or intrusion of the salt water into the fresh water lens. Based on a comparison of historic water quality (particularly chloride concentration) in northern lens wells and each corresponding well's location relative to estimated basal and parabasal lens areas, chloride concentrations of less than 30 mg/l probably indicate parabasal conditions in the underlying aquifer. Concentrations between 70 mg/l and 150 mg/l in wells indicate basal conditions in the underlying aquifer. Concentrations between 30 and 70 mg/l probably reflect the area overlying the salt water toe. Concentrations over 150 mg/l may indicate a critical upconing condition in the basal aquifer.

Wells in most areas of the northern lens have operated successfully and are not experiencing severe degradation of water quality as a result of upconing. In the Andersen Groundwater Subbasin and the northwest part of the Agana Groundwater Subbasin, chloride concentrations are generally elevated. In the Andersen Groundwater Subbasin, all wells, except for the well located at the golf course, were abandoned because they exhibited high chloride concentrations which made them useless as a drinking water supply. This problem may have arisen because the wells were drilled too deep into the fresh water lens, which increases upconing potential. The Tamuning area between the town of Agana and the Naval Air Station has historically exhibited elevated chlorides. This may be because rainfall runoff from the airport is diverted by storm drains to Agana Bay. Diverting the water in this fashion significantly reduces recharge to the groundwater system, thus allowing encroachment of salt water from Agana Bay toward Mount Barrigada.

The groundwaters have variable concentrations of total hardness (calcium and magnesium carbonate). The concentration is associated with the carbon dioxide content of the incident water and its action upon the limestone. The carbon dioxide is derived from both the atmosphere and from biological activity in the overlying soil. Also, additional hardness is derived from sea water interaction. Hardness levels of up to 400 mg/l are found in some groundwaters, particularly in the "A" Series well region.

Water hardness is an important water characteristic as hard waters require considerable amounts of soap to produce a foam or lather and also produce scale in metal water pipes, hot water heaters, and boilers. The hardness of water varies considerably from place to place although generally surface waters are softer than groundwaters. Waters are commonly classified in terms of the degree of hardness as follows:

0	-	75 mg/l	Soft
75	-	150 mg/l	Moderately Hard
150	-	300 mg/l	Hard
300	-	up mg/l	Very Hard

The optimum water hardness is usually considered to be in the range of 80 to 100 mg/l as $CaCO_3$. The limestone formations in northern Guam cause the Yigo water supply to be high in hardness, having an average hardness of 270 mg/l as $CaCO_3$.

Nitrogen has long been used as an indicator of pollution in ground and surface waters. Nitrate concentrations are generally indicative of waste contamination. Because people live over the groundwater lens, minor contamination is expected. For the most part, nitrate levels have remained reasonably low, in the range of 2 to 10 mg/l (as NO_3). However, Mink (1976) noted that the nitrate load from on-site sewage disposal systems is not sufficient to account for the nitrate levels observed in the lens. He felt that nitrates contributed from on-site disposal systems should not be any higher than 2 mg/l in the Northern Lens. He suggested that the nitrate-fixing, tree-like shrub called tangan-tangan (Leucaena glauca), which is very common throughout Northern Guam, could generate enough nitrate to account for at least 20 mg/l concentrations in the groundwater system. However, more research is needed to substantiate the magnitude of the impact that tangan-tangan has as a major nitrate source to the groundwater system.

Specific conductance, which correlates closely with total dissolved solids (TDS), is an indicator of overall water quality. Water produced from the northern lens exhibits specific conductance in the range between 300 and 1,300 micromhos and averages from 550 to 600 micromhos. This is equivalent to about 400 mg/l TDS. These values for specific conductance are somewhat high by drinking water standards, but, at these levels, do not constitute a health hazard. These levels are indicative of the often high chlorides associated with nearby salt water. Historically, specific conductance has usually remained steady from well to well. Those wells displaying above average specific conductance are usually the same ones that also exhibit high chloride concentrations caused by unusual hydraulic properties of the aquifer or by improper well design. If the general well design criteria that are outlined in the NGLS's

"Well Construction Manual" are followed, future wells should not exhibit unusually high specific conductance or chloride concentrations. Occasionally, wells such as Nos. D-13, A-16, and M-11 will be drilled properly yet have poor quality water, probably due to extreme anisotropic aquifer conditions in which vertical permeability far exceeds horizontal permeability. This condition cannot be predicted. However, proper well design can help insure that water quality remains high.

One factor which can greatly affect groundwater quality is the use of chemicals which can leach into the groundwater over a period of time, resulting in contamination of the aquifer. Local concern has arisen recently due to the development of golf courses covering significant portions of northern Guam and the expectation of additional golf course development in the future. The concern stems from the fact that the thin layer of topsoil overlying the extremely permeable limestone allows for very little filtration of chemicals such as the pesticides and fertilizers commonly used for golf course maintenance, before their incorporation into the groundwater lens. This concern must be addressed by government regulatory agencies, with resulting imposition of strict guidelines, close monitoring for compliance and heavy penalties for abuse, if contamination is to be averted. When faced with a similar situation, the Hawaii State Department of Health (DOH) instituted eight conditions as part of the requirement for permitting golf course development. These conditions are given in APPENDIX G and it is recommended that a similar plan be adopted by the government of Guam.

Distribution System Water Quality

The GEPA conducts a monitoring program on PUAG's water system to ensure that water quality is maintained within Guam's Safe Drinking Water Regulations (GSDWR). GEPA is the regulatory agency responsible for applying GSDWR to all public water producers and ensuring that all water supplied meets the established standards set by GSDWR. GEPA keeps track of sample results, conducts sanitary surveys, takes enforcement actions when necessary, and responds to water complaints. Annual Water System Sanitary Survey Reports (WSSSR) are prepared by GEPA which summarize the water quality findings. The results of the FY 88 and FY 89 Report are summarized below:

1. Most of PUAG's supplied water is drawn from groundwater sources, the quality of which is generally safe for drinking. The most common water quality problem encountered in the PUAG system is chloride contamination. The basic cause of chloride contamination is saltwater intrusion resulting from the

overpumping of a well. Overpumping occurs when the water demand imposed on a well exceeds the rate of recharge of fresh water to that specific area of the lens. A close monitoring of groundwater resources and land use programs is recommended to prevent further water contamination.

2. Occasional instances of bacterial contamination and turbidity occurred in the distribution system, generally in the Southern areas where surface supplies are supplemented by groundwater. Although check samples taken on the following days showed negative results, previous reports exist which indicate areas where contamination has occurred repeatedly. Attention should be focused on correcting this problem.

   In some instances, water quality analyses indicated a higher-than-normal contaminant concentration which was still below the MCL. For instance, in the Asan area, a total trihalomethane concentration of 86 μg/l was reported in March 1987, and the Agat area reported a concentration of 100 μg/l in September, 1986. The MCL for trihalomethane concentration is 100 μg/l. Preventative programs should be formulated and implemented to identify the potential causes of the contamination before the MCL is exceeded and the supply is rendered unusable. Corrective action should also be taken to resolve conditions that may cause fluctuation in water quality.

3. Review of PUAG water quality analyses over the five years prior to the WSSSR with respect to MCL compliance, and sampling and reporting techniques indicates that the number of samples taken in each service area and sampling points should be revised. An accurate statistical analysis is based on the sampling of a true cross section of a population. Sampling points should be selected to represent each different water source entering the system and conditions within the system, such as dead ends, loops, storage facilities, and old pipelines. The number of samples in each service area should be uniform and sufficient to permit accurate evaluation and determination of water quality in each of the areas, and thus in the entire system. This is not currently the practice in the PUAG system. For example, ninety (90) samples were taken in the Agafa Gumas/Inarajan areas, while in the same time frame only two (2) and four (4) samples were taken in the Harmom and Asan/Piti areas, respectively. The results of too many samples in some areas and not enough samples in others can result in misinterpretation of water quality in the system.

4. On many occasions, PUAG was not in compliance with the reporting requirements of GSDWR. A computerized data processing system is recommended to aid PUAG in the sampling, monitoring and reporting tasks, as well as in the investigation of violations. Without the aid of a computer, compliance with requirements would require a very extensive communications system and complex coordination of personnel staffs. Moreover, record keeping by means of data processing is more accurate and much faster than the existing methods, and would be a valuable aid to planner/engineers in the evaluation of performance of the water system.

5. Lead analysis performed by GEPA indicated that there is lead content in the range of 10-40 parts per billion (ppb) existing in production wells islandwide. The sources of lead have not been identified, but some believe that it is derived from the volcanic formation of the Island. Extensive study on the lead concentration in Guam's groundwater is essential to the public health. In the near future, new regulations will be implemented to lower the MCL with regard to lead in order to provide a greater degree of protection to the public health.

VIII

WATER SUPPLY AND TREATMENT ALTERNATIVES

CHAPTER VIII

WATER SUPPLY AND TREATMENT ALTERNATIVES

Introduction

In past years both the Federal Government and the Government of Guam have sponsored several studies of the water resources and their potential for development on the island of Guam. The original *Water Facilities Master Plan* (1979) cited the USGS report, *Geology and Hydrology of Guam, Marianas Islands* (1965) and the U.S. Army Corps of Engineers' report, *Ugum River Interim Report and Environmental Impact Statement* (1979) as providing the most comprehensive studies of southern Guam's surface water resources. Since 1979 the following additional studies have been completed which add significantly to the information provided by the previous reports: *Water Supply Analysis For The Guam Comprehensive Study*, USACOE (1982); and *Potential Water Resources Development*, U.S. Bureau of Reclamation (1984). Together, these studies provide valuable insight into the character of southern Guam's major watersheds, potential quantities of collectable surface water, resource availability and the economic as well as other limiting aspects of surface water development.

In 1982 the *Northern Guam Lens Study*, sponsored by the Guam Environmental Protection Agency (GEPA), was completed by Barrett, Harris & Associates, Inc. under the direction of Hydrologist, John F. Mink. The scope of work for the *Northern Guam Lens Study* (*NGLS*) was, first of all, to more accurately determine the limit of the limestone aquifer yield of the Northern Lens. A second objective was to reevaluate the sustainable yield, originally estimated in Mink's 1976 report, *Ground Water Resources of Guam: Occurrence and Development*, based on existing reports, hydrogeologic data that had been recently generated by GEPA through seismic and gravity surveys, a topographic survey and the drilling of eleven test wells. The *NGLS* is the most comprehensive report on the geology and hydrology of Guam's northern groundwater resources to date. Of particular importance to water master planning, the report describes the nature and extent of Guam's northern groundwater lens, provides estimates of the aquifer's sustainable yield, presents a recommended groundwater development and management program, and outlines the consequences of failure to implement such a plan.

As a result of this current effort to update the *Water Facilities Master Plan*, PUAG is currently conducting a Groundwater Program Evaluation (GWPE) as part of the $53 million bond water CIP implementation. The goals of the GWPE are to reevaluate the productivity of the Northern Groundwater Lens and recommend a well development program that will optimize groundwater development in northern Guam. PUAG's GWPE will examine drilling logs and well performance data collected in the nine years since the completion of the *NGLS*. In addition, the program will evaluate the results of time domain electromagnetic (TDEM) surveys of the volcanic basement in areas where seismic data was either scarce or ambiguous in the *NGLS* and will direct an exploratory well drilling program to refine the limits and potential productivity of various areas within the Northern Groundwater Lens.

This chapter draws freely from the results and conclusions of the studies referenced above, as well as the original *Water Facilities Master Plan* (1979), and specifically incorporates the more significant information from these studies into the water master plan. Reference should be made to these studies for more detailed descriptions and analyses of the summaries presented in this report.

Topography

The topography of Guam is broken into two distinct zones. The northern half of Guam is an undulating limestone plateau whose elevation varies from approximately 100 feet to 600 feet. It generally slopes to the southwest and is bordered by steep wave-eroded cliffs. Within this region there are three hills with a common basement complex of volcanic origin penetrating the limestone, and which rise to elevations of between 630 feet and 860 feet. There are no defined channels of any length in the limestone as all runoff quickly drains into the many fissures and sink holes that abound in the formation. On the three volcanic mountains there are short lengths of channels but these disappear within a short distance once the stream crosses the limestone. There are no perennial streams on the plateau but the area overlays an extensive groundwater supply in the form of a basal lens.

The southern half of Guam is characterized by rugged and deeply dissected uplands which are mostly underlain by volcanic rock. The land surface is crisscrossed by numerous channels which have eroded the terrain. The area is dominated by a mountain range which rises to a maximum elevation of 1332 feet at Mount Lamlam, with several other peaks rising to over

1000 feet. In some areas the mountains are surrounded by a narrow limestone plain that rises to some 200 to 300 feet.

There are some 40 streams that drain the volcanics of the southern area. The streams to the west tend to be steep, have a short stream length and drain small areas; usually less than 3 square miles. The eastern streams tend to drain larger areas with some as large as 28 square miles. These streams are steep in their upper reaches but they flatten out into gentle grades and wide flat valleys in the lower reaches.

The topographic relief of the Island is not very pronounced and there is no marked orthographic effect (*USGS* 1965). Thus, the overall rainfall pattern of the Island is reasonably uniform. However, the steepness of the stream grades and the relatively impervious nature of the underlying formations causes many of the streams to flow only during and immediately after heavy rainfall. Often no sustained base flow is observed.

Geology

Guam is divided into roughly two geologic regions, which basically correspond to the topographic regions discussed previously. The geology of the Island is more fully discussed by Tracy et al (1963), Stazek (1963) and Schlonges (1964).

The plateau in the northern region of Guam is basically Barrigada Limestone which lies upon an irregularly eroded base of volcanic rock of the Alutom Foundation. The base of this limestone formation is mostly below sea level. A veneer of Mariana Limestone also overlaps the main formation. The limestone has numerous caverns, fissures and other solution openings which give it a high permeability as opposed to the volcanic material which has a very low permeability. The limestone areas are overlain by a friable layer of top soil which was likely derived from materials transported to the site and which supports a heavy vegetative growth.

The southern portion of Guam consists mainly of a mix of pyroclastic rock and lava flows, clastic sediments originating from volcanic rock with occasional occurrences of limestone. Some Alifan Limestone forms caps on the peaks and ridges and some outcrop rock and caustic sediments are often weathered to a depth of 50 feet or more. The upper few feet are often granular and friable. The weathered and un-weathered rock has a low permeability;

however, the associated limestone is very permeable. Unconsolidated deposits of clay with some sands and silts have occurred in the bottom of the river valleys. These deposits generally have low permeability. The beaches are composed of highly permeable calcareous sands and gravel.

An Overview of the Water Resources of Guam

The fresh water resources of Guam fall into essentially two categories: the groundwater of northern Guam and the surface waters of southern Guam.

As reported in the original *Water Facilities Master Plan* (1979), the average rainfall on Guam is slightly less than one billion gallons per day. Approximately one-half this amount falls on the northern half of the island which is a highly permeable, limestone plateau. According to the *NGLS* (1982), surface runoff from northern Guam is slight--only about 1.44 MGD from the Fonte River in the Nimitz Hill watershed. Thus, once the rainfall has satisfied evapotranspiration requirements it is available to percolate into the underlying aquifers. These phenomena have allowed the formation of a well developed fresh water lens under much of the northern area.

In 1982, the *NGLS* estimated that recharge from rainfall to the area of potential production in the Northern Lens is about 112 MGD, taking into account evapotranspiration and runoff from the Fonte River. In addition, an estimated 53 MGD of recharge from rainfall infiltration occurs within the 4,000-foot wide coastal buffer zone to make the total estimated recharge for the Northern Lens 165 MGD.

The *NGLS* goes on to estimate the sustainable yield of the Northern Lens at approximately 60 MGD. The sustainable yield is defined in the *Aquifer Yield Report* of the *NGLS* as ". . . the maximum amount of water that can be continuously withdrawn from the fresh water lens without impairing the integrity of the lens and the water quality". As stated in the *Aquifer Yield Report*, the sustainable yield is not equal to recharge because continued leakage from the lens to the ocean along the coastline must be taken into account. By the *NGLS*'s own account, however, its estimates of the sustainable yield are conservative. As discussed later in the "Guam Groundwater" section of this chapter, there is good reason to believe a considerably higher sustainable yield may be obtained. In fact, the preliminary results of Mink's reevaluation of the productivity of the Northern Lens (June 1991) now indicate a sustainable yield of the entire lens in the range of 70 to 80 MGD. Of this, the amount available to PUAG is estimated at approximately 60 MGD.

The USGS (1965) asserts that of the average rainfall on the Island (which is estimated at 1.0 billion gallons per day), approximately 250 MGD goes to runoff from some 40 streams that drain the southern half of the Island. Assuming, as stated in the NGLS, that rainfall is uniformly distributed throughout the Island, about 50 percent of the incident rainfall for this half of the island is therefore transformed into runoff and flows into the sea.

Of these 40 streams, very few have sufficient flow and available dam sites that make them suitable for major development. In its *Ugum River Draft Interim Report and Environmental Impact Statement (1979)*, the U.S. Army Corps of Engineers indicated that only four drainage basins were considered capable of significant development. These were the Inarajan, Ugum, Ylig and Pago basins. The Corps estimated the following average annual flows for these basins:

River	Average Annual Flow (MGD)	Length of Record
Inarajan	11.2	1952-1979
Ugum	19.0	1952-1979
Ylig	18.7	1952-1979
Pago	16.6	1952-1979
Total	**65.5**	

The average annual flow represents the amount of water that may theoretically be developed. Although this quantity represents approximately 26 percent of the total runoff for southern Guam, the flows are highly variable and the average annual flows occur less than 22 percent of the time. Consequently, the Corps' study assumed that a "firm yield" of about 75 percent of the average annual flows (or about 49 MGD) could be realistically developed. The report concluded that the Ugum and the Inarajan rivers had the greatest potential for development. Of these two, the Ugum River was recommended as the more economical site to develop, requiring a total storage or about 1.4 billion gallons to provide a yield of 12 MGD at a 95 percent confidence level. Similarly a storage reservoir on the Inarajan River of about 1.6 billion gallons could provide a yield of 8.5 MGD from this river, at a 95 percent confidence level.

To summarize the available water resources, there appears to be at least 60 MGD of sustainable yield available to PUAG from the Northern Groundwater Lens. In the south a reliable yield of anywhere from 20 to 49 MGD is available depending on the volume of storage provided.

Guam Groundwater System

As previously described, the significant groundwater resources are found in the northern half of the Island. The limestone which underlies this area is very porous and has been a suitable medium for forming a Ghyben-Herzberg lens.

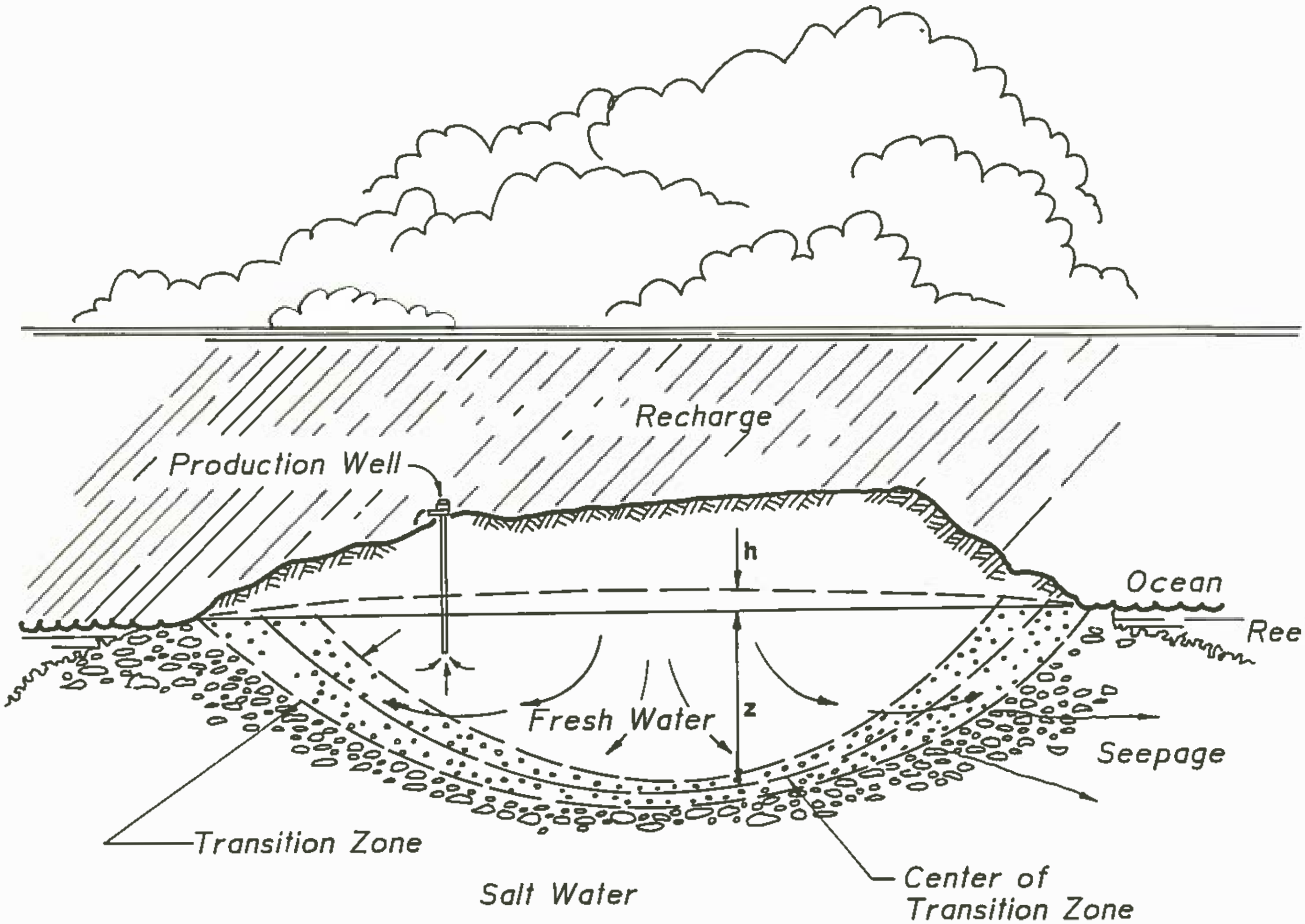
In a typical Ghyben-Herzberg system, shown in Figure 8-1, the water percolating from the surface of the island floats on the underlying sea water because of the latter's slightly higher density. The continued infiltration of fresh water causes the formation of a mound of fresh water, the depth of the mound being about 40 times the height of the mound above the surrounding sea level. The depth to which the sea water is depressed--i.e. the thickness of the fresh water lens--is described by the Ghyben-Herzberg relation:

$$z = 40h$$

where "z" and "h" are, respectively, the dimensions of the depth below sea level of the underground sea water surface and the depth above sea level to the top of the fresh water layer, as shown in Figure 8-1. By applying the Ghyben-Herzberg relation to known elevations of the fresh water surface, the size of the fresh water lens can be estimated.

An important assumption of the Ghyben-Herzberg model is that a sharp interface exists between the salt and fresh water. In reality, these two phases mix to form a transition zone with a salinity gradient varying from sea water to fresh. Obviously, the thickness of the transition zone will affect the amount of fresh water to be actually found in a lens described by the Ghyben-Herzberg model. On Guam, it is estimated that the thickness of the transition zone varies from approximately 27 to 50 feet.

The fresh water mound of the Northern Lens is, in some places, up to 6 feet above sea level, giving the lens a maximum thickness of about 240 feet including the portion below sea level. As the water flows outward from the lens in a radial direction it mixes with the sea water



z = 40h

SOURCE: NGLS GROUNDWATER
MANAGEMENT PROGRAM

FIGURE 8-1

GHYBEN-HERZBERG LENS FORMATIO

nearer the coast to form a band of increasing salinity. The radial symmetry of the lens on Guam is distorted by the outcrops of igneous rock associated with the mountains in the northeast corner of the Island and also by the underlying igneous strata which forms an impermeable barrier. Figure 8-2, from the *NGLS Aquifer Yield Report*, illustrates the several groundwater subbasins defined by these relatively impermeable volcanic formations. The boundaries of the subbasins represent the approximate ridgelines of the volcanics as determined by the seismic and gravity surveys and exploratory drilling conducted for the NGLS.

The characteristics of a groundwater lens are defined by physical factors which include the rate of fresh water recharge and the permeability and homogeneity of the media that contain the water. The presence of many fissures in the aquifer will cause the lens to exhibit localized discontinuities. These physical factors are discussed below as specifically relating to Guam's northern groundwater lens.

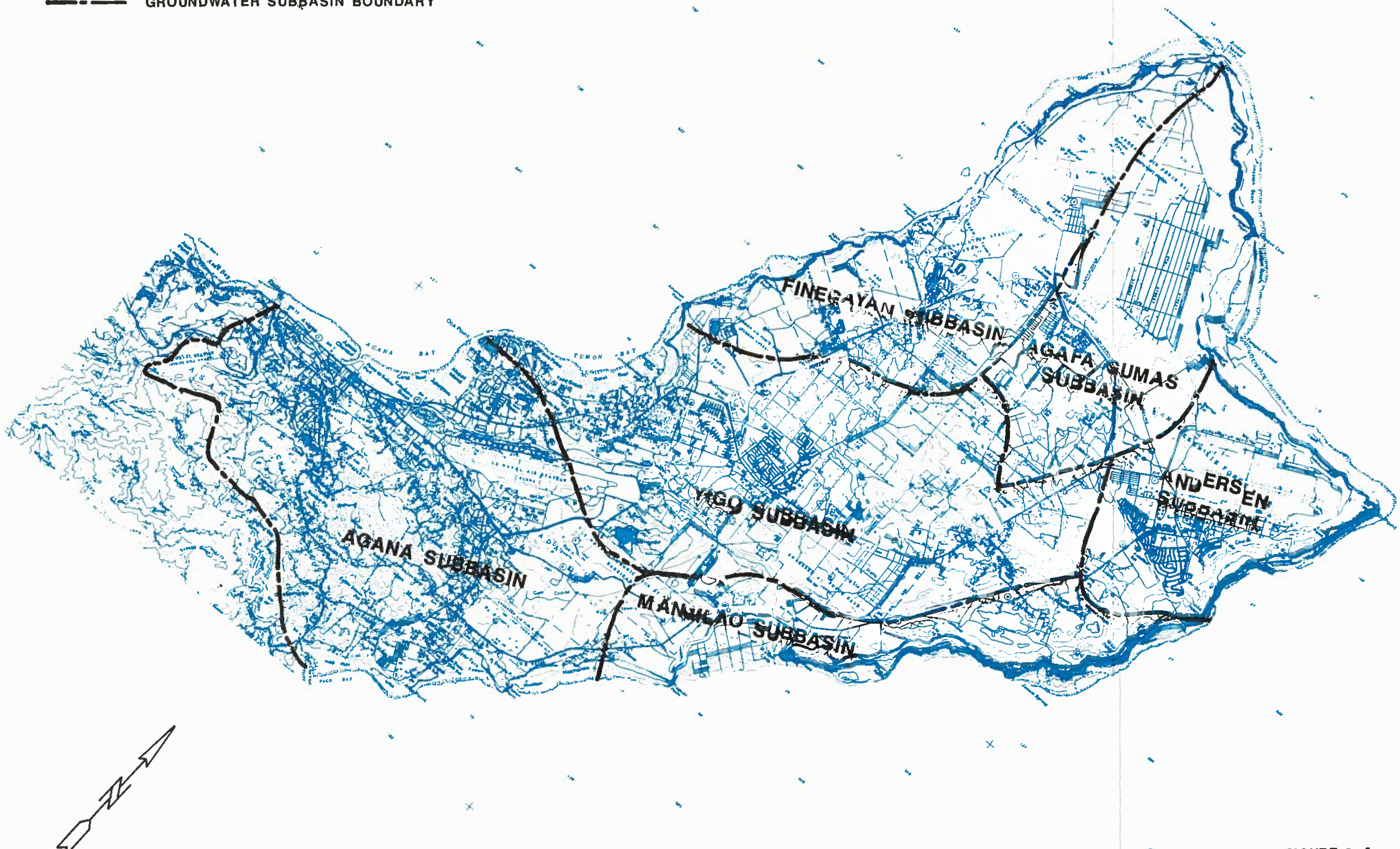
According to the *NGLS*, the permeability, or hydraulic conductivity, of the limestones of northern Guam varies from very high in the pure limestone areas of the Yigo-Andersen area (approximately 17,600 ft/day) to a somewhat lower value (about 1,500-3,000 ft/day) for the argillaceous limestones toward the center of the Island. In the regions of greatest permeability, the diurnal effects of tides as well as the effects of storm surges can be measured many thousands of feet inland. In these zones the constant rising and falling of the water table induces greater mixing and hence creates the transition zone. The mixing effect is not as significant in the less permeable areas.

Excessive extraction of groundwater will also reduce the volume of the fresh water lens and increase the zone of salinity. For example, during 1946, when there was heavy pumping associated with a high level of military activity, the contours indicating chloride concentrations of 500 parts per million in the groundwater almost met in the center of the Island. Once the pumping rate was reduced, the contours receded as the lens recovered in approximately two years time.

The *NGLS* describes two categories of fresh water lens--basal and parabasal--that are defined by the geology of the greater Northern Lens. These two lens types are illustrated in Figure 8-3. A parabasal lens is that portion of the freshwater lens directly underlain by the

LEGEND

GROUNDWATER SUBBASIN BOUNDARY



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SCALE IN FEET

SOURCE: NGLS AQUIFER YIELD REPORT

FIGURE 8-2

SUBBASIN LOCATION MAP

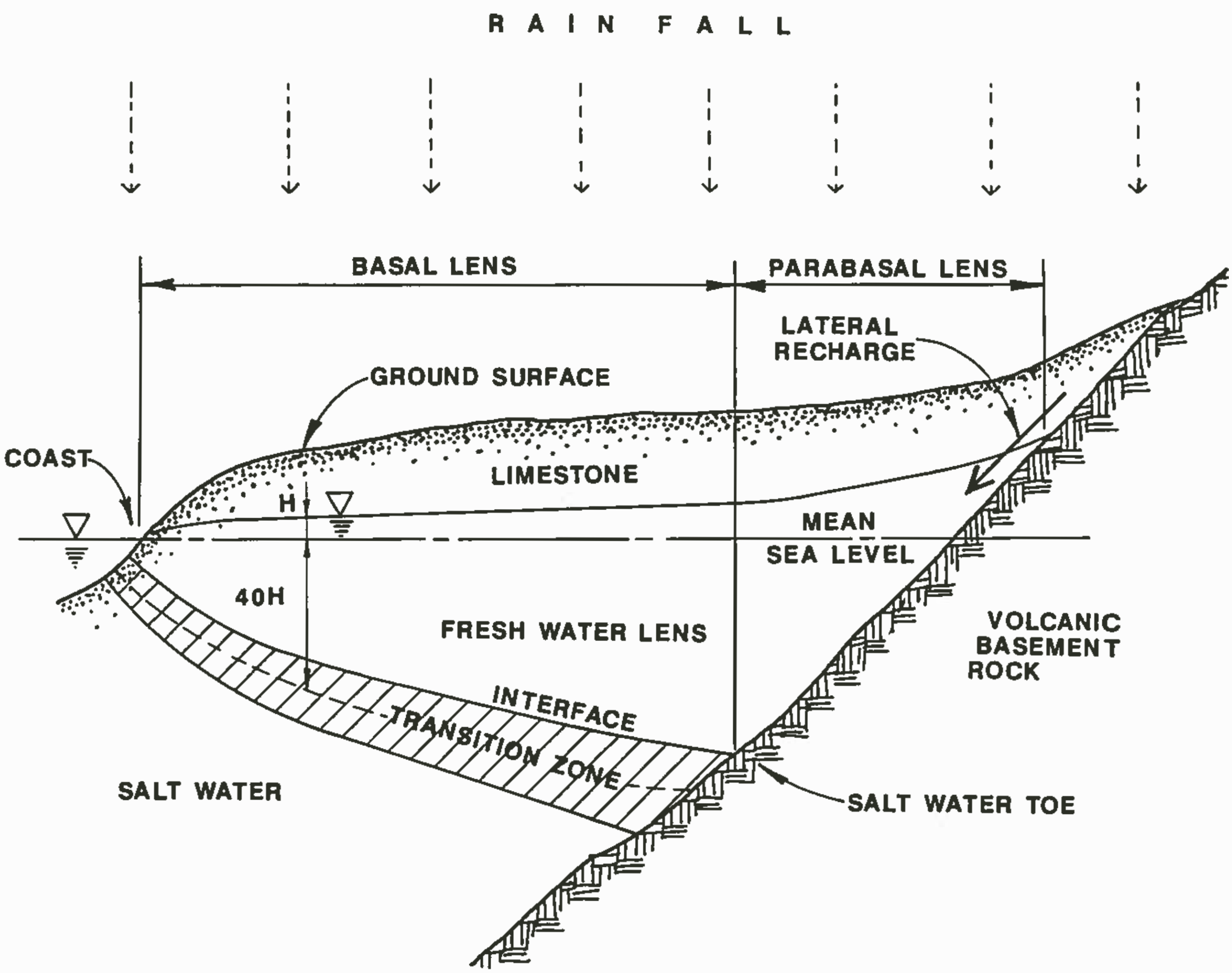


FIGURE 8-3

CROSS SECTION OF FRESH WATER LENS
WITH SHARP INTERFACE
IN A COASTAL UNCONFINED AQUIFER

SOURCE: NGLS AQUIFER YIELD REPORT

impermeable volcanic rock. The basal lens is a continuation of the parabasal lens except that it is directly underlain by salt water.

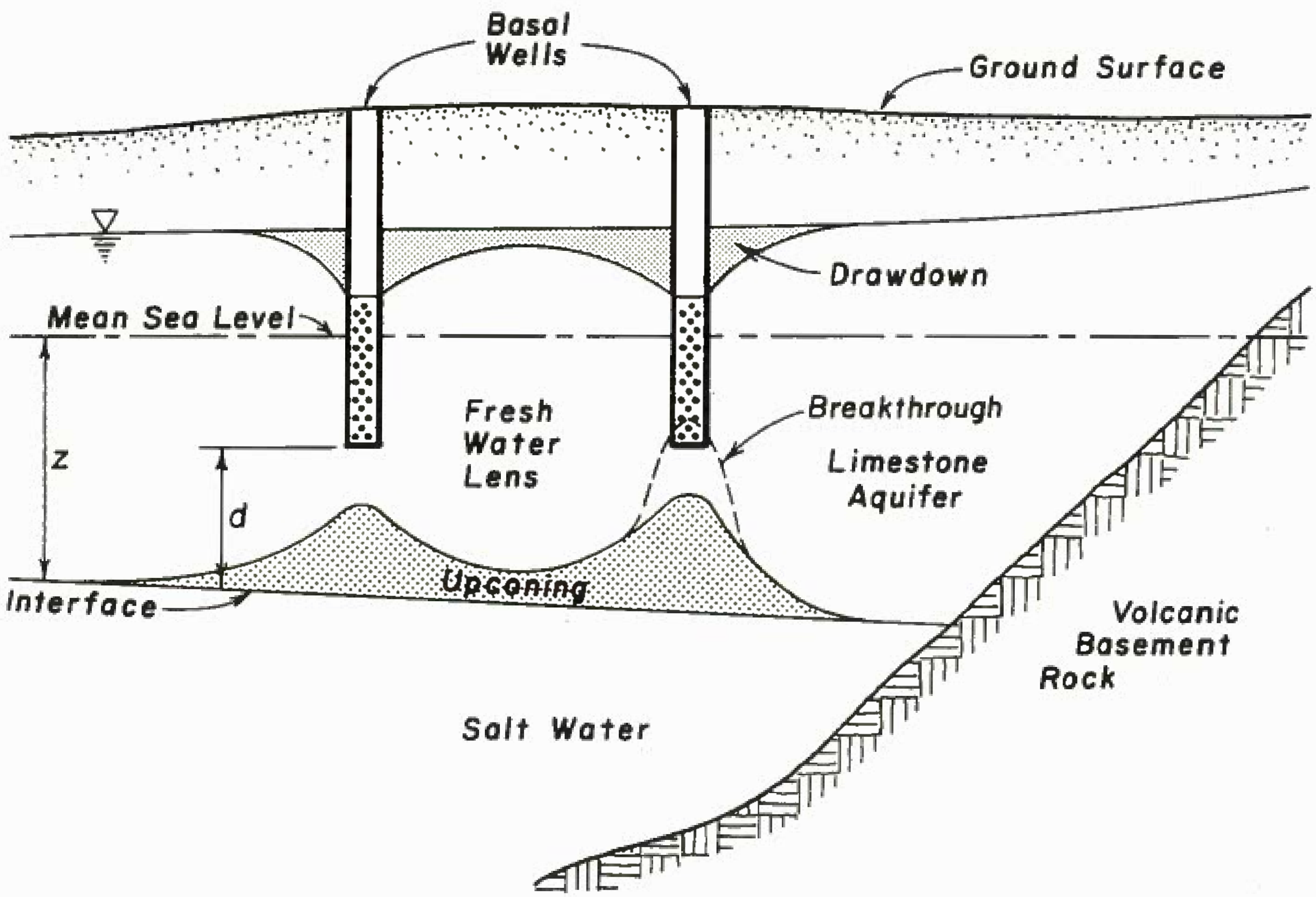
The importance of the distinction between these two types of lens is in the effects of pumping from them. As shown in Figure 8-4, salt water can rise vertically into a pumping well (upconing) located in the basal lens. Obviously, upconing does not occur in the parabasal lens because, by definition, there is no salt water directly below the lens of fresh water. However, overpumping of the parabasal lens could lead to intrusion of the salt water inland as shown in Figure 8-5. If the salt water toe migrates to a point beneath the pumping well, that well could then cause upconing.

Because of the potential for upconing, wells in the basal groundwater region must be pumped at rates lower than wells in the parabasal region. As stated in the *NGLS*, determination of pumping rates for wells should be based on the specific results of pump tests at the site. However, in general, ranges of 350 to 750 gpm for wells in the parabasal zone and 200 to 350 gpm in the basal zone were established in the *NGLS*.

Figure 8-6 from the *NGLS* shows the general distribution of the parabasal and basal lenses in northern Guam. The currently ongoing groundwater program evaluation is intended to help refine the limits of the parabasal and basal zones through time domain electromagnetic surveys and reviews of exploratory drilling results.

Recently there have been proposals for pumping brackish water from the buffer zone for irrigation supply. The rationale is that extraction of the brackish water near the outlet of the fresh water flux to the sea will have little effect on the up-gradient fresh water supply. This approach must be evaluated very carefully on a case specific basis before committing to any general policy. In some areas it may be a feasible approach to augmenting irrigation supplies. In other areas it risks endangering the integrity of the basal lens up-gradient from the pumping site.

The brackish water of the transition zone does not exist as a discrete, independent resource. It is continuous with the fresh water core and is actually just the freshwater mixed with small amounts of sea water. Disturbances of the brackish portion of the basal lens will therefore be reflected in the fresh water portion as well. In some areas this effect will be negligible.



SOURCE: NGLS AQUIFER YIELD REPORT

FIGURE 8-4

DIAGRAM OF PUMPING INFLUENCES ON THE TRANSITION ZONE

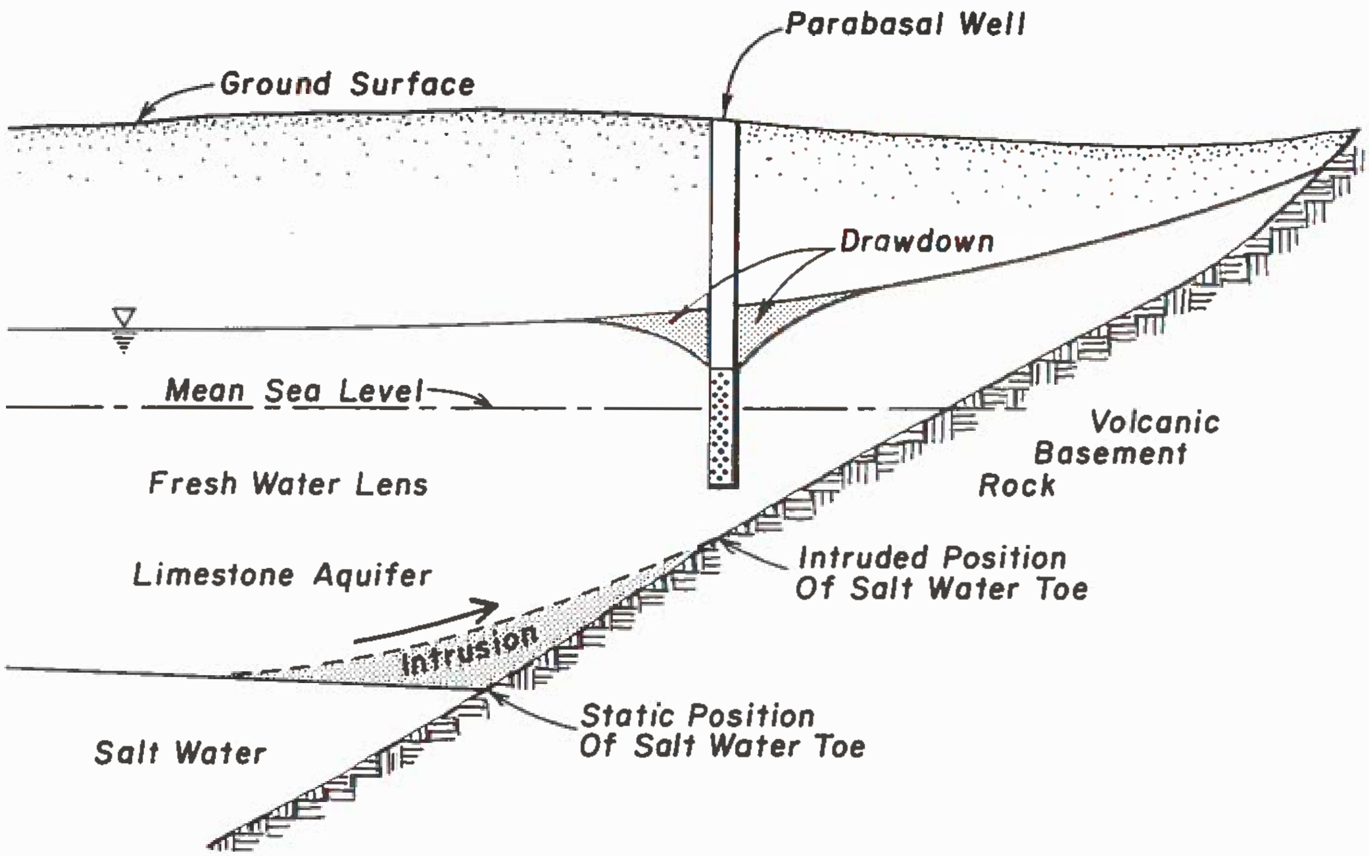
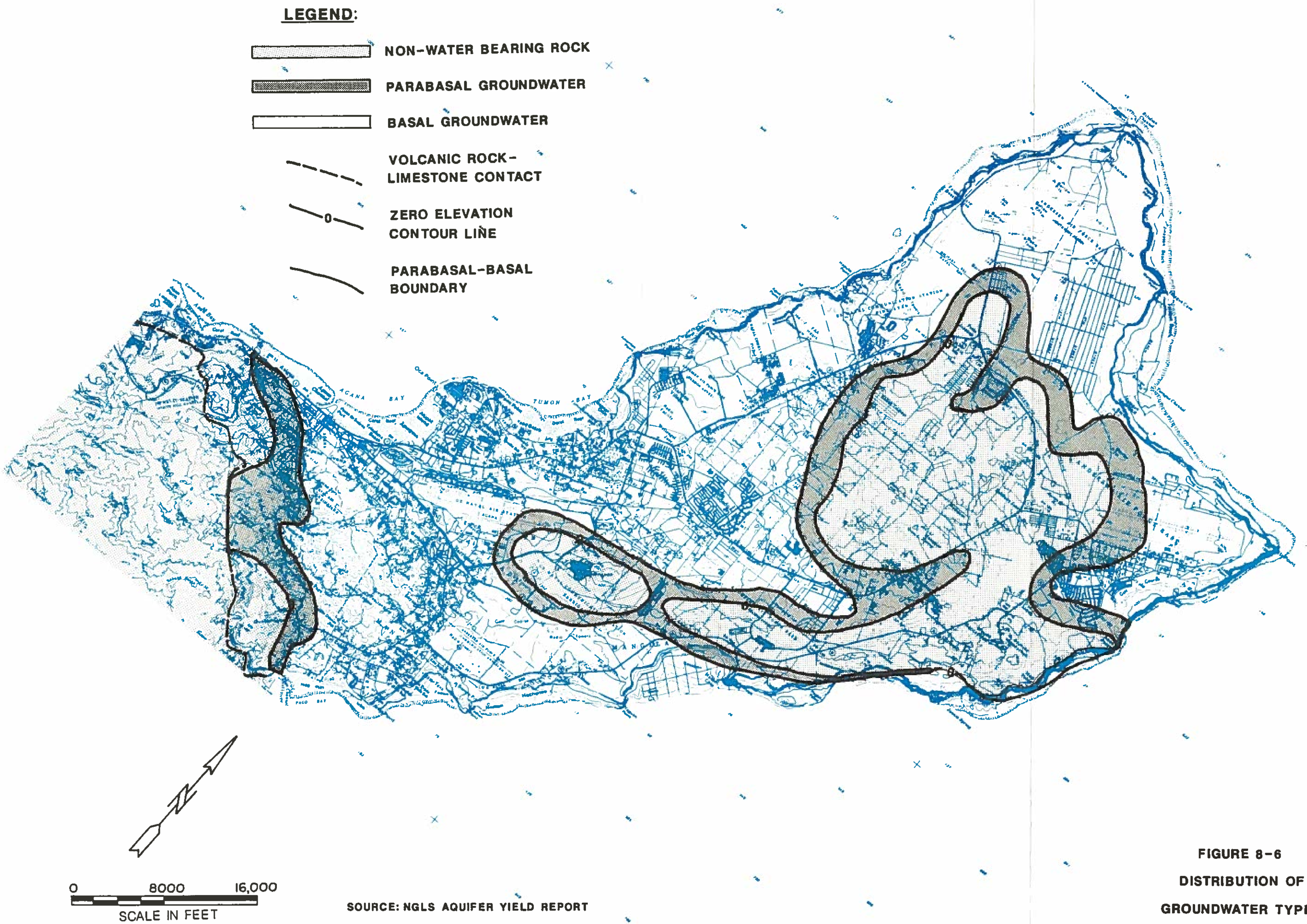


FIGURE 8-5

DIAGRAM OF SALT WATER INTRUSION TOWARD PARABASAL WELL

SOURCE: NGLS AQUIFER YIELD REPORT



SOURCE: NGLS AQUIFER YIELD REPORT

FIGURE 8-6
DISTRIBUTION OF
GROUNDWATER TYPES

Consequently, proposals to pump brackish water near the coast should be evaluated individually in relation to the particular local and regional groundwater environments.

The hydrodynamics of the *Northern Groundwater Lens* were first modeled in a preliminary manner by John F. Mink in his report, *Ground Water Resources of Guam: Occurrence and Development* (1976). Certain simplifying assumptions were made but these do not detractfrom the validity of the general conclusions drawn. His calculations were predicated on a lens height of 5.5 feet above sea level, a radius of 12,000 feet and a daily seepage to the sea of 100 cubic feet per foot of shoreline. The model showed that if the lens received no recharge for six months, its height would fall only 0.5 feet due to natural seepage. Also, if a draft of about 15 MGD was then imposed upon the lens, the extra decrease in height would be of the order of only 0.06 feet.

The hydrodynamics of the Northern Lens were also evaluated for the *NGLS* with a computer simulation of a steady state groundwater recharge of 112 MGD and a pumping rate of 60 MGD for a period of 5 years. Due to limitations of the model, steady cyclic conditions were never reached by the simulation. The primary limitation of the model was its lack of a long period data base. Consequently, any predictions resulting from the model should be viewed with considerable care and recognition of the model's limitation. Given this limitation, it is still worth noting that the results of the simulation generally supported Mink's previous calculations, by predicting a decrease in the lens's freshwater head of about 0.5 feet and an increase in saltwater head of only 0.25 feet at the end of the simulated 5 year period.

In the nine years since the *NGLS* was completed, data including well performance, water table elevations and groundwater quality have been regularly monitored and annually recorded by GEPA. The modelling currently being conducted for PUAG's GWPE has the advantage of this long term data base that was unavailable for the *NGLS*. The Program's preliminary conclusions, based on analysis of this long term data, were reported by Mink in his draft paper, "Groundwater In Northern Guam, Sustainable Yield and Groundwater Development" (June 21, 1991). Mink's analysis also concludes that virtually no long-term drop has occurred in the groundwater table since the *NGLS* was completed. In this same period of time an additional 12 production wells have been constructed on the Northern Lens and groundwater production has increased by approximately 34 percent.

The significance of these results is several fold. First, the apparent lack of long term impact to the fresh water table elevations with the increase in production suggests the Northern Lens has a high recharge rate and robust recoverability. This, in turn, supports the potential for withdrawing water at rates higher than the sustainable yield for short periods of time without damaging the integrity of the aquifer. While the *NGLS* does not specify what length of time would be acceptable for exceeding the sustainable yield, Mink's June 1991 report implies that a period of three months could be supported.

Second, particularly with regard to Mink's 1991 modelling and its long term data base, the results suggest a greater continuity in the groundwater aquifer than previously described in the *NGLS* model. Thus, wells could be expected to draw from a much greater area than the discrete Management Zones of the *NGLS*. With the advantage of the perspective allowed by GEPA's long term data base, Mink's methodology in modelling the Northern Groundwater Lens for the GWPE, and his conclusions, differ from those of the NGLS in several important respects.

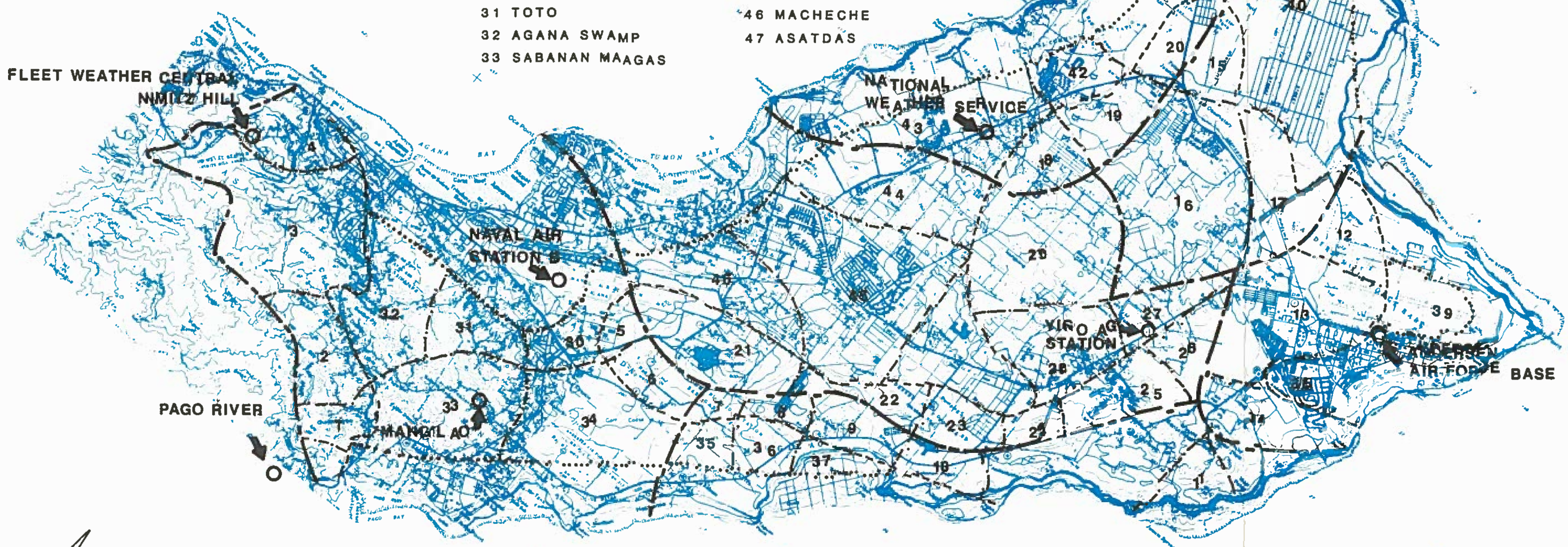
The most critical difference lies in the concept of hydraulically continuous Aquifer Systems as applied in the GWPE. The *NGLS* model estimated the sustainable yield of Guam's entire Northern Lens based on several conservative assumptions applied to 47 groundwater management zones, shown in Figure 8-7. However, although the Groundwater Management Zones provide a starting point for management of the groundwater resources, hydrologically, their boundaries are arbitrary—there are no actual geological or hydrological definitions of these zones within any particular subbasin. An arbitrary buffer zone, extending 4,000 feet inland from the coast, was also established from which it was assumed no fresh water production was to occur. This left only 67 of the 100 square miles of Northern Guam available for recharge and groundwater analysis. The 67 square miles was divided into the discrete Groundwater Management Zones based on the limited knowledge available with the hydraulic continuity of the lens. Hydrologic budgeting, including recharge and pumping calculations, was then performed on each independent zone.

PARABASAL MANAGEMENT ZONE

1 PAGO BAY
2 CHALAN PAGO
3 NIMITZ HILL
4 ANIGUA
5 MT. BARRIGADA SOUTH
6 MT. BARRIGADA EAST
7 MANGILAO SOUTH
8 MANGILAO NORTH
9 ADACAO
10 SABANAN PAGAT
11 JANUM
12 TARAGUE
13 SALISBURY
14 LUPOG
15 AGAFA GUMAS WEST
16 AGAFA GUMAS CENTRAL
17 AGAFA GUMAS EAST
18 CALLON TRAMOJO
19 FINEGAYAN EAST
20 POTTS
21 MT. BARRIGADA WEST
22 MOGFOG
23 MARBO SOUTH
24 MARBO NORTH
25 YIGO EAST
26 MT. SANTA ROSA
27 MATAGUAC
28 YIGO WEST
29 Y-SENGSONG

BASAL MANAGEMENT ZONE

30 BARRIGADA
31 TOTO
32 AGANA SWAMP
33 SABANAN MAAGAS
34 MANACA
35 ASBECO
36 TAGUAN
37 SASAJYAN
38 ANAO
39 ANDERSEN
40 NORTHWEST FIELD EAST
41 NORTHWEST FIELD WEST
42 FINEGAYAN WEST
43 NCS
44 DEDEDO NORTH
45 DEDEDO SOUTH
46 MACHECHE
47 ASATDAS



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SCALE IN FEET

Legend:

- GROUNDWATER SUBBASIN BOUNDARY
- PARABASAL - BASAL BOUNDARY
- MANAGEMENT ZONE BOUNDARY
- BOUNDARY FOR SAFE PUMPING
- RAINGAGE STATION

SOURCE: NGLS AQUIFER YIELD REPORT

FIGURE 8-7
GROUNDWATER MANAGEMENT ZONES
NOTHERN LENS

The approach as applied in the GWPE treats the entire Northern Lens as a continuum subdivided into functional aquifer categories. The aquifer categories are based on groundwater hydraulics with values for recharge being derived from a water balance. In this approach the entire 100 square miles of Northern Guam from the coast inland is considered in the hydrologic analysis.

In essence, a hierarchy of aquifer categories is presently proposed by Mink which would include an Aquifer Sector, subdivided into Aquifer Systems which are further subdivided into Aquifer Types. A more detailed explanation of this new hierarchy of aquifer categories is presented in Mink's report *Ground Water in Northern Guam: Sustainable Yield and Ground Water Development*, 1991.

Another significant difference in the GWPE's approach is in analyzing the Lens through a dynamic or transient model versus the steady state model applied in the *NGLS*. The steady state approach assumes an average rate of recharge, draft and an initial head in the system prior to the start of pumping. As such, it does not account for the significant effect of the seasons on dewatering and replenishing the basal lenses. This model is more appropriate to very large aquifers with relatively uniform recharge flux as is common in southern Oahu, Hawaii. In northern Guam the effects of the seasons on recharge cannot be ignored. Pumping during the dry season can cause a noticeable decline in head while heavy rains of the wet season result in greatly increased recharge and a sharp recovery of head. In the transient model, the seasonal variations in recharge are reckoned into the calculations and the continuity in groundwater action is taken into account from discharge at the coast line inland to a natural boundary such as a groundwater divide or the emergence of the basement above sea level.

Based on the results of this model and the analysis of GEPA's data, the conclusions of Mink's draft report for the GWPE are that the sustainable yield of the entire Northern Groundwater Lens is in the range of 70 to 80 MGD with 60 MGD available to PUAG.

Table 8-1 lists the Groundwater Management Zones from the *NGLS* along with their projected yields as used in preparation of this Plan until the ongoing groundwater program evaluation is completed. These projections must be continually examined and, if necessary, revised in the light of future well performance data and the results of ongoing exploratory well testing.

TABLE 8-1
STATUS OF GROUNDWATER MANAGEMENT ZONES

PARABASAL AQUIFER ZONES

GW ZONE NO.	GROUNDWATER SUBBASIN	GROUNDWATER MANAGEMENT ZONE	TOTAL YIELD (GPM)	TOTAL CURRENT PRODUCTION (GPM)	REMAINING YIELD (GPM)	PUAG WELLS UNDER CONST. (GPM)
1	Agana	Pago Bay	310	0	310	0
2	Agana	Chalan Pago	860	1190	-330	0
3	Agana	Nimitz Hill	2510	1544	966	966
4	Agana	Anigua	810	600	210	150
5	Agana	Mt. Barrigada South	210	150	60	0
6	Agana	Mt. Barrigada East	510	100	410	0
7	Mangilao	Mangilao south	220	0	220	0
8	Mangilao	Mangilao North	290	696	-406	0
9	Mangilao	Adacao	660	125	535	0
10	Mangilao	Sabanan Pagat	550	0	550	0
11	Mangilao	Janus	460	0	460	0
12	Andersen	Tarague	710	0	710	0
13	Andersen	Salisbury	1980	0	1980	0
14	Andersen	Lupog	1015	0	1015	0
15	Agafa Gumas	Agafa Gumas West	600	0	600	0
16	Agafa Gumas	Agafa Gumas Central	2920	471	2449	0
17	Agafa Gumas	Agafa Gumas East	1130	0	1130	0
18	Finegeyan	Callon Tranojo	660	410	250	0
19	Finegayan	Finegayan East	760	0	760	0
20	Finegayan	Potts	600	0	600	0
21	Yigo	Mt. Barrigada West	900	470	430	0
22	Yigo	Mogfog	450	0	450	0
23	Yigo	Marbo South	450	0	450	0
24	Yigo	Marbo North	240	0	240	0
25	Yigo	Yigo East	750	964	-214	0
26	Yigo	Mt. Santa Rosa	530	0	530	0
27	Yigo	Mataguac	610	0	610	0
28	Yigo	Yigo West	1320	610	710	0
29	Yigo	Ysengsong	2060	0	2060	0
TOTAL PARABASAL			25075	7330	17745	1116
SUBBASIN TOTALS		Agana	5210	3584	1626	1116
		Mangilao	2180	821	1359	0
		Andersen	3705	0	3705	0
		Agafa Gumas	4650	471	4179	0
		Finegayan	2020	410	1610	0
		Yigo	7310	2044	5266	0

BASAL AQUIFER ZONES

GW ZONE NO.	GROUNDWATER SUBBASIN	GROUNDWATER MANAGEMENT SUBBASIN	TOTAL YIELD (GPM)	TOTAL CURRENT PRODUCTION (GPM)	REMAINING YIELD (GPM)	PUAG WELLS UNDER CONST. (GPM)
30	Agana	Barrigada	260	183	77	0
31	Agana	Toto	430	50	380	0
32	Agana	Agana Swamp	870	0	870	0
33	Agana	Sabanan Maagas	1200	1391	-191	0
34	Agana	Manaca	1150	0	1150	0
35	Mangilao	Asbeco	230	0	230	0
36	Mangilao	Taguan	210	464	-254	0
37	Mangilao	Sasaijyan	90	0	90	0
38	Andersen	Anao	240	0	240	0
39	Andersen	Andersen	390	0	390	0
40	Agafa Gumas	N.W. Field East	2360	0	2360	0
41	Finegayan	N.W. Field West	870	0	870	0
42	Finegayan	Finegayan West	440	1085	-645	0
43	Finegayan	NCS	1110	752	358	0
44	Yigo	Dededo North	1340	1098	242	0
45	Yigo	Dededo South	2400	4321	-1921	0
46	Yigo	Macheche	870	253	617	0
47	Yigo	Asatdas	1330	1137	193	0
TOTAL BASAL			15790	10734	5056	0
SUBBASIN TOTALS		Agana	3910	1624	2286	0
		Mangilao	530	464	66	0
		Andersen	630	0	630	0
		Agafa Gumas	2360	0	2360	0
		Finegayan	2420	1837	583	0
		Yigo	5940	6809	-869	0

SOURCE: NGLS; PUAG Yield Summary, September 1989

However, for the purposes of the *WFMPU*, the available groundwater supply is based on the previously established Groundwater Management Zones.

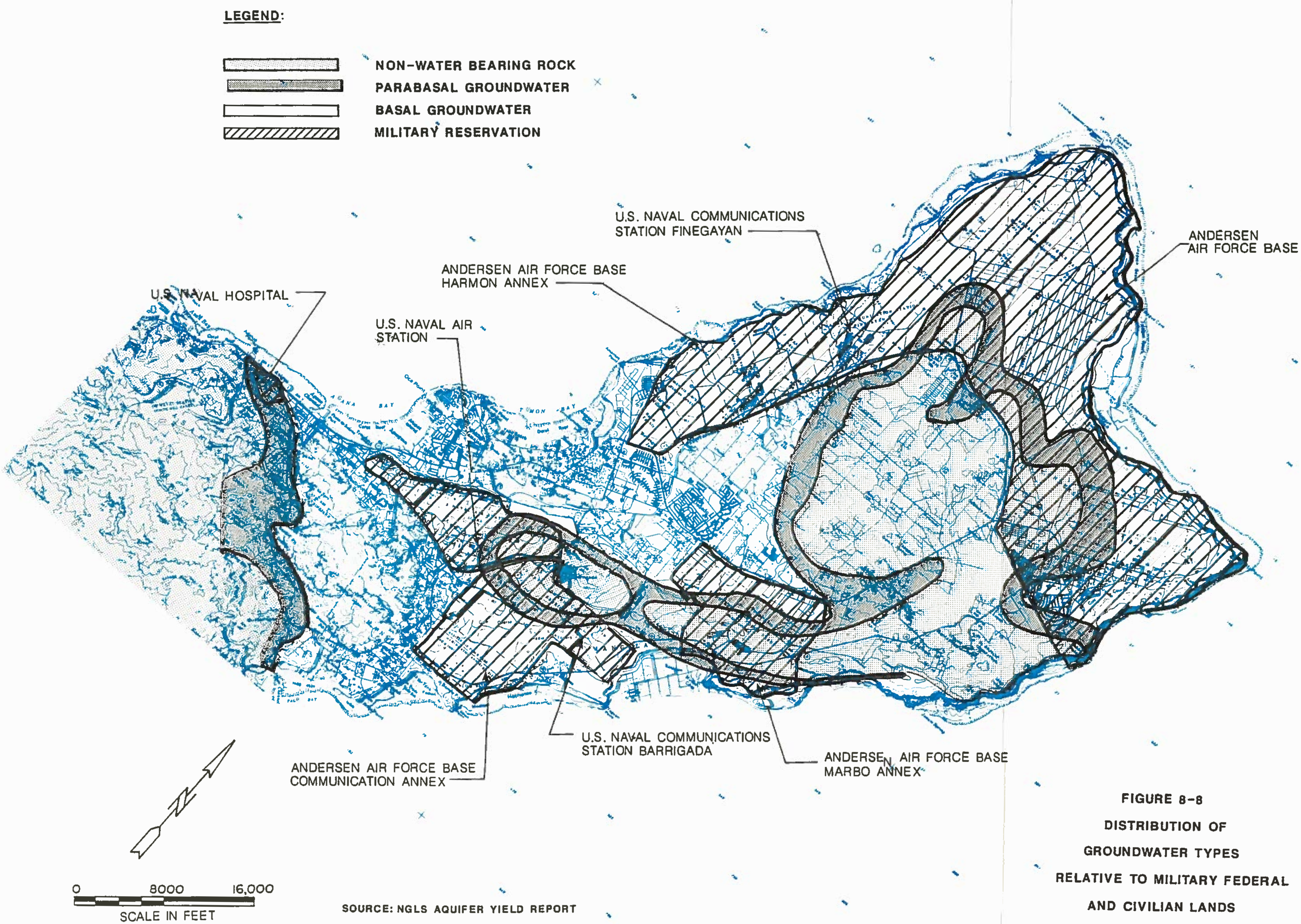
New technologies may also increase the yield of various zones. For example, underground "dams" have been constructed across aquifer drainages in Japan by drilling cores at close intervals and filling them with relatively impermeable substances such as a bentonite clay. This technique works best in aquifers of lower permeabilities and might be very successful in the Agana Swamp area where groundwater now flows out to sea.

Current information, then, suggests that with a *carefully and conscientiously* implemented groundwater management program, it is likely that considerably more yield can be sustained by the Northern Lens than was originally reported by the *NGLS* study.

Access to the groundwater is just as critical a factor to water master planning as the total amount of the lens's yield. Guam's Public Law No. 17-87 and Executive Order 89-5 reserves all waters on or below the surface of Guam for the People of Guam. Although this is intended to give PUAG a legal basis to withdraw water from wherever it can be found, the realities of obtaining a site suitable for direct, vertical pumping may make such withdrawal difficult. Figure 8-8 highlights the areas of U.S. military reservations relative to the basal and parabasal groundwater. It is estimated that approximately 25 percent of the Northern Lens's sustainable yield lies under lands occupied by the U.S. military, and is not directly accessible for civilian use. Outside the military reservations, private property would have to be acquired or easements obtained to provide access to additional groundwater resources.

Groundwater Quality Management

The Government of Guam has properly acknowledged the importance of regulating land use in the recharge areas of the groundwater lens in several of its planning documents. The Government of Guam has also entered into a memorandum of understanding with the U.S. Environmental Protection Agency concerning the protection of this resource, which has been designated as a sole source aquifer. Protection of the long-term sustainable yield of the lens requires the enactment and strict enforcement of land use, waste discharge, and well design, construction, and operation regulations. In its several volumes, including "Appendix A: Operation and Maintenance Manual", "Appendix B: Well Operations Organization Manual", "Appendix C: Well Construction Manual", and "Appendix D: Laws, Regulation, and



SOURCE: NGLS AQUIFER YIELD REPORT

FIGURE 8-8

DISTRIBUTION OF GROUNDWATER TYPES RELATIVE TO MILITARY FEDERAL AND CIVILIAN LANDS

Agreements Manual", the *Groundwater Management Program* of the *NGLS* presents programs, including draft regulations and legislation, necessary for the proper development and maintenance of Guam's northern groundwater system. Most of the recommendations for groundwater management from the original *Water Facilities Master Plan* (1979) and the *Groundwater Management Program* volume of the *NGLS* have been implemented by GEPA and PUAG and should still be followed. However, some of the recommendations that have not been implemented and are still needed are summarized as follows (original recommendations from the *NGLS* shown in italics).

- *Legislate that minimum lot size for a single dwelling within the groundwater protection zone not be less than 40,000 square feet if an on-site wastewater disposal system is used. Proposals for higher densities must include provisions for public sewer system.*

  Although not yet enacted by legislation, this recommendation has been implemented, to a limited degree, by GEPA and PUAG in their permitting capacities. To enable broader and consistent application, this recommendation should be enacted as a law or formal zoning regulation.

- *Construct a wastewater collection system in Harmon Industrial Park.*

  Although a wastewater collection system has been constructed in the Harmon Industrial Park since the *NGLS*, the area between the Korean Commercial Center west of Harmon Plaza and Fort Muna is still not serviced. Portions of the existing collection system are now also inadequate and should be upgraded.

- *Amend the well operation and maintenance contract to provide more specific maintenance and reporting requirements and procedures.*

  This contract was not renewed and PUAG has been responsible for well operation and maintenance since the contract's expiration. However, PUAG has stated its intention to initiate a new contract for well operations and maintenance, with more specific requirements included. This contract should be formalized as soon as possible since PUAG currently lacks the manpower and equipment to properly maintain the wells.

- *Evaluation of well production and recharge data should be conducted every five years to ensure that capacities of management zones and priorities for well development are up to date. Wells should be developed in the first and second priority zones listed in the Groundwater Management Program volume of the NGLS, unless future analysis indicates an improved order.*

- *Representatives of the Government of Guam and the military meet and negotiate a comprehensive and mutually beneficial program for the development of the Northern Lens.*

- *PUAG should procure additional funding to implement well construction and related activities and increase water rates to cover other groundwater management activities.*

  In 1986 PUAG raised water rates to cover the actual costs of water production. However, the increase was abrupt--increasing Guam's exceptionally low rates by as much as 200 percent--and met with considerable public opposition. A more gradual increase over a greater period of time with a structure that fairly represents the demands imposed by different user categories might be more successful and is still recommended. In addition, PUAG has recently procured a $53 million bond issue for capital improvements including additional wells in the Northern Lens. However, as indicated in Chapter IX of this report, additional money must be procured to implement all the CIPs necessary to meet the water demands projected for year 2010.

As the *NGLS* shows, the rational placement, construction and operation of all wells is also critical for the proper management of the aquifer. Past experience on Guam has shown that excessive pumping of wells can easily lead to the intrusion or upconing of sea water and hence degradation of the water quality.

The plan for well development proposed in the *NGLS* is one approach to regulating the number, location and production rate of wells to match the estimated yield a given area can support. Although the results of the GWPE may alter some aspects of this plan, it is, on the whole, expected to remain applicable. Elements of the *NGLS* plan are presented as follows.

Table 8-2 lists the management zones, proposed well numbers and sizes of first and second priority well fields recommended by the *NGLS* for development. The general locations of these fields are shown in Figure 8-9. Table 8-3 lists priority for development of the groundwater management zones, based on the Well Development Priority Matrix that was recommended in Chapter 6 of the *Groundwater Management Program* volume of the *NGLS* as well as pumping rates recommended by the *NGLS*.

With additional information a more successful management program for the basal lens might be developed. The primary need is for analysis of well log information, observations of the fluctuations in the thickness and horizontal extent of the basal lens and the underlying transition zone under varying conditions of recharge and demand, that have been collected by GEPA and USGS over the last 10 years as well as evaporation and other basic climatologic data. Such analysis can enable the formulation of the necessary management practices that will optimize the yield of the lens on a sustainable basis. The volumes of the *Groundwater Management Program* provide the additional guidelines necessary for the proper development and maintenance of the Northern Lens.

The greatest potential for pollution of the groundwater from civilian sources is from the application of pesticides and fertilizers from agricultural and golf course operations and from septic tank leachate. Although land use regulations are supposed to limit the density of development with onsite wastewater disposal, they are not effectively enforced. The only real protection of the groundwater, in this case, will be for all developments to be connected to sewer systems.

If intensive irrigation is to be expanded on Guam, sound farming and golf course maintenance practices must be encouraged to insure the efficient use of water, fertilizers, and other agricultural chemicals. For instance, poor irrigation practices, the excessive use of fertilizers and pesticides, their misapplication or the application of improper fertilizers and pesticides will easily increase the prospect for groundwater pollution. Efficient farming and proper siting of irrigation enterprises can reduce the input of most pollutants to acceptable levels. The objective of all such practices should be to control the level of pollutants which cannot be totally eliminated, to levels that can be flushed by outward seepage of the Ghyben-Herzberg lens system. Similarly, sound urban run-off and land use management practices, as described in the Department of Public Works' *Storm Drainage Manual*, should be pursued to maintain

TABLE 8-2
PROPOSED WELL DEVELOPMENT PRIORITIES

	Remaining Available Yield (gpm)	Recommended Well Sizes (gpm) 200	350	500	750
First Priority Wells					
Y-Sengsong	1,350	-	-	1	1
Adacao	650	-	-	1	-
Sabanan Pagat	550	-	-	1	-
Mt. Barrigada West	900	-	-	1	-
Yigo West	850	-	-	-	1
Agafa Gumas Central	2,650	-	-	4	-
Yigo East	650	-	-	1	-
Sub-Total		**0**	**0**	**9**	**2**

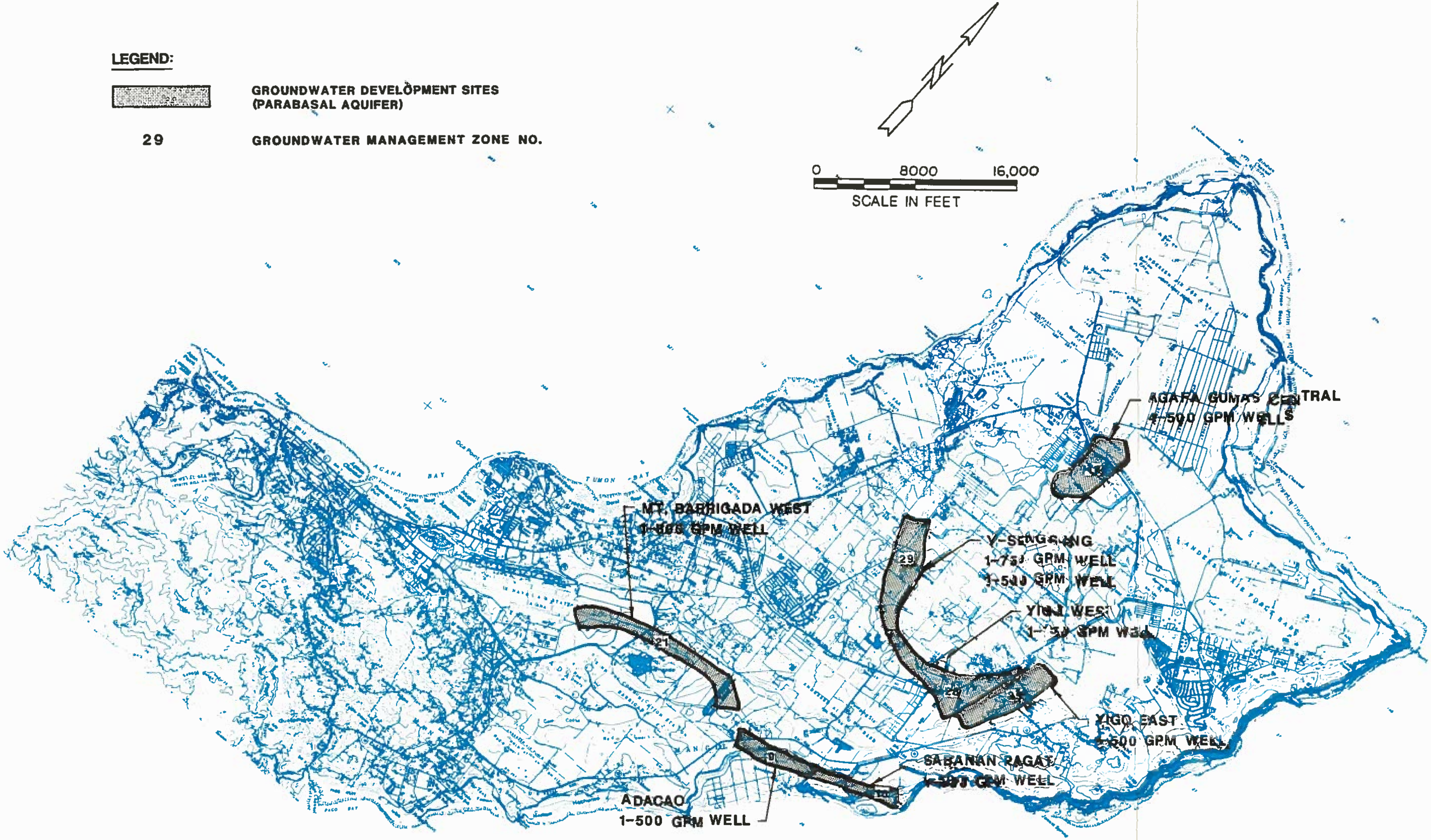
Total Yield of First Priority Wells = 6,000 gpm (8.6 mgd)

	Remaining Available Yield (gpm)	200	350	500	750
Secondary Priority Wells					
Finegayan East	750	1	-	1	-
Mt. Santa Rosa	500	-	-	1	-
Mataguac	600	-	-	1	-
Dededo North	1,200	6	-	-	-
Mt. Barrigada West	400(1)	-	1	-	-
Agafa Gumas Central	650(1)	-	-	1	-
Nimitz Hill	1,150	4	-	-	-
Lupog	1,000	-	-	2	-
Sub-total		**11**	**1**	**6**	**0**

Total Yield of Second Priority Wells = 5,550 gpm (8.0 mgd)

(1) Assumes construction of first priority wells reduces remaining available yield. See text.

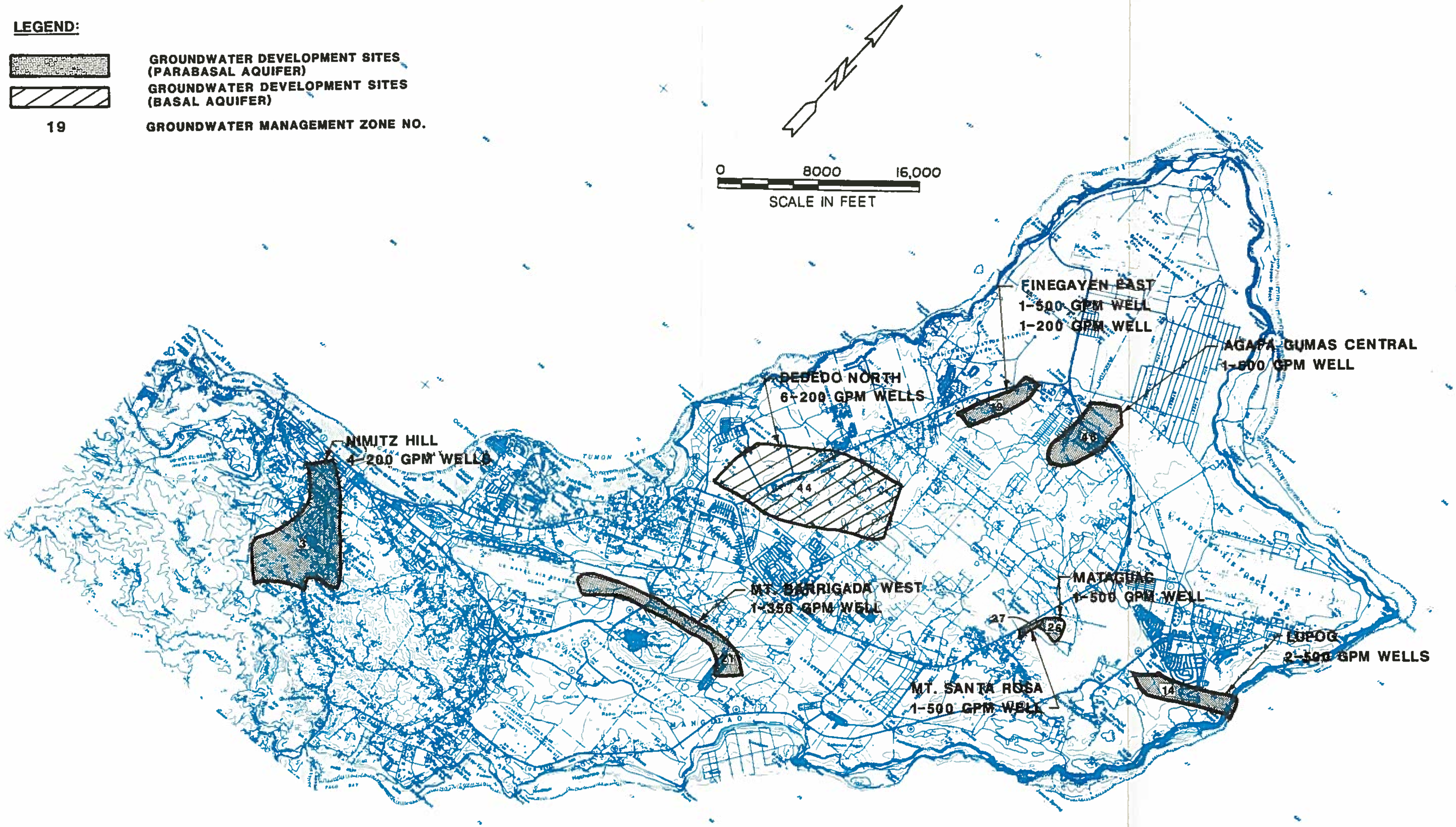
Source: NGLS, "Groundwater Management Program" 1982



SOURCE: NGLS GROUNDWATER MANAGEMENT PROGRAM

FIGURE 8-9a

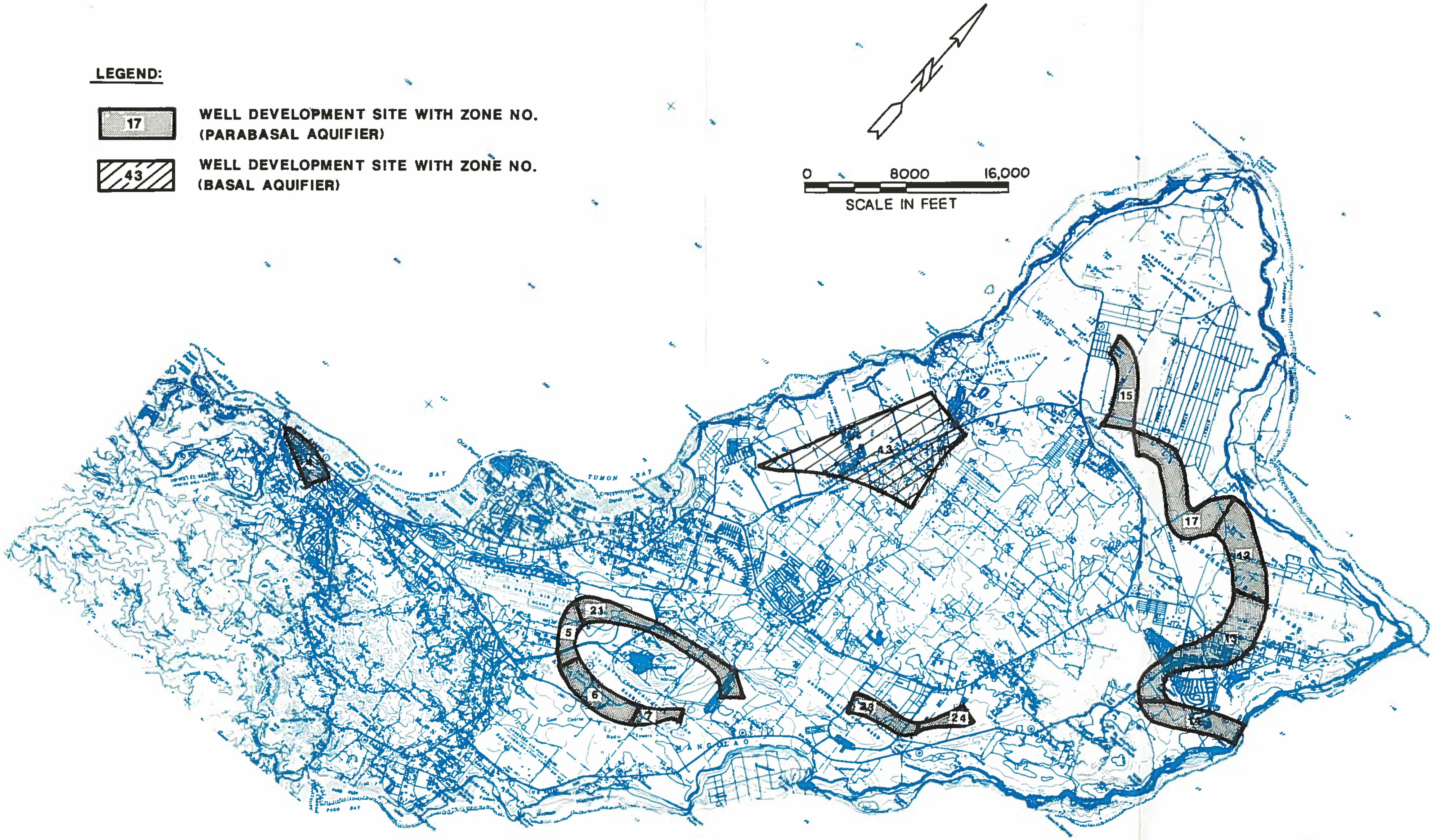
FIRST PRIORITY CIVILIAN WELLS



SOURCE: NGLS GROUNDWATER MANAGEMENT PROGRAM

FIGURE 8-9b

SECOND PRIORITY CIVILIAN WELLS



SOURCE: NGLS GROUNDWATER MANAGEMENT PROGRAM

FIGURE 8-9c
POTENTIAL MILITARY
WELL DEVELOPMENT SITES

TABLE 8-3
NGLS WELL DEVELOPMENT PRIORITIES

G.W. TYPE	G.W. ZONE	GROUNDWATER MANAGEMENT ZONE	NGLS SUST. YIELD (GPM)	NGLS RECOMMENDED PRODUCTION						CURRENT PROD. (GPM)	REMAINING YIELD (GPM)
				No. of Wells by Size (GPM)							
				IG	200	350	500	750	TOTAL GPM		
PARABASAL	16	Agafa Gumas Central	2920	--	--	--	5	--	2500	471	2449
PARABASAL	29	Ysengsong	2060	--	--	--	1	--	1250	0	2060
PARABASAL	9	Adacao	660	--	--	--	1	--	500	125	535
PARABASAL	28	Yigo West	1320	--	--	--	--	1	750	610	710
PARABASAL	10	Sabanan Pagat	550	--	--	--	1	--	500	0	550
PARABASAL	21	Mt. Barrigada West	900	--	--	1	1	--	850	470	430
PARABASAL	25	Yigo East	750	--	--	--	1	--	500	964	-214
PARABASAL	19	Finegayan East	760	--	1	--	1	--	700	0	760
PARABASAL	26	Mt. Santa Rosa	530	--	--	--	1	--	500	0	530
PARABASAL	27	Mataguac	610	--	--	--	1	--	500	0	610
PARABASAL	14	Lupog	1015	--	--	--	2	--	1000	0	1015
PARABASAL	3	Nimitz Hill	2510	--	5	--	--	--	1000	1544	966
BASAL	44	Dededo North	1340	--	6	--	--	--	1200	1098	242
BASAL	32	Agana Swamp	870	--	2	--	--	--	400	0	870
PARABASAL	6	Mt. Barrigada East	510	--	--	--	1	--	500	0	510
PARABASAL	4	Anigua	810	--	4	--	--	--	800	0	810
PARABASAL	18	Callon Tramojo	660	--	1	--	--	--	200	410	250
PARABASAL	1	Pago Bay	310	--	1	--	--	--	200	117	193
BASAL	31	Toto	430	--	2	--	--	--	400	50	380
BASAL	46	Macheche	870	--	4	--	--	--	800	3	867
PARABASAL	8	Mangilao North	290	--	--	--	--	--	0	696	-406
PARABASAL	13	Salisbury	1980	--	--	--	4	--	2000	0	1980
BASAL	33	Sabanan Maagas	1200	--	--	--	--	--	0	1391	-191
BASAL	34	Manaca	1150	--	5	--	--	--	1000	0	1150
PARABASAL	15	Agafa Gumas West	600	--	--	--	1	--	500	0	600
BASAL	37	Sasajyan	90	--	--	--	--	--	0	0	90
PARABASAL	17	Agafa Gumas East	1130	--	--	--	2	--	1000	0	1130
PARABASAL	2	Chalan Pago	860	--	--	--	--	--	0	1190	-330
PARABASAL	24	Marbo North	240	--	1	--	--	--	200	0	240

TABLE 8-3 (cont)
NGLS WELL DEVELOPMENT PRIORITIES

G.W. TYPE	G.W. ZONE	GROUNDWATER MANAGEMENT ZONE	NGLS SUST. YIELD (GPM)	NGLS RECOMMENDED PRODUCTION No. of Wells by Size (GPM) IG	200	350	500	750	TOTAL GPM	CURRENT PROD. (GPM)	REMAINING YIELD (GPM)
PARABASAL	11	Janum	460	4	--	--	--	--	400	0	460
PARABASAL	20	Potts	600	--	--	--	1	--	500	0	600
PARABASAL	22	Mogfog	450	--	--	1	--	--	350	0	450
BASAL	47	Asatdas	1330	--	--	--	--	--	0	1137	193
BASAL	43	NCS	1110	--	3	--	--	--	600	752	358
BASAL	30	Barrigada	260	--	--	--	--	--	0	183	77
BASAL	36	Taguan	210	--	--	--	--	--	0	464	-254
PARABASAL	12	Tarague	710	--	1	--	1	--	700	0	710
PARABASAL	23	Marbo South	450	--	--	1	--	--	350	0	450
BASAL	45	Dededo South	2400	--	--	--	--	--	0	4321	-1921
BASAL	40	N.W. Field East	2360	--	11	--	--	--	2200	0	2360
PARABASAL	5	Mt. Barrigada South	210	--	1	--	--	--	200	0	210
PARABASAL	7	Mangilao South	220	--	1	--	--	--	200	0	220
BASAL	41	N.W. Field West	870	--	4	--	--	--	800	0	870
BASAL	35	Asbeco	230	--	1	--	--	--	200	0	230
BASAL	38	Anao	240	--	1	--	--	--	200	0	240
BASAL	42	Finegayan West	440	--	--	--	--	--	0	1085	-645
BASAL	39	Andersen	390	--	2	--	--	--	400	0	390
		TOTAL	40,865	4	57	3	25	2	26,850	17,081	23,784

NOTES: 1) IG represents infiltration gallery or horizontal type well production required. Assumes maximum productivity is 100 gpm. Further subsurface investigations are required.

Source: NGLS; PUAG Well Summary, September 1989 the present level of infiltration of rain water with a minimal pollutant load. With respect to the permitting of golf course developments, a set of qualifications was recommended in Chapter VII which have also been proposed in Hawaii and are intended to enhance the protection of groundwater resources from pollution by pesticides and fertilizers applied to these developments. The qualifications are listed in Appendix G.

Following the recommendation of the *NGLS*, the Guam EPA has been tasked with the responsibility of regularly monitoring the Northern Lens and permitting any well development there. GEPA's on-going monitoring program measures water quality and fluctuations of the elevation and configuration of the basal lens and underlying transition zone. The results of the monitoring program are published annually in GEPA's *Groundwater Management Program Annual Report.* Some of the results of GEPA's water quality monitoring are compared in Chapter VII of this report with values reported in the *NGLS.*

Given proper management controls there appears to be a good possibility of maintaining an average day sustainable yield of 60 MGD for PUAG's system. Thus the resource should be able to produce between 2 and 3 times its present production rate and supply much of the needs of Guam in the near future. However, without such controls it is entirely conceivable that even current yields cannot be sustained. Under such a condition, the question of growth controls must be addressed or else future water development costs will be significantly inflated over those presently anticipated to be achievable.

Surface Water Supply

Virtually all the surface runoff that flows to the sea is carried by some forty streams that drain the southern half of the Island. The hydrologic characteristics of these streams are very similar because the meteorologic conditions across the Island are homogeneous and the geomorphology of the basins are similar. All the streams may be characterized as being flashy, that is, they rise very rapidly in response to rainfall because of the steep slopes and the low permeability of the underlying strata. They also have fairly rapid recessions with little sustained base flow, and exhibit marked seasonality because of the distinct seasonal pattern of the rainfall.

The frequency-distribution curve prepared by the USGS and shown on Figure 8-10 summarizes much of the statistical information about surface stream flow in southern Guam.

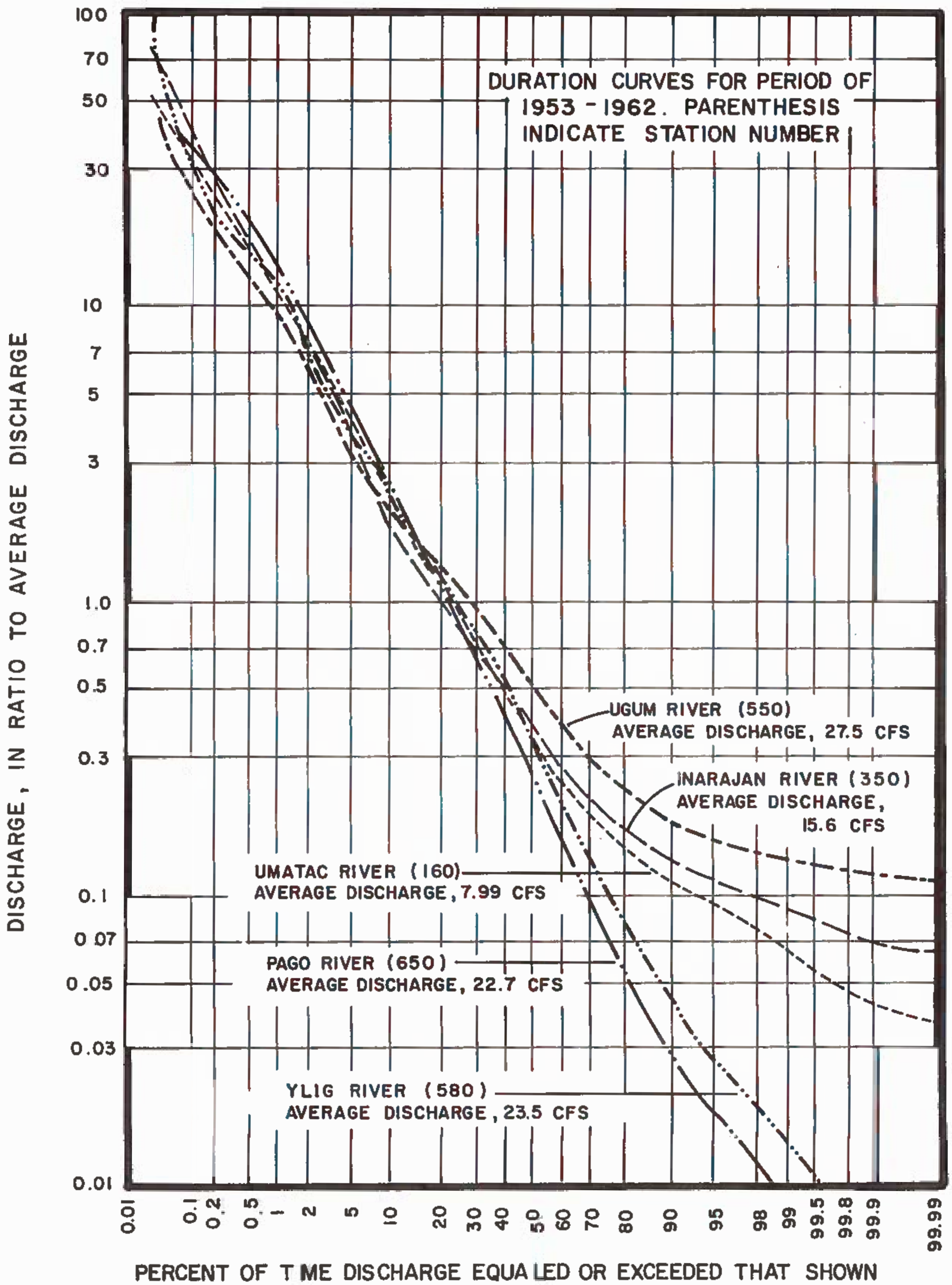


FIGURE 8-10

FLOW DISTRIBUTION CURVES FOR SOUTHERN GUAM RIVERS

SOURCE: U.S. GEOLOGICAL SURVEY

The discharges for the five rivers shown in the curves have been normalized. A river's flow is normalized by dividing its discharge at various points in time by the river's average flow. Figure 8-10 shows that the normalized curves for the various rivers of southern Guam are virtually the same for discharges greater than a river's mean flow. As a result of this coincidence, if flow data obtained from one river, over a short period of time, is greater than its mean flow it can be used to draw general conclusions about flow on the other rivers. Figure 8-10 shows that in all the rivers a flow greater than their mean occurs 20 to 25 percent of the time, a flow greater than 10 times the mean occurs one percent of the time and 30 times the mean about 0.1 percent of the time. These statistics indicate that the flows are quite variable with little persistence. For flows less than the mean there is a divergence between the streams because of the varying contribution to base flow from groundwater sources.

As part of the study leading to the original Water Master Plan and this report, the work papers and progress reports of the Corps of Engineers pertaining to its Ugum River studies were examined. On the basis of an independent analysis of stream flow characteristics in the southern portion of Guam and examination of many of the storage sites considered by the Corps, it is concluded that the development of any significant surface water supply will be quite costly as compared with other sources of supply. The steepness of the terrain limits the effective capacity of most potential storage sites and the unit cost of water so developed will likely be high. However, as water demand is expected to exceed sustainable yield from the northern aquifer in the near future, it will be necessary to develop new water supply sources. One possible method of supplying year 2010 requirements would be the development of these surface sources. While there are a number of possible storage sites, the two which appear to be the most promising are located on the Ugum and Inarajan Rivers, and are shown in Figure 8-11. These two sites should be given the greatest priority in any future surface water development program.

The USACOE has preliminarily identified potential reservoir sites on the Ugum and Inarajan Rivers. Area-capacity curves for each site, as prepared by the USACOE are presented in Figure 8-12. Flow duration curves and families of storage-yield probability curves, presented in Figures 8-13 and 8-14, are significant and useful for assessing the practical limits of the sustainable yield which could be developed at each of the two sites.

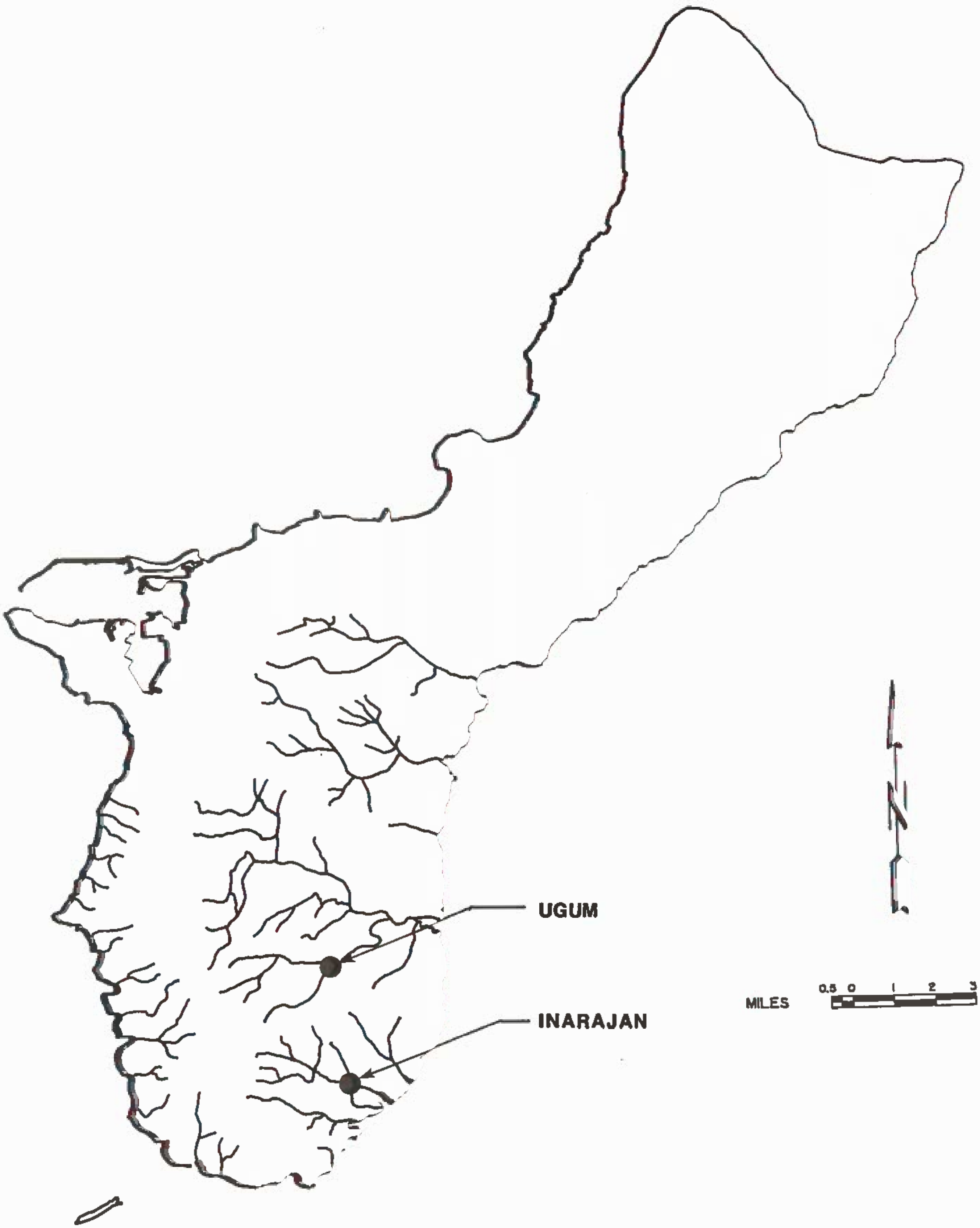
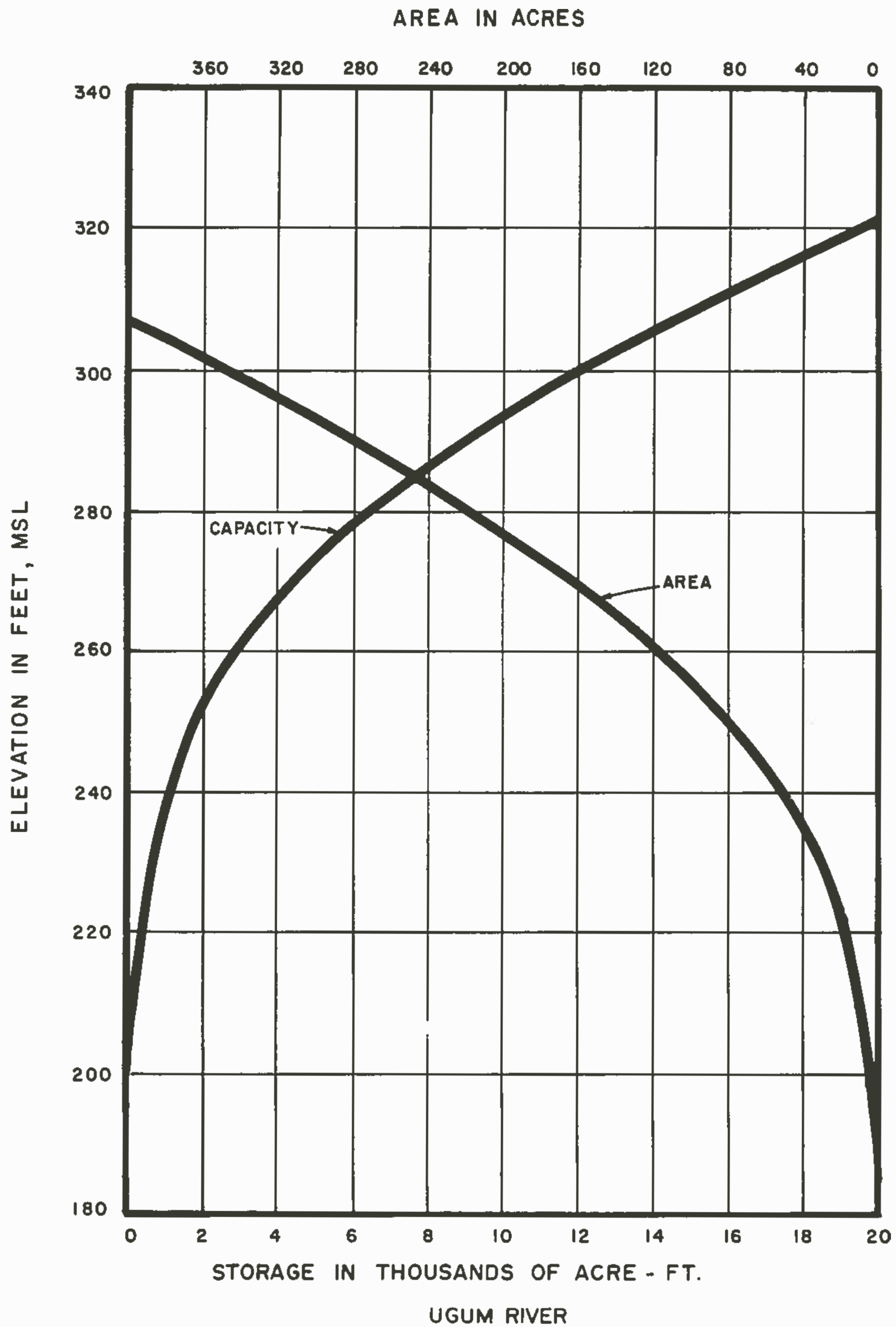
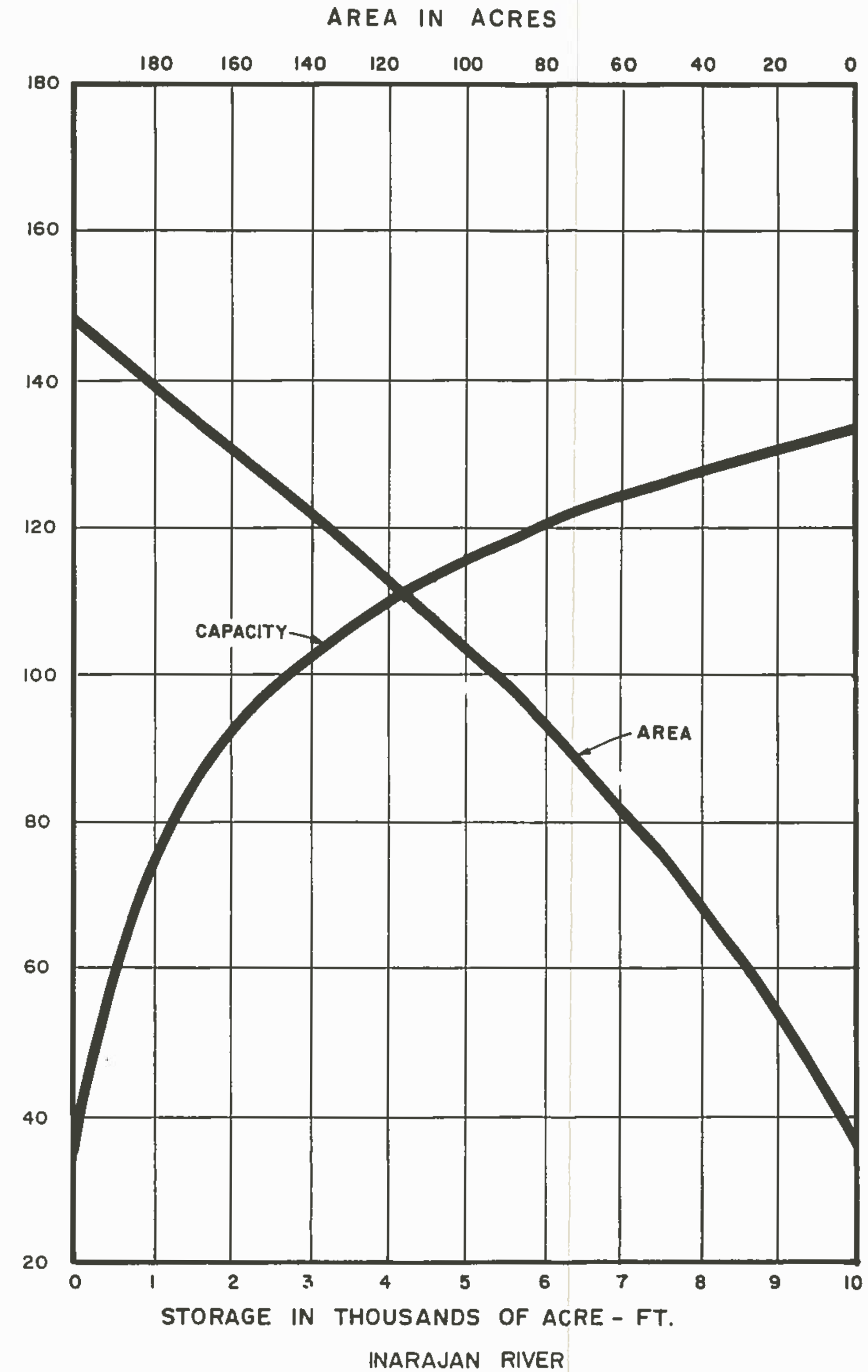


FIGURE 8-11

POTENTIAL STORAGE SITES

SOURCE: US ARMY CORP OF ENGINEERS





SOURCE: U.S. ARMY CORPS OF ENGINEERS

FIGURE 8-12

AREA-CAPACITY CURVES

UGUM AND INARAJAN RIVERS

storage required by the year 2010 and thus reduced the overall storage deficit. In summary, by the year 2010 approximately 55 MG of additional storage will be required.

Approximately 26 MG, or 45 percent, of the 55 MG additional capacity is required to meet projected hotel demand. While resorts and hotels are predicted to have the most significant impact on water facilities in the future, other commercial facilities would also have an effect. If these hotels and other commercial enterprises with high water consumption provided their own storage, the capital outlay required of PUAG would be significantly reduced. Such an arrangement would also benefit the owners of these facilities by providing greater assurance of the continuity of supply during times of system stress such as typhoons. In addition, it would seem to follow that by reducing the capital outlay required of PUAG, developers incorporating storage into their own facilities would also be reducing impact fees necessary to provide infrastructure service for development throughout the Island. While an expenditure for storage would still have to be made, the developer would have better control over how the money was spent and, especially, the timeliness with which the service was provided. Although this approach to developing storage should be explored, no such policy is now effect. Consequently, the estimate of required additional storage is conservative and assumes the entire amount shall be provided by PUAG.

Figures 9-2A, 9-2B, 9-2C and 9-2D, located at the end of this book, show the locations of the additional storage capacity required by the year 2010. The locations are approximate since more in-depth engineering analysis will be required to select the exact location prior to final design. Wherever possible, transmission mains were routed through the reservoirs by using separate inlet and outlet lines. In this way the reservoirs provide a pressure reducing function and decreases the need for PRVs at some locations. A hydraulic profile of the reservoir system is shown in Figures 9-3A and 9-3B.

In general, an attempt was made to use ground level storage as opposed to elevated storage tanks based primarily on the lower capital and operations and maintenance (O&M) costs of ground level storage reservoirs.

Regional Water Service Area "A" - As can be seen from Table 9-1, Service Area "A" will require a distribution storage capacity of 12 MG by the year 2010. The present storage capacity for Region "A" consists of a 0.5 MG reservoir located in the Yigo subregion, the 3

MG Barrigada Reservoir, the 1 MG Astumbo Reservoir and the 1 MG Mt. Santa Rosa Reservoir. The 0.5 MG Ground Reservoir located near Dededo cannot be considered part of Service Area "A" due to the fact that it serves Service Area "B." In addition, the Barrigada Reservoirs also serve Barrigada Heights Reservoir and contributes to the Route 15 flow to Mangilao Reservoir. As a result, at least 7 MG of additional storage capacity must be provided.

As shown in Figure 9-1, a total of four major pressure zones are defined by the existing elevations and pressure requirements of the Service Area "A". The highest of these zones, served by Mt. Santa Rosa Reservoir, intersects Marine Drive, Route 9 and Route 15. The next two zones intersect Route 3, Marine Drive and Route 15 and are served by Yigo, proposed Agafa Gumas, and Astumbo and Barrigada reservoirs respectively. The lowest zone intersects Marine Drive near Route 16 and would be served most directly by Barrigada Reservoirs and the proposed Agafa Gumas and, to some extent, Astumbo Reservoir. Yigo Reservoir would serve to step pressure down from the Mt. Santa Rosa pressure zone. The proposed Agafa Gumas Reservoir would reduce pressure from the Yigo pressure zone and Astumbo would reduce pressure from the Agafa Gumas pressure zone to serve the Dededo area.

As shown in Figure 9-2A, and Table 9-1, large capacities are planned for the Agafa Gumas Reservoir and the additional storage at Yigo and Astumbo Reservoirs to take advantage of their elevations and proximity to the major well fields. In this way pumping costs would be minimized and large reserves would be available to supply smaller storage sites in the lower pressure zones by gravity.

Regional Water Service Area "B" - Table 9-1 indicates that approximately 37 MG of additional storage will be required by the year 2010. Figure 9-2A shows the proposed location of storage reservoirs required for the year 2010. Of the total 44.5 MG storage required, approximately 23 MG would be required primarily for the coastal areas from Tumon to Agana, this area being the most densely populated and having the most stringent fire flow requirements. Most of the proposed additional storage is located at existing reservoir sites with the exception of the 5 MG in Barrigada (new Mongmong-Toto-Maite Reservoir), the 6 MG near the Airport Industrial Park, the 1 MG on Nimitz Hill and the 1 MG at Asan. It is expected that the storage will be constructed in increments as the demand increases. Increments projected for the years 2000 and 2010 are given in the list of Capital Improvements in Appendix H.

As shown in Figure 9-1, a total of three major pressure zones will be required in order to maintain pressures within acceptable limits. Two zones are located along Marine Drive. Pressures in these zones, which are served by the Tumon, Tumon Loop, Mongmong-Toto-Maite, Mangilao and Agana Heights Reservoirs, may have static pressure somewhat in excess of 100 psi at the lowest elevations. Pressure regulating valves will be required in these areas. The specific locations and settings of the valves must be determined by the designer of the pipeline. Where pressure regulation is not recommended because of restrictions to fire flows which may occur in commercial areas, high pressure pipe and fittings would be required. The third zone includes the developed areas around the loop formed by Routes 4, 8, and 10 and is served primarily by Mangilao and Chaot reservoirs.

As previously discussed, the Barrigada Reservoirs are intended to serve as the hub of distribution from the north to central regions of Guam. Stepping the pressure down from the Yigo, Agafa Gumas and Astumbo pressure zones, the Barrigada site would redistribute supply to the lower pressure zones of Dededo, Tamuning, Mangilao and Barrigada villages. The large storage capacity of this site facilitates its function as a source of reserve supply for these lower pressure zones as well as the Barrigada Heights Reservoir. An alternate site of the same elevation is located between the Barrigada Reservoirs and Route 16 on Government of Guam Lot 5382. According to the Guam Airport Authority's (GAA) *Water Facilities Master Plan* (Barrett Consulting Group; February 1989), this site also has the potential for production well development. As such, the location is well suited for providing additional supply and storage at an elevation that would support the Barrigada Reservoirs's function as a water distribution hub for the high demand areas of Central Guam.

The new reservoir proposed for the Airport Industrial Park or Macheche area will step pressure down from the Barrigada pressure zone to a level appropriate for the lower Tamuning zone. At the same elevation as Dededo Reservoir, this storage will be close enough to Oka Point to provide appropriate service pressures. The addition of this reservoir is as much for hydraulic considerations as for providing storage capacity. If site constraints limit the amount of storage that can be provided at this location, the remaining capacity required to service eastern Tamuning could be sited at the alternate Barrigada site, discussed above, on

Government of Guam Lot 5382 by a connection from a Lot 5382 reservoir to the transmission line between the Barrigada Reservoirs and that proposed for the Airport Industrial Park or Macheche vicinity.

The reservoir proposed for Route 16, between Barrigada Heights and Toto, will step pressure down from the Barrigada pressure zone to the lower Barrigada and Mongmong-Toto-Maite zones. At the same elevation as the Mangilao and Chaot Reservoirs, this new site will provide much needed balance to the western portion of this service area by decreasing the distance between points of demand and source of supply.

New storage is proposed on Nimitz Hill to provide adequate service to existing civilian development in this area. In addition, it serves as a point from which water could be boosted to higher elevations to enable further civilian development between Nimitz Hill and Sinifa.

Regional Water Service Area "C" - It can be seen from Table 9-1 that by the year 2010, Service Area "C" will require approximately 2 MG of additional storage. The present storage capacity consists of the 1 MG Santa Rita Reservoir and the 1 MG Sinifa Reservoir. As shown in Figure 9-2C, a future 1 MG reservoir is proposed for Santa Rita near Torres School, as well as 2 MG in the Pagachao area located south of New Agat Village along Route 2. PUAG's preferred site for the latter reservoir is within the Pagachao GHURA housing at a location formerly proposed for a storage reservoir. However, there is currently some controversy with an adjacent landowner over ownership of this site. An alternative site would be at the same elevation in the Ascola Sita area somewhat south of the Pagachao site.

An additional 0.5 MG reservoir is proposed adjacent to Route 2 on the east, above Sella Bay, as one of PUAG's $53 milliion bond projects. Although not essential from the standpoint of additional storage capacity, this reservoir will serve a hydraulic function by stepping pressure down from the proposed reservoir at Jumollong Manglo pass and will provide some service to the area west of Route 2. In addition it will serve as an intermediate point for boosting additional supplies to the reservoir at Jumollong Manglo pass.

Due to the very high elevation of the Sinifa Reservoir, a total of four pressure zones are required for the Agat-Santa Rita water system. These zones are shown in Figure 9-1. As shown in Figure 9-3B, a primary function of the proposed new Santa Rita Reservoir is to provide a transition between pressure zones. An additional function would be to buffer the sometimes erratic flow downstream of the flow regulating valve in the Navy connection from Fena Treatment Plant.

Regional Water Service Area "D" - Again with reference to Table 9-1, approximately 14.6 MG of storage will be required for Service Area "D" by the year 2010, 8.7 MGD of which must be provided by additional storage. Disregarding the numerous small storage tanks presently found in Service Area "D," it would appear that this system will be severely lacking in adequate storage by the year 2010. The areas most lacking in storage will be Yona and Inarajan. In Area "D" individual storage facilities are required for each subregion because booster pump stations and pressure regulating stations allow flow in only one direction.

A new 0.5 MG reservoir is proposed for the Jumollong Manglo pass on Route 4 above Umatac. This reservoir would be supplied by booster pumps at the proposed Sella Bay Reservoir. Like the new reservoir proposed above Sella Bay, the primary function of the Jumollong Manglo Reservoir is hydraulic. At the high point of the distribution line between Agat and Umatac, the reservoir provides water service and pressure distribution to the area that is not immediately dependent on booster pumps. Hourly variations in demand could cause frequent starts and short run times if the area was serviced directly by booster pumps from the proposed Sella Bay Reservoir. This condition is undesirable for booster pump operations and maintenance as well as service in that it can cause surges at the tap. The proposed reservoir, however, can respond to the hourly variations in demand with a relative constancy of pressure and supply. In addition, booster pump operations are more controlled and spread apart making for more efficient operation and less maintenance. Together with the existing 0.5 MG storage at Umatac subdivision and 0.2 MG storage at Umatac Village, no additional storage is required for Umatac.

An additional 1 MG of storage is proposed for the Merizo reservoir to meet the requirements for the design year 2010.

The existing 1 MG reservoir at Malojloj does not have the elevation to provide adequate service pressure to the residences in its immediate vicinity. A 65-foot standpipe adjacent to the existing reservoir will provide the needed pressure and will be easier to maintain than an elevated reservoir. An additional 1 MG will be required in the Inarajan area to meet projected

2010 demands. However, a portion of this storage may be provided by the proposed Dandan resort to satisfy their share of the projected demand.

The 1 MG Windward Hills Reservoir No. 2 will be insufficient for the Talofofo area by the year 2010. An additional 1.5 MG will be required to meet the projected demands. The 0.1 MG Windward Hills Reservoir No. 1 provides additional capacity; however, being at a slightly higher elevation than No. 2, it is hydraulically out of balance. Part of the Talofofo system includes a pipeline running along Route 17 to the Agat-Santa Rita area. It may be desirable to provide a 1 MG reservoir along this pipeline. In addition to providing a break in pressure zones between Windward Hills and Sinifa, the reservoir would serve as an equalization tank for the proposed booster pump station.

Yona will require 7 MG of storage by 2010 in addition to the existing 1 MG Pulantat Reservoir. At least 1 MG of this additional capacity will be required solely for the proposed Miyama Hills Resort and is to be provided by the resort's developer.

As shown in Figures 9-1 and 9-3B, the majority of Region "D" is served by one pressure zone which parallels the coast and is directly served by the Ugum, Malojloj, Inarajan, Merizo, Umatac Subdivision, Umatac Village and the proposed Ija Reservoirs. However, Umatac Subdivision, Malojloj, Pulantat and Windward Hills Reservoirs serve their own individual higher pressure zones as well as the coastal pressure zone.

Supply Improvements

PUAG's present sources of water supply include wells, springs, surface intakes and military allotments. It was assumed that the use of military water would continue at existing levels through the year 2010. There is, however, a definite potential for "trading" water with the military. In the north, approximately 25 percent of the ground water lies under land occupied by the military. Only about 11 percent of this quantity is actually used by the military, although the Navy currently transports water from Fena Reservoir north, all the way to Naval Communications Station (NCS). PUAG could provide supplies from its northern wells in exchange for additional supplies from Fena to serve the Agat-Santa Rita area. In addition, the U.S. Military could allow PUAG to develop, maintain and operate wells on military reservations in exchange for a share of the water developed.

All of the existing wells, springs and intakes owned and operated by PUAG were located on a base map, Figure 4-3. From Table 5-3 it can be seen that the 1989 PUAG production from all sources, including purchases from the military, was approximately 24 MGD. From Table 5-19, it is projected that production required by the year 2010 will equal approximately 113 MGD (maximum day demand) for combined general civilian and hotel use. The PUAG deficit will therefore be about 89 MGD based on present supply capability and projected maximum day demand. As discussed in Chapter VIII, the largest and most economical source to help satisfy this deficit is the ground water of Guam's Northern lens.

Table 8-1 lists the total sustainable yield of each ground water management zone as defined in the *Northern Guam Lens Study (NGLS)* (1982). In addition, Table 8-3 lists the type of ground water (basal or parabasal), the nominal production of existing wells, the remaining yield and the total nominal production of PUAG wells now under construction within each management zone. As discussed in Chapter VIII, the 60 MGD ground water supply cited in the *NGLS* is believed to be a conservative estimate of the daily yield that can safely be sustained by Guam's northern aquifer. Furthermore, the *NGLS* stated that this sustainable yield could be exceeded for limited periods of time without degrading the ground water lens. The following three assumptions were therefore made in establishing the ground water supply considered available to meet year 2010 requirements.

1) An average day supply of 60 MGD can be obtained by PUAG from the northern ground water lens, either entirely from wells located on Government of Guam property or a combination of shared production from civilian and military wells. As discussed in Chapter VIII, this assumption is supported by several factors. One is the virtual lack of change in the ground water table elevations over the northern lens in the face of a significant increase in production since the last estimate of sustainable yield was made by the *NGLS*. Another is the very conservative assumptions made in the *NGLS* estimate, as described in Chapter VIII.

2) The northern lens can sustain, for limited periods of time, a maximum day demand of approximately 90 MGD and an average day, maximum month demand of approximately 72 MGD in addition to current levels of military demand;

3) Water purchases from the military will remain constant at their current rate of about 4-5 MGD.

If the average day supply potentially available for the year 2010, including the Ugum Intake and existing supplies from the military, was therefore taken as 67 MGD. Maximum day supply would be 97 MGD. As discussed in Chapter VIII, preliminary modeling and reanalysis of the Northern Ground Water Lens's sustainable yield, being conducted for PUAG as part of its implementation of the $53 million Bond water CIP program, supports the assumption that these levels may be attainable. However, the assumptions must still be considered tentative until an updated analysis of the lens and its potential yield have been completed. As more exploration and production well development are carried out, the limits of the aquifer's sustainable yield will become more clearly defined. Consequently, any conclusions or assumptions made regarding the aquifer's character and productivity, including those made in this report, must be continually reevaluated in light of the most recent data.

If the maximum sustainable yield accessible to GovGuam turns out to be less than the planned 60 MGD, other methods of water supply would then have to be developed to supply the difference. For average day demands, this difference would be in addition to the 10 MGD deficit projected by this study for the year 2010. The revised maximum day deficit would be equal to 1.5 times the difference determined under average day demand. Methods to be considered for meeting these deficits were discussed in Chapter VIII and include water conservation, water reclamation, the development of additional surface water sources, and desalination of either brackish water or sea water.

The number and general location of wells required by the year 2010 was estimated in order to conduct the hydraulic analysis. The *NGLS* report was used as the primary guide in determining both the approximate number and location of additional wells as it was the most authoritative source on Guam's ground water available during the preparation of the *Water Facilities Master Plan Update*. However, the Ground Water Program Evaluation now being conducted by PUAG is expected to propose significant revisions to the categorization of the northern Guam's aquifer systems. The Evaluation is also expected to propose a revised estimate of the Northern Ground Water Lens's sustainable yield as well as a revised well development program. Consequently, the well development schedule proposed in this report should be reviewed and, where necessary, revised once PUAG's Ground Water Program Evaluation is complete.

In order to establish the number, size and location of additional wells required for year 2010, the following approach was applied.

1) Initially, the assumed maximum day yield of 90 MGD was distributed over the ground water management zones in approximately the same proportion as their estimated share of the 60 MGD yield cited in the *NGLS*. The new yields were then redistributed among some zones in response to the preliminary findings of Mink's reanalysis of the hydrodynamics of the Northern Groundwater Lens for PUAG's Groundwater Program Evaluation.

2) Table 9-2 lists the wells placed into service since the NGLS as well as their nominal production rates. A complete list of existing wells and their characteristics is given in Appendix D. Existing production and the nominal production of wells under construction in each zone were subtracted from the yield derived for each zone in step 1. No additional production was assigned to zones now testing higher than 150 mg/l in chlorides unless it appeared that pumping could be safely conducted with smaller production wells--e.g. 100 gpm instead of 200 gpm wells.

   Where a zone's current production exceeded its available yield, the additional production was deducted from adjacent zones.

3) Although a significant portion of the northern ground water lies under military reservations, portions of this yield were considered accessible to PUAG. The basis for this consideration is primarily the character of the ground water-bearing strata in some areas. The relative characteristics of the strata containing Guam's northern ground water are described in the *NGLS* volume "Aquifer Yield Report". It appears that the high porosities and permeability of much of the northern lens could permit withdrawal of water from considerable lateral distance without appreciable drawdown. The high mobility of the ground water is reflected in the recharge rates described in the *NGLS* for the lens in general and the virtual lack of change in water table elevation over the last 10 years. Thus, the movement of the ground water within aquifer systems makes the concept of discreet pockets of water as described by the ground water management zones somewhat artificial. The fact that ground water within aquifer systems of the northern lens, if not officially, may be at least actually shared, speaks

TABLE 9-2
WELLS DRILLED SUBSEQUENT TO *NGLS* REPORT

Zone No.	Ground Water Management Zone	Well No.	Nominal Capacity (gpm)
3	Nimitz Hill	A23	255
		A25	253
		A31	175
31	Toto	A26	N/A
33	Sabanan Maagas	A28	230
45	Dededo South	D16	200
		D17	200
		D18	200
		EX5A	220
		GH501	200
		M-15	20
44	Dededo North	D19	250
		D20	250
		D21	250
43	NCS	F9	200
		F10	200
		H1	180
21	Mt. Barrigada West	M17a	415
		M17b	280
28	Yigo West	Y5	20
		Y6	200
25	Yigo East	Y7	700
		Y9	430
TOTAL			**5688**

Source: *Ground water Management Program Annual Report 1989*, GEPA even more strongly for the cooperative development and management of this valuable resource by the military and PUAG.

Proposals by the *Water Facilities Master Plan Update* for well development, including the number, size and location of wells required for the year 2010, are based upon the *NGLS* priority groupings and matrix. Table 9-3 lists the proposed wells by recommended priority of development, and shows the management zone, number and sizes of wells. It should be emphasized that this list is tentative, *especially* the number and size of wells within any management zone. It has been prepared primarily as a budgetary and general planning tool and is intended as a baseline or starting point for the ground water analysis now being initiated by PUAG. This list should not be applied as an absolute punchlist or well construction schedule. New and important information will be obtained not only by PUAG's current ground water analysis program but by data obtained as each new exploratory and production well is brought on line. Proper development of the northern ground water requires that the development program presented in this report be continually reevaluated by qualified hydrologists in light of the latest data.

Under the year 2010 scenario projected by the Update, the assumed maximum day supply of 97 MGD is deducted from the demand of 113 leaving a balance of about 16 MGD that will have to be satisfied by sources other than ground water. For planning purposes, it was assumed that the additional supply would come from the development of surface water in southern Guam. Specifically, dams on the Inarajan and Ugum rivers were assumed with firm yields (excluding discharge to maintain stream flow) of 7 and 11 MGD respectively. The potential for these dams is discussed in the U.S. Army Corp of Engineers' *Ugum River Draft Interim Report and Environmental Impact Statement* (June 1979). Under these assumptions, it will still be necessary to transmit approximately 9 MGD of flow from northern Guam to the south to meet year 2010 projected maximum day demand.

To establish point sources of supply for hydraulic analysis, the yields projected in Table 9-3 were assigned to existing and potential well field sites throughout the northern and central areas. In addition, source nodes were established for Fena, Ugum and Inarajan Dams. Although the locations chosen were somewhat arbitrary, the distribution attempted to reflect the relative contributions expected of the various well fields. The actual location of future wells, as well as their realized production, may have a significant effect on final line sizing.

TABLE 9-3
PROPOSED WELL DEVELOPMENT PRIORITIES

ZONE NO.	GROUND WATER MANAGEMENT ZONE	TYPE	PROPOSED PRODUCTION No. of Wells by Size (GPM) IG	100	200	350	500	750	To (GP
16	Agafa Gumas Central	PB	--	--	--	--	12	--	6000
29	Ysengsong	PB	--	--	1	--	1	4	3700
9	Adacao	PB	--	--	--	--	2	1	1750
10	Sabanan Pagat	PB	--	--	--	1	1	--	850
21	Mt. Barrigada West	PB	--	--	--	1	2	--	1350
28	Yigo West	PB	--	--	1	--	--	4	3200
25	Yigo East	PB	--	--	1	--	3	--	1700
19	Finegayan East	PB	--	--	1	--	2	--	1200
26	Mt. Santa Rosa	PB	--	--	--	1	1	--	850
27	Mataguac	PB	--	--	--	--	2	--	1000
44	Dededo North	B	--	--	6	--	-	--	1200
3	Nimitz Hill	PB	--	1	3	4	1	--	2600
14	Lupog	PB	--	--	--	--	9	--	4500
32	Agana Swamp	B	--	--	3	5	--	--	2350
18	Callon Tramojo	PB	--	--	3	--	--	--	600
4	Anigua	PB	--	--	4	--	--	--	800
31	Toto	B	--	--	3	--	--	--	600
46	Macheche	B	--	--	5	--	--	--	1000
8	Mangilao North	PB	--	--	--	1	1	--	850
34	Manaca	B	--	--	5	5	--	--	2750
37	Sasajyan	B	--	2	--	--	--	--	200
2	Chalan Pago	PB	--	--	1	--	--	--	200
24	Marbo North	PB	--	--	5	--	--	--	1000
11	Janum	PB	7	--	--	--	--	--	700
22	Mogfog	PB	--	--	--	2	--	--	700
47	Asatdas	B	--	--	1	2	--	--	900
30	Barrigada	B	--	--	2	--	--	--	400
43	NCS	B	--	17	--	--	--	--	1700
36	Taguan	B	--	4	--	--	--	--	400
45	Dededo South	B	--	--	2	--	--	--	400
5	Mt. Barrigada South	PB	--	--	2	--	--	--	400
42	Finegayan West	B	--	3	--	--	--	--	300
20	Potts	PB	--	--	--	--	1	--	500
35	Asbeco	B	--	--	14	--	--	--	2800
TOTAL WELL IMPROVEMENTS			7	27	63	22	38	9	49

Notes:
1. IG represents infiltration gallery or horizontal type well production required. Assumes maximum productivity is 100 gpm.
2. Final priority and capacity of each well field may vary subject to further analysis of test well data and aquifer productivity.
3. This assignment of wells assumes zone 16 production also draws from zones 12, 15, 17, 39 and 40; zone 14 production a draws from zones 13 and 38; zone 8 production also draws from zones 6 and 7; and zone 24 production also draws from zo 23.
4. B = Basal groundwater; PB = Parabasal groundwater

This situation stresses the need for an update of the *NGLS* and continual re-evaluation of the *Water Facilities Master Plan* as new information on the productivity of the northern lens comes to light.

Hydraulic Analysis

A hydraulic analysis is conducted by assuming flows and pipeline diameters to check the water system for operation as planned. Typically, the analysis consists of calculating hydraulic grade lines (HGL) for each section of pipeline at the assumed flows. If the HGLs for the entire system match at each node (pipeline junction point) and if the pressures are within the limits specified, then the assumed pipe diameters and flows are acceptable and a balanced system results. If the HGLs do not match, then modifications in assumed flows and pipe diameters must be made to produce a balanced system.

In the case of the *Water Facilities Master Plan Update*, the actual hydraulic analysis was performed on PUAG's computer model of the existing water distribution system with projected improvements. PUAG's model utilizes the *Municipal Hydraulics* program by Professor Alvin G. Fowler. Fowler's program applies the Newton-Raphson method of iterative analysis for balancing the HGLs and generates its own pseudo-loops for the solution of network problems. Before the piping network could be analyzed using PUAG's computerized water system model, it was necessary to locate key points of demand, supply and storage. Location of storage reservoirs and supply points were discussed earlier in this chapter. The following discussion addresses the basis for modeling points of demand and flows in the system.

Points of Demand - The basis for locating the numerous points of demand was the population projection for the year 2010 distributed according to municipalities as shown in Table 3-13. Key demand nodes corresponding to critical junctions in the existing PUAG computer model of the water system were selected within each municipality. Since present day demands already existed on the PUAG computer model they were retained. To model the projected year 2010 demand scenario, the difference between present day demands and the maximum day demands projected for each municipality was then apportioned among the key nodes.

PUAG's computer model of Guam's water storage and distribution system is set up for daily operational use and has assigned present day demand and supply to a wide distribution of nodes within a network of pipes ranging from 2 to 16 inches in diameter. Since the objective of the planning effort was to analyze primary transmission systems, some simplifications of PUAG's model were required. As described above, key nodes were selected from the existing distribution model and assigned the additional demand projected for year 2010. The same process was repeated for distribution of supply. The distribution of both projected demand and supply attempted to reflect the population densities projected by the growth trend analysis and the likely concentration of water resources presented in both the *NGLS* and the USACOE Ugum River study. Once the points of demand, supply and storage were assigned, it was possible to develop a piping network connecting the primary inputs and outputs to the system. By summation of all supply and demand points within an area, the quantity of importation or exportation was determined. Flows were then assumed for each transmission main and a water balance was performed at each junction.

After the projected demands and supplies were entered into the model, preliminary pipe sizes were entered for the major transmission lines. Once the HGLs for a water system balanced, the system was checked for proper pressures, flows and velocities. Pipe diameters were then revised as necessary and pressure reducing valves and pump stations were employed between pressure zones as required to produce an overall balanced system. The results of the analysis are described in the following section on distribution system improvements.

Transmission System Improvements

In general, a water distribution system consists of a network of pipelines, pump stations, and valves which together form a system that provides water from sources of supply and storage to points of demand at the proper flows and pressures. The distribution pipelines in the system are typically categorized as transmission mains, distribution mains and individual service lines. For the purposes of this water master planning effort, only the transmission lines were considered.

Figures 9-2A, 9-2B, 9-2C, and 9-2D depict the Island-wide transmission network derived from the hydraulic analysis for the year 2010, assuming a maximum day 90 MGD ground water supply capability.

Regional Water Service Area "A" - As established by the 1982 *NGLS*, Service Area "A" is the major water-producing region on Guam. Due to this fact, it was necessary to provide large diameter lines which would carry exported water to the other three service areas. The major transmission main improvements for Service Area "A" are shown on Figure 9-2A. As can be seen, the majority of the lines consist of 12-, 16-, 20-, 24- and 30-inch diameter pipes. An important consideration in sizing lines for Service Area "A" is the location of points at which the sources of supply would be applied. As previously described, it was necessary to assume the locations and productivity of future wells for planning purposes. The end result of this process could be the undersizing or over-sizing of certain sections of pipeline in Service Area "A" depending on actual ground water productivity. Again, it is emphasized that reevaluation of pipeline sizes proposed in this report be continually made as new well production data comes to light.

The Update projects that approximately 16 MGD of water supply will be developed in the regions of Agafa Gumas, Finegayan and Yigo. Large diameter mains are required in order to move this supply south without excessive head loss. The mains follow Routes 1, 3, 9, Y-Sengsong Road from the proposed Agafa Gumas Reservoir to Astumbo Reservoir and Dededo. These lines will feed the heavily developed areas in Service Area "B" as well as the southern portions of Guam via Routes 10 and 15. In addition, due to the large exportation from Service Area "A," it is advantageous to have a strongly looped system. Thus if one line is inoperable the others will still be able to provide critical supplies as well as balance pressures over the service area. The primary function of the transmission main from Agafa Gumas to Astumbo and Dededo is to provide a direct untapped supply line from the Northern Well fields to the Barrigada Reservoirs. At the same time, it loops and provides a vital backup to the existing Route 1 main.

The transmission main proposed for Routes 3, 9, and 1 will provide the main loop connecting the Yigo, Agafa Gumas and Finegayan areas. Collecting supplies from the Agafa Gumas and Finegayan well fields it will carry the water south to the high demand centers of Tumon and Tumuning.

Other mains between Yigo and Astumbo and from Route 3 along Ysengsong Road to Astumbo and Dededo further grid the northern transmission loop and serve to balance the pressures and flows within this region. A new main is also projected for the Yigo area to carry water developed in the Lupog area to the new main on Route 9. The new mains being constructed along Route 15 are intended to transfer water from the Yigo well fields south to Mangilao.

The major transmission line from Agafa Gumas to Astumbo and Dededo, as well as the 12-inch line from Yigo to Astumbo, cross a water conservation area. In the past, these routes have raised objections by the Guam Environmental Protection Agency (GEPA) for fear that transmission lines would encourage development in these areas with subsequent degradation of the conservation area. However, from an engineering standpoint, the mains are necessary to properly loop and balance the northern transmission system. One possible safeguard would be for PUAG to prohibit distribution connections to these transmission mains, reserving them solely for the purpose of transmission and system balancing. Despite GEPA's warnings, development of the area by both golf courses and private residences is currently taking place. It may be that, ultimately, the best protection for this area is to prohibit development without complete sanitary connections and provision for the recharge of rainfall runoff.

Regional Water Service Area "B" - Service Area "B" has some water production capability but not enough to be self sufficient. In addition, flow exported from Area "A" must travel through Area "B" to Area "C" and "D." As a result, Area "B" serves as both an importer and exporter of water.

Importation occurs at essentially three major locations: one via Route 1 in the Tamuning subregion; one via the Barrigada Reservoir and the third via Route 15 through Mangilao. The major exportation location is along Route 4 to Yona. These points of importation and exportation have a significant effect on sizing of the transmission system. Recommended improvements to Service Area "B" are shown in Figure 9-2B.

The Oka point area of Tamuning is currently served by the Dededo, Tamuning and Agana Heights Reservoirs and now experiences low pressures during peak demand hours. This is largely because the elevations in the Perezville area are too high to be adequately served by the Tumon Reservoir and too far from Dededo Reservoir. The Oka Point area would be divided into two service areas by valving off existing lines in order to provide adequate supply and pressure while minimizing the need for construction along Marine Drive. Those areas west of Farenholt Avenue would comprise one service area and those to the east, the other.

Approximately 15 MGD will be carried to Tumon and east Tamuning from Dededo and Agafa Gumas via Routes 3 and 1 to Ypao Road by a 24-inch diameter trunk line while a network of 12- and 16-inch lines along the coast provide flow to the resort and commercial areas.

Approximately 8 MGD will be imported to east Tamuning by the existing 12- and 14-inch diameter mains from Dededo and approximately 6 MGD would be imported from the Barrigada and new Airport Industrial Park Reservoirs via the 24- and 16-inch mains along Macheche Road and Route 10A. Approximately 4 MGD would be carried to west Tamuning and east Agana from the junction of Route 8 and Marine Drive by existing 14- and 16-inch lines.

About 3 MGD will be boosted along Route 1 from its junction with Route 4 via a new 16- and 20-inch main to provide flows for Asan, Piti, Commercial Port and Nimitz Hills.

The proposed 12-inch main from Agana Springs will supply approximately 1.5 MGD to the Mongmong-Toto-Maite subregions. Another 4.5 MGD will be imported to the Mongmong-Toto-Maite and Barrigada areas by a new 16-inch main from Barrigada and the new Route 16 Reservoir. Additional 2 MGD from Mangilao will be carried in by the new 12-inch main connecting Dairy Road to the Toto distribution system and existing 12-inch Route 8 transmission main.

A total of about 4 MGD is expected to be imported from Dededo and Yigo to Mangiloo via Route 15. This is projected to increase to about 8 MGD between Carnation Road and Mangilao Reservoir during maximum day demands.

The exportation of water from north and central Guam occurs via Route 4 to Yona and is approximately 9 MGD for maximum day demand.

The majority of the "A" series wells are located within the area formed by Routes 4, 8, and 10 and provide a large portion of the maximum day supply for Area B. Due to a relatively even distribution of points of demand and supply around this loop, line sizes would be fairly uniform if exportation requirements were neglected. However, such is not the case and as a result, line sizes in portions of the loop are large with respect to maximum day demands for the area alone. The existing 12-inch line along Route 10 and proposed 16-inch line between Routes 15 and 4 carry the majority of the 9 MGD flow exported to the south. For the most part, the remainder of the lines transport water within the loop and consist mainly of 12-inch pipe.

Regional Water Service Area "C" - Proposed improvements for Service Area "C" are shown in Figure 9-2C. By the year 2010, it is anticipated that Service Area "C" will be importing approximately 3 MGD in addition to its present allotment from Fena Reservoir. The additional flows will originate primarily from the Ugum River Dam and be boosted first through a 16-inch main, along with 2 MGD for Talofofo and 2 MGD for Yona, to the Windward Hills Reservoirs. Next an upgraded Windward Hills Booster Station will move the flow through the 14-inch trunk main to the Cross Island Reservoir. From here, the 3 MGD will be boosted again through the 14-inch main on Route 17 to Sinifa Reservoir for distribution to the Agat-Santa Rita systems.

As stated in the original Water Master Plan, additional pipeline could be run from the Piti area south along Route 2 to the Agat-Santa Rita area. For the given design period, however, it would be used mainly to increase reliability and thus is not a high priority item.

One problem with sizing lines in the Agat-Santa Rita area is the fact that one of the controlling reservoirs, the 1.0 MG Sinifa Reservoir, is at a very high elevation. Its use thus requires substantial reduction in pressure, which is one of the functions of the new Santa Rita Reservoir. One advantage, however, of having the reservoir at a high elevation is that smaller diameter pipelines could be used and thus reduce pressure through friction head loss.

The proposed pipeline system serving the Western portion of Region "C," will consist of the new 14-inch line along Route 17 with 12-inch and 8-inch loops from Sinifa Reservoir to the new 16-inch main at Route 2. This 16-inch main will then carry flows to the southern end of the service area at the Pagachao Reservoir or its alternate site, Ascola Sita Creek. From this point the proposed Tumag Booster Pump Station will move flows to the new reservoirs on Route 2 near Sella River. Flows will be boosted again from the Sella Reservoir to the new reservoir on the Route 2 pass near Mt. Jumullong Manglo for ultimate distribution to the Lofon, Achugao and Facpi areas to the north and Umatac to the south.

Regional Water Service Area "D" - Service Area "D" consists essentially of isolated villages extending along the eastern and southern shores of the Island. Few loops occur within the system since there is essentially one-way flow from Talofofo to Umatac. As shown in Figure 9-2D, the backbone of the system is the existing main which extends the entire length of the system along Route 4 and ranges in diameter from 12- to 16-inches. At a point near the intersection of Routes 4 and 17, the 16-inch diameter line will reduce, connecting to the existing 12-inch main from Windward Hills Reservoir and to the 14-inch main that will import water to the Agat-Santa Rita area. The existing 12-inch main along Route 17 will then function as a distribution line for development in the Cross-island area.

About 18 MGD of the water needed for Service Areas "C" and "D" will be provided by the Ugum and Inarajan Dams through the existing 8- and 12-inch mains that run along Route 4. About 9 MGD of maximum day flow will be imported directly from the northern ground water lens via Route 15 and from Service Area "B" via Routes 4 and 10. This water will flow south through the Route 4 coastal pipeline with its pressure being reduced or increased, as required, by pump stations and pressure regulating valves.

Overview of Proposed Water System Improvements Implementation

Water system improvement projects were developed based on the findings described in the previous sections. The proposed improvement projects are shown in Figures 9-2A through D and are listed with estimated costs in Appendix H, "Proposed Capital Improvement Projects". The projects required to the year 2000 are listed in order of recommended priority, from an engineering perspective, as a result of meetings with PUAG staff. It is expected that the order of these priorities may change as the Government evaluates them in the light of future financial and budgetary constraints.

The required storage reservoir improvements are presented under two time frames, primarily to indicate that they can be implemented in increments—5 MG in storage, for example, could be implemented in 2 and 3 MG increments.

As explained in Chapter VIII and above, the proposed well improvements are based on the assumption that the Northern Lens can be developed to provide PUAG with a maximum day supply of 90 MGD. It should be stressed that the location, number and sizes of the wells presented in the Well Improvements list should *not* be taken as an absolute punchlist or well construction schedule to be immediately embarked upon. Rather, it should serve as a reference for budgeting and a starting point for the ongoing ground water analysis that must be conducted as a responsible well development program is carried out. Based on the rating of ground water management zones for well development by the *Northern Guam Lens Study*, the list is intended primarily to provide a sense of what may be required in terms of budget and effort if the 90 MGD of maximum day ground water supply is to be developed.

The development of dams on the Ugam and Inarajan Rivers will be major undertakings, not just from the standpoint of construction but also the need to obtain the necessary land and procure environemntal clearances. They are also the more expensive of the proposed improvements and will require considerable maintenance and periodic dredging. Feasibility studies and financial planning for these two projects cannot begin too soon if they are to be in place to serve the demands projected for year 2010.

The majority of the proposed improvements to Guam's water system are in response to the projected growth related to tourist related development. As explained in Chapter III, this trend is largely driven by, and therefore dependent on, the Japanese economy. Consequently, the rate of growth and development on Guam could change dramatically in a short period of time. The same effect could occur with a sudden redeployment of U.S. Military forces to the Island. It is therefore recommended that implementation of the capital improvements proposed in this study be reevaluated with regard to the latest growth trends every five years or before any major funding obligation for water system capital improvements is entered into by the Government of Guam.

Preliminary Cost Estimates

In the development of a capital improvement program, it is necessary to prepare planning level cost estimates in order to: 1) determine the magnitude of the overall program; 2) develop a staged construction program to meet funding limitations; and 3) establish a suitable financing program. Execution of the last two items are largely outside the scope of this Update. However, the planning level cost estimates developed herein, will provide the necessary basis for implementing these two tasks.

A list of recommended capital improvements and their estimated year 1991 costs are provided in Appendix H. Project costs include the design and construction services by the engineer and others involved in the process until the constructed project is turned over the owner. The cost components are as follows.

- Base Construction Cost
- Contingencies
- Engineering, Design, Survey and Construction Management
- PUAG Administration
- Gross Receipts Tax
- Bond Council, Printing and Discount
- Legal

Base construction costs were derived from an evaluation of construction bid records from DPW and PUAG as well as the U.S. Navy's Cost Data Book for Guam. Factors were then applied to these base costs to reflect the estimated contribution of the various other cost components to the total project cost.

Project contingencies are included to account for unforseen construction problems and contract change orders. In preliminary engineering studies, for example, it is not possible to define the exact locations of some facilities or conditions which may have a substantial bearing on the actual cost of the proposed improvements. To allow for such difficulties or variations in a programmed improvement a significant contingency of 30 percent has been applied to the base construction cost for each project.

Engineering costs include all services associated with design and construction management of the projects. Design services include preparation of construction plans and specifications, participation in public information programs, surveying, geotechnical and architectural services, securing permits, assisting in agency plan review, and contract bidding and award. Construction services include inspection, construction check surveying, preparation of pay estimates, submittal and shop drawing review, preparation of change orders and grant administration. Engineering and construction services were estimated at 25 percent of the base construction cost.

PUAG administration includes agency administration time and expenses incurred directly by PUAG staff in managing the project apart from normal operations. PUAG administration costs have been assumed at 20 percent of base construction costs.

Gross receipts tax is approximately 4 percent in Guam and applies to any product or service involved in the project.

Bond council, printing and bond discount include those costs associated with preparing, marketing, printing and selling bonds. These costs are normally about 4 percent of the base construction costs.

Legal expenses will be incurred by the Government's legal counsel throughout the project. The costs will include possible condemnation of private property, review of construction contracts and bonds, review of claims and any other litigation arising out of construction. Typically these costs have been about one half of one percent (0.5%) of the base construction costs.

In total, the project costs identified above will add about 90 percent to the base construction cost. In this plan, Guam construction cost estimates are multiplied by a factor of 1.90 to derive year 1990 project planning level costs.

The actual future cost to PUAG will, of course, depend on many factors including the rate at which current costs increase over time. Although continental U.S. inflation rates have been relatively moderate, rates on Guam have been driven much higher by the boom in private development. The Guam Department of Commerce has not tracked construction costs in the past but the consumer price index over the past year has increased by an annual rate of almost 11 percent. The Department staff anticipate higher rates of inflation in the future, due to predicted construction on Guam. Therefore the *Water Facilities Master Plan Update* suggests a projected inflation rate of 15 percent to assess future capital cost requirements.

Military Water Supply Connections

Chapter IV, "Existing Water Facilities," indicated that the Air Force and the Navy deliver water to PUAG at numerous locations throughout the Island. A list of the supply connections and their geographical locations was presented in Table 4-5 and on Figure 4-14, respectively. Of the 62 total connections identified in Table 4-5, 39 are active connections—i.e., connections where water is delivered to PUAG on a regular basis.

The water supply and distribution system improvements proposed in this report will allow many of the existing military connections to be eliminated. As an example, after the construction of PUAG water mains along Route 8 and Mongmong-Toto Road is complete, water supply connections N-27, N-28, N-29, N-31 and N-32 can be abandoned. However, due to the substantial costs of constructing water conveyance facilities that are isolated from nearby distribution systems, it is not economically feasible to immediately abandon all of the supply connections. For example, the water supplied to Agat-Santa Rita by the Navy will be required for the foreseeable future.

Other supply connections serving a few remote customers will likely remain in service in the future as well. Many of the existing connections serve isolated customers that are located on military lands or in areas that are designated as conservation areas by the Bureau of Planning (BOP).

In addition to PUAG's complex water supply and distribution system, both the Navy and Air Force maintain extensive water supply and conveyance systems as shown on Figure 4-14. As discussed in Chapter IV, the Navy's primary source of water supply is Fena Reservoir. After treatment, the Fena water supply is delivered to various Navy installations throughout the Island, the most northern reservoir being the Navy's Barrigada Reservoir. The Navy's Barrigada Reservoir is located just to the south of the Barrigada Heights Subdivision, approximately 14 miles from Fena Water Treatment Plant. The Air Force also conveys some of its water supply from great distances. For example, the Tumon Maui Well is located approximately 10 miles to the south of the Route 15 entrance to Andersen Air Force Base.

In summary, with a few exceptions, each of the three major water suppliers, the Air Force, Navy and PUAG, are autonomous as they maintain their own water system facilities to meet their water demands. Needless to say, the energy costs and capital improvement investments to maintain three separate water systems are substantial. In light of these circumstances it appears beneficial to develop an agreement between the military and Government of Guam to exchange obligations to serve various water service areas rather than to continue to expend the large capital and operation costs required to convey water supplies great distances. An "exchange of service areas" agreement would maximize the use of water supplies near the location of origin. For example, rather than providing costly water transmission facilities and pumping costs to transport water from the northern aquifer to the Agat-Santa Rita area, the

Navy and PUAG could develop an agreement whereby PUAG would supply Navy water demands in the northern areas and the Navy would continue to supply the water needs of Agat-Santa Rita. Similar agreements could be developed between the Air Force and PUAG. Particularly in times of cutbacks in military spending, as is currently the case, the development of additional ground water on military lands by PUAG in exchange for a share of the water supply could be of considerable benefit to both the military and PUAG. In order to consummate such agreements, it is essential that the reliability and quality of the exchanged water supplies be absolutely assured.

In theory, this approach appears quite attractive and logical. However, there are many factors that must be considered besides those related to economics and engineering. A few of the problems that must be resolved prior to utilization of an "exchange of service areas" approach are listed:

- In Guam, the quality of water varies according to the supply source. The treated water from Fena Reservoir is lower in hardness and generally of better quality than that obtained from the northern aquifer. As such, the desirability of the treated surface supply, for some applications, is greater than that developed from ground water supplies.
- The Navy has expressed their concern over PUAG's degree of reliability. Reliability must be evaluated in terms of water quality, available water supply, and operation and maintenance practices.
- Due to the nature of military operations, it is critical that water supplies be available and readily accessible to meet critical emergency situations. PUAG's water supply facilities are not provided with adequate standby facilities and therefore cannot produce water during power outages.

Following recommendations of the original Water Master Plan, meetings have been initiated between the government of Guam, the Navy, and the Air Force to discuss these foregoing questions. Some advances have been made in these areas, the most notable being the exchange of the Air Force's Tumon Maui Well for equivalent production wells further north. It is suggested that further discussions focus on the joint development of the ground water resources within military reservations. Particular attention should be given to PUAG's ability, with funding from private developers, to finance ground water exploration and development in a time of reduced military budgets.

The update of the *Water Facilities Master Plan* has been developed with the assumption that the recommended agreements will not occur within the near future. The master plan reflects those improvements that will be required by PUAG to satisfy their water demands independently of military water system facilities. If an "exchange of service area" agreement with the Navy and/or Air Force is established, modifications in the 20 year capital improvement program will be necessary. Periodic revisions of the program will be necessary in any event.

APPENDICES

A

APPENDIX A

CONVERSION FACTORS FOR UNITS OF MEASURE

The Government of Guam presently utilizes the well-known "English units" measurement system; however, there is a current world-wide effort to establish a standard system of units for measurement. The Systeme International d'Unites (SI system) is proposed as an attempt to standardize the many systems used throughout the world. The SI equivalent units for commonly used "English units" that are found in the Water Facilities Master Plan are listed below:

Customary Units			SI Units	
Name	**Symbol**	**Multiplier**	**Name**	**Symbol**
Linear:				
inch	in	x 25.40	millimetre	mm
foot	ft	x 0.305	metre	m
mile	mile	x 1.609	kilometre	km
yard	yd	x 0.914	metre	m
Area:				
square inch	sq in	x 645.2	millimetre^2	mm^2
square foot	sq ft	x 0.093	metre^2	m^2
acre	acre	x 0.405	hectare	ha
square mile	sq mile	x 2.590	kilometre^2	km^2
Volume:				
cubic foot	cu ft	x 0.028	metre^3	m^3
gallon (US)	gal	x 3.785	litre	l*
acre-foot	ac-ft	x 1220	metre^3	m^3
million gallons	MG	x 3785	metre^3	m^3
Mass:				
pound	16	x 0.454	kilogram	kg
Pressure:				
pound force/square inch	psi	x 6.895	kilopascal	kPa
pound force/square inch	psi	x 0.070	kilogram/sq centimeter	kg/sq cm*
head of water at 39°F	ft	x 2.989	kilopascal	kPa

Customary Units			SI Units	
Name	Symbol	Multiplier	Name	Symbol
Rate of Flow:				
cubic feet/second	cfs	x 0.028	$metre^3$/second	m^3/s
gallons/day	gpd	x 0.0038	$metre^3$/day	m^3/d
gallons/minute	gpm	x 0.063	liter/second	l/s
gallons/capita/day	gpcd	x 3.785	liter/capita/day	l/person/day
gallons/day	gpd	x 0.0038	kiloliter/day	kl/d
million gallons/day	mgd	x 0.044	$metre^3$/second	m^3/s
Power:				
horsepower	hp	x 0.746	kilowatt	kw
Velocity:				
foot/second	fps	x 0.305	metre/second	m/s

* not an SI unit but generally used and accepted.

B

APPENDIX B

WATER FACILITIES MASTER PLAN

SCOPE OF WORK

Intent

It is the intent of this project to update the Guam Water Facilities Master Plan for the Public Utility Agency of Guam. The project will be undertaken in two phases. Phase I will involve the development of a Conceptual Master Plan addressing the major water production, transmission and storage requirements on an islandwide basis. Phase II will involve the development of a detailed master plan document. The tasks and activities in the two phases are as follows.

PHASE I - CONCEPTUAL PLAN

Task A - Data Collection

Consultant shall gather and compile existing available data for the purpose of evaluating existing water use, production and water system requirements. Data shall include the following:

1. Population/Tourism/Economic: Consultant shall obtain available population estimates from the Bureau of Planning and Department of Commerce. Consultant shall also obtain available data regarding visitor industry activities including tourist arrivals, projections for visitor totals, hotel rooms, and other visitor industry activities. Consultant shall obtain economic data available from the Department of Commerce, the Department of Agriculture, the Guam Economic Development Authority and other government agencies as may be appropriate.

2. Water Production: PUAG shall provide Consultant with existing tabulated water production data from PUAG, the USGS, and the GEPA as may be appropriate. Such tabulated data shall indicate total water production from each of the groundwater management zones identified in the Northern Guam Lens Study report, dated December 1982.

3. Water System Data: PUAG shall provide Consultant with an updated system map based on the water system computer model which will be used for this master planning effort. PUAG is responsible for the updating of the model and represents that the model is current and reflects all known major water transmission and distribution lines which have been constructed and connected as part of the island-wide water system. Consultant shall not be responsible for collecting any as-built or record drawings or other information regarding the existing water system. PUAG shall also be responsible for providing any information regarding water system facilities currently under design or in the construction stage.

4. Water Usage Data: Consultant shall obtain water consumption data as available from PUAG including residential, commercial, institutional and other customers served by PUAG. The data shall be obtained from water meter records and PUAG shall assist in providing data on a village and regional area basis.

5. Military Data: The Consultant shall obtain water system data as available from the military including water production, consumption and other usage. The data shall also include physical information about water system facilities as may have an impact on the total water production and consumption of PUAG including locations of metered connections between the military and PUAG's systems. It is understood that the water systems serving U.S. Air Force facilities have been incorporated into the Islandwide Water System Model created by PUAG.

6. Agricultural/Other: The Consultant shall obtain agricultural data as available from the Department of Commerce, the Government of Guam Department of Agriculture and the U.S. Department of Agriculture's Soil Conservation Service for the purpose of developing estimates of agricultural water usage and needs.

   The Consultant shall also obtain data as available from hotel, commercial and industrial businesses for the purpose of estimating the water requirements of this sector of the economy. PUAG shall make available the Tumon Bay Infrastructure Study currently being completed.

<u>Task B - Data Analyses</u>

Consultant shall analyze the data obtained in Task A, above, for the purpose of developing estimates of present and future water demands on a Regional Service Area basis. Data analysis shall include a projection of population and economic activities based on the available development capacity and existing zoning uses of the land areas in each Regional Water Service Area. Where development trends indicate a change in the future zoning of a particular land area, the Consultant shall notify PUAG. Appropriate uses, other than those shown on the existing zoning maps, will then be agreed upon prior to making the projections. Data analyses and any projections of population and economic activity shall be based on information obtained, as defined in Task A above, by a certain date to be designated by mutual agreement at the start of the project.

Consultant shall develop water demand projections for the planning period based on the population and economic activity projects as defined above.

Task C - Hydraulic Modeling Update

Consultant shall participate in the hydraulic modeling of the islandwide water system only to the extent of:

1. Providing technical advice to PUAG staff regarding water demand and production estimates;

2. Providing technical advice regarding the modeling of storage tanks, booster pump stations and other facilities and appurtenances;
3. Providing advice as to the design flow scenarios to be analyzed; and

4. Interpreting the results of the computer simulations undertaken by PUAG staff.

All data input shall be the responsibility of PUAG and all computer costs shall be borne by PUAG.

Task D - Development of Conceptual Plan

Consultant shall prepare a conceptual and preliminary water facilities master plan based on the data collection, analyses, and computer simulations undertaken in this phase of the project. The conceptual plan shall focus on the islandwide water production, storage and major transmission facilities.

The primary purpose of the conceptual plan is to develop an overview of the 20-year Capital Improvement Program that would be required to meet the needs identified in the preceding tasks. One of the major objectives of this task is to review and verify the scope, magnitude, sizes and general location of the facilities proposed to be designed and constructed by PUAG under the $53 million bond issue.

Consultant shall prepare a schematic presentation of the Conceptual Water Master Plan and provide descriptions of the projects and facilities to be designed and constructed. The Consultant shall present the Conceptual Master Plan in a series of workshops, within the period of one week, to be held on Guam. The workshops will be oriented primarily to PUAG and other Government of Guam and U.S. agencies, as appropriate. PUAG shall have the sole discretion regarding attendees at the workshops.

PHASE II - MASTERPLAN DOCUMENTATION AND PREPARATION

Task A - Evaluation of Existing System

Consultant shall evaluate the existing water system including:

1. Assessment of water supply/demand relationship of each system.

2. Analysis of information provided by PUAG regarding current water system leakage surveys and rehabilitation efforts and historical production and consumption data to determine the accounted-for water demand component.

3. Evaluation of physical condition of existing facilities to perform their intended function. This evaluation shall be based on information provided by PUAG.

4. Identification of existing water system facility deficiencies based on the evaluations above.

Task B - Establish Water Requirements and Basic Design Criteria

Consultant shall establish water requirements and basic design criteria for the development of the islandwide water system facilities. The Consultant shall perform the following tasks and activities:

1. Review all existing data on water use including:

   a. Domestic: Evaluate current per capita consumption and estimate future per capita consumption considering effects of current water shortages and present water conservation policies as well as possible future per capita water increases stimulated by improved living standards and availability of water-consuming appliances.

      The Consultant shall develop a statistical method for verifying domestic consumption. At the option of PUAG, the Consultant may be tasked with implementing the verification study. An adjustment in the Consultant's fee will be negotiated if PUAG chooses to exercise this option.

   b. Industrial/commercial/tourism: Establish water demands by specific major use from available data and projections as may be available from other Government of Guam agencies.

c. Fire: Review available data and determine high- and low-value districts as well as probable fire flow requirements.

d. Determine and project needs for other beneficial uses.

2. Develop water demand schedules and required water quality criteria for the years 1990, 1995, 2000, 2005 and 2010. The water demand schedules shall:

   a. Include domestic, industrial, tourist, military, fire, and other major consumptive and non-consumptive uses.

   b. Utilize water quality criteria for various uses, as presented in the Guam Safe Drinking Water Standards by the Guam Environmental Protection Agency. It is understood that the current Guam Safe Drinking Water Standards reflect the current Federal Safe Drinking Water Standards.

   c. Estimate demand variations based on existing data.

   Consultant shall review the effect of possible reclamation on future water demands in this task.

<u>Task C - Water Supply Assessment</u>

Consultant shall review, evaluate and assess the water supply resources and production capabilities on the island based on the data obtained or supplied in Phase I. This assessment shall compare the available resources and production capabilities with the existing and projected water requirements of the island. The activities to be undertaken include:

1. Review available data related to surface and groundwater sources and storage.

2. Review groundwater management policy and practices of PUAG, GEPA and the military.

3. Review data on the physical characteristics of existing major wells and evaluate current annual production in comparison with the Groundwater Management Program of the Northern Guam Lens Study.

4. Review the study of existing surface supply sources as contained in the report prepared by the Bureau of Reclamation.

5. Review existing water quality data and compare with Safe Drinking Water Standards.

6. Evaluate wastewater reclamation potential based on literature review.

7. Determine adequacy of existing supply in terms of quality and quantity peaking factors to meet projected demands for the years 1990, 1995, 2000 and 2010.

Task D - Water Distribution and Storage Assessments

The Consultant shall review, evaluate and assess the water distribution and storage facility requirements to meet the projected water demands for the years 1990, 1995, 2000 and 2010. This assessment shall be based on the hydraulic model of the system as prepared by PUAG and the simulations of various water system operating conditions and demands as performed with the model by PUAG staff. Consultant shall participate in the hydraulic modeling and computer simulation exercises as delineated in Phase I, Task C and as indicated in the following.

The activities to be undertaken in this task include:

1. Review the water system schematic which was used as a basis for the hydraulic computer model developed by PUAG and provide PUAG staff with technical advice regarding the modeling of the various existing water system facilities.

2. Evaluate the capability of the existing water system network to meet the present and estimated future water demands.

3. Develop scenarios to be modeled by PUAG staff representing proposed islandwide water system improvements and review the results of the network simulations with PUAG staff.

4. Develop system improvement projects based on the results of the network simulations including preliminary project cost estimates. The project cost estimates shall include engineering design, construction management, project administration and appropriate contingencies.

Task E - CIP Program Development

The Consultant shall develop a three-stage program for implementation of the system improvements identified in the foregoing tasks. The stages shall be:

Stage 1 - From the Present to the Year 1995

Stage 2 - From 1995 to 2000

Stage 3 - From 2000 to 2010

The projects shall be scheduled in priority on the basis of need. Such need will be determined in the master planning assessments previously conducted and in consultation with the Chief Officer and his staff. The priority schedule shall consider the capital investment requirements for implementing each project.

Task F - Preparation of Water Facilities Master Plan Document

Upon completion of the tasks and activities described above, the Consultant shall prepare the Guam Water Facilities Master Plan Update report to include:

1. Description of all work performed;

2. Basic planning criteria;

3. Proposed water system improvements including size, location and capacity of all major facilities;

4. Preliminary construction and project cost estimates for all projects and stages of the CIP Program;

5. Results of the Hydraulic Analyses as provided by PUAG presented in the form of an Appendix to the Report (separate volume);

6. Recommendations for future investigations as may be identified as a result of the inspections, evaluations and assessments of the existing facilities; and

7. All plates, maps and figures necessary to define the plan.

The Consultant shall prepare a draft report for review by the PUAG and upon receipt of review comments, prepare a final report.
Submittals

The Consultant shall submit copies of the various products of the Study, marked with the appropriate submittal and date to the Chief Officer, Public Utility Agency of Guam in accordance with the following schedule:

SUBMITTAL SCHEDULE

No.	Submittal Item	Calendar Days After NTP
1	Summary of Planning Workshops	30
2	Population/Economic Projections	60
3	Preliminary Conceptual Plan	85
4	Present Conceptual Plan	100
5	Preliminary Capital Improvement Plan	100
6	Final CIP	190
7	Preliminary W.F.M.P.U. Document	215
8	Final WFMPU Document (Within 30 days of receipt of review comments on Preliminary Master Plan Document	

Compliance with the schedule is premised on the timely provision of all necessary information, documents, drawings, access and other services and equipment required of the Government.

 (2/7/90)

C

APPENDIX C

RECOMMENDED SYSTEM MAINTENANCE PROGRAM

OPERATION AND MAINTENANCE MANAGEMENT PLAN

WATER BRANCH

PUBLIC UTILITIES AGENCY OF GUAM

November 7, 1986

Operation and Maintenance Management Plan
Water Branch
PUAG
November 7, 1986

Table of Contents

Table of Contents

Table of Contents

Table of Contents

List of Figures

OPERATION AND MAINTENANCE MANAGEMENT PLAN
November 7, 1986

INTRODUCTION

The Public Utility Agency of Guam (PUAG) operates and maintains water and wastewater systems serving primarily the non-military population of Guam. The purpose of this report is to briefly describe the current management of water operations at PUAG, to recommend changes in management procedures leading to increased efficiency of system-wide service, and to show a schedule of anticipated dates to institute recommended changes.

ORGANIZATION

Supply, distribution, storage, and treatment of PUAG's water system are the responsibility of the Operations Division, one of three divisions at PUAG. Each division (Administration, Engineering, and Operations) functions under the supervision of the Chief Officer and the Deputy Director for PUAG. See Figure 1 for Divisional Organization.

OPERATIONS DIVISION

The Operations Division functions to:

1. Operate and maintain PUAG's water and wastewater systems.

2. Monitor the quality of water and wastewater discharge in accordance with local and Federal environmental regulations and standards.

3. Provide the necessary building and grounds maintenance support to all operating divisions and sections within PUAG.

4. Coordinate with Procurement and Supply for establishing a working inventory of parts and equipment for maintenance and metering services.

5. Respond in a timely manner to outside requests through the Chief Officer to meet PUAG's operational commitments.

To accomplish these purposes four branches were created within the Operations Division and are directed by the Chief of

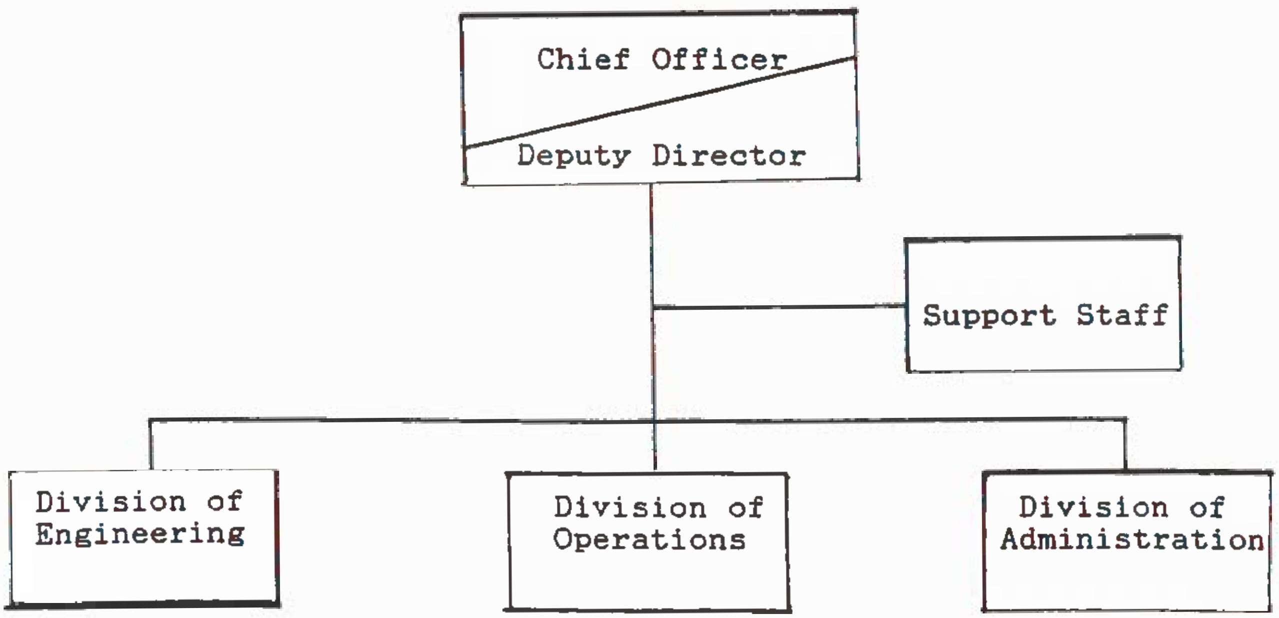


FIGURE 1

PUAG DIVISIONAL ORGANIZATION CHART

Operations. The four branches within the Operations Division are:

1. Water,
2. Wastewater,
3. Laboratory Services, and
4. Building and Maintenance Equipment Support.

An administrative support staff is part of each of the four branches, each supervised by a manager. Figure 2 is an organizational chart showing the structure of the Operations Division. The Operations Division has the largest staff at PUAG with a total of 260 full time employees.

Of these four branches, the Water Branch operates PUAG's water system, Laboratory Services provides the mechanism for checking water quality, and Building and Maintenance Equipment Support (Support) performs some of the mechanical repair and installation on the water system's hydraulic components.

Currently the position of Chief of Operations is vacant and has not yet been filled. In the interim the Deputy Director directs the Operations Division.

<u>Chief of Operations</u> - The administrator in this position is ultimately responsible for supporting and maintaining the effective and efficient operation of water and wastewater services. This manager supervises, coordinates, and monitors the work activities of the four branches within the Division.

The Chief of Operations represents the Division at Agency staff meetings and is responsible for submitting the Division's annual operating budget, coordinating the Division's work with other PUAG divisions, rectifying and alerting top management of emergencies, reviewing contracts for construction of new facilities or repairs to existing ones, reviewing maintenance contracts, and recommending training for the Operations Division staff.

The Chief of Operations coordinates requests from top management with the four branch chiefs within the Operations Division.

Because of the complexity of the water system and the fact that it is larger than the wastewater system, a significant portion of the Chief of Operations time is spent with the problems and needs of the water system.

The person selected for this position is key to determining the emphasis placed on projects undertaken by the Operations Division. The person has high visibility with the public because of the frequency of public requests made upon the Operations Division for water and wastewater services.

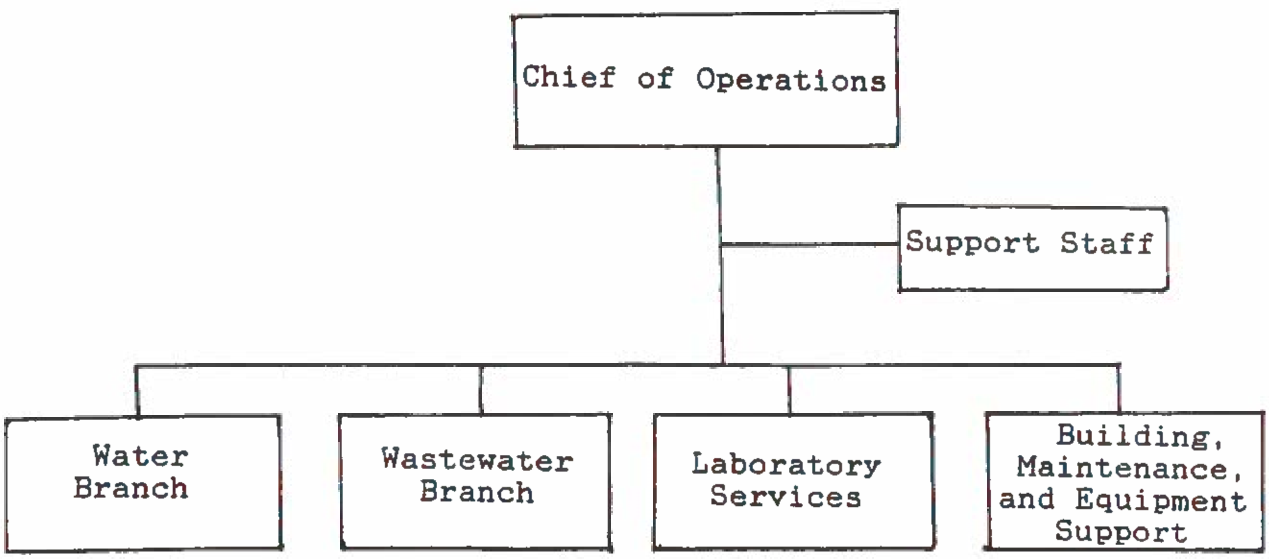


FIGURE 2

OPERATIONS DIVISION
ORGANIZATIONAL CHART

The position requires a technical background in management, hydraulics, water quality, and water and wastewater treatment. Conducting effective public involvement is also a very important aspect of this position.

Utility Operations Superintendent - Water - The Water Branch maintains a 24-hour, 7-day per week operation. In order to maintain the water system at all hours of the day and provide continuity in managing the system when the water manager, assistant water manager, or section superintendents are not present (swing and graveyard shifts, weekends and holidays), the position of UOS was created and was to be filled by someone knowledgeable about operating and managing the water system.

The concept of the UOS was that at all times there was someone located at the central office familiar with the operation and management of the entire water system from production wells to water meters. The person filling this position would be capable of coordinating and supervising routine work activities during swing, graveyard, weekend, and holiday shifts, and have the authority to direct and implement immediate operational changes based on a thorough understanding of system operations when emergencies arise and managers or superintendents are not present.

This position as it was originally envisioned included direct responsibility for "Base Control" operations assembling personnel and equipment to maintain system operations, coordinating the efforts of shift workers and crews to investigate and alleviate system problems, maintaining constant communication with Water Source Supply operators, Maintenance, Repair, and Replacment workers, Construction workers, and Meter Services, and recording activities occurring during the assigned shift.

The UOS also was charged with issuing tools and supplies through a tool supply room, and keeping a log of tools and supplies being used.

The UOS made arrangements for transportation needs during the shift and was also given the responsibility to contact the media disseminating information concerning water problems affecting customers. A priority of restoring service to the system was also given to the UOS and it was the UOS's responsibility to implement restoration in a timely and efficient manner.

Efforts were made through the Civil Service Commission to make this a classified position with an acceptable salary to attract talented people; however, the position was not approved. Volunteers to fill the unofficial position were recruited within PUAG even though their backgrounds were insufficient with respect to overall knowledge of system management and operation. Currently, there are two UOS shifts, swing and graveyard with 3 UOS employees who rotate assignments throughout the week.

Employees filling this position are primarily from the

Maintenance, Repair, and Replacement Section (this section is discussed in more detail later in this plan) with additional assistance coming from Source and Supply, and Construction. The effect of using employees trained for construction or roving curtails the effectiveness of all three sections (Source and Supply, Maintenance, Repair, and Replacements, and Construction) because these sections then become understaffed to perform their assigned work activities.

It has been recognized by water and administrative managers that the UOS concept has not developed effectively into practice. The underlying reason for this has been the demands and responsibilities put upon those untrained employees selected for this position who lack an overall knowledge of the system required to make effective operational decisions.

The duties of the position have become that of a dispatcher, communicating between field personnel and work crews coordinating the efforts of shift workers during non-business hours. The tool room has been eliminated because records were not kept nor were supplies restocked. The UOS does not make decisions concerning operation of the system, instead, water managers are contacted and responsibility of the system remains with them at all times.

WATER BRANCH

Composed of four sections and 121 employees, this branch (see Figure 3) is responsible for operating PUAG's water system, and to see that maintenance and replacement of equipment is scheduled, budgeted, and implemented. The four sections within this branch are:

1. Water Supply Source,
2. Maintenance, Repair, and Replacement,
3. Construction, and
4. Meter Services.

The Water Branch is administered by a Water Distribution System Manager (Water Branch Manager) and Assistant Water Distribution System Manager (Assistant Branch Manager) with support staff. The managers supervise and coordinate the efforts of the four sections mentioned above through section superintendents. The branch manager reports directly to the Chief of Operations providing information for water system operation, budgets, maintenance, replacement and repair implementation, training needs, and reporting and rectifying system emergencies. Now the branch manager reports directly to the Deputy Director until the position of Chief of Operations is filled.

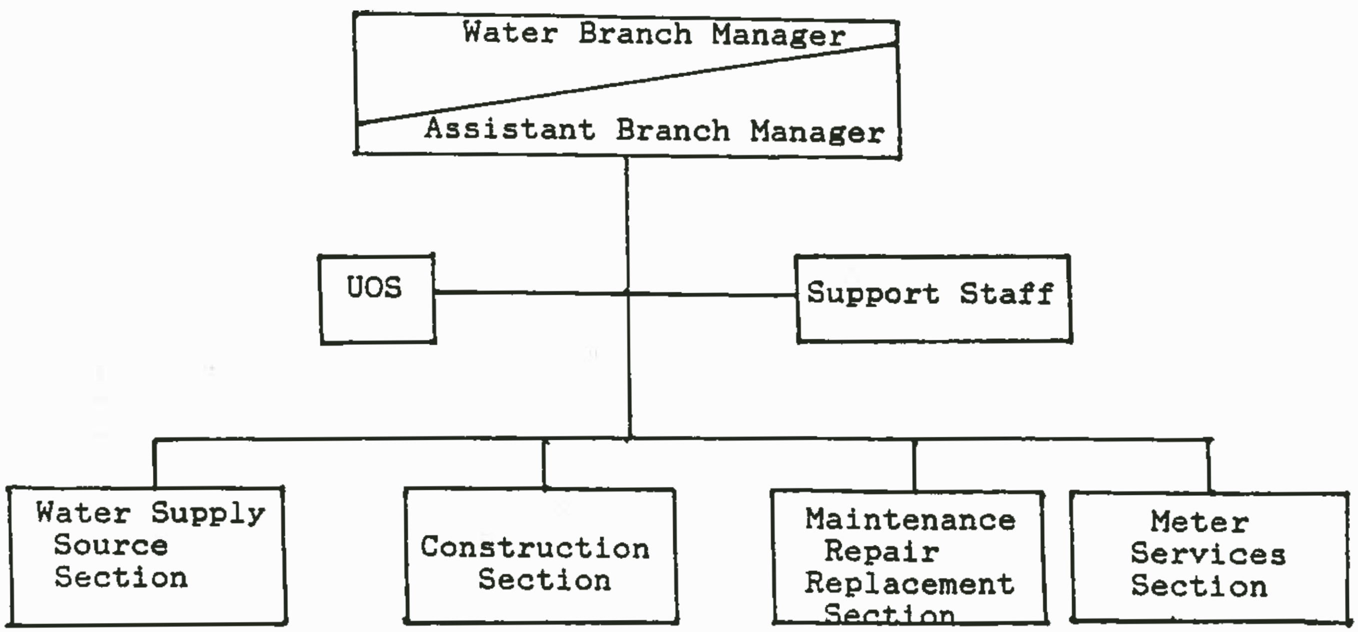


FIGURE 3

WATER BRANCH
ORGANIZATIONAL CHART

Qualifications for the Water Branch Manager and Assistant Branch Manager include a technical background in hydraulics and water quality, management skills emphasizing budgeting and scheduling, experience in construction methods, understanding of recurring and preventive maintenance programs, and operational knowledge of water systems.

Because all classified positions at PUAG are filled through the Civil Service System, position descriptions accompany every position at PUAG, including all positions in the Operations Division and the Water Branch. Positions descriptions are written and reviewed by employees and their supervisors. Position descriptions define what is required of the employee with regard to duties performed, the level of skills required, and any training needed to increase the employee's effectiveness and meet standards set up by the American Water Works Association, and such agencies as the Guam Environmental Protection Agency, and the Federal Environmental Protection Agency.

Certification was not a prerequisite to filling any of the positions within the Water Branch before Public Law 14-31 was enacted. At this time, some staff within the Water Branch are still performing their duties without certification even though their job descriptions now require this. These employees are encouraged to obtain certification on their own and in-house training has been given to those seeking certification. PUAG has also coordinated with the Guam Environmental Protection Agency to administer certification exams for PUAG employees.

PUAG has tried to meet compliance with Public Law 14-31 requiring certification as part of the position descriptions. Currently, Water Treatment Plant Operator positions require water treatment certification even though PUAG does not operate a single water treatment plant. These operators, at the same time, are maintaining the distribution of water, yet are not required within the definition of their job descriptions to possess water distribution certification. More is mentioned about certification under Water Treatment Plant Operator Position Description.

Evaluation standards are written for each employee and are reviewed by employees' supervisors. Standards are reviewed only once a year between supervisor and employee. Efforts have been made to shorten the period of evaluation to a semi-annual or quarterly basis, but have not succeeded.

Training needs for increasing the effectiveness of employees are recognized within the performance standards and are mentioned in performance evaluations. The effectiveness of training programs to date depends greatly on the ability of PUAG's training officer recognizing the appropriate course work for employees.

Water Supply Source Section

This section, also known as Source and Supply, is responsible for the delivery of water to PUAG's customers from the production wells located primarily in the Northern Guam Lens and surface and spring sources of water located in southern Guam. It maintains, monitors, and operates all water system valves, booster pumps, reservoirs, and maintains the supply of chlorine at chlorination sites. This section is not responsible for the operation of production wells since this is covered by a well maintenance contract with a private contractor.

Organization - This section is headed by a Water Treatment Plant Superintendent and a Water Treatment Plant Supervisor. There are 3 Water Treatment Plant District Supervisors, one for each of three water districts. Supervisors coordinate the activities of Water Treatment Plant Leaders, two grades of Water Treatment Plant Operators, Utility Workers, and Maintenance Workers. The UOS, filled by staff within the Water Branch, coordinates the activities of the shifts during non-business hours. Figure 4 shows the organizational structure within the Source and Supply Section.

Currently there are 45 full time employees within Source and Supply. There are 8 employees assigned to perform maintenance during the day shift and a crew of 4 to rove throughout the week. During the swing shift, there are 5 employees assigned to maintain and rove the system. During graveyard shift, there are 3 employees assigned to maintain and rove the system. Shifts are maintained throughout the week.

Water Treatment Plant Position Descriptions - The description of classified positions beginning with "Water Treatment Plant ..." for supervisors, leaders, and operator I and II contains a requirement for water treatment certification. Many of the employees hired within Source and Supply before promulgation of Public Law 14-31 have not obtained certification. Furthermore, certification is for operating water treatment plants which are nonexistent on PUAG's water system. To comply with the law, those responsible for the operation of the distribution system must be certified for distribution operation, not for treatment.

Within Source and Supply, staff possessing distribution operator certification include : 1 superintendent, 1 supervisor, and 1 operator II.

The staff possesing water treatment plant operator certification include 1 superintendent, 1 leader, and 2 operator II's.

Water Treatment Plant Leaders and Operators - Water Plant Leaders and Operators within Source and Supply have two distinct duties, maintenance and roving. Leaders take instructions from supervisors and coordinate but do not supervise operators, utility workers, and maintenance workers.

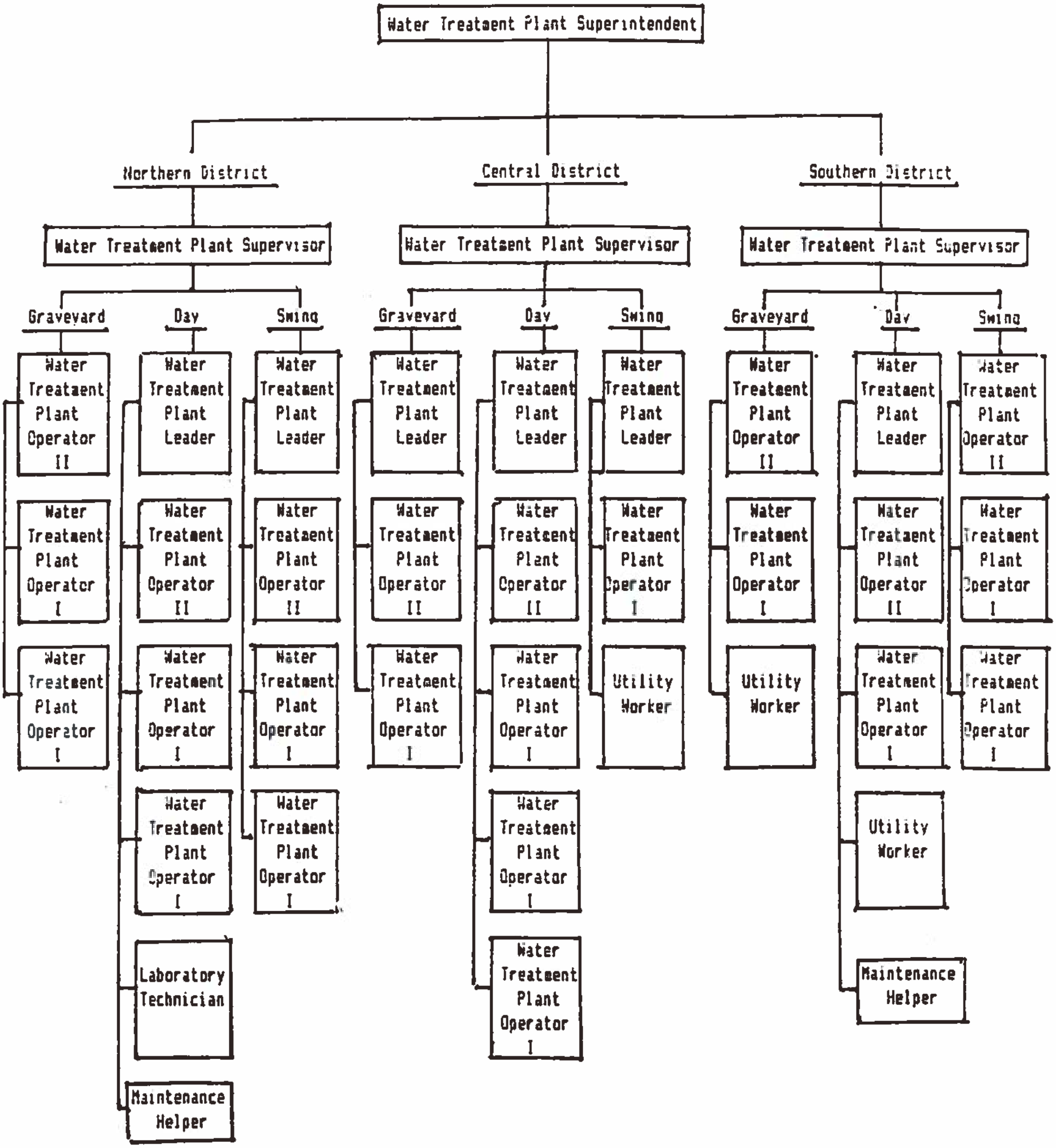


FIGURE 4

WATER SUPPLY AND SOURCE
ORGANIZATIONAL CHART

Maintenance consists of maintaining the structures and areas surrounding structures, repairing booster pumps, replacing chlorine cylinders, cleaning out dams and spring boxes, recharging flouridators, and similar routine tasks.

The roving function is that of a monitor roving around the district checking reservoir levels, adjusting valves, checking pressures, reading water and power meters, and collecting similar operational information. Information on pressures throughout the system, valving, reservoir elevations, globe valve pressure settings, booster pump operation, and totalized volumes of flow at master meter sites are reported to base control by radio or telephone during a shift.

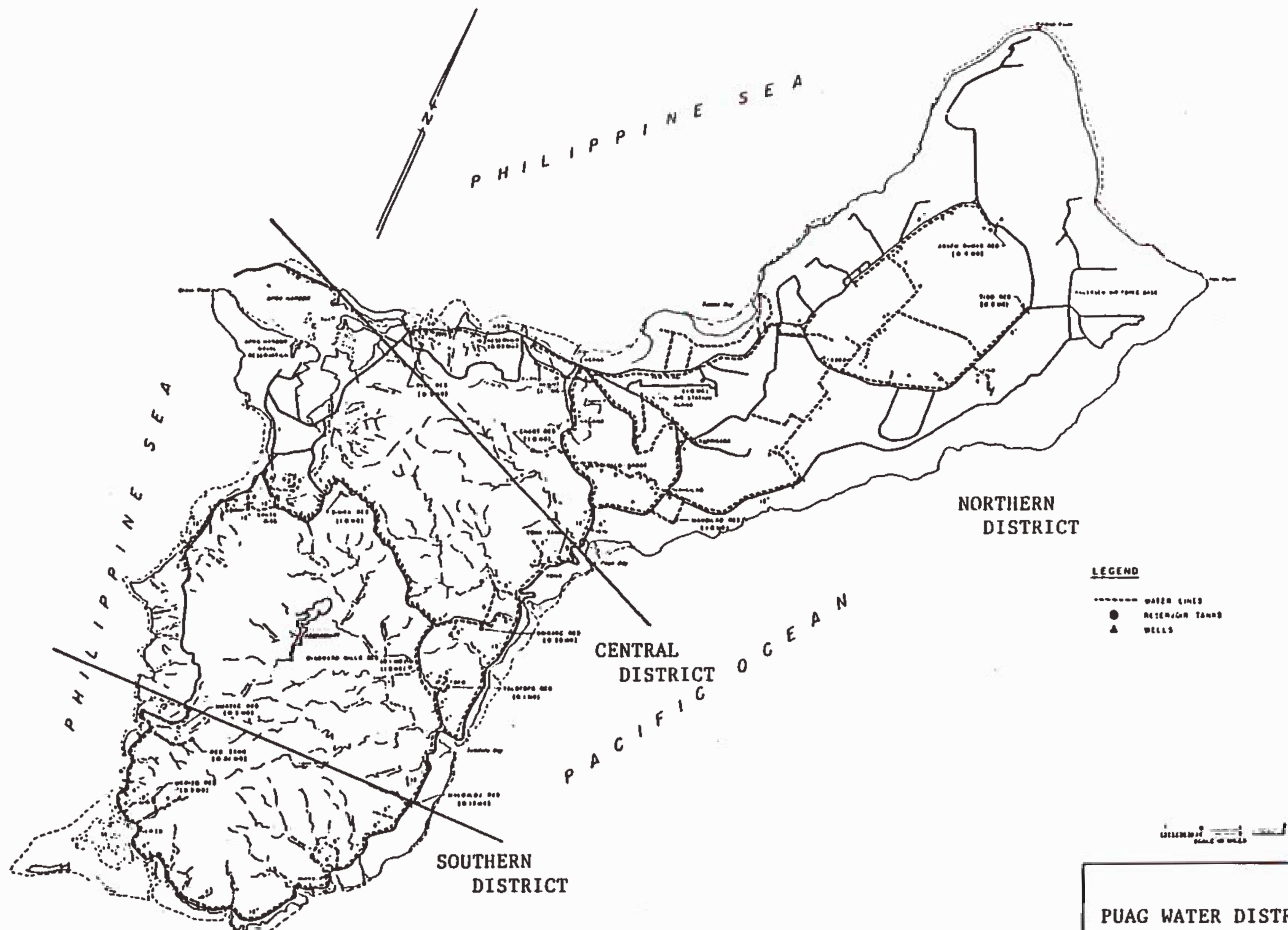
In any emergency, it is normally the rover who is the first person to know and report it. In the case of an emergency, it is the duty of the Source and Supply section to isolate the damaged area, assess the extent of the problem or damages, and inform base control of the situation. For this reason, a rover may not be able to accomplish regularly scheduled monitoring of the system if called upon for emergency situations.

Personnel within the section rotate between maintenance and roving, and also rotate shifts. Swing and graveyard shifts are normally staffed exclusively by rovers and not by maintenance personnel. The district supervisors determine the schedules of their employees.

Water Districts - The three water districts are the Northern, Central, and Southern. See Figure 5 for delineation of water districts. The Northern District extends from Finegayan and Yigo villages to Pago Bay, across to Agana, and includes the Asan-Piti and Nimitz Hill areas. The Central District includes the area from Pago Bay south to Malojloj Booster Pump Station, and includes the areas of Windward Hills, Talofofo, and Agat-Santa Rita. The Southern District extends from the Malojloj Booster Pump Station south through Malojloj, Inarajan, Merizo, and Umatac.

Within the operation of each district, there are three shifts: day, swing, and graveyard. Each shift has a shift leader and a crew of operators. Day shifts are larger than either swing or graveyard shifts.

System Maps - Part of the responsiblity of maintaining service to PUAG customers is to know where all pipelines are located including transmission mains, distribution mains, and service laterals. A problem that has plagued the management of PUAG's water system in the past and still today is the location of its water system. Inadequate records have been kept on all hydraulic features of the water system and rovers and maintenance workers do not have an up-to-date set of maps showing the location of the existing water system. There is no inventory of pipelines kept at PUAG except for studies performed by contract that are one-time



PUAG WATER DISTRICTS

FIGURE 5

attempts to verify the location of water mains. Very few inventories are kept of water mains, valves, or meter locations.

The result of an inadequate inventory of system features has lead to difficulties in understanding how the system responds to changing conditions between supply and demand.

Gate Valves - Source and Supply operates all valves throughout the water system and is responsible for knowing where valves are located and if they are open or closed, or broken. In the event of emergencies such as water main breaks or leaks, rovers assigned to one of three districts on Guam are responsible for isolating the problem, securing all necessary lines, and estimating the extent of damages to the system. This is communicated to base control and relayed to the water managers or UOS by radio or telephone.

To date, no map exits showing where all PUAG valves are located nor identifying the valves' status: open, closed, or inoperable. There is no system used to identify valves by number or letter, designate these on a map, and paint this code on the valve box or marker in the field.

Also, there is no system inventorying the type, size, number of turns to open or close, installation date, maintenance record, of gate valves located on the system. There is no system other than senoir staff familiar with valve location showing new employees where they are. As a result, many valves existing on the water system are unidentified, and the status of valves being open or closed, or even operable, is not always known. Efforts to program funds for valve detection and inventorying have been suggested but never implemented.

Large scale maps of complex valving areas where several transmission and distribution lines are connected, where pressure reducing valves exist with bypasses, or where multiple valves exist within a small area have been diagramed at one time, but are not entirely accurate. Rovers must determine the function of complex valving arrangements by turning valves and deducing what the net effect is with or without the use of the diagrams.

Standard operating procedures are not written down for various configurations of system operation.

There is no preventive maintenance program followed where valves are excercised at least once a year to determine if valves are working properly.

Globe Valves - The Source and Supply section maintains all the globe valves located on the water system including altitude valves, pressure reducing valves (PRV's), pressure reducing and sustaining valves (PRSV's), and check valves. Rovers monitor the system and report on the operation of the above valves. Many of the PRV's and PRSV's have gages indicating pressures and these are reported on activity logs and reported to base control.

Although the location of globe valves on the system are known by many of the staff within this section (because there are fewer of these compared to gate valves), again, no record exists on the type, size, date of installation, problems, recommended pressure settings, or maintenance performed on these valves. In many instances, the valves are not even functioning and are either bypassed or manually adjusted. Efforts to receive training and learn about the operation and maintenance of these valves have occurred, but implementing a preventive maintenance program has not.

Communication between the Engineering Division and Operations Division has not been complete in the past. Decisions to include globe valves on newly designed system features are not always coordinated through the Water Branch. For this reason, many PRV's are bypassed because their need is not always understood by the Water Branch. At the same time, various configurations of system operation may not have been related to the designers when globe valves have been designed into the system.

Booster Pumps - All twenty-two booster pumps are maintained by Source and Supply. Rovers routinely monitor all pumps and do minor repairs to pumps and appurtenances, if necessary. Several of the staff in Source and Supply have become so adept at repairing and aligning pumps that repairing pumps, once the responsibility of Maintenance, Repair and Replacement, has become a function of Source and Supply.

Source and Supply is now responsible for removing pumps from booster pump locations and bringing them into the central office for repair. Repair is then performed by those rovers skilled in the repair of pumps, but not always with the proper tools. Source and Supply only fixes the pumps, electric motors are repaired by Building and Maintenance Equipment Support or they are contracted out for repair. When pumps and motors are repaired and placed back in the field for operation, Source and Supply installs the pump, and Building and Maintenance Equipment Support installs the motors.

Records of the performance of pumps, the type of pump and motor, date of installation, records of repairs, capacity, design head, standard operating procedures, pumping efficiencies, power meter numbers and accounts, and other pertinent data to examine the operation of pumps are not collected, nor is this information kept on records. There is no inventory kept of spare parts to fix pumps or motors. Few of the pumps have backup motors or pumps for replacement should one fail, although standby pumps have recently been ordered. Also, pumps are not routinely checked for performance in any kind of preventive maintenance program.

Design of booster pumps originating from the Engineering Division are not always coordinated through the Water Branch for standard system operating procedures. On the other hand, the Water Branch does not always send requisitions for replacement pumps to Engineering for review to insure that system curves clearly identify what ranges of design head and capacity are needed for pump selection.

Reservoirs - Source and Supply also maintains reservoirs by reporting the volume stored, performing ground maintenance, and adjusting controlling valves leading to and from reservoirs. Reservoir levels are read three times a day and reported to base control. Most of the reservoirs employ altitude valves to maintain reservoir levels and prevent overflowing. Few of the altitude valves function properly and rovers must make adjustments with valves to isolate reservoirs to keep them from overflowing.

There is no way to tell the level of reservoirs over an elapsed period unless 24-hour pressure recorders are stationed at the reservoirs. PUAG does not have recorders available to record levels of all reservoirs and rovers are assigned to report levels three times a day.

Water qualities within some reservoirs must be monitored because circulation is restricted by outside line pressures. When these conditions occur, system configuration is changed to allow reservoirs to feed into the water system and circulate water within reservoirs.

Maintenance records for reservoirs are not kept such as periodic inspection of cathodic protection, examination of external paint surfaces, internal inspection, or exercising of valves connecting the reservoir to the water system.

Chlorination and Flouridation - This section also monitors and if necessary replaces chlorine cylinders and replenishes flouridations units. Both of these chemical units are stationed at production wells and several booster pumps stations.

Chlorination cylinders are set on scales so that the weight of the cylinders can be monitored and replaced when empty. Many of the cylinders are unprotected from exposure to the sun. Efforts are underway to construct shelters to shade and protect chlorination and flouridation units, chlorine pumps, and the deep well pump controls.

Flouridation units are set up at the majority of the production wells and the level of sodium flouride solution monitored by rovers. The supply of sodium flouride is replenished when necessary.

Production Wells - The production wells on Guam are operated and maintained under contract to keep the production well, pumps, motors, appurtenances, gages, meters, and fencing intact and operating. The well contractor is paid on a production quota and is rewarded or penalized if production surpasses or falls below a predetermined production level. The contractor also maintains the chlorination system keeping them in normal operating condition, but is not responsible for monitoring the chlorine supply, replacing empty cylinders, or setting the chlorine demand. They maintain the grounds inside and surrounding the fenced-in area of production wells.

On several occasions, Source and Supply has not been informed immediately about productions wells that are out of service. This has lead to problems of supply and demand without sufficient lead time to make adjustments to the water system or give public notice about potential problems. The well maintenance contract states that the contractor will keep PUAG informed of production wells at all times. It is the responsibility of the contractor to notify PUAG if wells are not producing. Because Source and Supply is not in direct contact with the well maintenance contractor, there is an additional problem of communicating the disposition of production wells to this section within PUAG.

Emergency Generators - Emergency generators located at several production wells are maintained by the Building and Maintenance Equipment Support Branch within the Operations Division.

Maintenance, Repair, and Replacement Section

This section performs the work required for replacing, relocating, and repairing broken or damaged water lines, valves, fire hydrants and other appurtenances, and performs preventive maintenance on all fire hydrants.

Organization - A Water Sewer Maintenance Superintendent and Supervisor manage the section coordinating with the Assistant Branch Manager. The superintendent and work supervisor direct the activities of three shifts: graveyard, day, and swing, with the responsibility of water main and service lateral maintenance, emergency repair, and road repair.

Work assignments are assigned by the superintendent and work supervisor based on the priority of repair. Leaks or damages to the water system are reported by rovers, meter readers, the public, or through base control. These reports are recorded and prioritized based on the degree of severity and availability of equipment to perform repairs. Work assignments involve the repair of water mains and service laterals, leaking or broken valves, damaged fire hydrants, or leaking or broken water meters.

Records are kept of repairs made to water mains and fire hydrants. No attempt has been made to correlate the frequency of repairs to the size, capacity, age, or location of water mains.

Because the position of UOS has not evolved as planned, several of the maintenance workers share the responsibility of assisting base control with coordinating work activities during nonbusiness hours. This affects the availability of workers to repair the water system during swing and graveyard shifts, as well as weekends and holidays.

The superintendent prepares a budget for staff, vehicle use, and estimated use of equipment for the year. The volume of supplies such as pipe fitting, valves, clamps, and similar appurtenances are estimated from previous quarters and costs are projected for restocking Procurement and Supply.

Training workers within this section consists of attending a safety seminar held annually by the Department of Public Works. Other than this, workers receive little outside training.

There are a total of 23 full time employees within this section composed of Water Sewer Maintenance Superintendent, Supervisor, Leaders, Workers, and utility workers. Vacant positions are filled, at times, by Trades Helpers and Meter Readers. Figure 6 shows the organizational structure within this section.

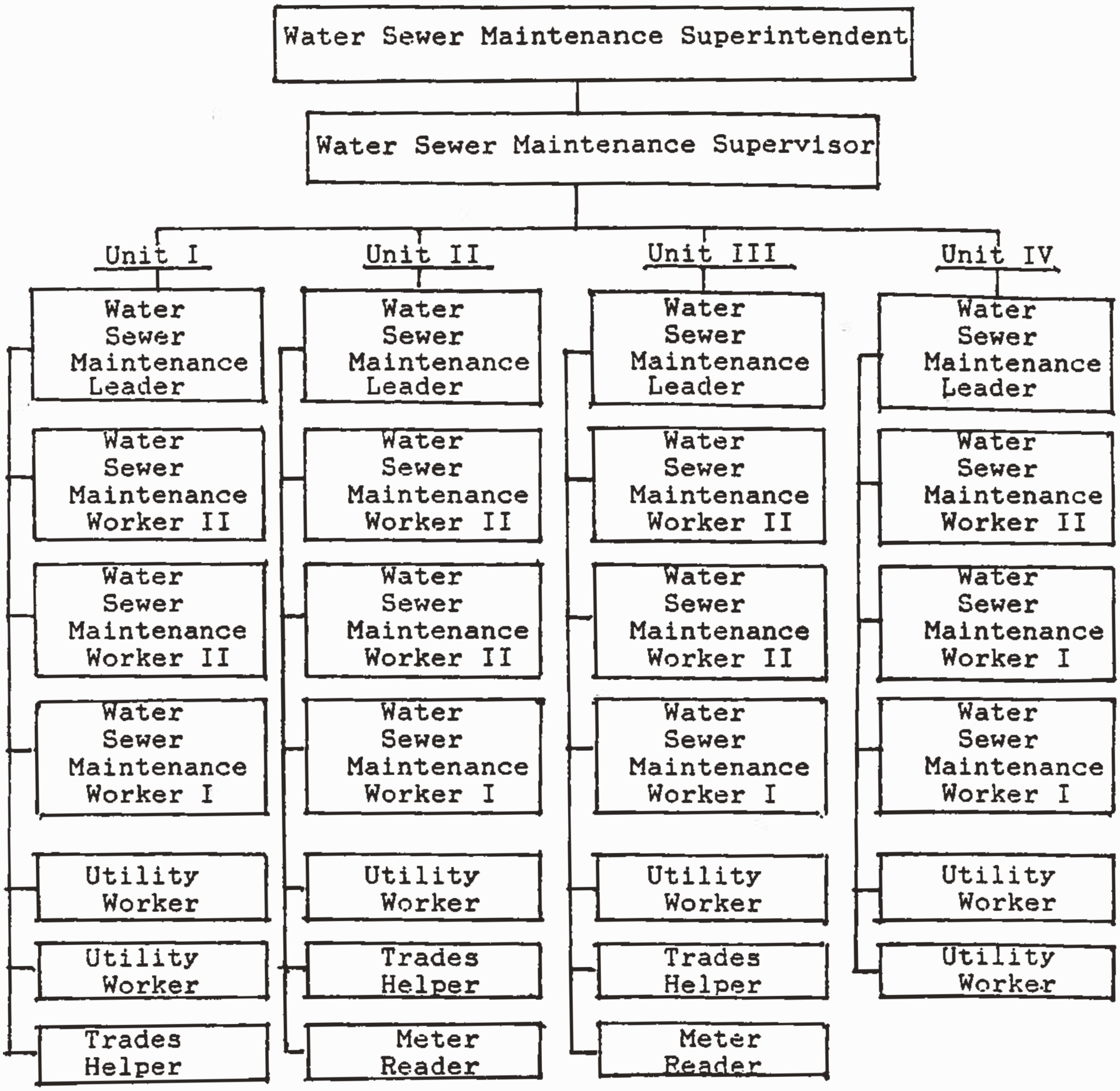
<u>Water Sewer Maintenance Worker Position Description</u> - The position descriptions for Water Sewer Maintenance Superintendent, Supervisor, Work Leader, and Worker I and II do not specify distribution certification as a requirement. Repair work performed by this section involves exposing the water system to potential contamination, and requires disinfection procedures to restore service and water quality.

At this time, no one within Maintenance, Repair, and Replacement possesses either distribution or water treatment plant operator certification.

<u>Water Main and Service Lateral Maintenance</u> - Water main and service lateral maintenance involves performing all repair on pipes and valves within PUAG's system. It operates 24 hours a day, 7 days a week to repair water mains, valves, and distribution and service laterals. The priority of work is established by the superintendent and work supervisor, and on the availability of equipment needed to make repairs.

<u>Emergency Repair</u> - Emergency repair is available at all times to respond to any emergency that occurs. Conditions for responding to emergencies include water main breaks, reported water line and major fire hydrant damage, and broken water meters. The amount of work currently performed to repair breaks around the island prevents any other work from being conducted. There is insufficient staff to provide the manpower required to maintain the water system.

<u>Road Repair</u> - Maintenance, Repair, and Replacement is equipped to repair roads and sidewalks damaged by repairing broken water mains, lines, or fire hydrants. Road repair has been done without the use of compacters in the past, but now compacters are used for compacting road backfill. This has improved the quality of patchwork and problems associated with settling.



Note: Units Rotate Shifts, one unit is on graveyard shift, one on day shift, and one on swing shift.

FIGURE 6

MAINTENANCE, REPAIR, AND REPLACEMENT ORGANIZATIONAL CHART

Equipment - The Maintenance, Repair, and Replacement Section obtains heavy equipment from Support Services and must share two PUAG backhoes with the rest of the needs of the Agency. For this reason, there are times when certain excavation work cannot be performed if backhoes are used by another division or section. Emergencies have occurred when backhoes are unavailable and a rented one is obtained from a vendor. If rental of a backhoe occurs during nonbusiness hours, the UOS must contact the Procurement and Supply Officer, who in turn arranges for rental of the backhoe, otherwise, authorization must be obtained from the Assistant Water Manager, Water Manager, Deputy Director or Chief Officer before a backhoe can be rented.

Trenching - When deep excavation is required shoring of side walls has been lacking and the safety of those working in the excavation has been in jeopardy. Because most excavation occurs only four to five feet deep, most work does not require shoring, and for this reason, PUAG does not own any shoring equipment.

During the repair of many of the larger distribution and transmission lines, workers have to make repairs within excavated trenches while water is still conveyed through the main. The reason for this is due to unidentified valves on the water system. Rovers secure water mains with valves they know about, however many times this is not enough to stop the flow through mains. The result is that repair work is done in less than desirable conditions and is, at times, delayed by efforts to try and secure the line. Contamination is also a potential problem.

Tools and Supplies - Maintenance crews are given only a few tools and supplies to work with. When a work order is issued to a crew, the crew visits the site first to determine what the problem is, and determines the equipment required to fix it. Upon returning to the Central Office, an internal request is prepared and requires the authorization of the Assistant Branch Manager or the section superintendent before equipment can be issued. The work crew then obtains equipment on the internal work list from Procurement and Supply. This occurs only during the day shift.

During swing shift, Procurement and Supply have staff available to issue equipment to work crews submitting an internal request for tools and supplies. The swing shift does without authorization from the Assistant Branch Manager or the section superintendent. Swing shift crews must also visit the site first before preparing the equipment list, similar to the day shift.

The graveyard shift makes repairs with equipment that they have acquired. No equipment is issued during the graveyard shift.

Construction Section

This section is organized similarly to the Maintenance, Repair, and Replacement Section and is responsible for installing new waterlines or replacing existing lines improving system service and efficiency. The type of construction performed by this section is limited to installation and relocation of smaller distribution lines 2- to 4-inches in diameter, and installation of water mains 6- to 12-inches in diameter. Construction also installs water meters at times and maintains fire hydrants. Water line projects are usually Federally or locally funded capital improvement projects. Many of the construction jobs assigned to the Water Branch are shared by Maintenance, Repair, and Replacment and Construction Sections.

Organization - The section is headed by a Water Sewer Maintenance Superintendent and Supervisor who report to the Water Branch Manager. The superintendent and supervisor are in charge of two units, each composed of a leader and workers. Positions within this section are filled by Water Sewer Maintenance Leaders, Worker II's, Worker I's, Utility Workers, Trades Helpers, and Meter Readers. Certification is not a requirement for filling positions within this section.

At this time, no one within Construction possesses distribution or water treatment plant operator certification.

Currently, there are 16 full time employees within this section. This section provides one person to assist base control as a UOS. Figure 7 shows the organizational structure within this section.

Budgets prepared by the superintendent of this section are for staff salaries, vehicles, and miscellaneous operating expenses. The cost of materials for pipe is provided by the funds for construction of new distribution or service lines from Federal and local grants.

Training needs of staff within this section are met similarly to those in Maintenance, Repair, and Replacement by sending employees to attend an annual safety seminar sponsored by the Department of Public Works.

Work assignments develop as requests for service come in to PUAG. These are prioritized by the section superintendent unless a special request has been made from top management. These assignments are then scheduled by the superintendent and work supervisor with the construction leaders.

Workers are required to have job orders specifying the supplies and equipment to be used before anything is delivered to them, the same process used by Maintenance, Repair,and Replacement.

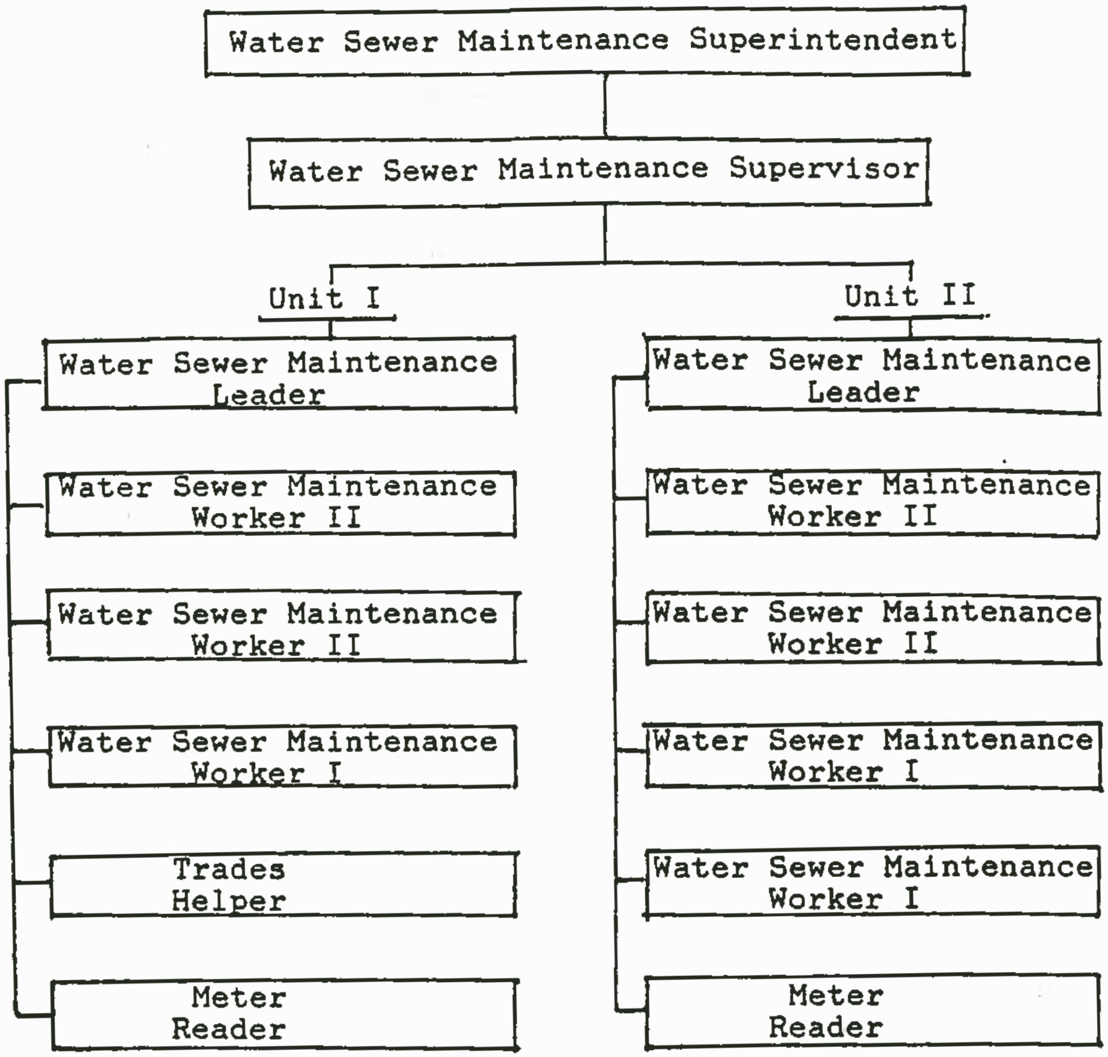


FIGURE 7

CONSTRUCTION SECTION
ORGANIZATIONAL CHART

Fire Hydrant Maintenance - Construction is responsible for preventive maintenance on all fire hydrants within PUAG's system. It performs a preventive maintenance program keeping hydrants in working order at all times by replacing damaged hydrants with new hydrants, fixing damaged or broken valves controlling hydrants, and keeping them painted, accessible and visible at all times. Because spare parts for damaged hydrants are unavailable, damaged fire hydrants are replaced with new hydrants rather than replacing worn or damaged parts.

Meter Services Section

The Meter Services Section, the fourth and final section within the Water Branch, installs and services water meters, and repairs faulty meters. It is also responsible for reading meters on a monthly basis and establishing meter reading cycles and routes.

Organization - The section is headed by a Meter Services Superintendent reporting to the Water Branch Manager, however much of the superintendent's direction comes from the Department of Administration's PUAG Support staff (DOA Support Staff) which oversees the billing of water and wastewater services. The reason for this is because PUAG is a line agency of the Government of Guam and all revenues collected for water and wastewater services are put into the general fund for the Government of Guam. Operating expenses for PUAG are then budgeted and paid out of Government of Guam funds. The DOA Support Staff serves as the administrative staff for billing of services and collection of funds for PUAG services rendered.

The Meter Services Superintendent manages the section's Installation, Relocation, and Elevation Unit, the Meter Reading Unit, and the Meter Shop Unit, but receives customer orders for meter installation, relocation, verification, and disconnection from DOA Support Staff. Supervision of the Meter Services Section by the Water Branch Manager or Assistant Branch Manager is limited because of this arrangement.

The section is composed of a Meter Services Superintendent, a Water Sewer Maintenance Leader and Workers, a Water Meter Reader Supervisor and Water Meter Readers, a Water Meter Repair Supervisor and Water Meter Repairmen. None of the positions require certification although meter readers, repairmen, and maintenance workers install, relocate, and disconnect meters leaving the distribution system exposed, at times, to potential contamination.

At this time, no one within Meter Services possesses distribution or water treatment plant operator certification.

Currently there are 27 full time employees in the meter services section. Figure 8 shows the organizational structure within this section.

The superintendent prepares the section's budget by accounting for staff salaries, estimating vehicle use, and estimating the cost of meters and associated parts. The meter installation, relocation, and elevation unit installs new or repaired meters, repairs leaking meter connections, and keeps meters clean from debris to expedite the reading of meters. The work requests are received through PUAG's customer service section and coordinated with DOA Support Staff.

Water Meters - Inventory of meters is taken every three months to keep an adequate supply of meters in stock. Meters installed are not all of the same manufacturer because of procurement procedures. The request for new meters is put out for bid and given to the lowest bidder. The result is that PUAG installs several different manufactured meters. The problem of having several different manufacturers of meters has been recognized and efforts are underway to standardize the meters used for customer service. Employees also receive training arranged by PUAG's Training Officer as the need arises.

Employees within the Meter Section receive training in the United States from the manufacturers of meters on a regular basis. Training addresses the repair of meters, calibration techniques, installation, and quality control of meters.

Meter Installation, Relocation, and Disconnection Unit - This unit is instructed by the superintendent and work supervisor to install, relocate, or clean meters based on reports received from DOA Support Staff through customer service.

Meter Reading Unit - The meter reading unit reads meters every month for billing purposes. This unit also reports all discrepancies such as leaking meters, service lines, buried meters, damaged or non-registering meters, or missing meters. They prepare reports on meter problems and perform minor repair on leaking meters when reading meters. The also answer customer complaints received through customer service and DOA Support Staff and investigate reasons for these complaints.

Questions related to meters are usually brought to the attention of customer service and are related to DOA Support Staff for accounting purposes. These probelms are recorded and sent to the Meter Section for verification. Meter readers, as mentioned above, also report damaged or broken meters, or meters that can not be located. This unit takes these reports and locates, replaces or repairs meters as needed.

Meter Shop Unit - The meter shop is responsible for reconnection of metered service, termination of service, verification of meter accuracy, and repair and replacement of non-registering or damaged meters.

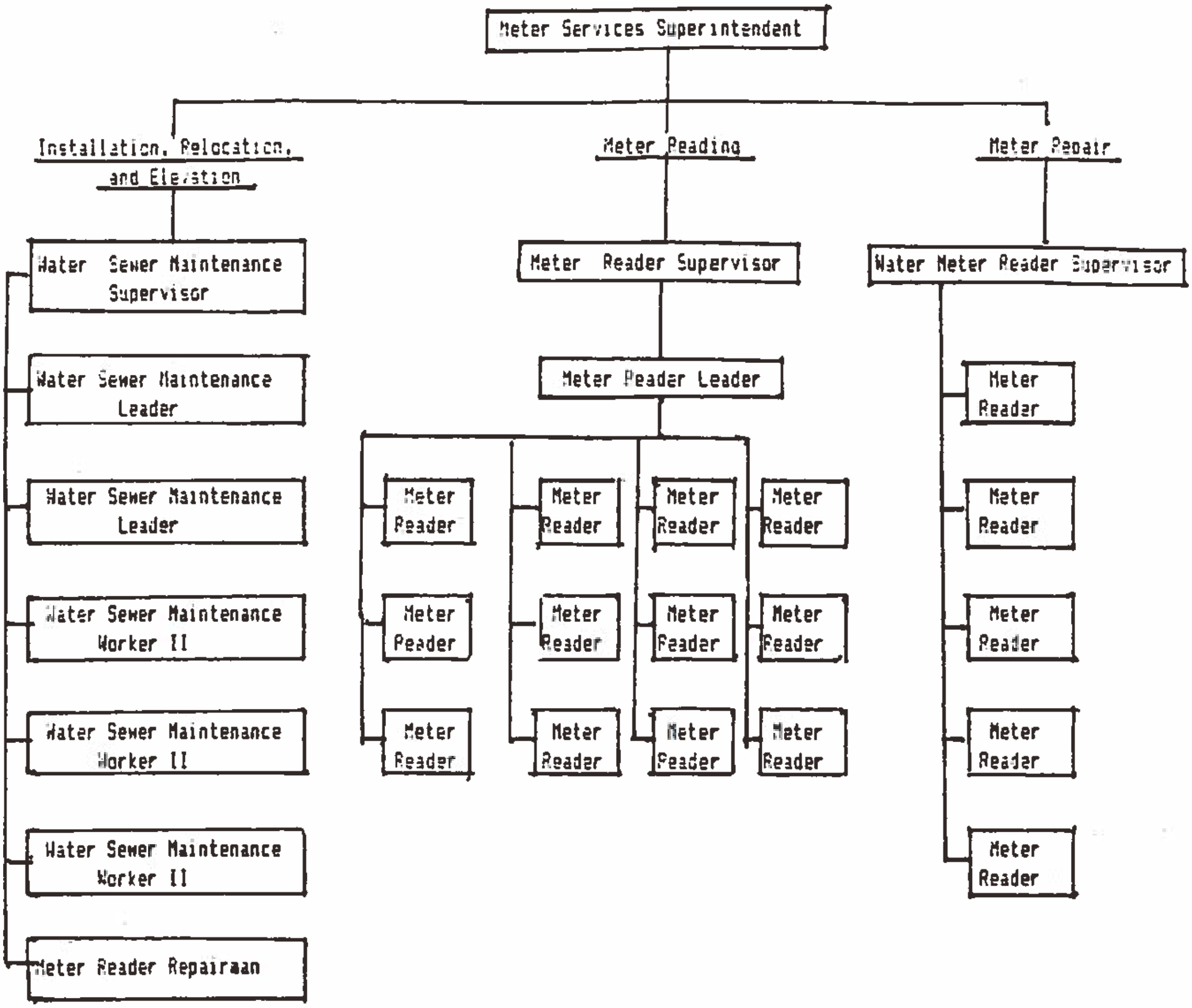


FIGURE 8

METER SERVICES
ORGANIZATIONAL CHART

Meters are only replaced if they are not registering. Leaking meters are fixed to the extent that the meter installation, relocation, and disconnection unit can make repairs on the meters. Meters are also tested for accuracy at the request of the customers, and a charge is assessed for this service. A portable unit is available to test all sizes of meters on PUAG's water system.

Calibration Laboratory - Requests have been made for a calibration laboratory where meters larger than 2-inches can be tested for accuracy. PUAG can calibrate small meters up to 2-inches in diameter. PUAG had no way of calibrating large meters other than testing meters in the field against a portable calibrating meter, or measuring the volume of flow against meter readings. With a calibration laboratory, a preventive maintenance program could be initiated and the accuracy of metered consumption increased. To date, funds have not been appropriated for a new and larger calibration laboratory.

Because calibration of large meters is not occurring, the percentage of water lost because of under-registering meters is not known. Also, with a calibration laboratory, an inventory of meters can be initiated to determine, through data received on meter perfomance, what meter is best suited for Guam.

Currently, without adequate laboratory equipment, no preventive maintenance program exists to insure the accuracy of meters used in the field.

Damaged Meters - Damaged meters found in the field have been replaced with new meters, but many times these are found to be damaged again soon after installation. Efforts to correct the problem have lead to an increase in illegal taps made on the distribution system. The solution for dealing with damaged meters at this time is to reinstall a working meter if a meter is found to be damaged, and if the reinstalled meter is found to be damaged, then a flat fee is charged to the consumer. In this way, a minimum charge is collected from those with recurring damaged meters, otherwise no charge would be collected. Enforcing laws to deal with meter vandalism is difficult because it is nearly impossible to find the responsible person causing the meter damage. Approximatley 25 percent of all nonregistering meters are damaged.

Illegal Taps - Taps made to PUAG's water system that are unmetered are illegal, and accounts which do not reflect the intended water usage are also illegal (domestic consumption established under an agricultural rate is an example of this). It is not known what percentage of loss within the water system is attributed to illegal taps, however supporting evidence indicates that the impact is significant. Monthly consumption data do not fluctuate, yet during the dry season water supply barely matches demand.

Teams have been established to investigate illegal taps, but without measurable success. Amnesty campaigns have occurred where those connected illegally turning themselves in are not charged for retroactive consumption.

Those caught any other time with illegal taps or accounts are charged for estimated retroactive usage and are connected to the water system with a meter or proper account classification.

WATER QUALITY

Monitoring and maintaining a clean water supply to meet or exceed the Safe Drinking Water Standards and Regulations set forth by the Environmental Protection Agency of Guam (GEPA), and to meet Federal standards established by the US Environmental Protection Agency, is accomplished by the Laboratory Services Branch within the Operations Division. The Dededo Water Laboratory is set up to schedule and collect samples of PUAG's water system, and to perform the analyses for chemical, organic, and bacterialogical data used to measure water quality. Water samples are routinely collected from production sources, mostly wells, and throughout the distribution system to insure that the drinking water meets all standards set forth by law.

In addition to meeting the safe drinking water standards, the Dededo Laboratory is currently responsible for maintaining the flouridation units being installed at production well locations. This duty will eventually become the full responsibility of Source and Supply.

In the event that water samples show signs of contamination, the Dededo Laboratory notifies the Deputy Director (formerly notified the Chief of Operations), who in turn notifies the Chief Officer. GEPA is notified of the situation and a second sample is collected by laboratory technicians and the GEPA. If the second sample confirms the level of contamination is unacceptable, then steps are taken to alert the village commissioner of the problem, isolate the problem area from the remainder of the water system, determine the source of the contaminant, and take necessary measures to restore the safe quality of water to the affected area, if possible; otherwise, no action is taken.

RECOMMENDED CHANGES TO THE ORGANIZATION

In order to improve PUAG's water operations, the following recommendations are given as a means towards improving the efficiency of operations and are divided into three categories: organizational, management, and training.

Recommended Organizational Changes

1. Base Control Unit - PUAG recognizes the importance of monitoring the water system at all times and mentioned this in discussing the UOS position (page 5). In the process of drafting this report, it became evident that establishing effective communications concerning operational decisions on the distribution system requires a fully staffed base control unit. Equipment exists and is used for radio and telephone communications, and water system managers are already in responsible positions to take action whenever necessary, and at all times.

What is lacking is a position assigned to operate base control, and part of the reason that the UOS position was created was to provide for this need.

It is recommended that the existing, unofficial position of UOS be eliminated and that the position of Assistant Section Superintendent be created for each section except Meter Services. Those selected for this position then become responsible for communicating information between field and office personnel, which is essentially done now by the UOS.

The assistant superintendent will not be responsible for making major decisions on system operation, but will be trained and held responsible for the transfer of informantion to Duty Officers who are. In addition, the assistant superintendent will be familiar with planning and estimating repair work based on reported incidents.

The base control unit will be composed of three assistant superintendents from Source and Supply, two from Maintenance, Repair, and Replacement (to become Repair and Replacement), and another from Construction (to become Recurring Maintenance). Because this position will be budgeted for, filling the need for base controllers will not result in understaffing these sections which happens now. Figures 9, 10, and 11 show where this position lies within the organizational structure for each section.

Assistant superintendents will continue to keep records of the system as they do now and report on accomplished activities continuing from shift to shift. A set of updated system maps will be kept at base control for reference to reported incidents.

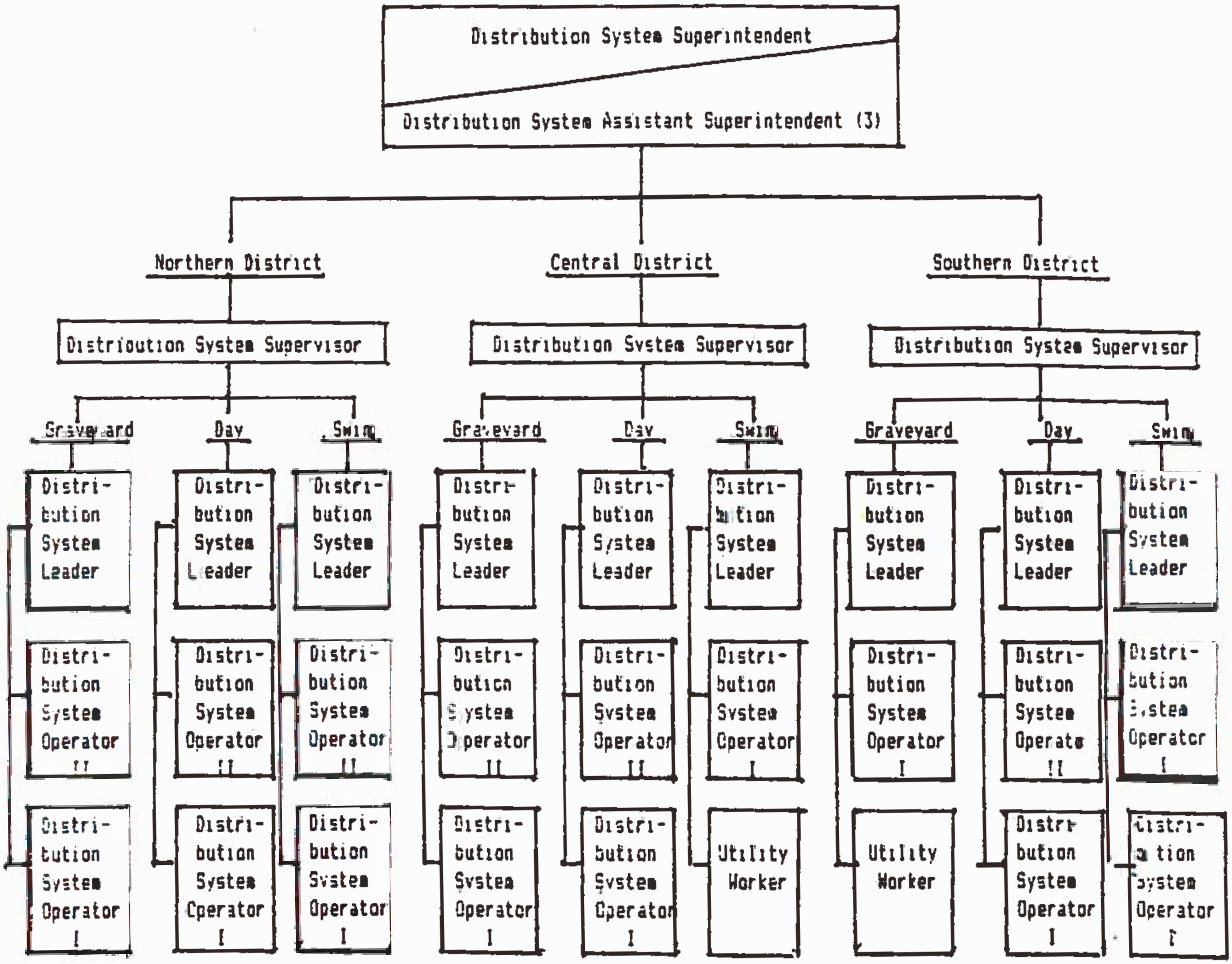
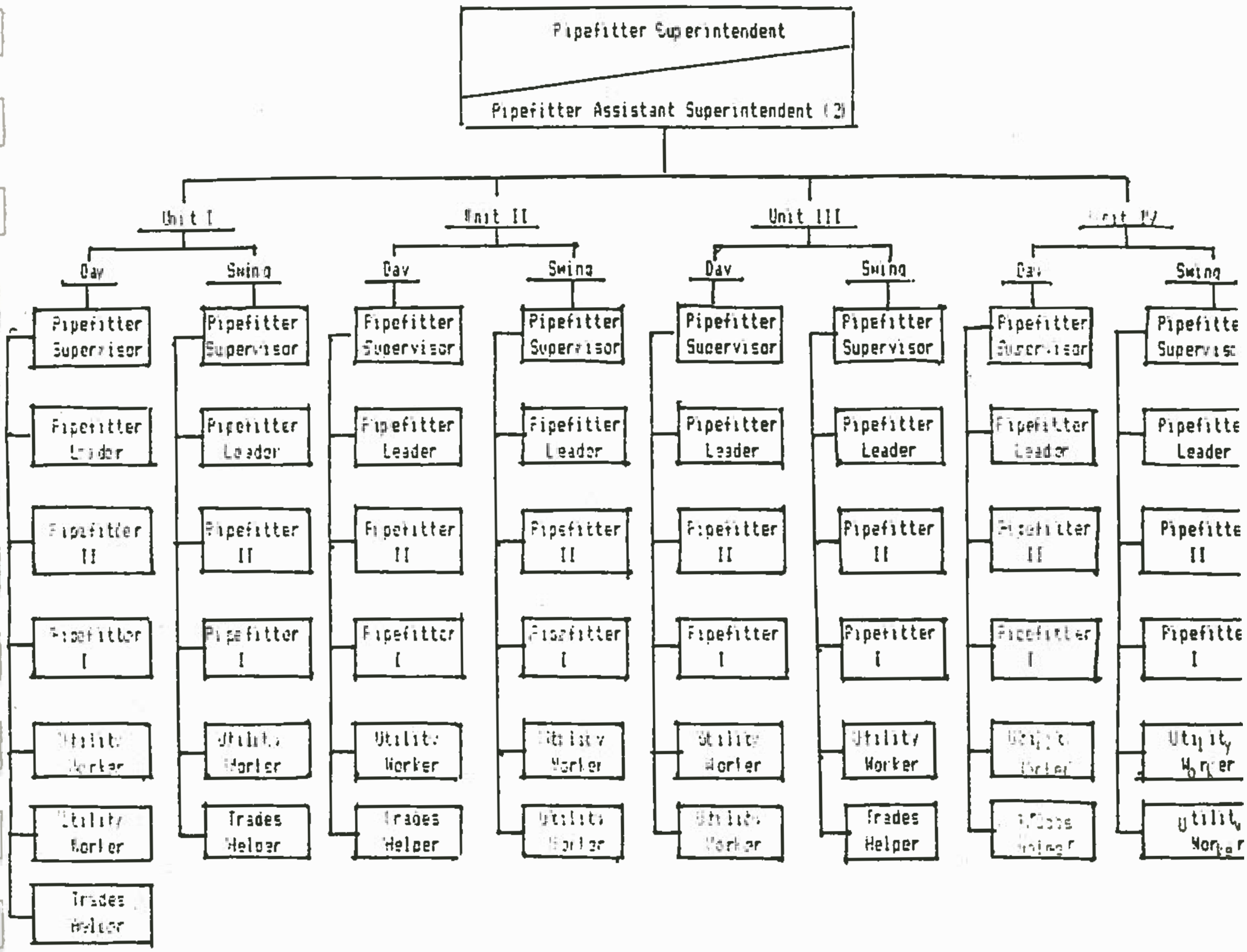


FIGURE 9

WATER SUPPLY AND SOURCE SECTION
REVISED ORGANIZATIONAL CHART



Note: Units rotate shifts, one unit is always ready to mobilize for emergencies after business hours and on weekends.

FIGURE 11

REPAIR AND REPLACEMENT SECTION
REVISED ORGANIZATIONAL CHART

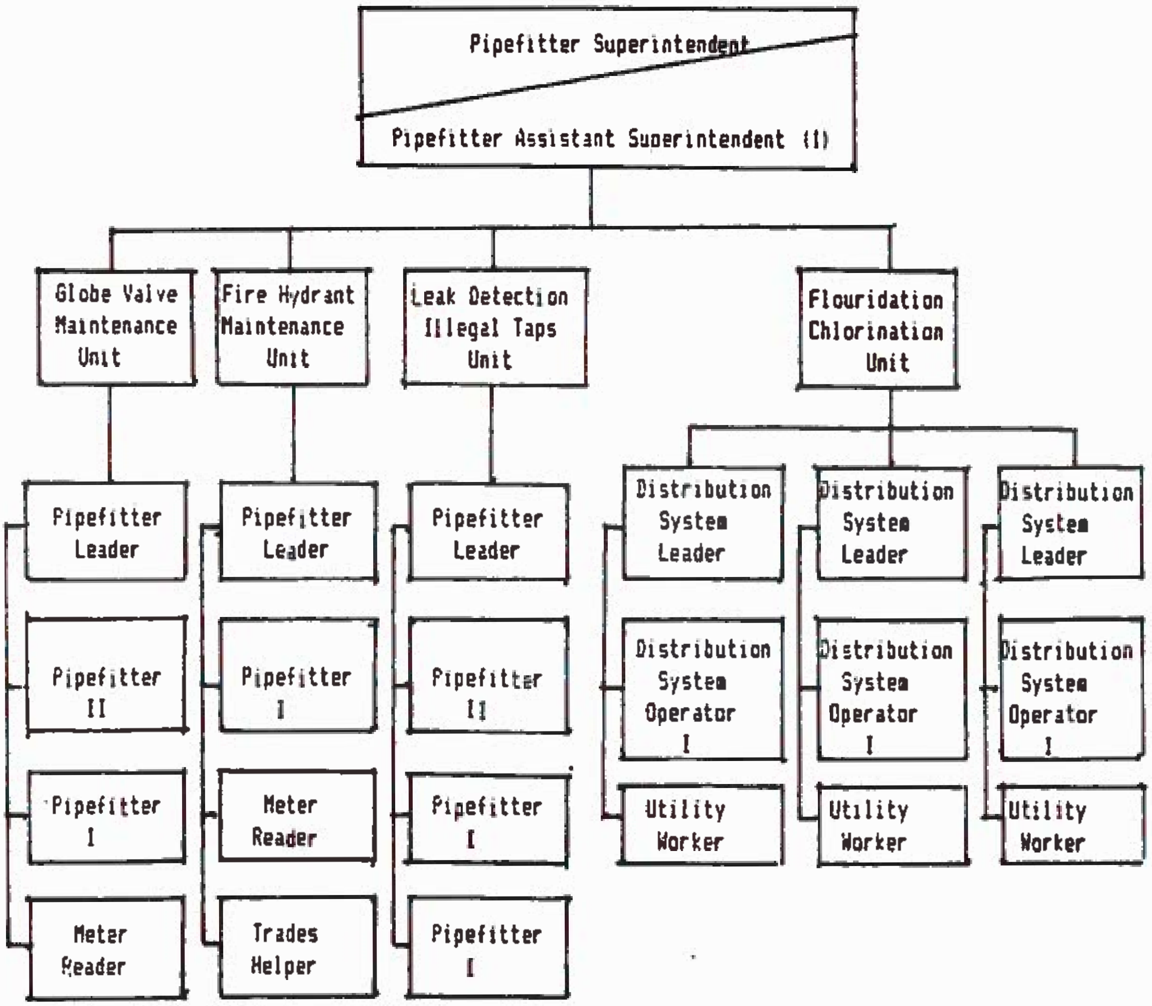


FIGURE 11

RECURRING MAINTENANCE SECTION
ORGANIZATIONAL CHART

Qualificiations for an assistant superintendent are complete familiarization with system-wide operation, and the ability to communciate effectively.

In the meantime and until the above position can be created, PUAG will continue to use the current UOS staff as base controllers until the new position can be approved by the Department of Administration and the Civil Service Commission. UOS staff will continue to coordinate from base control, at the Central Office, and one of the water managers or section superintendents will be on call as the Duty Officer to provide supervision and operational assistance as required. Duty Officers are to be compensated for all overtime spent for being on call and for any additional time involving supervision or operational assistance.

2. Redefine the Position and Title of Water Treatment Plant Superintendent, Supervisor, Leader, and Operator - The positions beginning with the title of "Water Treatment Plant ..." shall be redefined to that of "Distribution System ...". The requirement for water treatment certification will be replaced with a requirement for possessing Distribution Certification to reflect the changes in the job responsibilities.

The entry level into Source and Supply is a Utility Worker, and does not require certification. Advancement to Distribution System Operator I or II, or rover, will require certification. Because this is only a change in the position title and description, there are no organizational changes resulting from this reassignement of job duties. Certification of all operators complies with Public Law 14-31 which requires distribution operators to possess distribution certification.

When redefining the duties of a Distribution System Operator, duties will reflect those of a rover responsible for knowing how the water system operates within a given area of jurisdiction, and knowing where every waterline, valve, reservoir, or controlling device is located and how it is operated within this area. Operators will be required to keep a log of system operations concerning the adjustment of any controlling device, and an account of time spent on all job assignments.

In addition to knowing how the system is configured for optimum operation, the rover will be required to exercise all gate valves within a given service area on a periodic basis for maintenance purposes.

Job performance evaluations will incorporate standards to measure an individual's understanding of the system, and a quota system established for exercising valves.

Advancement through Source and Supply begins with being assigned to a crew leader as a Utility Worker within a water district. Utility Workers obtaining certification can advance to Distribution Operator I and II and will be expected to familiarize themselves with the operation of the water system within the crew leader's area of responsibility. Roving will be a mobile position and all rovers can expect to move to other areas under different crew leaders as familiarity of the water system is gained. The service area for operational responsibility will become larger as operators graduate from Distribution System Operator I to II, and on to crew leader, shiftleader, district supervisor, assistant superintendent, superintendent, and finally water manager. Filling any position beyond district supervisor will require an understanding of the entire water system as a prerequisite.

Distribution System Operators will perform minimal maintenance such as cleaning screens, replacing broken meters or gages, greasing joints, or fixing exposed minor leaks. All other minor maintenance will be assigned to Maintenance, Repair, and Replacement. Any kind of repair to booster pumps will be assigned to Support Services.

Additional manpower must be provided to Support Services if it is required to repair pumps. The additional manpower must also have the necessary skills to assemble and disassemble PUAG booster pumps, and the tools required to do this. Spare parts for pumps must also be available for repairs made to pumps. Work on pump motors can be contracted out, and repair work rendered on motors or pumps will be administered by Support Services.

3. Redefine the Position and Title of Water Sewer Maintenance Superintendent, Supervisor, Leader, and Worker to Pipefitter - Similar in effect to changes made to Water Treatment Plant Operators, the job position of Water Sewer Maintenance Worker must be changed to that of Pipefitter. The change in position description will incorporate distribution certification as a requirement for meeting the position description, and more accurately define duties related to repairing, relocating, and replacing pipes, valves, and meters of all diameters and sizes, and include standard installation procedures, disinfection of exposed waterlines, and cross connection prevention.

4. Reassign all Grounds Maintenance to Support Services - Distribution System Operators will no longer perform grounds maintenance on exposed pipes, reservoirs, pumping stations, fencing, or building structures. All maintenance will be returned to Support Services. This requires that Support Services be increased in staff to accomodate the additional maintenance.

5. Reassignment of the Construction Section - All construction performed by the Construction Section will be transferred to Maintenance, Repair, and Replacement if it involves repairing damaged pipelines or installing service laterals. All other construction will be bid out for contract.

Any other nonrecurring work will be transferred to the Maintenance, Repair, and Replacement Section. The Construction Section will be renamed the Recurring Maintenance Section and four subsections will be established to perform valve maintenance, fire hydrant maintenance, leak detection and investigation of illegal taps, and flouridation-chlorination maintenance. Figure 11 shows the organizational change to occur within this redefined section.

Work duties to be done by these four subsections can be performed during the day and will not require a swing or graveyard shift, and can be done with the staff already within this section. The duties for each subsection are described below.

5.1 Globe Valve Maintenance - A unit consisting of a crew leader and three pipefitters will be established to identify, inspect, maintain, exercise, repair, and schedule for periodic replacement all globe valves used by PUAG.

Certification will be required to fill these positions.

5.2 Fire Hydrant Maintenance - A second unit consisting of a crew leader and three others will be established to perform all fire hydrant maintenance including identification, exercising of the fire hydrant valve only, grounds maintenance around the fire hydrant, painting, inspection, and replacement of worn parts on all fire hydrants that are part of PUAG's system.

The first task to be completed will be accounting for all fire hydrants in place on the water system. Once completed, the crew will keep a log of maintenance performed on all fire hydrants and dates for exercising valves.

Any major maintenance, relocation, installation, or replacement of fire hydrant valves or fire hydrants requiring excavation will be turned over to Maintenance, Repair, and Replacement.

Certification will be required to fill pipefitter positions.

5.3 Leak Detection and Illegal Taps - A third unit will be established consisting of a crew leader and a three others to check the transmission and distribution system for leaks. To begin with, the leak detection unit will visually survey all waterlines for leaks and investigate for illegal taps. All leaks will be recorded and reported to Maintenance, Repair, and Replacement for repair.

When as many visual leaks as practical are identified and repaired, PUAG should bugdet for sonic correlation leak detection equipment.

This unit will also be responsible for investigating illegal taps to decrease losses attributed to non-metered uses.

Certification will be required to fill Pipefitter or Distribution Operator positions.

5.4 Flouridation-Chlorination Maintenance - The final unit to be established under the Recurring Maintenance Section is a unit to replenish flouridation reservoirs and replace chlorine cylinders at locations where these are installed on the water system. Currently, Source and Supply replenishes and replaces these chemicals and the crew that performs this work consisting of a work leader and seven others will be transferred to this section. Certification will be a requirement for pipefitters or distribution operators filling these positions.

Common to all the units mentioned above, a quarterly recurring work schedule will be submitted by each subsection supervisor with an estimation made for materials, equipment, and labor required to perform their duties.

6. <u>Redefine Duties to Be Performed Within Maintenance, Repair, and Replacement Section</u> - All nonrecurring work will be performed by the Maintenance, Repair, and Replacement Section which will be retitled the Repair and Replacement Section. The internal organizational change increases the number of shifts (coinciding with the hours of Procurement and Supply) and provides two maintenance workers for each Water District, and a spare unit for emergencies on holidays or weekends. The change to this section and new job position titles (pipefitters) are shown in Figure 10.

Duties performed within this section will encompass the following kinds of work typifing the relationship between Repair and Replacement and the other sections:

6.1 Emergency Repairs: Emergency repairs to broken transmission and distribution lines effecting large service areas will have high priority with respect to other assignments from other sections within the Water Branch. Assessment of repair needs will be coordinated through Source and Supply and the Dispatchers. Disinfecting repaired pipe will be standard procedure in making pipe repairs and recorded on work orders.

6.2 Broken Valves: Valves identified as broken or inoperable will be reported by Source and Supply to Repair and Replacement for repair if salvagable, or replacement.

6.3 Damaged Fire Hydrants: Fire hydrants which cannot be repaired in place by the Recurring Maintenance Section will be replaced with new hydrants by Repair and Replacement and damaged hydrants given to Recurring Maintenance for restoration.

6.4 Leaking Waterlines: All leaks identified by the Leak Detection and Illegal Taps Unit will be reported to Repair and Maintenance. Repairing leaks then becomes the responsibility of Repair and Replacement.

6.5 Globe Valve Repair: All work on globe valves requiring the use of heavy equipment to replace or extract globe valves will be coordinated through Repair and Replacement; however, fixing the globe valve remains the responsibility of the Globe Valve Unit.

6.6 Service Laterals: All new pipe installation except for new service lines or service connections should be contracted out. Repair and Replacement will still install small reaches of service laterals for customer hookups. The need for these will be coordinated through Meter Services Section and the Engineering Division.

6.7 Meter Installation, Relocation, and Repair: Coordinated through Meter Services, Repair and Replacement will help install, replace, or relocate water meters when this work cannot be performed by meter services alone. Deep excavation is an example of when Repair and Replacement will be required to help with water meter repair, installation or relocation.

7. Parts, Labor, and Equipment Cost Accounting System - Repair and Replacement should establish a method to account for parts and equipment used for work assignments so that costs can be assigned to specific work items such as labor, parts, tools, and heavy equipment. It is highly recommended that a cost accounting system be developed by establishing the position of planner estimator who develops a bookkeeping system used to estimate future working expenses and develop production standards.

Data Base and electronic spreadsheet software for a personal computer compatible with existing computers should be employed as part of the plan for developing a cost accounting system.

8. Water Distribution Certification - It is highly recommended that certification within the Water Branch and the Operations Division pertaining to the water system be correlated to salary level. Figure 12 shows the level of certification and position title that PUAG's Water Branch should achieve in conjunction with changes in job positions mentioned above and below. PUAG must meet minimal certification of those in charge of water distribution if it is to comply with Public Law 14-31, and all positions beginning with pipefitter or distribution system operator will be certified. If position descriptions are not rewritten to include certification as a requirement, it is doubtful if salary level can be related to certification, nor will there be any incentive to acquire certification as employees rise through organization.

9. Well Maintenance Technician - PUAG's contract for well maintenance needs improvement by assigning two trained employees familiar with routine pump maintenance and the location of PUAG's 86 production wells to oversee contract administration. These employees would keep files on all previous and future records for each well included in the maintenance contract. A collateral duty will be to measure pumping efficiencies at all wells and schedule routine preventive maintenance for the production well pumps and appurtenances. As part of a preventive maintenance program, those filling this position will see that required spare parts are kept in supply.

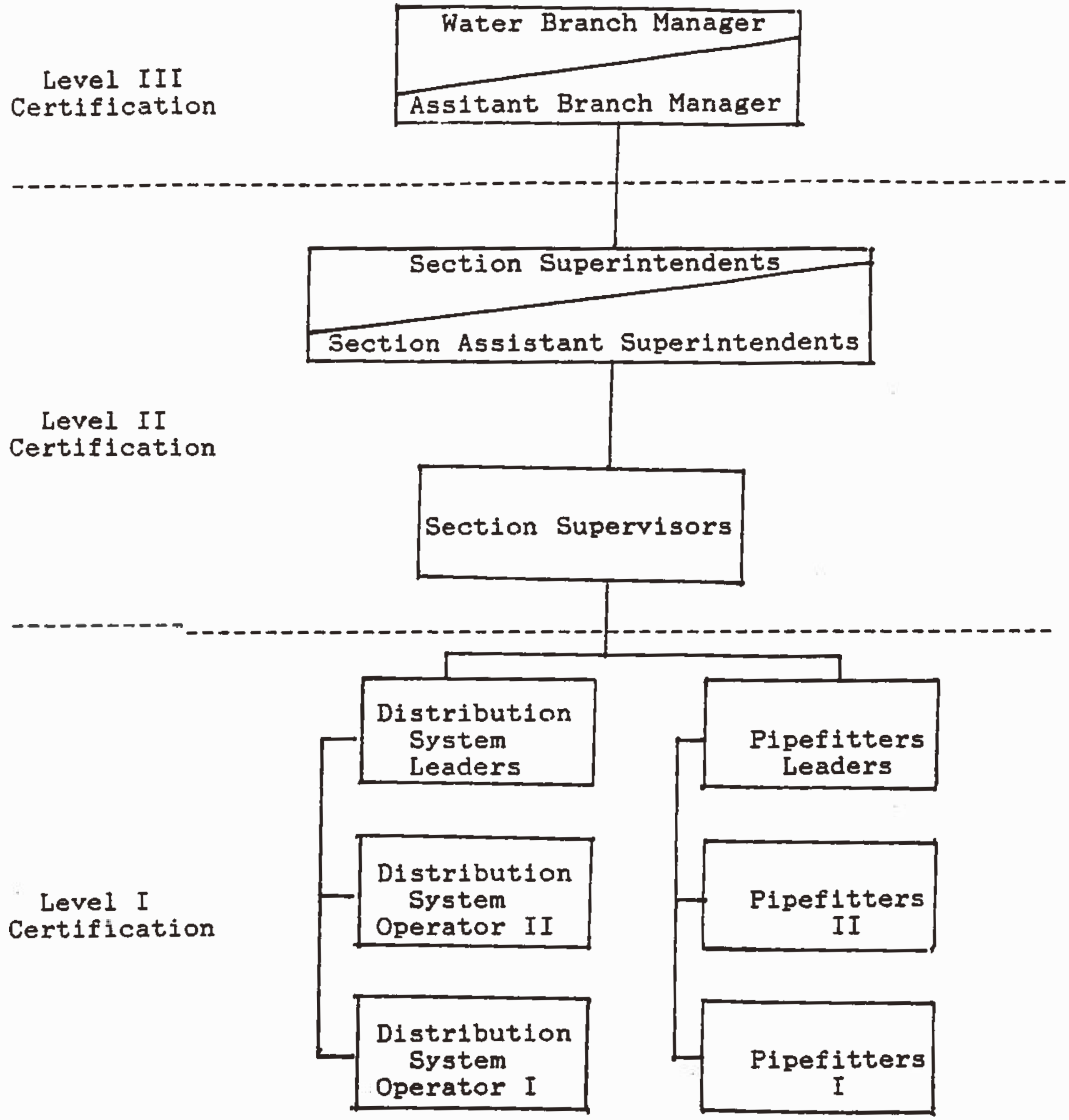


FIGURE 12

RECOMMENDED DISTRIBUTION CERTIFICATION
VERSUS
LEVEL OF RESPONSIBILITY

10. Combining Customer Service with Meter Services - PUAG will remove Meter Services from the Water Branch and place it within the Administration Division under the Finanical Affairs Branch to enable Customer Services to be more closely associated with Meter Services. Meter Services will continue to operate as a section providing the same services as it does now. The only organizational change within this section will be changing the position of Water Sewer Maintenance Worker to that of Pipefitter to include certification as a prerequisite for filling the position.

Figure 13 shows the organization of the Administration Division incorporating Meter Services.

PUAG and Meter Services recognizes the expense and problems caused by recurring damage to water meters and the problem of illegal taps, both in the category of account and illegal connections. Solutions to address these problem are required and is the primary reason for creating the Leak Detection Illegal Taps Unit under the Recurring Maintenance Section (see Recommendation 5 and 5.3 above).

Complete autonomy is highly recommended and would allow PUAG, among other things, to combine DOA Support Staff with Customer Services and Meter Services and eliminate the overlapping of functions bewteen PUAG and the Department of Administration.

11. Compliance with the Safe Drinking Water Act - PUAG needs to comply with the Safe Drinking Water Act by informing areas found to be contaminated of the potential problem. PUAG needs to establish a mechanism where laboratory results of contamination are confirmed, the affected area located, and the problem reported to residents in the affected areas in an effective way without causing undue alarm.

Recommended Management Changes

1. System Maps - It is recommended that a set of updated maps be developed at the earliest possible date to show the location of existing transmission and distribution lines, and service laterals; the size of these lines; the type of pipe; location of all gate valves, globe valves, and other hydraulic appurtenances; all reservoirs; all booster pumps; and the location of any master meters situated on PUAG delivery system.

Water transmission and distribution maps should be updated and assigned a number and date for reference. During working hours, all Supply Section rovers and maintenance operators should carry and updated version of transmission and distribution maps within the areas of their responsibility.

2. Pipe Inventory - All pipeline used by PUAG for distribution should be inventoried and records kept of the location, length,

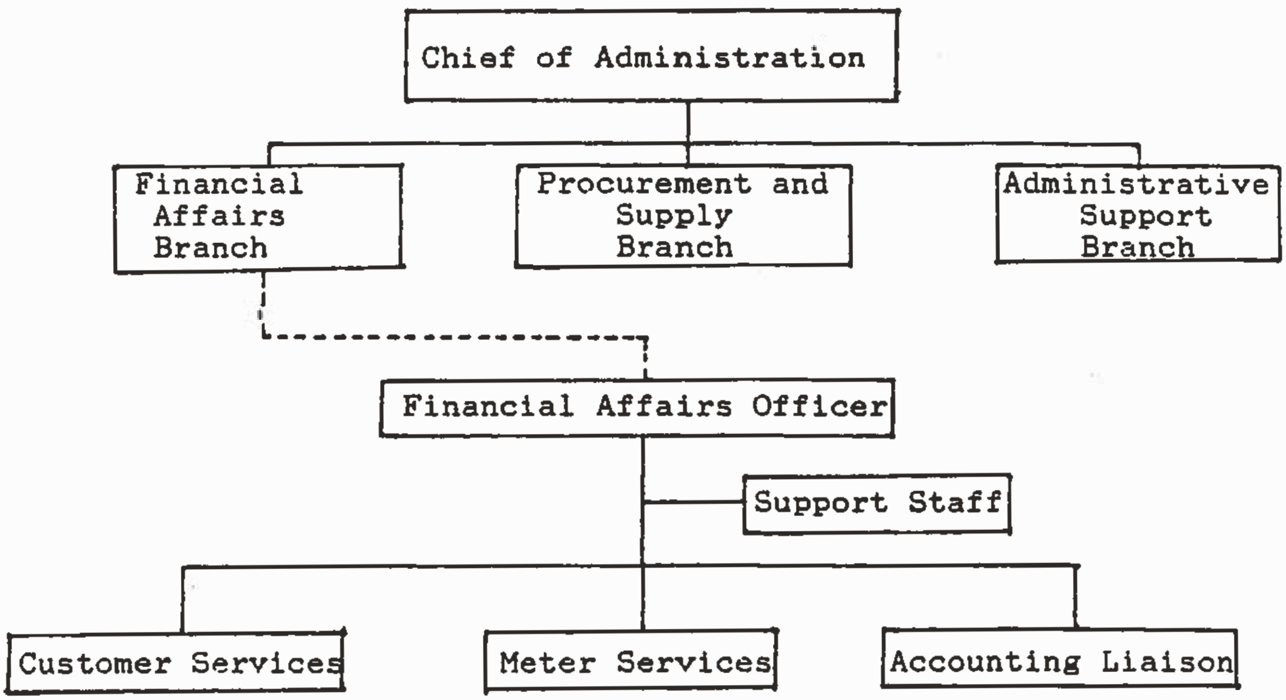


FIGURE 13

METER SERVICES SECTION
REORGANIZED UNDER THE DIVISION OF ADMINISTRATION

manufacturer, contractor, depth, size, date installed, and location and frequency of leaks and repairs. These records should then be periodically reviewed for planning and budgeting purposes to replace worn sections of pipe, or pipelines with insufficient capacity.

3. Gate Valve Identification, Operation, and Inventory - It is highly recommended that, in addition to developing maps showing the location of gate valves on the distribution system, all valves be designated and identified by a coded system. Valves should be identified by number or letter and identified as such on maps. Likewise, valve boxes should be painted or marked in the field for easy identification.

Once valves are identified in the field, the position of the valve, open or closed, should be noted at all times and kept on record at the dispatcher's office. Based on the opening and closing of valves, standard operating procedures can be established for system operation. This will help rovers know what the status of valves are and allow them to make the correct changes for efficient system response.

A record should be established for each gate valve on PUAG's system to show the valve's manufacturer, size, number of turns to open or close, date installed, and other maintenance performed on the valve. In addition, the record should show the date when the valve was last exercised and be used to schedule periodic valve exercise.

All gate valves should be exercised at least once a year. This can be accomplished if an inventory of valves exists, the exercising of valves is scheduled as part of the rovers' routine duty and rover performance determined by a quota system for exercising a certain number of valves. The date of exercising and the condition of valves should be recorded every time a valve is exercised.

4. Large Scale Gate Valve Maps - Where many gate valves occur in a small area, larger scale maps should be developed to show valves corresponding to distribution mains, booster pumps, PRV's, service laterals, or bypasses for easier valve identification.

5. Booster Pumps - It is recommended that all major maintenance on pumps no longer be performed by Source and Supply. All major maintenance will be performed by Support Services. Rovers would not perform any service other than notifying base control of problem pumps. It would be the responsibility of base control to contact the proper authorities within the Water Branch so that Support Services can be scheduled to service the pump.

Rovers will be responsible for keeping performance records on all booster pumps so that when poor performance is encountered prior to pump failure, arrangements can be made for repair. Pump performance records should be maintained at each booster pump by rovers for monitoring pump performance.

The performance of pumps will be measured weekly by rovers testing for wire to water efficiency and discharge to capacity pumping. In addition, Support Services should be provided staff to measure electric loads on all booster pumps at least weekly.

Records kept on booster pumps and motors will be kept at the booster pump station for reference, and also kept in rover's reports for office records. Based on these records, periodic maintenance should be scheduled on all pumps to replace worn bearings or seals and inspect other pump parts before failure occurs.

It is also recommended that Engineering Division's design and review of new pump stations be coordinated through the water branch to insure that the pumps fit into the planned operation of the water system and not vice versa. Likewise, the Water Branch should review specifications for pump replacements with Engineering to insure that a pump suits a system curve prepared for the replacement pump.

6. Reservoirs - One of the first indications currently used to gage the stability of the water system is the rate at which reservoir levels fluctuate. Demands made on reservoirs are also important for understanding daily use patterns. For both of these reasons, reservoirs must be monitored at all times. PUAG must investigate a possible telemetering program to record the level of reservoirs throughout the day and at all reservoirs. These data should be recorded for statistical evaluations and presented to managers and superintendents for evaluating system operation.

Records must also be kept of the cathodic protection installed for each reservoir and this protection must be inspected on a scheduled basis for effectiveness or replacement. The exterior and interior coatings on the reservoirs must be inspected periodically, touched up where necessary before corrosion occurs, and budgeted and scheduled for repainting.

7. Meter Calibration - PUAG must budget for an adequate calibration laboratory and staff to calibrate all meters used by PUAG. In addition, a preventive maintenance program should begin in conjunction with an adequate calibration laboratory to periodically check the accuracy of registering meters to insure that PUAG is not under-registering water consumption.

Recommended Training

Training should be directed towards improving the technical understanding of the water system, how to better manage the work loads and staff available, and how to manage construction contracts.

1. Technical Training - The following is suggested as recommended technical training for employees who are responsible for operating and maintaining the water system.

1.1 System Hydraulics: Specific hydraulic operation of the system should be taught and should include a brief course in elementary hydraulics. The course should include a description of PUAG's system as a whole and how it operates in general, it's operation within the three districts, and the function of hydraulic features within these districts.

1.2 Deepwell Construction, Operation, and Maintenance: A person selected to administer the deepwell maintenance contract should be trained to understand deepwell operation and maintenance to insure efficient operation of PUAG's production wells.

1.3 Fire Hydrant Operation and Maintenance: This category of training would be most profitable and economical eliminating some of the waste attributed to replacing defective hydrants with totally new units. The majority of fire hydrant defects are limited to leaking valve seats, missing caps, worn valve stems, defective threads on hydrant butts, all of which are repairable without replacing the entire unit.

1.4 Globe Valve Operation and Maintenance: The majority of hydraulic controls in use on PUAG's water system are globe valves. Pump control valves, no-slam-slow-closing check valves, pressure reducing valves, pressure reducing and sustaining valves, and altitude valves are all a type of globe valve and many are in a state of disrepair. Training to understand and maintain these valves will improve their performance and this will translate into improved service to customers and reduced inventory for new valves.

1.5 Pump Design, Selection, and Operation and Maintenance: Training is required to teach rovers about pump selection and operation, how to measure pump efficiencies, and how to evaluate normal operation. Those who repair or maintain pumps before they break down on the advice of trained rovers can be taught how to replace worn parts so that the useful life of a pump can be extended and costly back up pumps can be reduced in number.

1.6 Waterline Repairs: Standard methods for waterline repair including excavation, shoring, replacement, coupling, backfill, tamping, and road cover need to be reviewed periodically.

2. Management Training - Management training should be directed towards learning supervisory skills, and techniques for budgeting time and personnel to the maximum benefit of the Agency. It is highly recommended that staff members within the Operations Division attend annual meetings held by professional societies and associations such as the American Water Works Association to keep abreast of available technology and to exchange ideas on how to manage a water system with other water utilities.

3. <u>Construction Managment Training</u> - This is recommended for the Engineering Division which will assume responsibility of contracted construction projects. While the Engineering Division has experience in managing construction projects, additional staff will be needed to undertake work under contract, and new staff must be trained to manage new construction projects.

SCHEDULE FOR IMPLEMETATION OF RECOMMENDED CHANGES

A schedule showing a step by step approach to implementing each recommendation follows after the general narration given below. Each recommendation is given in terms of its function (organizational, management, or training) and is further broken down into activities leading to the implementation of the recommendation. Lead units responsible for performing each facet of a recommendation have been identified as are other responsible units within and outside PUAG. Beginning and ending dates, activitiy durations, and estimated capital and annual costs are included.

To complete all recommendations, PUAG requires approximately three to four years to pursue the objectives stated in the Implementation Schedule. The overall cost to accomplish the recommendations is estimated at an additional $637,540 in capital costs and $784,700 in annual costs. The cost per recommendation is estimated in the Implementation Schedule.

Implementation of Organizational Recommendations

1. Base Control Unit - To begin with, the position of Assistant Superintendent for each of the Sections within the reorganized Water Branch (three for Source and Supply, two from Repair and Replacement, and one from Recurring Maintenance) must be created. Based on the salary level and degree of responsibility of this position, Level 2 Distribution Certification will be a requirement to fill the position.

Drafting a job description and obtaining approval through the Civil Service Commission is estimated to take three months. This is the first milestone for completing this recommendation. The Water Branch Manager and section superintendents will be responsible for drafting these job descriptions. The process of obtaining approval from the Civil Service Commission is that of the Personnel Officer and Chief Officer at PUAG. Final approval of the new positions is a decision made outside of PUAG's responsibility. Final approval for the position is targeted for March 1987.

With Civil Service Commission approval, additional funds for salary amounting to approximately $110,000 will be required. Funds for these positions must be appropriated by the Legislature before they can be advertised and filled. The process to seek supplemental funds, advertise the positions, and fill them is approximately 2 months. Seeking funding for these positions is the responsibility of Deputy Director and Chief Officer. Filling the positions is the responsibility of the Personnel Officer, the

Superintendents of each section, and the water managers. Base control could be functioning by September 1987.

2. Redefine the Water Treatment Plant Position and Title - Implementation of this recommendation is dependent on Department of Administration and Civil Service Commission approval of the position description. It is the responsibility of the Water Branch Manager, Assistant Water Manager, the Source and Supply Superintendent, and the Personnel Officer to draft a position description of a Distribution System Operator I and II. Three months will be necessary to draft the position of Distribution System Operator, and seek approval of this position.

The intent of PUAG's management is to maintain the salary level of the Distribution System Operator equal to that of the Water Plant Operator. The impact of redefining this position is negligible in terms of additional cost to the Water Branch. The impact of redefining this position does not impact the number of staff within Source and Supply, Recurring Maintenance, Repair and Replacement, nor Meter Services; but will require Support Services to increase in size in order to provide grounds maintenance away from the Central Office and the Laboratory, and to retrieve, install, service or repair booster pumps.

Staff levels in Support Services must be increased by 11 to incorporate these additional responsibilities. A unit of two employees, one electrician and pump mechanic, will be required to service and check booster pumps used in water conveyance only. A unit of 9 employees, three for each water district, are required to perform grounds maintenance on all water conveyance and storage facilities. The additional cost in terms of staff will be approximately $200,000 per year.

The position of pump mechanic will have to be created and approved similar to other positions described above. A supplemental appropriation will also be required from Guam Legislature to provide funds to increase staffing levels within Support Services. This recommendation could be implement by December 1987.

3. Redefine the Water Sewer Position and Title - This title and position need to be changed for the same reasons as stated above for Water Treatment Plant titles. Certification is required when handling the water distribution system and must become part of the position description. The cost to PUAG is minimal and amounts to staff time only because no additional manpower or positions are created.

The Water Branch Chief, the Personnel Officer, and the Chief Officer are responsible to see that this is carried out. This recommmnedation can be implemented by September 1987. Again, the Civil Service Commission and the Department of Administration must approve of the changes before implementation can occur.

4. Reassign all Grounds Maintenance to Support Services - Removing grounds maintenance from Source and Supply will require 9 more positions be created within Support Services. Three teams, one for each water district, are required to perform continuous maintenance.

It is the responsibility of the Personnel Officer, Support Services Mananger, the Deputy Director, and the Chief Officer to see that positions are created and filled. A supplemental budget request will be required from the Legislature to accomodate this change. It is estimated that 3 months are required for seeking funding and justification for the new jobs.

The recommendation can be implemented by December 1987 and the cost has already been identified within the implementation of item 2 above ($153,000 out of $200,000).

5. Reorganization of the Construction Section - Reorganization of the Construction Section to perform the duties of the Recurring Maintenance Section is shown in Figure 11. Changes have also be made to position descriptions.

Reorganization requires a 30 day notice and public hearings if the structure of this section is changed. Organizational change is not dependent on redefining position descriptions, and will require two months to implement. The water branch managers, construction section superintendent, Deputy Director, and Chief of Operations are responsible for seeing that these changes are put into effect.

No additional amount of funding will be required for the flouridation and chlorination unit. Eight employees from Source and Supply will need to be moved to Recurring Maintenance to implement this change. This can be accomplished as soon as reorganization is approved.

In summary, there is no cost to organize the Recurring Maintenance Section, and this can be done as soon as reorganization procedures are completed. This can become implemented by July 1987.

6. Redefine the Repair and Replacement Section - At the same time that Recurring Maintenance is undergoing organizational changes, Maintenance, Repair, and Replacement can be reorganized to become the Repair and Replacment Section. It is estimated that to maintain the water system and respond to emergencies with respect to ongoing organizational changes, 18 additional staff will be required, with additional vehicles, tools, and equipment. The increased cost to improve Replacement and Repair Section is estimated at $305.000 for salaries and operational needs, and $167,000 for new vehicles, tools, and equipment.

This recommendation can be implemented by the end of October

1987.

7. Parts, Labor, and Equipment Cost Accounting System - Basically, all PUAG needs at this time to begin a cost accounting system for parts, labor, and equipment is a software program to run on a Wang System OIS 61, and someone assigned the responsibility of maintaining these records and applying the results for operational and maintenance (O&M) needs.

Software will cost between $500-$1,000 and two people will be assigned to conduct cost accounting duties. The person assigned to this job needs familiarity in utility planning, accounting, and accounting and experience in water utility O&M. The second person assigned to this position will serve as a technical aide and can be trained on-the-job. Annual salary for two people is estimated at $40,000.

Positions of planner estimator and planner estimator aide will have to be created and supplemental funding for these requested from the Legislature. Five months will be needed to draft position descriptions, obtain approval from the Department of Administration and seek supplemental funding. Once the position planner estimator has been filled, the first responsibility will be finding suitable software estimated to take one month.

It is estimated that this recommendation can be implemented by November 1987.

8. Water Distribution Certification - Efforts are currently underway to get as many Water Treatment Plant Operators certified as possible using staff within PUAG to provide training. Implementation is required by law and PUAG is making every effort to require that job descriptions be changed to include distribution certification as a qualification.

Figure 12 shows the targeted certification level assigned to various levels within the Water Branch. Meeting these levels of certification is dependent on changing position descriptions to require certification at the appropriate level. Changing the position descriptions will be done by the Water Branch Manager and Section Superintendents. Implementation of these new positions is dependent on Department of Administration and Civil Service Commission approval.

Those not certified or not meeting targeted certification at this time will be allowed to retain their positions; however, filling future job vacancies will strictly adhere to position descriptions and required certification.

Ultimately, it is the responsibility of the Chief Officer, the Chief of Operations, the Water Branch Manager, and Section Superintendents to see that certification becomes a necessary element in filling positions, and that higher levels of certification are directly related to higher levels of responsibility, management, and salary.

This recommendation can be implemented by April 1987.

9. Well Maintenance Technician - PUAG has a trained well maintenance technician working within the Systems Analysis Branch. In addition, the Systems Analysis Branch at PUAG has begun a program to measure well efficiencies and serves as a back-up for the well maintenance technician. These improvements are ongoing and are the responsibility of the Chief Engineer and Systems Analysis Branch Chief. No additional funds are needed at this time for completing this recommendation. Much of this recommendation is already completed.

10. Combining Customer Service with Meter Services - Transferring Meter Services to the Division of Adminstration will take place immediately subject to announcing the change and holding public hearings at PUAG to make the change official. Figure 13 shows the organizational change for Meter Services. This can be accomplished by August 1987, and is the responsibility of the Chief Officer, the Personnel Officer at PUAG, and the Meter Services Superintendent. No additional costs are needed to effect this change.

Combining Customer Services, Meter Services, and DOA Support Staff is totally dependent on PUAG achieving complete autonomy and subject to the decision of the Administration.

Changes within the Water Branch and the creation of a Leak Detection - Illegal Taps Unit within the Recurring Maintenance Section addresses the need to reduce and eliminate this problem. Implementing this change has already been discussed above (Implementation Item 5).

PUAG is exploring ways to address the problem of damaged water meters. Plans are being formulated within the next three months to implement a program to reduce this problem. The Meter Services Section Superintendent and Chief Officer are in charge of this program.

11. Compliance with the Safe Drinking Water Act - PUAG implements a process where village commissioners are informed of diagnosed contamination within the water system at this time. This mechanisms informs the public without creating undue alarm and has been accepted locally as complying with the law.

Activities to review the Safe Drinking Water Act are shown in the implementation schedule and the review process is estimated to be complete by the end of May 1987

Implementation of Recommended Management Changes

1. System Maps - PUAG is in the process of collecting information on its water system to update inaccurate system maps developed in 1975. Implementating a program to update system maps will require at least four years and should be completed by July 1990.

For data collection purposes, the water system has been divided into 10 service areas as follows:

Date		Service Area
1-3/86	1.	Finegayan
4-12/86	2.	Yigo
1-3/87	3.	Dededo
4-7/87	4.	Barrigada
8-11/87	5.	Tamuning - Tumon
11/87-1/88	6.	Agana
2-5/88	7.	Agana Heights, Sinajana, and Chalan Pago
6-7/88	8.	Mangilao
8-11/88	9.	Yona, Talofofo, Malojloj, Inarajan, Merizo, and Umatac
12/88-2/89	10.	Agat and Santa Rita, Asan, Piti, Nimitz Hill, Adelup

Each area requires 3 months of field verification, data transfer onto system maps, and office review. Service areas where many unknown 2-inch waterlines exist will require an additional 1 to 3 months to complete. These are areas 1, 2, 3, 9, and 10. The above dates are the targeted completion dates per service area, however as waterlines are discovered or as development occurs, systm maps will have to be revised.

The Systems Analysis Branch has already completed the Finegayan Service Area and it is under office review. Surveying the Yigo Service Area is proceding and, because of the extensive area served by 2-inch waterlines, will require an extra 7 months. The Chief of the Systems Analysis Branch is responsible to see that these areas are surveyed and system maps updated.

2. Pipe Inventory - Concurrent with the developmentof the system maps, all pipelines and pertinent information related to them is

being collected and recorded. This task has been undertaken and is the responsibility of the Systems Analysis Branch. Completion dates for this inventory are the same as for completing the system maps mentioned above. This recommendation can be completed by April 1990.

3. Gate Valve Identification, Operation, and Inventory - PUAG is commited to finding all valves on its system, create an inventory on them, and begin a program to exercise valves within the next year. With the assistance of the Systems Analysis Branch, the Source and Supply Section is responsible for identifying, recording, and exercising all known valves.

An inventory of all valves shown on existing system maps will be completed by September 1990. Initiating a valve maintenance program is dependent upon the restructuring of the Source and Supply Section. The Section Superintendent, Water Branch Manager, and Chief of Operations will be responsible for completing the inventory.

4. Large Scale Gate Valve Maps - Implementing this recommendation is related to updating system maps, and follows the same completion schedule. The Source and Supply Superintendent, Water Branch Manager, and Chief of Operations will be responsible for completing these maps. This recommendation can be completed by June 1990.

5. Booster Pumps - Implementation of this recommendation is dependent on the reorganization of Source and Supply and Support Services. The maintenance and monitoring of booster pumps is related to organizational changes and can be completed by April 1988.

6. Reservoirs - Implementing this recommendation is dependent on the reorganization of the Water Branch and Support Services, and obtaining approximately $375,000 to purchase a telemetering system and $25,000 annual maintenance charge. If Administrative and Legislative approval is obtained this recommendation can be implemented by August 1987.

7. Meter Calibration - PUAG will request money for a calibration laboratory in the fiscal year 1987 budget. Implementation of a program to use a larger calibration laboratory should be in process by October 1987, assuming funds are forthcoming.

Implementation of Recommended Training

A detailed description of activities to complete for recommended training is given in the Implementation schedule. Training is estimated to cost $88,500 per year. Without adequate training, it is doubtful that employees will improve their skills and improve the condition of the water system.

16 AUG 1990

MEMORANDUM

TO: Administrator, Guam Environmental Protection Agency

FROM: Chief Officer

SUBJECT: Safe Drinking Water Act (SDWA) Compliance

Please refer to your memorandum of May 17, 1988, regarding enforcement strategy for PUAG's compliance with the subject act. This memorandum serves as the sixth progress report on the implementation of the Operation and Maintenance Plan (O&M Plan) for the Water Branch, dated November 7, 1986, and subsequently approved by the U.S. Environmental Protection Agency.

We have attached an update of the status of each recommended item as it appears in the O&M Plan.

JOSEPH F. MESA

Attachment (1)

cc: U.S. Environmental Protection Agency, Region IX
Water Manager
(with copy attachment to each)
SGAEA
Chief Officer

T.JOHNSON/J.MESA;egg
8/7/90

Status of Tasks in the
Implementation Schedule for the
Operation and Maintenance
Management Plan
Water Branch
Public Utility Agency of Guam

July 31, 1990

A. Organizational Recommendations:

Overall Goal:	To better define the job functions for the Water Operations Division, recognizing the need to initiate and perform preventative maintenance in order to reduce long term operational expenses.
Overall Responsibility:	Office of the Chief Officer, Water Operations Division Manager, and Water Sectional Superintendents.

A.1. Establish a Classified, fully funded position to man PUAG Base Control.

The Control Center will be housed within the remodeled water and sewer operations building. It will be manned around the clock by both water and wastewater personnel. Telemetering of PUAG water and wastewater facilities are a part of the Control Center plan. New positions are being reviewed and created concurrently with the development of the center. The Control Center began limited operation with 10 reservoirs on line in January 1990 from a temporary location within the Operation and Maintenance building. Installation of the telemetry equipment began late in calendar year 1989 and is approximately. Currently all 21 water reservoirs are on line along. All sites should be on line by the end of Fiscal Year 1990.

A.2. Within Source and Supply Section, rename and re-define position descriptions and job factors incorporating water distribution certification as a requirement for distribution operators, in an effort to achieve better management and operational control over the water system. Position descriptions for this section may be applicable to other sections where employees manipulate distribution or system features for repair or replacement purposes.

The Water Branch has been reorganized into a division and is now the Water Operations Division. In-house training of Water Distribution System Operators began on September 28, 1988. The first class was completed on February 15, 1989. Three additional classes have been completed. A total of 43 PUAG employees have successfully completed one of the first four classes. Seventy-nine (79) students have attempted the classes; 56 from PUAG, 13 from the Andersen Air Force Base, and 10 from the Navy Public Works Center. In total 64 have successfully completed the course. We have rewritten the position descriptions of the operators to include certification as a prerequisite for employment.

A.3. Redefine water and sewer positions and titles to incorporate distribution certification in the requirements to fill these positions, to more accurately define duties related to repairing, relocating, and replacing pipes, valves, and meters, and to include standard installation and disinfection methods as part of job responsibilities and evaluation criteria.

See Item A.2 above.

We have rewritten the position descriptions of waste water operators and included certification as a prerequisite for employment.

Classes in waste water plant operation were given to PUAG employees by the firm of GMP Associates, Inc. in connection with the startup of the new treatment plant near Inarajan.

A.4. Designate all ground maintenance to Support Services Branch to eliminate this function from Source and Supply and consolidate all ground maintenance within Support Services.

No action has been taken on this item. Additional consideration will be given this item over the next few months as we assess how the current organization is working and what additional steps might be taken to improve it even further.

A.5. Rename the Construction Section to that of Recurring Maintenance Section (RMS) for the purpose of establishing a section within the water branch to routinely maintain the following:

a. all globe valves,
b. fire hydrants,
c. fluoridation-chlorination units, and
d. conduct leak detection and illegal tape investigations.

This has been accomplished. We have reviewed, reclassified as necessary, and rewritten position descriptions for this section.

A.6. Redefine the functions and duties of the MRRS to that of Replacement and Repair Section (RRS) in order to consolidate all repairs and replacement of pipelines, valves, and other heavy appurtenances to this section. Certification will become a prerequisite to filling positions of responsibility where disinfection is required when performing repairs or replacements to the water system. Additional staff (18 additional pipefitters) are required in order to perform the work being relinquished by the reorganization of other sections.

This has been accomplished. We have reviewed, reclassified as necessary, and rewritten position descriptions for this section.

A.7. A parts, labor, and equipment cost accounting system and capable staff are required to build a data base for estimating actual operating costs associated with maintaining the water system, and to provide a basis from which to project expenses for recurring work and to a certain extent emergency repairs.

The contract for this system was signed on September 30, 1988 and the system has been installed. Training of PUAG personnel to operate the system has been completed and the system is fully operational.

A.8. Water distribution certification is required by law. The objective here is to incorporate certification into all positions that are responsible for the distribution of and quality of water.

See item A.2.

A.9. Move the Well Maintenance Technician to SAB and administer well maintenance contract from SAB.

This item has been completed. Also, the well maintenance contract expired on September 30, 1989. We are performing this function in-house. The organizational changes necessary to accomplish well maintenance in-house have been implemented.

A.10. Combine Meter Services with Customer Services to better coordinate the activities of meter installation, disconnection, and relocation with billing and accounting, all combined under PADM.

We have decided not to implement this recommendation because it is not needed since installation of the Financial Management Information System. We now have better coordination between these functions.

A.11. Meet Compliance with the Safe Drinking Water Act (SDWA) by providing a mechanism to inform affected water users of confirmed contamination within the distribution system, and steps to be taken to restore service affected areas.

Such a mechanism is now in place.

B. Management Recommendations:

Overall Goal: To Update the knowledge of the water system and commit it to maps. drawings, microfiche, computer file, or some other means of storage for reference purposes.

Overall Responsibility: Office of the Chief Officer, Chief of Operations, and Systems Analysis Branch.

B.1. Update system maps to show where all pipelines, valves, globe valves, reservoirs, pumps, wells, and other structures or devices pertinent to the production and distribution of water.

This item has been completed. However, most of the maps must be further updated as the computer model is used to analyze the system and the pipeline inventory is completed (see item B.2). We are participating in a Guam Government wide task force to plan and implement a Geographic Mapping System which would be used as a common base for all agencies for map production. Also we have begun the necessary procurement procedures for installation of a Computer Aided Design and Drafting System (CADD) which will be used in part to complete the update of the maps. The CADD system should be installed before the end of Fiscal Year 1990.

B.2. Develop an inventory of pipelines used by PUAG for water transmission and distribution.

This item is an ongoing part of the system modeling effort. Modeling of the PUAG water system is completed. The model will be integrated with the CADD system (see item B.1 above)

B.3. Identify Gate Valves on the water system, create inventory of gate valves, and perform preventive maintenance by exercising valves on an established schedule.

We are considering the use of an American Water Works Association computer software for this purpose.

B.4. Develop large scale maps showing complex valving areas for operators and field crew to be used for easy identification of valves.

See item B.3 above.

B.5. Consolidate repair of booster pumps into SUP, and establish a schedule to perform periodic inspections of pumps, preventive maintenance of pumps, and data files on the performance of pumps.

Consolidation of repair of booster pumps into SUP has not yet been accomplished. Additional consideration will be given this item over the next few months as we assess how the current organization is working and what additional steps might be taken to improve it even further. We are currently looking at different records keeping computer software to keep track of preventative maintenance an inspection and repair of booster pumps.

B.6. Upgrade the system used to monitor reservoir levels.

Telemetering plans have been made to monitor the entire PUAG water and waste water systems. Motorola was awarded the contract for installation of the telemetry system and the first phase of the system was operational in January 1990. We plan to install the telemetering system in conjunction with the PUAG Base Control Unit (see item A.1).

B.7. Budget for a larger meter calibration lab so that meters of all sizes can be tested and that capacity exists to begin a program to rotate all meters through the calibration lab for testing, cleaning, adjustment, and related maintenance.

No action on this item. A larger meter calibration lab was budgeted for but the funds were reprogrammed for construction of an electrical maintenance facility which was considered a higher priority. The electrical facility has been completed and funding of the meter calibration laboratory will be budgeted.

C. Training Recommendations:

Overall Goal: To provide the necessary training and education for operators, pipefitters, and management related to the efficient operation of a water utility and to provide adequate preparation for achieving distribution system operator certification.

Overall Responsibility: Office of the Chief Officer and Administrative and Personnel Support Services.

C.1. Provide technical training to employees covering the operation of hydraulic devices used on the water system. Training courses will be graduated for beginners, intermediate, and advanced operators, pipefitters, and managers and offered on a rotational and repetitive schedule.

A. System Hydraulics: course work to include elementary hydraulics covering the subjects of pressure, gradients, closed conduit flow, head loss, pipeline capacity, water hammer, surges, back flow, water quality (detention time, chlorination, fluoridation, and disinfection); all related to PUAG's water system and directed to answering questions on distribution certification examinations.

One hydraulics class was completed early in Fiscal Year 1989; in conjunction with the University of Guam Water and Energy Research Institute (WERI). Another more advanced (intermediate) class began in February 1989 and was completed in May 1989. This class included use of a computer model of the PUAG system for design of capital improvements. An additional course in hydraulics is planned in Fiscal Year 1990.

One class in chlorination was given in Fiscal Year 1988.

See items A.2 and A.8 with regard to operator certification.

B. Deepwell Construction, Operation, and Maintenance: train employees responsible for administering the well maintenance contract how deep well pumps are to be sized, operated, and maintained to increase the efficiency of operation.

Funding for this training is included in the Fiscal Year 1990 budget. Discussions have been held with the Air Force with regard to its procedures for well maintenance at facilities for Andersen Air Force Base. See item A.9.

C. Fire Hydrant Operation and Maintenance: training to identify the working parts of a fire hydrant, proper maintenance procedures and schedules, and how to repair broken hydrants.

Funding for this training is included in the Fiscal Year 1990 budget. We are considering the use of American Water Works Association computer software for hydrant maintenance scheduling.

D. Globe Valve Operation and Maintenance: training is needed to teach operators how globe valves work, how to adjust them, how to maintain them, and how they should be designed into a water system. These include PRVs, PRSVs, Altitude Valves, Mercury Pods, Pump Control valves and Air release valves.

Funding for this training is included in the Fiscal Year 1990 budget. We are considering the use of American Water Works Association computer software for globe valve maintenance scheduling.

E. Pump Design, Selection, and Operation and Maintenance: Using the slide course purchased from the Public Health Service, get a qualified teacher to administer the course to operators, pump mechanics pipefitters, and electricians on a semiannual schedule.

Funding for this training is included in the Fiscal Year 1990 budget. Some of this instruction is included in the operator training classes. See item A.2.

F. Waterline Repairs: To teach and review standard methods for repair, disinfection, compaction, road repair, safety, and record keeping.

Funding for this training is included in the Fiscal Year 1990 budget.

C.2. Management Training: Provide training in supervision, budgeting, and time management to improve management skills and increase productivity.

1. Determine the needs of managers within the Water Branch. The subjects listed under the Objective column are suggested as the most urgently needed courses, and are not to be construed as the only ones necessary.

A. PERT: Planning, Evaluation, Revision Technique is needed to establish goals and objectives for the Water Branch and provide a mechanism to measure how well goals are being achieved.

Funding for this training is included in the Fiscal Year 1990 budget.

B. MBO: Management by Objective, setting goals to be attained and taking steps to see goals accomplished.

Funding for this training is included in the Fiscal Year 1990 budget.

C. Time Management: Learn skills of managing time, delegating work assignments, responsibility, and authority.

Time management training was held for several PUAG employees in March 1989. Additional sessions are scheduled during Fiscal Year 1990.

D. Attend the AWWA Annual Conference.

Representatives of PUAG attended the annual conferences in Fiscal Year 1989 and 1990.

C.3. Construction Management Training. To train managers, supervisors, and work leaders how to set schedules for getting work assignments done, and a means for estimating the time and cost to perform future work.

Funding for this training is included in the Fiscal Year 1990 budget.

D

APPENDIX D

SUMMARY OF PUAG WELL'S
PHYSICAL AND OPERATING CHARACTERISTICS

GWM Zone	GW Type	Well Number	Date Drilled (1)	Approx. Ground El. (ft)	Approx. Bottom El. (ft)	Static Water Level (ft) (1)	Pumping Water Level (ft) (1)	Capacity (gpm)	Disch. Press. (psi)	Chlorination	Chlorides (mg/l)
		Physical Characteristics						Operating Characteristics			
		A - Series									
3	PB	A - 1	1965	68.31	-153	76.6	102	260	138	NONE	20.0
2	PB	A - 2	1965	119.41	-52	106.1	161	N/A	67	NONE	20.0
3	PB	A - 3	1966	103.85	-262.55	105.8	172	220	80	NONE	18.0
2	PB	A - 4	1966	N/A	-160	133.9	148	220	75	YES	34.0
3	PB	A - 5	1966	146.14	-177	137.4	144	240	65	NONE	16.0
3	PB	A - 6	1967	153.33	-154	142.0	150	250	150	YES	28.0
2	PB	A - 7	1967	N/A	N/A	126.0	155	205	46	YES	22.0
2	PB	A - 8	1967	N/A	N/A	109.0	171	230	164	NONE	24.0
33	BA	A - 9	1967	185.78	-50	180.5	187	N/A	N/A	N/A	172.0
33	BA	A - 10	1967	190.25	-25	184.5	N/A	N/A	N/A	NONE	202.0
2	PB	A - 11	1967	173.63	-167	131.8	195	170	86	NONE	18.0
2	PB	A - 12	1968	138.45	-200	231.0	N/A	220	104	N/A	18.0
33	BA	A - 13	1973	130.38	-194	N/A	149	N/A	106	N/A	364.0
33	BA	A - 14	1973	210.06	N/A	206.0	210	185	68	NONE	310.0
30	BA	A - 15	1973	199.03	-52	194.5	208	175	70	N/A	150.0
		A - 16	ABANDONED	---	---	---	---	---	---	---	220.0
33	BA	A - 17	1973	193.77	-39	192.8	121	170	82	YES	396.0
33	BA	A - 18	1973	194.97	-45	193.4	N/A	160	N/A	NONE	402.0
1	PB	A - 19	1973	135.93	-24.1	133.3	N/A	150	54	N/A	N/A
		A - 20	ABANDONED	---	---	---	---	---	---	---	---
33	BA	A - 21	1974	183.1	-51	182.2	170	160	N/A	NONE	N/A
		A - 22	ABANDONED	---	---	---	---	---	---	---	---
3	PB	A - 23	N/A	38.38	-47	N/A	N/A	250	40	YES	22.0
3	PB	A - 25	N/A	58.33	-10.6	N/A	N/A	225	78	YES	24.0
31	BA	A - 26	N/A	N/A	N/A	N/A	N/A	N/A	N/A	NONE	128.0
		A - 27	ABANDONED	---	---	---	---	---	---	---	---
33	BA	A - 28	N/A	N/A	N/A	N/A	N/A	N/A	82	N/A	188.0
3	PB	A - 31	N/A	N/A	N/A	N/A	N/A	265	70	YES	20.0
		A - 32	1989	120	-50	N/A	N/A	225	70	YES	N/A
		AG - Series									
16	PB	AG - 1	N/A	469.98	-27	N/A	N/A	250	115	N/A	N/A
16	PB	AG - 2	1968	505.97	-77	N/A	N/A	85	N/A	YES	18.0
16	PB	HGC - 2 (2)	N/A	470.20	-78	N/A	N/A	650	N/A	YES	N/A
		AL - Series									
		AL - 1	ABANDONED	---	---	---	---	---	---	---	---
		AL - 2	ABANDONED	---	---	---	---	---	---	---	---

SOURCE : GEPA, Summary of Well Inspections (1st & 2nd Part of FY '89), Groundwater Management Report FY '88 (4th Quarter); PUAG, Chemical Analysis FY '89.

(1) Data obtained from 1979 Water Facilities Master Plan, as no updated records were available.

(2) Data obtained from Hatsuho Golf Course.

APPENDIX D

SUMMARY OF PUAG WELL'S
PHYSICAL AND OPERATING CHARACTERISTICS

GWM Zone	GW Type	Well Number	Date Drilled (1)	Physical Characteristics: Approx. Ground El. (ft)	Approx. Bottom El. (ft)	Static Water Level (ft) (1)	Pumping Water Level (ft) (1)	Operating Characteristics: Capacity (gpm)	Disch. Press. (psi)	Chlorination	Chlorides (mg/l)
		D - Series									
45	BA	D - 1	1965	381.98	-36	379.3	404	185	14	YES	70.0
45	BA	D - 2	1965	381.51	-35	377.8	382	215	19	NONE	62.0
45	BA	D - 3	1965	383.62	-23	N/A	399	N/A	12	NONE	44.0
45	BA	D - 4	1965	383.59	-24	378.0	390	170	N/A	NONE	38.0
45	BA	D - 5	1965	377.75	-34	N/A	413	155	10	NONE	60.0
45	BA	D - 6	1966	396.66	-35	N/A	400	175	25	NONE	54.0
45	BA	D - 7	1966	387.98	-50	382.0	388	240	17	NONE	52.0
45	BA	D - 8	1966	414.24	-35	410.5	424	120	38	NONE	120.0
45	BA	D - 9	1968	388.03	-29	383.0	387	130	28	NONE	174.0
45	BA	D - 10	1968	390.63	-25.2	384.6	390	N/A	54	NONE	N/A
45	BA	D - 11	1969	392.96	-37	389.0	N/A	170	38	NONE	64.0
44	BA	D - 12	1971	421.44	-42	417.4	432	200	35	NONE	18.0
44	BA	D - 13	1971	400.22	-60	397.0	415	N/A	N/A	NONE	352.0
45	BA	D - 14	1973	318.9	-60	315.3	325	162	62	NONE	56.0
45	BA	D - 15	1974	363.22	-49	N/A	N/A	198	49	NONE	106.0
45	BA	D - 16	N/A	329.26	-37	N/A	N/A	N/A	N/A	N/A	88.0
45	BA	D - 17	N/A	301.14	-45	N/A	N/A	N/A	80	YES	134.0
45	BA	D - 18	N/A	N/A	N/A	N/A	N/A	195	52	YES	86.0
44	BA	D - 19	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	74.0
44	BA	D - 20	N/A	N/A	N/A	N/A	N/A	240	50	YES	68.0
44	BA	D - 21	N/A	N/A	N/A	N/A	N/A	170	40	YES	76.0
		EX - Series									
45	BA	EX -5A	N/A	N/A	N/A	N/A	N/A	205	N/A	NONE	42.0
8	PB	EX -11	N/A	N/A	N/A	N/A	N/A	195	45	N/A	34.0
		F - Series									
42	BA	F - 1	1969	424.73	-37	420.0	434	210	160	YES	128.0
42	BA	F - 2	1972	450.41	43.3	446.7	451	85	N/A	YES	132.0
42	BA	F - 3	1972	455.2	-37	452.0	454	N/A	175	NONE	122.0
42	BA	F - 4	1975	N/A	N/A	460.0	465	N/A	62	NONE	70.0
43	BA	F - 5	1975	390.83	-35	386.0	546	95	135	N/A	88.0
43	BA	F - 6	1975	346.99	N/A	347.0	N/A	115	60	NONE	274.0
43	BA	F - 7	1975	N/A	N/A	360.0	507	110	160	NONE	68.0
18	PB	F - 8	1975	439.45	N/A	428.0	N/A	115	170	NONE	16.0
43	BA	F - 9	N/A	393.78	-50	N/A	N/A	145	10	YES	70.0
42	BA	F - 10	N/A	436.87	-50	N/A	N/A	N/A	70	YES	N/A
42	BA	F - 11	N/A	440.85	-50	N/A	N/A	N/A	40	N/A	158.0
42	PB	F - 12	1989	470.63	-25	441.2	448.4	300	N/A	N/A	N/A

SOURCE : GEPA, Summary of Well Inspections (1st & 2nd Part of FY '89), Groundwater Management Report FY '88 (4th Quarter); PUAG, Chemical Analysis FY '89.

(1) Data obtained from 1979 Water Facilities Master Plan, as no updated records were available.

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		GH - Series									
45	BA	GH - 501	N/A	414.45	-50	N/A	N/A	190	35	N/A	92.0
		H - Series									
43	BA	H - 1	N/A	439.51	N/A	N/A	N/A	180	28	YES	130.0
		M - Series									
36	BA	M - 1	1965	395.27	-54	398.1	401	150	N/A	YES	168.0
36	BA	M - 2	1968	402.70	-48.3	396.0	404	N/A	108	NONE	102.0
8	PB	M - 3	1967	422.48	-50	418.3	423	185	36	NONE	36.0
8	PB	M - 4	1967	442.37	-51	418.2	423	160	24	N/A	22.0
45	BA	M - 5	1969	273.49	-132	267.2	295	138	98	NONE	66.0
45	BA	M - 6	1969	326.29	-80	320.6	361	137	N/A	YES	N/A
45	BA	M - 7	1969	289.41	-51	284.2	289	205	82	NONE	42.0
8	PB	M - 8	1970	486.47	-52	N/A	N/A	N/A	26	NONE	26.0
36	BA	M - 9	1970	448.62	-40	N/A	N/A	168	25	N/A	186.0
		M - 10	ABANDONED	---	---	---	---	---	---	---	---
		M - 11	ABANDONED	---	---	---	---	---	---	---	---
45	BA	M - 12	1973	272.05	-109	N/A	N/A	N/A	28	NONE	96.0
45	BA	M - 14	1974	N/A	N/A	269.5	281	200	N/A	YES	50.0
45	BA	M - 15	N/A	295.77	-53.76	N/A	N/A	200	70	YES	74.0
9	PB	M - 16B	N/A	N/A	N/A	N/A	N/A	143	100	NONE	42.0
21	PB	M - 17A	N/A	N/A	N/A	N/A	N/A	125	140	YES	80.0
21	PB	M - 17B	N/A	N/A	N/A	N/A	N/A	200	100	N/A	60.0
		MJ - Series									
		MJ - 1	ABANDONED	---	---	---	---	---	---	---	38.0
		MJ - 5	ABANDONED	---	---	---	---	---	---	---	---
		Y - Series									
28	PB	Y - 1	1966	415.16	-46.2	408.0	427	120	104	YES	22.0
28	PB	Y - 2	1967	414.72	-50	N/A	N/A	145	200	NONE	22.0
25	PB	Y - 3	1973	415.82	-53	412.0	418	155	100	YES	N/A
47	BA	Y - 4	1974	397.85	-52.15	394.5	413	N/A	44	YES	26.0
28	PB	Y - 5	N/A	433.35	-50	N/A	N/A	160	108	YES	52.0
		Y - 6	N/A	428.43	-50	N/A	N/A	N/A	100	N/A	22.0
25	PB	Y - 7	N/A	412.48	-63.75	N/A	N/A	96	96	YES	22.0
25	PB	Y - 9	N/A	N/A	N/A	N/A	N/A	400	118	NONE	20.0
		YL - Series									
		YL - 4	ABANDONED	---	---	---	---	---	---	---	---
		YL - 5	ABANDONED	---	---	---	---	---	---	---	---

SOURCE : GEPA, Summary of Well Inspections (1st & 2nd Part of FY '89), Groundwater Management Report FY '88 (4th Quarter); PUAG, Chemical Analysis FY '89.

(1) Data obtained from 1979 Water Facilities Master Plan, as no updated records were available.

APPENDIX D

SUMMARY OF PUAG WELL'S
PHYSICAL AND OPERATING CHARACTERISTICS

GWM Zone	GW Type	Well Number	Date Drilled (1)	Approx. Ground El. (ft)	Approx. Bottom El. (ft)	Static Water Level (ft) (1)	Pumping Water Level (ft) (1)	Capacity (gpm)	Disch. Press. (psi)	Chlorination	Chlorides (mg/l)
		Physical Characteristics						Operating Characteristics			
		Private Wells									
		COR - 1	N/A	133	-67	N/A	N/A	125	60	NONE	N/A
		RCA - 1	N/A	362.25	-0.34	N/A	N/A	N/A	38	YES	15.4
		FM - 1	N/A	140.53	-5.87	N/A	N/A	65	42	YES	130.8
46	BA	BCC	N/A	204.02	-5.08	N/A	N/A	140	60	NONE	114.9
		IE - 1	N/A	N/A	N/A	N/A	N/A	75	75	NONE	329.0
		HRP - 1	N/A	328	-83	N/A	N/A	610	10	NONE	221.4
		HRP - 2	N/A	340	-62	N/A	N/A	245	44	NONE	221.0
16	PB	HGC - 3 (3)	N/A	468.4	-107	19.9	19.7	600	N/A	NONE	12.0
		Air Force Wells									
45	BA	MW - 1	N/A	346.61	-41.01	N/A	N/A	335	10	NONE	N/A
45	BA	MW - 2	N/A	350.6	-27.61	N/A	N/A	245	5	NONE	N/A
47	BA	MW - 3	N/A	405.4	N/A	N/A	N/A	250	6	NONE	N/A
47	BA	MW - 5	N/A	418.18	N/A	N/A	N/A	185	55	NONE	N/A
47	BA	MW - 6	N/A	394.87	N/A	N/A	N/A	445	79	NONE	N/A
47	BA	MW - 7	N/A	367.84	N/A	N/A	N/A	290	92	NONE	N/A
47	BA	MW - 8	N/A	356	N/A	N/A	N/A	475	117	NONE	N/A
47	BA	MW - 9	N/A	468	N/A	N/A	N/A	280	112	NONE	N/A
		BPM - 1	N/A	495.97	-14.78	N/A	N/A	150	28	NONE	N/A
		TMT - 1	N/A	654	N/A	N/A	N/A	950	145	YES	N/A
		Navy Wells									
42	BA	NCS - A	N/A	428.9	-34.1	N/A	N/A	200	N/A	YES	163.0
42	BA	NCS - B	N/A	412.87	-30.13	N/A	N/A	N/A	N/A	YES	N/A
44	BA	NCS - 2	N/A	363.68	-46.32	N/A	N/A	195	82	YES	107.2

SOURCE : GEPA, Summary of Well Inspections (1st & 2nd Part of FY '89), Groundwater Management Report FY '88 (4th Quarter); PUAG, Chemical Analysis FY '89.

(1) Data obtained from 1979 Water Facilities Master Plan, as no updated records were available.

(3) Data obtained from Hatsuho Golf Course.

E

APPENDIX E

LIST OF WASTEWATER RECLAMATION RESEARCH AND DEMONSTRATION PROJECTS IN CALIFORNIA

1. **Evaluation of Long-Term Effects of Use of Reclaimed Water for Food Crop Irrigation**

   Project objectives: Evaluation of potential benefits and problems associated with the use of reclaimed water for food crop irrigation.

   Cost: $0.6 million (est.) Duration: 5 years (est.)

   Sponsoring agencies: State Water Resources Control Board
   Department of Water Resources
   Department of Health
   Environmental Protection Agency

2. **Health Aspects of Groundwater Recharge in the Montebello Forebay**

   Project objectives: Monitoring and evaluation of existing groundwater recharge by spreading with reclaimed water with emphasis on reclaimed water pollutants, such as stable organics, virus, and bacteria.

   Cost: $1 million (est.) Duration: 3 years (est.)

   Sponsoring agencies: State Water Resources Control Board
   Department of Health
   Department of Water Resources
   Environmental Protection Agency
   Los Angeles County Sanitation District
   Los Angeles County Flood Control District
   Central and West Basin Water Replenishment District

3. **Groundwater Recharge in Avalon, Santa Catalina**

   Project objectives: Monitoring predischarge and postdischarge conditions in a groundwater basin previously unaffected by reclaimed water, study of behavior of pollutants in the soils and sediments in the underground environment.

   Cost: $1 million (est.) Duration: 3 years

   Sponsoring agencies: State Water Resources Control Board
   Department of Health
   Department of Water Resources
   Environmental Protection Agency
   Southern California Edison

4. Organic Identification and Virus Monitoring for Water Factory 21

Project objectives: Identification and monitoring of organics and viruses during and after advanced wastewater treatment, and compare effectiveness of various processes.

Cost: $1 million (est.) Duration: 3 years

Sponsoring agencies: State of Water Resources Control Board
Department of Health
Department of Water Resources
Department of the Interior, Office of Water Research and Technology
Orange County Water District

5. Assessment of Wastewater Reuse Potential by Industries

Project objectives: To obtain more information on the ability and willingness of major industries in coastal metropolitan areas to use reclaimed waters.

Cost: $0.5 million (est.) Duration: 1 year

Sponsoring agencies: State Water Resources Control Board
Department of Health
Water and Sanitation Districts in coastal metropolitan areas
Department of Water Resources
Environmental Protection Agency
Los Angeles Chamber of Commerce and/or large industrial users.

6. Economic Comparison for Wastewater Reclamation in Total Water Management System

Project objectives: Develop an economic comparison model to assess the value of reclaimed water in a total water management system.

Cost: $0.1 million (est.) Duration: 1 year (est.)

Sponsoring agencies: State Water Resources Control Board
Department of Water Resources
U. S. Bureau of Reclamation
Metropolitan Water District

7. Evaluation of Agricultural Irrigation Projects Using Reclaimed Water

Project objectives: Evaluation of potential benefits and problems associated with the use of reclaimed water for crop irrigation.

Sponsoring agencies: State Water Resources Control Board

8. Report of the Scientific Advisory Panel on Groundwater; Recharge with Reclaimed Wastewater

Project objectives: To define the health significance of using reclaimed water for groundwater recharge to augment domestic water supply, evaluate the benefits and risks associated with groundwater recharge with reclaimed water, and provide detailed background information needed for the establishment of statewide criteria for groundwater recharge with reclaimed water.

Sponsoring agencies: State Water Resources Control Board
Department of Water Resources
Department of Health

9. Interim Guidelines for Economic and Financial Analyses of Water Reclamation Projects

Project objectives: To present procedures, forms and examples for performing economic and financial analyses of proposed water reclamation projects being studied under the State and Federal Clean Water Construction Grant Program for the purpose of (1) elaborating on EPA regulations and make them specific to reclamation projects and (2) to assist engineers and financial advisors in performing appropriate economic and financial evaluation.

Sponsoring agencies: State Water Resources Control Board

10. San Diego Area Water Reuse Study

Project objectives: To provide policy and direction for water reclamation planning in the San Diego region through the identification of potential markets for reclaimed water and the conceptual development of projects to best serve those markets.

Sponsoring agencies: Environmental Protection Agency
State Water Resources Control Board
County of San Diego
City of San Diego

WASTEWATER RECLAMATION STANDARDS AND REGULATIONS

The following table and category definitions are taken from the November 1991 Newsletter of the Hawaii Chapter, Water Pollution Control Federation. They are intended to present an example of the range of standards and regulations now being used throughout the U.S.

Current regulations are generally divided into the following water reuse categories:

- **Unrestricted urban reuse** - irrigation of areas in which public access is not restricted, such as parks, playgrounds, school yards, and residences; toilet flushing, air conditioning, fire protection, construction, ornamental fountains, and aesthetic impoundments.

- **Restricted urban reuse** - irrigation of areas in which public access can be controlled, such as golf courses, cemeteries, and highway medians.

- **Unrestricted recreational reuse** - an impoundment of water in which no limitations are imposed on body-contact water recreation activities.

- **Restricted recreational reuse** - an impoundment of reclaimed water in which recreation is limited to fishing, boating, and other non-contact recreational activities.

- **Agricultural reuse - food crops** - irrigation of food crops which are intended for human consumption, often further classified as to whether the food crop is to be processed or consumed raw.

- **Agricultural reuse - non food crops** - irrigation of fodder, fiber and seed crops, pasture land, commercial nurseries, and sod farms.

- **Environmental reuse** - reclaimed water used to create artificial wetlands, enhance natural wetlands, and to sustain stream flows.

- **Industrial reuse** - reclaimed water used in industrial facilities primarily for power plant cooling system make-up water, boiler-feed water, process water, and general washdown.

The following list, released by the Hawaii Chapters Water Pollution Control Federation, is an overview of current water reuse regulations and guidelines illustrating the most and least stringent quality requirements (not necessarily from only one state) for the above intended uses:

Water Quality Requirements Based On Intended Use

Reuse application	Water Quality Requirement, where specified		
	Parameter	Most stringent	Least stringent
Unrestricted urban use	BOD_5, mg/l TSS, mg/l NTU, units Total coliform (MPN), cfu/100ml	5 5 2 non-detectable	30 30 5 200
Restricted urban use	BOD_5, mg/l TSS, mg/l NTU, units Total coliform (MPN), cfu/100ml	5 5 5 non-detectable	30 90 none 1,000
Unrestricted recreational use	BOD_5, mg/l TSS, mg/l NTU, units Total coliform (MPN), cfu/100ml	none none 1 2.2	none none 2 200
Restricted recreational use	BOD_5, mg/l TSS, mg/l NTU, units Total coliform (MPN), cfu/100ml	10 none 3 2.2	none none 5 1,000
Agricultural reuse - food crops	BOD_5, mg/l TSS, mg/l NTU, units Total coliform (MPN), cfu/100ml	20 5 1 non-detectable	30 25 3 1,000
Agricultural reuse - non food crops	BOD_5, mg/l TSS, mg/l NTU, units Total coliform (MPN), cfu/100ml	20 10 none 2.2	75 90 none 2,000
Environmental reuse - wetlands	BOD_5, mg/l TSS, mg/l NTU, units Total coliform (MPN), cfu/100ml Ph, units Dissolved oxygen, mg/l	5 5 none 1,000 6.5 - 8.6 6	none none none none none none
Industrial reuse	BOD_5, mg/l TSS, mg/l NTU, units Total coliform (MPN), cfu/100ml	20 5 none 3	30 none none none

BOD_5 - five day biochemical oxygen demand
NTU - nephelometric turbidity unit
cfu - colony forming unit
TSS - total suspended solids
MPN - most probable number

F

APPENDIX F

GUAM ENVIRONMENTAL PROTECTION AGENC
AHENSIAN PRUTEKSION LINA'LA GUAHAN
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GUAM WATER QUALITY STANDARDS

Adopted July 18, 1987

A. T. LIZAMA
Board Chairman

ATTESTED TO: DONNA M. CRUZ
Board Secretary

APPROVED:

E. Barrett-Anderson
ELIZABETH BARRETT-ANDERSON
Attorney General

Date: 9/30/87

"ALL LIVING THINGS OF THE EARTH ARE ONE"

STATEMENT OF POLICY

It shall be the public policy of Guam to:

1. conserve, protect, maintain, and improve the quality of the waters for drinking water supply and food processing, for the growth and propagation of aquatic life, for marine research and for the conservation of coral reefs and wilderness areas, and for domestic, agricultural, commercial, industrial, recreational and other legitimate uses;

2. provide that no pollutant discharge into any water be allowed, unless (a) the discharge first receives processing which will assure the pollutant removal or provide the control technology necessary to protect the designated beneficial uses of the waters, and (b) the discharge meets the effluent limitations established for that discharge; and

3. provide for the prevention, abatement and control of new and existing water pollution.

Further, under the terms of the U. S. Water Pollution Control Act 92-500 as amended by all Public Laws through 1986:

1. it is the national goal that the discharge of pollutants into navigable waters be eliminated by 1990;

2. it is the national goal that wherever attainable, an interm goal of water quality, which provides for the protection and propagation of fish, shell-fish and wildlife, and provides for recreation in and on the water, be achieved by July 1, 1988; and

3. it is the national policy that the discharge of pollutants in toxic amounts be prohibited.

To assist in obtaining this goal all discharges will be controlled (permitted) either through the National Pollutant Discharge Elimination System (NPDES) or through the Guam Environmental Protection Agency's local permit program.

Therefore, pursuant to the authority contained in the Guam Water Pollution Control Act (Sections 47104 and 47108 of Chapter 47, Title 10 of the Guam Code Annotated), which authorized the formulation of standards of water purity and classification of waters according to their most beneficial uses, the Guam Environmental Protection Agency hereby adopts the following standards of water quality for Guam. All references to classify water quality in the following Water Quality Standards shall mean quality not less than those meeting the Guam Primary Safe Drinking Water Standards (GPSDWS), Chapter 53, Title 10 of the Guam Code Annotated.

Waters whose existing quality was better than the established standards as of April 1968, will be maintained at the same high quality existing at that time.

Waters whose existing quality is less than the established standards for their use due to the presence of substances, conditions, or combinations thereof attributable to domestic, commercial and industrial discharges or agricultural, construction and other land-use practices, shall be improved to comply with the established standards. However, in such cases where the natural conditions are of lower quality than criteria assigned, the natural conditions shall constitute the water quality criteria. Water quality criteria in boundary areas shall be established so that the most stringent standard applies. When more than one set of Water Quality criteria apply, including overlap of category designation or at a boundary water between two categories, then the more stringent standard shall prevail.

Waters will not be lowered in quality unless and until it has been affirmatively demonstrated to the Administrator of the Guam Environmental Protection Agency with an Environmental Impact Statement that such a change is justifiable as a result of necessary social, environmental, or economic development, and that such development will not interfere with or become injurious to any uses made of, or potentially possible in, such waters. Any industrial, public or private project or development will require, as part of the initial project design, provision for the pollutant removal or control technology necessary to protect the designated use of receiving waters or maintain the existing high quality of the receiving waters.

The purpose of these Water Quality Standards is to prevent degradation of water resources resulting from pollution sources. It is not the intent of these standards to restrict activities which may cause pollution but rather to regulate such activities. An Environmental Protection Plan (EPP) will be prepared by all developers, contractors, and others prior to construction initiation to ensure that water resources will not be degraded. This EPP will be submitted to the Guam Environmental Protection Agency for approval.

SECTION I

CATEGORIES OF WATERS

The following categories of waters relate to the different liquid components of the hydrologic cycle. All categories of water, Marine, Surface and Groundwater are referenced on the Water Classification Map. Scaled down copies of these maps are included in these standards enabling readers to understand their relative position, application and use.

A. MARINE WATER

This major type of water includes all coastal waters off-shore from the mean high tide level, including estuarine waters, lagoons and bays, as well as brackish and other inland waters that are subject to the ebb and flow of the tides. Refer to Water Classification Map.

Category M-1 EXCELLENT

The uses to be protected in this category of waters are conservation of wilderness areas including protection of natural aquatic life, marine scientific research, aesthetic enjoyment and recreation activities which are compatible with the intended use. This category of water shall remain free from pollution attributed to domestic, commercial and industrial discharges, shipping and intensive boating, or maricultural, construction and other practices which may impair their intended use. Furthermore, there shall be no zones of mixing within this category water.

Category M-2 GOOD

The uses attributed to this category of waters are intended to protect the propagation and survival of a balanced and indigenous population of marine organisms particularly shellfish and coral reefs. Other important and intended uses include mariculture activities, aesthetic enjoyment and compatible recreation inclusive of whole body contact and related activities.

Category M-3 FAIR

General use, commercial and industrial uses are intended for this category of marine water. Specific intended uses include the following: shipping and navigation, marinas, protection of aquatic life, industrial cooling, water supply, aesthetic enjoyment and compatible recreation of a limited body contact nature.

B. GROUNDWATER

This major type of water encompasses all subsurface waters and includes basal and parabasal water, perched water, all water below the groundwater table, water percolating through the unsaturated zone (Vadose Water), all saline waters below and along the perimeter of the basal fresh-water body (freshwater lens), and water on the surface that has been collected with the specific intent of rechanging or disposing of that water to the subsurface by means of injection, infiltration, percolation or other means. Refer to Water Classification Map. The Northern Guam Water Aquifer which is the Principal Source Aquifer and any other groundwater resource as they are identified shall continue to receive protection under Guam's groundwater regulations.

Category G-1 RESOURCE ZONE

The primary use of groundwater within this zone is for drinking (human consumption) and this use must be protected. Virtually all water of the saturated zone of Guam is included. Specifically it includes all water occurring in the saturated zone below the groundwater table, all vadose water occurring in an unsaturated zone interval extending 100 feet (30.5 m) above any water table, or to within 20 ft. of the ground surface of all fresh groundwater bodies, and all water of the basal and parabasal freshwater bodies, and all water of and below the freshwater/salt-water transition zone beneath the basal water body (Examples A-1, A-2, A-3, MJ1, MJ5).

Because any water discharges within this zone will (by definition) be tributary to groundwater bodies which are actual or potential sources of fresh, potable water supply, no pollutant discharges to the groundwater wihin this zone will be allowed.

Category G-2 RECHARGE ZONE

Water within this zone is tributary to, replenishes and recharges the Category G-1 groundwater and must be of drinking water quality before it enters the Resource Zone. All water discharges within the Recharge Zone must receive treatment to the degree necessary to protect the underlying Category G-1 groundwater from any contamination.

Category G-2 includes all waters which are collected and recharged or disposed of within a zone which is bounded above by G-3 and below by G-1. Vertically, this zone extends from 20 ft (6 m) below the surface to the upper surface of the Category G-1 waters. Methods which may result in discharges to groundwater within this zone consist primarily of dry/injection wells.

It is recognized that water within this zone will percolate through soil/rock media before reaching the Resource Zone. In this way it may undergo some degree of natural treatment consisting of filtration and subsequent purification. However, the degree of treatment is not easily demonstrated. Thus, due to the need to protect G-1 waters and considering the difficulty in tracing pollutants reaching the G-1 zone to a particular source, discharge limitations have been established to regulate discharges to the G-2 zone. All discharges must meet the discharge limitations established in Table III of Section III.

All discharges within this zone which are not required to have construction and/or discharge operating permits under existing regulations may be required by the Agency to obtain such permits under these regulations. It is not the intent of these standards to require a discharge to have more than one permit.

Category G-3 BUFFER ZONE

Category G-3 includes all waters which are collected and disposed of or recharged at or near the existing ground surface. Vertically, the zone for this category extends from the surface to 20 ft (6 m) below the surface. Disposal methods which may result in discharges to groundwater within this zone include, but are not limited to, ponding basins, rapid infiltration, slow rate land treatment, surface or spray irrigation and all subsurface discharges (seepage, leaching).

For reasons similar to those discussed for Category G-2, discharge limitations for G-3 are also established in Table III Section III. Discharges equal to or less than 10,000 gallons per day (gpd) within the G-3 zone are designated by G-3a. Water quality criteria for all discharges within zone G-3 which are greater than 10,000 gpd are designated G-3b. This differentiation in criteria addresses the fact that minor discharges typified by small scattered individual dwelling units probably have less adverse impact on underlying groundwater than major point source discharges and thus are allowed less restrictive water quality limits (i.e. equivalent to primary treatment).

All discharges within this zone which are not required to have construction and/or discharge permits under existing regulations may be required by the Agency to obtain such permits under these regulations (refer to the Underground Injection Control Regulations).

C. SURFACE WATERS

This major type of water encompasses the majority of surface fresh-water and includes, (1) waters that flow continuously over land surfaces in a defined channel or bed, such as streams and rivers, (2) standing water in basins such as lakes, marshes, swamps, ponds and reservoirs, either natural or man-made and (3) all waters flowing over the land either as unconfined sheet runoff, or as runoff confined to channels with intermittent flow. Refer to Water Classification Map. Waters not included under the Surface Water Category are those waters which are collected with the specific intent of disposal by recharging them into the ground (i.e., ponding basins).

Category S-1 HIGH

Surface waters within this zone are used for drinking water resources, conservation of wilderness areas, and propagation and preservation of aquatic life and aesthetic enjoyment. It is the objective that these waters shall be kept free of substances or conditions attributable to domestic, commercial and industrial discharges, or agricultural, construction or other land-use practices that impair their uses. No pollutant discharges will be permitted into S-1 waters via discharge or as a result of land uses adjacent to S-1 waters. Mixing zones will not be allowed within the boundaries of Category S-1.

Category S-2 MEDIUM

Surface waters within this zone are used for recreational purposes including water contact recreation, for use as potable water supply after adequate treatment is provided, and for propagation and preservation of aquatic wildlife and aesthetic enjoyment.

Category S-3 LOW

Surface waters within this zone are primarily used for commercial, agricultural and industrial water supply. Aesthetic enjoyment and compatible recreation are acceptable in this zone, as well as maintenance of aquatic life. Compatible recreation may include limited body contact activities. All discharges within this zone which are not required to have construction and/or discharge permits under existing regulations may be required by the Agency to obtain such permits under these regulations.

SECTION II

WATER QUALITY CRITERIA

A. GENERAL CRITERIA APPLICABLE TO ALL TERRITORIAL WATERS

All waters shall meet generally accepted aesthetic qualifications, shall be capable of supporting desirable aquatic life, and shall be free from substances, conditions or combinations thereof attributable to domestic, commercial and industrial discharges or agricultural, construction and land-use practices or other human activities that:

1. cause visible floating materials, debris, oils, grease, scum, foam or other floating matter;

2. produce visible turbidity, settle to form deposits or otherwise adversely affect aquatic life;

3. produce objectionable color, odor, or taste, directly or by chemical or biological action;

4. are toxic or harmful to humans, animals, plants or aquatic life; and

5. induce the growth of aquatic life.

Analytical testing methods for these criteria shall be in accordance with the most recent editions of Standard Methods for the Examination of Water and Wastewater (APHA, AWWA, WPCF), Methods for Chemical Analysis of Water and Wastes (U.S. Environmental Protection Agency), and other methods acceptable to GEPA and possessing adequate procedural precision and accuracy.

Effects of high temperature, biocides, pathogenic organisms, toxic, corrosive, or other deleterious substances at levels or combinations sufficient to be toxic or harmful to human, animal, plant or aquatic life or in amounts sufficient to interfere with any beneficial use of the water, shall be evaluated as a minimum, by use of a 96-hour bioassay as described in the most recent edition of Standard Methods for the Examination of Water and Wastewater. Survival of test organisms shall not be less than that of controls which utilize appropriate water. Failure to determine presence of toxic substances by this method shall not preclude determination of excessive levels of toxic substances on the basis of other criteria or methods.

B. SPECIFIC NUMERICAL WATER QUALITY CRITERIA

1. Microbiological Requirements	Applicable to	
Concentrations of total coliform bacteria at any point shall not be increased from natural conditions at any time.	M-1	S-1
The fecal coliform bacteria count shall not exceed an arithmetic mean of 70 per 100 ml during any 30-day period nor shall any sample exceed 400 per 100 ml at any time.	M-2	S-2
The fecal coliform bacteria count shall not exceed an arithmetic mean of 200 per 100 ml during any 30-day period nor shall any sample exceed 400 per 100 ml at any time.	M-3	S-3

To determine compliance with the above microbiological requirements where a "30-day period" is specified, a minimum of four samples shall be collected at approximately equal intervals.

NOTE: Where shellfish are collected for human consumption, the microbiological standard for M-1 waters shall apply.

2. pH

The pH of fresh and estuarine waters shall be 6.5-8.5 and 7.0-9.0 for marine waters. Variations of more than 0.5 pH units from ambient shall not be allowed except due to natural causes.	M-1 M-2 M-3	S-1 S-2 S-3

3. Nutrients

Phosphorus:

Orthophosphate (PO_4-P) shall not exceed 0.025 mg/1	M-1	
Orthophosphate (PO_4-P) shall not exceed 0.05 mg/1	M-2	S-1
Orthophosphate (PO_4-P) shall not exceed 0.10 mg/1	M-3	S-2 S-3

Nitrogen:

Nitrate-nitrogen (NO_3-N) shall not exceed 0.10 mg/1	M-1	
Nitrate-nitrogen (NO_3-N) shall not exceed 0.20 mg/1	M-2	S-1
Nitrate-nitrogen (NO_3-N) shall not exceed 0.50 mg/1	M-3	S-2 S-3

Guam's groundwater has nitrate-nitrogen concentrations up to 5 mg/1. It is not the intent of these standards to require treatment in excess of the best available secondary wastewater treatment. Point source discharges will be regulated by permits specifying effluent standards and operational requirements.

Activities which may result in non-point discharges of nutrients shall be conducted in accordance with the best management practices reasonably determined by the Agency to be necessary to preclude or minimize such discharges of nutrients.

In all cases, discharges containing nutrients, primarily nitrogen and/or phosphorus shall be treated to the extent necessary to prevent the growth of aquatic species which create a public nuisance or interfere with beneficial uses as defined in Section I.

4. Dissolved Oxygen

Concentrations of dissolved oxygen shall not be decreased below 75 per cent saturation at any time, as influenced by salinity or naturally occurring temperature variations. Where natural conditions cause lower dissolved oxygen levels, controllable water quality factors shall not cause further reductions.	All waters of the Territory

Table I. Saturation D. O.

Freshwater Sat. mg/l	Freshwater 75% Sat. mg/l	Temperature °C	Marine Water Salinity ppt	Marine Water Sat. mg/l	Marine Water 75% Sat. mg/l
7.6	5.6	30	32	6.2	4.6
8.2	6.2	26	32	6.7	5.0

5. Salinity

Marine-Waters: No alterations of the marine environment shall occur that would alter the salinity of marine or estuarine waters more than + 10% of the ambient conditions, except when due to natural conditions.	All Marine and Estuarine Waters of the Territory	
Fresh-Water: The maximum allowable amount of chlorides and sulfates shall be 250 mg/l, and the total dissolved solids shall not exceed 500 mg/l or 133% of the ambient condition. The salinity of fresh-water sources shall not be increased more than 20% above ambient by discharges of saline water.		S-1 S-2 S-3

6. Total Filtrable Suspended Solids

Concentrations of suspended matter at any point shall not be increased from ambient conditions at any time, and should not exceed 5 mg/l except when due to natural conditions.	M-1	S-1
Concentrations of suspended matter at any point shall not be increased more than 10% from ambient at any time, and should not exceed 20 mg/l except when due to natural conditions.	M-2	S-2
Concentrations of suspended matter at any point shall not be increased more than 25% from ambient at any time and should not exceed 40 mg/l except when due to natural conditions.	M-3	S-3

7. Turbidity

Turbidity at any point, as measured by nephelometric turbidity units (NTU), shall not exceed 0.5 NTU over ambient conditions except when due to natural conditions.	M-1	S-1

	Turbidity values (NTU) at any point shall not exceed 1.0 NTU over ambient conditions except when due to natural conditions.	M-2 M-3	S-2 S-3
	Since debris, rapidly settling particles and true color give low readings when using Nephelometric methods in making turbidity determinations and one or more of these conditions may exist in marine and surface water, secchi disc determinations will be used when these conditions exist. Secchi disc visibility shall not decrease by more than 5 meters from ambient conditions except when due to natural conditions.		
8.	Radioactive Materials		
	Discharges of radioactive materials at any level into any waters of the territory is strictly prohibited.	All Waters of the Territory	
9.	Temperature		
	Water temperature shall not be changed more than 1.0°C (1.8°F) from ambient conditions, outside an established mixing zone.	All Waters of the Territory	
10.	Concentrations of Oil or Petroleum Products		
	Those that exceed the limits described below are unacceptable. a) Detectable as a visible film, sheen, discoloration of the surface, or by odor; b) causes tainting of fish or invertebrates, damage to the biota, or objectionable taste in drinking; or c) forms an oil deposit on the shores or bottom of the receiving body of water.	M-1 M-2 M-3	S-1 S-2 S-3

11. Pesticides

Concentrations of pesticides shall not exceed one percent (0.01) of the 24-hour LC_{50} value determined using the receiving water in question and the most sensitive species of aquatic organisms affected.

Where the concentration based on the LC_{50} data exceeds the recommended maximum concentrations, the maximum concentrations shall constitute the criteria.

For the listing of all pesticides (Organochlorides, Organophosphates, Carbamates, Herbicides, Fungicides, Defolliants, and Botanicals) please refer to the U.S. Water Quality Criteria "Blue Book."

NOTE:

The setting or publishing of maximum concentrations (limits) for specific pesticides and other toxics should in no way be construed as official approval or authorization for their use where such use is contrary to U.S. Environmental Protection Agency or other Federal or local regulations which now exist or may be enacted at some future time.

12. Toxic Substances

In order to provide maximum protection for the propagation of fish and wildlife, concentrations of toxic substances (persistent or non-persistent, cumulative or non-cumulative); (a) shall not exceed 0.05 of the 96-hour LC_{50} at any time or place, nor should the 24-hour average concentration exceed 0.01 of the 96-hour LC_{50} or, (b) shall not exceed levels calculated by multiplying the appropriate application factor by the 96-hour LC_{50} values determined by using the most sensitive species of aquatic organism affected. Whichever value (a or b) is less shall be the maximum allowable concentration, unless this value exceeds the Maximum Numerical Limit, then the numerical limit shall constitute the maximum allowable concentration.

Criteria for the 65 toxic pollutants listed by EPA under authority of Section 307 (a) (1) will be as published in summary form in 45 FR 79318 or any subsequent revision and are incorporated by reference into the Guam Water Quality Standards. A list of the 65 toxic pollutants is given in Appendix A.

In addition to the 65 listed toxics, Table II taken from the 1972 Water Quality Criteria report, U.S. EPA, known as the "Blue Book", shows the maximum allowable concentrations and application factors for additional toxic substances.

Table II. Additional Toxic Pollutants not include in Appendix A.

* Substance	Maximum Numerical Limit Marine Water	Maximum Numerical Limit Fresh Water	Application Factors
Aluminum	0.2 mg/1	1.0 mg/1	.01
Ammonia	0.02 mg/1		.05
Barium	0.5 mg/1		.05
Boron	5.0 mg/1		.1
Bromine (free)	0.1 mg/1		-
(as Bromate)	100 mg/1		-
[1]Chlorine (free, residual)	0.01 mg/1		.1
Fluoride	1.5 mg/1	0.8 mg/1	.1
Iron	0.05 mg/1	3.0 mg/1	-
Manganese	0.02 mg/1		.02
Molybdenum	-		.05
Sulfide	0.005 mg/1		.1 (Applicable to 20-day LC_{50} data)
[2]Uranium	0.0 mg/1		.01
Vanadium	-		.05

* Total amounts in indicated chemical state or form

[1]Greater concentrations of Chlorine may be used to treat a source of drinking water in order to meet the requirements of Subsection II.B.1. of these standards.

[2]Naturally occurring Uranium has been reported in concentrations of 0.003 mg/1 (seawater and 0.00004 mg/1 (river water).

NOTE: Whenever natural concentrations of any toxic substance or element occur and exceed the limits established in these standards, this greater concentration shall constitute the limit, provided that this natural concentration was not directly affected by man-induced causes.

SECTION III

EFFLUENT LIMITATIONS

A. GENERAL CRITERIA

The Agency reserves the right to amend or extend the following criteria as improved standard methods are developed or revisions consistent with the enhancement of water quality are justified:

1. All sewage shall be treated to the degree required by the Agency to achieve standards of water quality prior to being discharged to the waters of the Territory. Industrial waters and other wastes shall also be treated to the degree required by the Agency.

2. Dilution of the effluent from any wastewater source as a sole means of treatment is not acceptable as a method of treatment of wastes in order to meet the standards set forth in this Section. Rather, it shall be the obligation of any person discharging pollutants of any kind to the waters of the Territory to provide the best pollutant removal or control consistent with technological feasibility, economic reasonableness, and sound engineering judgment. In making a determination as to what degree of treatment is the best pollutant removal or control within the meaning of this paragraph, any person shall consider the following:

   a) the degree of waste reduction that can be achieved by process change, improved house-keeping and recovery of individual waste components for reuse; and

   b) whether individual process wastewater streams should be segregated or combined.

3. Measurement of pollutant concentrations to determine compliance with the effluent limitations shall be made by the discharger at the point immediately following the final treatment process and before mixing with other waters. Points of measurement shall be designated by the Agency in an individual permit, after consideration of the elements contained in this section. If necessary, the concentrations so measured shall be recomputed to exclude the effect of any dilution that is improper under this standard.

4. Every person discharging effluent to the waters of the Territory shall submit operating reports to the Agency at a frequency to be determined by the Agency. Such reports shall contain information regarding the volume of effluent discharged, and the concentrations of those physical, chemical and bacteriological parameters which shall be specified by the Agency; and any additional information the Agency may reasonable require.

5. In addition to other requirements no effluent shall, alone, or in combination with other sources, cause a violation of any applicable Water Quality Standard. If the Agency finds that a discharge which complies with treatment requirements under the Authority of Section III-A of these standards would cause or is causing a violation of Water Quality Standards, the Administrator shall take appropriate action under Section 47109 of the Water Pollution Control Act to require the discharge to meet whatever effluent limits are necessary to ensure compliance with the Water Quality Standards. When such a violation is caused by the cumulative effect of more than one source, several sources may be joined in a schedule of compliance. Measures necessary for effluent reductions will be determined on the basis of technical feasibility, economic reasonableness, and fairness to all dischargers.

6. And finally no effluent shall alone or in combination with other sources be discharged into near shore waters.

B. MIXING ZONES IN RECEIVING WATERS

Whenever a Water Quality Standard is more restrictive than the corresponding effluent standard, then an opportunity may be allowed by the Agency for the mixture of an effluent with its receiving water provided that the zone in which mixing occurs will not adversely affect the designated uses of the receiving waters. If mixing zones are used, Water Quality Standards for a receiving water must be met at every point outside of the boundaries of the designated mixing zone. The following criteria apply to all mixing zones:

1. Whenever mixing zones are allowed, zones of passage, i.e., continuous water routes of the volume, area, and quality necessary to allow passage of free-swimming and drifting organisms with no significant effects produced on their populations, shall be provided.

2. Where two or more mixing zones are in close proximity, they shall be so defined that a continuous zone of passage for aquatic life is available.

3. Biologically important areas, including spawning and nursery areas, shall be protected.

4. No criteria shall be set aside in the mixing zone which shall cause conditions in the mixing zone to become lethal to aquatic life and wildlife which may enter the zone or become injurious to human health in the event of a temporary exposure.

5. The area or volume of an individual mixing zone shall be limited to an area or volume that will minimize impacts on uses.

6. The discharge shall not violate the basic standards applicable to all waters (Section II A and Section III E) nor shall it unreasonably interfere with any actual or probable use of the water within the mixing zone.

7. For those water quality criteria eligible for a mixing zone, alternate limits will be established if the limits in II B are to be revised in the zone of mixing.

C. BOUNDARIES OF NON-THERMAL MIXING ZONES

Non-thermal discharges shall be permitted by the National Pollutant Discharge Elimination System (NPDES) permit process or through the Guam Environmental Protection Agency's local permit program only after careful analysis of the nature of the effluent and a thorough study to assess the consequences of the effluent upon the environment. Mixing zones for non-thermal discharges shall be based on the following models, taking into consideration the criteria in Section III B above.

1. Mixing Zones for Non-Thermal Discharges into Surface Waters

For non-thermal discharges into streams and rivers the mixing zone will be limited to no more than 1/4 of the cross sectional area and/or volume of flow of the stream, leaving at least 3/4 free as a Zone of Passage. The mixing zone shall not extend more than 5 stream widths downstream from the point of discharge. Mixing zones will not be allowed in standing bodies of water.

2. Mixing Zones for Non-Thermal Discharges into Coastal Waters.

For non-thermal discharges to coastal waters the mixing zone shall be equal in depth to the depth of the water over the diffuser, in width to twice the depth of the water plus the width of the diffuser, and in length to twice the depth of the water plus the length of the diffuser, with the diffuser geographically centered within the mixing zone, but in no case shall the discharge be permitted into near shore waters.

All discharges to marine waters will comply wtih the Ocean Discharge Criteria promulgated under Section 403 (c) of the federal Clean Water Act.

D. MIXING ZONES FOR THERMAL DISCHARGES

Thermal discharges pertain to effluent water with a temperature component either above or below ambient conditions of the receiving body of water. All thermal discharges, existing or proposed, into receiving bodies of water shall be subject to criteria established in Section 316 (a) of the Federal Water Pollution Control Act (FWPCA), Public Law 95-217. Thermal discharges shall be permitted by the National Pollutant Discharge Elimination System (NPDES) permit process or through the Guam Environmental Protection Agency's local permit program only after careful analysis of the nature of the effluent and a thorough study to assess the consequences of the effluent upon the environment.

1. All Above-Ambient Discharges:

   a) Shall conform to a zone of mixing defined for that particular discharge on a case-by-case basis. This zone of mixing shall be defined by the following references or other references depicting appropriate thermal mixing zone models.

      - Water Quality Criteria, March 1973. EPA.
      - Quality Criteria for Water, July 1976. EPA.
      - Biological Methods for the Assessment of Water Quality. American Society of Testing and Materials, July 1976.

      And take into consideration the following criteria:

      - Time of exposure
      - Concentration of effluent
      - Depth of discharge
      - Type of environment
      - Volume of discharge
      - Mass emission rate of critical materials
      - Aesthetics and the assessment of damage to biota on the population basis

      Although final authority in defining a zone of mixing rests with the GEPA, it is intended that cooperation between the discharger and the Agency will result in the most appropriate zone.

b) Shall not increase the temperature of the receiving body of water to cause substantial damage or harm to the flora and fauna or interfere with the beneficial uses assigned therein.

c) Shall comply with all other water quality criteria as defined in these standards, unless specific criteria are established in the discharge permit.

d) These zones of mixing shall be monitored by the discharger on a regular schedule established by the NPDES Permit and/or GEPA Discharge Permit, to ensure compliance with established criteria.

e) If the Agency, pursuant to notice and opportunity for public hearings, finds evidence that a discharge has caused substantial damage, it may require conversion of such discharge to an approved alternative method. In making such a determination, the Agency may consider:

1. The nature and extent of damage to the environment.

2. Projected lifetime of discharge.

3. Adverse economic and environmental impacts, marine and terrestrial, resulting from such conversion.

4. All available data, reports, surveys and projects related to the discharge.

5. Such other factors which may prove to be appropriate.

2. Above-Ambient Discharges in Existence Prior to Approval of These Standards.

a) Shall be given special attention when defining a zone of mixing. All criteria established for part D-1 above, shall apply with special emphasis on specific criteria listed in part D-1a.

b) It is the intent of this section to establish a reasonable zone of mixing for discharges not in compliance with existing laws, codes and practices.

c) Description of mixing zones for Tanguisson and Piti/Cabras Power Plants.

1. Tanguisson Power Plant Zone of Mixing

The zone of mixing for the Tanguisson Power Plant is defined as a rectangle of approximately 10,000 m^2 with the following reference points.

Northern boundary - North side of intake channel

South boundary - 1969 ft (600 m) south of intake channel

Eastern boundary - Shoreline at mean high tide

Western boundary - 591 ft (180 m) off-shore to a depth beyond the reef margin of about one meter which is the top of the zone of passage.

2. Piti/Cabras Zone of Mixing

The zone of mixing for the Piti/Cabras Power Plants combined is the Piti Channel, recently dredged to a depth of 10 ft., from the power plants to a distance 300 ft. (100 m) back from where the channel joins the harbor proper and from there to a depth of about one meter to a line from the GORCO Pier and the Navy Fuel Pier on Dry Dock Island.

3. Below-Ambient Discharges.

All below-ambient discharges shall follow the same guidelines set down for thermal discharges and be evaluated on a case-by-case basis.

E. PROHIBITED DISCHARGES

1. No person shall cause or permit:

a. the discharge of any wastes or wastewaters regardless of volume, unless authorized by the Administrator under Section 47106 of the Water Pollution Control Act or unless subject to control or modification required by a schedule of compliance established by the GEPA Board of Directors;

2b. the discharge of any pollutant in toxic amounts, including substances which may accumulate to toxic amounts during the expected life of organisms in the receiving water, which are lethal to, or which produce deleterious genetic, physiological, or behavorial effects in the organisms;

3c. the discharge of any radiological, chemical, biological warfare agents, or radioactive wastes and contaminated radioactive materials from research and medical facilities.

4d. any discharge which would substantially impair anchorage and navigation, including any discharge which the Secretary of the Army, acting through the Corps of Engineers, finds would result in this damage;

5e. any discharge to which the Administrator of the United States Environmental Protection Agency has objected in writing pursuant to any right to object provided by the Federal Water Pollution Control Act, as amended;

6f. any discharge which is in conflict with an approved Territorial plan;

7g. the discharge of sewage from vessels while moored, berthed or docked, or underway in waters of the Territory except through a properly functioning Coast Guard approved type II Marine Sanitation Device; and

8h. any pollutant discharge into M-1, S-1, or G-1 waters as defined in Section I of these Standards.

i. any discharge of visible floating materials including scum and foam.

2. All vessels exceeding 400 gross tons which are berthed or docked in the waters of the Territory, without fully functional U.S. Coast Guard approved oil pollution prevention devices (for longer than 72 hours detention) must be completely encircled with flotation booms to contain any discharged oil. The Administrator may require any vessel, regardless of gross tonnage, operating ability, oil pollution prevention devices, duration of moorage or dockage time, to be completely encircled with floating booms if in his opinion such measures are necessary to control potential oil discharges into Territorial waters including, but not limited to, instances where excessive oil is present on the vessel's deck or in the vessel's bilges; when major machinery repairs are undertaken; or when a vessel cannot close its scuppers effectively during bunkering operations.

F. LAND DISPOSAL OF TREATED WASTEWATERS

1. Approval of land disposal of treated liquid waste water requires that:

a) wastewaters shall be restricted to the premises of the disposal site.

b) provision shall be made by the discharger for monitoring the quality of the effluent with the exception of single family dwelling units unless there are more than five (5) units connected to a single system, or the Agency requires it after identifying a potential hazard.

c) all data and reports resulting from the groundwater monitoring program shall be submitted to the Agency.

d) land disposal shall not create a public health hazard, a nuisance condition or an air pollution problem;

e) these standards cannot be applied to water/wastewater to be reused to produce products which may end up in the human food chain, such as crops, animal feed or animal products. The Agency will consider such reuse on a case-by-case basis using available guidelines.

2. The evaluation for a permit for land treatment and/or disposal of wastewater(s) should include, but not necessarily be limited to, consideration of the following item:

a) The type of wastewater(s) proposed for disposal. (The wastewater(s) should be biologically degradable but other wastewater(s) will be considered provided it can be shown that disposal of the wastewater(s) will not adversely affect the designated use of the waters underlying or adjacent to the disposal site.

b) The nature of the earth material(s) underlying the disposal site. (The applicant must provide positive assurance that the earth material (s) underlying the proposed disposal site will not allow movement of pollutants into underlying groundwaters.)

c) The vegetative cover of the disposal site. The selection of a vegetative cover should reflect the disposal season(s), the duration and frequency of disposal and the response of the vegetative cover to the wastewater. If the wastewater proves to be deleterious to vegetative cover, a higher degree of treatment or another means of disposal will be required.

3. Improperly and/or inadequately treated sewage shall not be allowed to accumulate on the ground surface in such a manner that it may create a health hazard and/or a nuisance condition.

4. It shall be a violation of these standards to store, dispose of, or allow to accumulate any deleterious material adjacent to or in the immediate vicinity of any streams, rivers, or marine waters in a manner that such material will directly or indirectly enter such waters. Such material shall include, but not be limited to sewage sludge, trash, rubbish, garbage, oil, gasoline, chemicals, sawdust, accumulations of manure, and stockpiles of soil.

5. In case of accidental spills of deleterious materials, responsible persons in charge shall immediately notify the Administrator of any such spills and make every reasonable effort to contain spilled material in such a manner that it will not pollute waters of the Territory.

6. Wastewater discharged to disposal wells for underground disposal shall receive, prior to discharge, treatment necessary to protect potable water resources and any adjacent marine waters or fresh surface waters. See Table III.

G. EFFLUENT DISCHARGE LIMITATIONS FOR GROUNDWATER CATEGORIES G-2 and G-3

Any water percolating to the groundwater table is in a state of transition from being a discharge to becoming part of a useable body of water. Because of the difficulty involved in tracing the source and eliminating pollutants after they have reached the groundwater table, limitations for discharges to G-2 and G-3 waters are established in Table III. This Table provides criteria for some common water quality parameters. The Agency will set limits for other parameters as necessary on case-by-case basis.

The Agency will allow the application of G-3a discharge limitations to flows greater than 10,000 gallons per day if it can be shown by an engineering feasibility study that there will be no significant adverse effect on the waters of the Territory.

The Agency also reserves the right to set more stringent standards than those shown in Table III if there is reason to believe that significant environmental damage will result from any discharge. Effluent limitations have not been set for G-1 waters because the Agency does not anticipate such discharges. However, should such discharges be contemplated into G-1 waters, they must be of drinking water quality and meet drinking water standards.

TABLE III

Limitations for Discharges to Categories G-2 and G-3

Groundwater Category	Fecal Coliform	COD (mg/1)	pH	Chlorides (mg/1)	Ortho-phosphate (PO_4-P) (mg/1)	Nitrate-Nitrogen (NO_3-N) (mg/1)	Oil and Grease (mg/1)
G-2	200/100 m/1	20	6-10	250	10	10	5
G-3a (10,000 gpd)	-(2)	300	6-10	500(1)	25	30(3)	50
G-3b (10,000 gpd)	400(4)/100 ml	50	6-10	500(1)	25	50(3)	50

(1)in the outside of the Groundwater Protection Zone this limit is increased to 2000 mg/1

(2)concentrations to be established on a case-by-case basis by the Agency

(3)for animal feedlot operations higher discharge limitations may be permitted on a case-by-case basis

(4)daily average is based on a minimum of 15 samples per month

SECTION IV

DEFINITIONS

The following definitions are used for the purpose of clarification where such terms, phrases and words are used or implied in the text of these Water Quality Standards.

ADMINISTRATOR: Primary responsible person of the Guam Environmental Protection Agency

ADVERSELY AFFECT: Damage to the waters of the Territory of Guam that result in any of the following:

1. Substantial increase in abundance or distribution of any species or representative of the highest community development achievable in receiving waters of comparable quality.
2. A substantial decrease of formerly indigenous species.
3. Change(s) in community structure to resemble a simpler successional stage than is natural for the locality and season in question.
4. Unrealistic appearance, odor or taste of the waters.
5. Elimination of an established or potential economic or recreational use of the waters.
6. Reduction of the successful completion of life cycles of indigenous species, including those of migratory species.
7. Substantial reduction of community heterogeneity or trophic structure.

AGENCY: Guam Environmental Protection Agency (GEPA).

AMBIENT: Existing conditions in surrounding waters taking into account minor established human activity at that time and place (should approach natural conditions that would be present without the presence of human activities).

AQUIFER: A water-bearing stratum of permeable rock, sand or gravel.

BASAL GROUNDWATER: Fresh groundwater floating directly on sea water.

BEST POLLUTANT REMOVAL OR CONTROL: A feasible process which, as demonstrated by general use, demonstration process or pilot plants represents good engineering practice at a reasonable cost at the time a discharge permit is issued by the Agency.

BIOTA: The animal, plant and microbial life of a region.

BOARD: Board of Directors for the Guam Environmental Protection Agency.

BOUNDARY: A fine line as applied to groundwaters, but as applied to surface and marine waters the line may shift due to storm conditions, tides, water current changes and surface winds.

COASTAL WATERS: Includes near-shore, off-shore and estuary waters within the jurisdiction of the Territory of Guam.

COLIFORM BACTERIA:

a. TOTAL COLIFORM BACTERIA: All of the aerobic and facultative anaerobic gram-negative, non spore-forming, rod-shaped bacteria that ferment lactose broth with gas formation within 48 hours at $35^\circ C \pm 0.5^\circ$.

b. FECAL COLIFORM: That portion of the coliform group which is present in the gut or the feces of warm-blooded animals. It generally includes organisms capable of producing gas from lactose broth in a suitable culture medium within 24 hours at $44^\circ C + 0.2^\circ C$. This elevated temperature will eliminate nonfecal and noncoliform organisms and selectively culture fecal coliform bacteria.

COMMUNITY: An association of living organisms in a given area or region in which the various species are more or less interdependent upon each other.

CONSERVATION: Planned management of a natural resource to prevent exploration, destruction or neglect.

DIRECT MOVEMENT: The movement of effluent through the soil and under-lying rock strata in such a manner that pollutants which would adversely impact on the designated uses of the receiving water are not removed. They would be removed by strata that provided for a slower filtered passage.

DISCHARGE: The direct or indirect outflow of wastewater, substance or material from any domestic, commercial, industrial, agricultural or any other source into air, land and waters of the Territory of Guam.

DISCHARGER: Any person or entity that discharges any wastewater, substance or material into the waters of the Territory of Guam whether or not such substance causes pollution.

EFFLUENT: Any point source discharge directly or indirectly into waters of the territory or to any storm drain, and the runoff from land used for the disposition of solid wastes, wastewater, or sludge.

EFFLUENT LIMITATION: Any restriction or prohibition established under Territorial or Federal Law including, but not limited to parameters for toxic and non-toxic discharges, standards of performance for new sources, or ocean discharge criteria. The restrictions or prohibitions shall specify quantities, rates and concentrations of chemical, physical, biological and other constituents which are discharged to the waters of the Territory of Guam.

EMERGENCY PLAN: The corrective procedure to be followed in the case of oil or toxic substances spills, or in the case of damage caused by natural phenomena.

ENVIRONMENTAL IMPACT STATEMENT - A written document required by the National Environmental Policy Act (NEPA) for all projects on federal lands, using federal funds, or requiring federal permits to insure that the policies and goals defined in the Act are infused into federal programs and actions. The statement shall provide a complete and fair discussion of significant environmental effects and reasonable alternatives to avoid or minimize adverse impact.

ENVIRONMENTAL PROTECTION PLAN - A written document required by the Agency prior to the start of construction in which the developer/contractor describes the methods/equipment selected for use in the development, the environmental problems expected during and after development and the methods or equipment chosen to avoid, mitigate or control adverse effect on the environment.

ESTUARY: A region of interaction between near-shore waters and rivers within which tidal action and river flow bring about mixing of fresh and salt water.

FECAL COLIFORM: See "Coliform".

FWPCAA: Federal Water Pollution Control Act Amendments of 1972, as amended by the 1977 Clean Water Act.

HIGHER DEGREE OF TREATMENT: Any physical, biological and/or chemical method directed at removing a specified portion of the remaining pollutants after secondary treatment.

HYDROLOGIC CYCLE: That natural system dealing with the properties, distribution, and circulation of water on the surface of the land, in the soil and underlying rocks, and in the atmosphere.

INDUSTRIAL WASTE: Any discharge containing gaseous, dissolved or suspended material resulting from any process of industry, manufacturing, trade or business or from the processing of any natural resource, together with such sewage as may be present, which may pollute the waters of the territory.

LAND TREATMENT: Any treatment of wastewater which involves the use of plants, soil surface and the soil matrix for wastewater treatment, including irrigation systems, infiltration systems, overland flow systems and other systems of wastewater treatment via land application.

LETHAL CONCENTRATION-50 PERCENT (LC_{50}): That concentration of a toxic substance in water which for a given time period causes 50 percent of the exposed individuals of an aquatic test organism to die.

LIMITED BODY CONTACT: Any recreational or other use in which contact with the water is either incidental or accidental and in which the probability of ingesting appreciable quantities of water is minimal.

LINE OF MEAN HIGH WATER: The shoreline as indicated on the 1:24,000 Series (Topographic) Maps of the Island of Guam prepared by the U.S. Geological Survey.

MARINE SANITATION DEVICE: Equipment or process for installation on vessel or water craft which is designed to receive, retain, treat, or discharge sewage or other pollutants or any process to treat such sewage, or other pollutants which has received U.S. Coast Guard approval.

MIXING ZONE: The area or volume of a water body within which effluent(s) shall become physically mixed with the receiving waters through initial dilution. Initial dilution is the process through which the wastewater immediately mixes with the receiving water due to the momentum of the waste discharge and the difference in density between the discharge and the receiving water. The total area or volume of water designated as a mixing zone shall be limited to that area or volume which will not interfere with biological communities or populations of important species to a degree which is damaging to the ecosystem and which will not cause substantial damage to or impairment of designated water uses within the mixing zone or in surrounding waters. A mixing zone shall be considered designated only when approved by the Guam Environmental Protection Agency and when concurrence of the U.S. EPA has been received.

MUNICIPAL WASTES: Water carrying human and animal wastes from homes, buildings, industrial establishments and other places either alone or in combination with industrial wastes.

NATURAL CONDITIONS: The resulting water quality in the absence of any measurable pollutional effect due to human activities.

NEAR-SHORE WATERS: All coastal waters lying within a defined reef area; all coastal waters of a depth of less than ten fathoms (60 feet, 18.3 m); and all coastal waters greater than 10 fathoms up to 1000 feet (305 m) off-shore where there is no defined reef area.

NEW SOURCE: Any wastewater sources, the construction of which is commenced on or after the 1968 effective date of these standards.

NPDES PERMIT: National Pollutant Discharge Elimination System (permit). A federal permit used as the principal regulatory tool for reducing the quantity of pollutant discharges to the waters of the territory and for obtaining data on point source discharges.

OFF-SHORE WATERS: All coastal waters beyond the limits defined for "near-shore waters" to the Territorial Limit as recognized by International Law.

OUT FALL: The conduit from its connection to a wastewater treatment facility to its outlet through diffusers into off shore waters.

OIL SPILL PREVENTION DEVICES: Shall mean any U.S. Coast Guard approved device, such as an oil/water separator, a sludge tank (for oily deposits), a standard discharge connection or other equipment or apparatus required by the MAROL Convention of 1973/1978 for the prevention of oil pollution by vessels.

OTHER WASTES: Garbage, municipal refuse, sand, offal, oil tar, chemicals and all other substances which may pollute the waters of the territory.

PARABASAL GROUNDWATER: Fresh groundwater hydraulically connected with basal water but lying directly on impermeable basement rock.

PASSAGEWAY: A continuous stretch where water characteristics are affected only by the environment in such a manner that the free flow or continuous drifting of biota is always possible.

PERMIT: A permit issued pursuant to Section 47106 of the Guam Water Pollution Control Act.

PERSON(S): Means any individual, firm, partnership, association or corporation, both public and private, including the agencies of the government of Guam and of the United States of America.

POINT SOURCE: Any discernible, confined and discrete conveyance including, but not limited to, any pipe, ditch, channel, tunnel, conduit, well discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft from which pollutants are or may be discharged.

POLLUTANT: Any substance, refuse or waste capable of polluting the waters. See Pollution.

POLLUTION: Alteration of the physical, chemical or biological properties of any waters of the Territory which adversely and unreasonably impairs the water quality of the territory or which renders said waters hazardous to human health or harmful or determinal to the aquatic and wildlife in or about the waters or to the most beneficial uses of the waters.

POTABLE WATER RESOURCES: Waters of the Territory actually used or intended to be used for drinking water or general domestic use.

RECEIVING WATER(S): Water(s) of the Territory into which wastes or waste-waters are, or may be, discharged.

SECONDARY TREATMENT: The following degree of pollutant removal:

1. Biochemical oxygen demand (five-day)

    a) The arithmetic mean of the values for effluent samples collected in a period of 30 consecutive days shall not exceed 30 mg/1.

    b) The arithmetic mean of the values for effluent samples collected in a period of seven consecutive days shall not exceed 45 mg/1.

    c) The arithmetic mean of the values for effluent samples collected in a period of 30 consecutive days shall not exceed 15 percent of the arithmetic mean of the values for influent samples collected at approximately the same times during the same period (85 percent removal).

2. Suspended solids

    a) The arithmetic mean of the values for effluent samples collected in a period of 30 consecutive days shall not exceed 30 mg/1.

    b) The arithmetic mean of the values for effluent samples collected in a period of seven consecutive days shall not exceed 45 mg/1.

c) The arithmetic mean of the values for effluent samples collected in a period of 30 consecutive days shall not exceed 15 percent of the arithmetic mean of the values for influent samples collected approximately the same times during the same period (85 percent removal).

3. Fecal coliform bacteria

a) The arithmetic mean of the value for effluent samples collected in a period of 30 consecutive days shall not exceed 200 per 100 ml.

b) The arithmetic mean of the values for effluent samples collected in a period of seven consecutive days shall not exceed 400 per 100 ml.

4. pH. The effluent values for pH shall remain within the limits of 6.0 to 9.0.

SCHEDULE OF COMPLIANCE: A schedule of corrective measures and times including an enforceable sequence of actions or operations leading to compliance with any control regulation or effluent limitation.

SEWAGE: The water-carried waste products from the residences, public buildings, institutions or other buildings, including the excrementitious or other discharge from the bodies of human beings or animals, together with such ground water infiltration and surface water as may be present.

SURFACE WATERS: Any natural or artificial water source including all streams, lakes, ponds, impounding reservoirs, inland watercourses and waterways, springs, irrigation systems, drainage systems and all other inland water bodies or accumulated waters. For the purpose of this regulation, the term does not include coastal waters or those subject to the ebb and flow of tides.

THERMAL DISCHARGE: Discharge of water into the environment which has temperature component either above or below the temperature of the receiving body of water.

TOXIC: Lethal, teratogenic or mutagenic, or otherwise damaging to man or other living organisms.

TRANSITION ZONE: In basal water the interface between the bottom of the freshwater lens and the underlying saltwater. Salinity is low at the top of the transition zone and increases to that of seawater at the bottom of the zone.

WASTEWATER: Sewage, industrial waste, or other waste, excluding thermal discharge, or any combination of these, whether treated or untreated, plus any admixed land runoff.

WATER QUALITY STANDARDS: The designated water body uses or classifications and the criteria to protect those uses and classifications.

WATERS OF THE TERRITORY: All waters within three miles from the high water-line surrounding Guam, streams, lakes, wells, springs, irrigation systems, marshes, watercourses, waterways, drainage systems and other bodies of water, surface and underground, natural or artificial, publicly or privately owned.

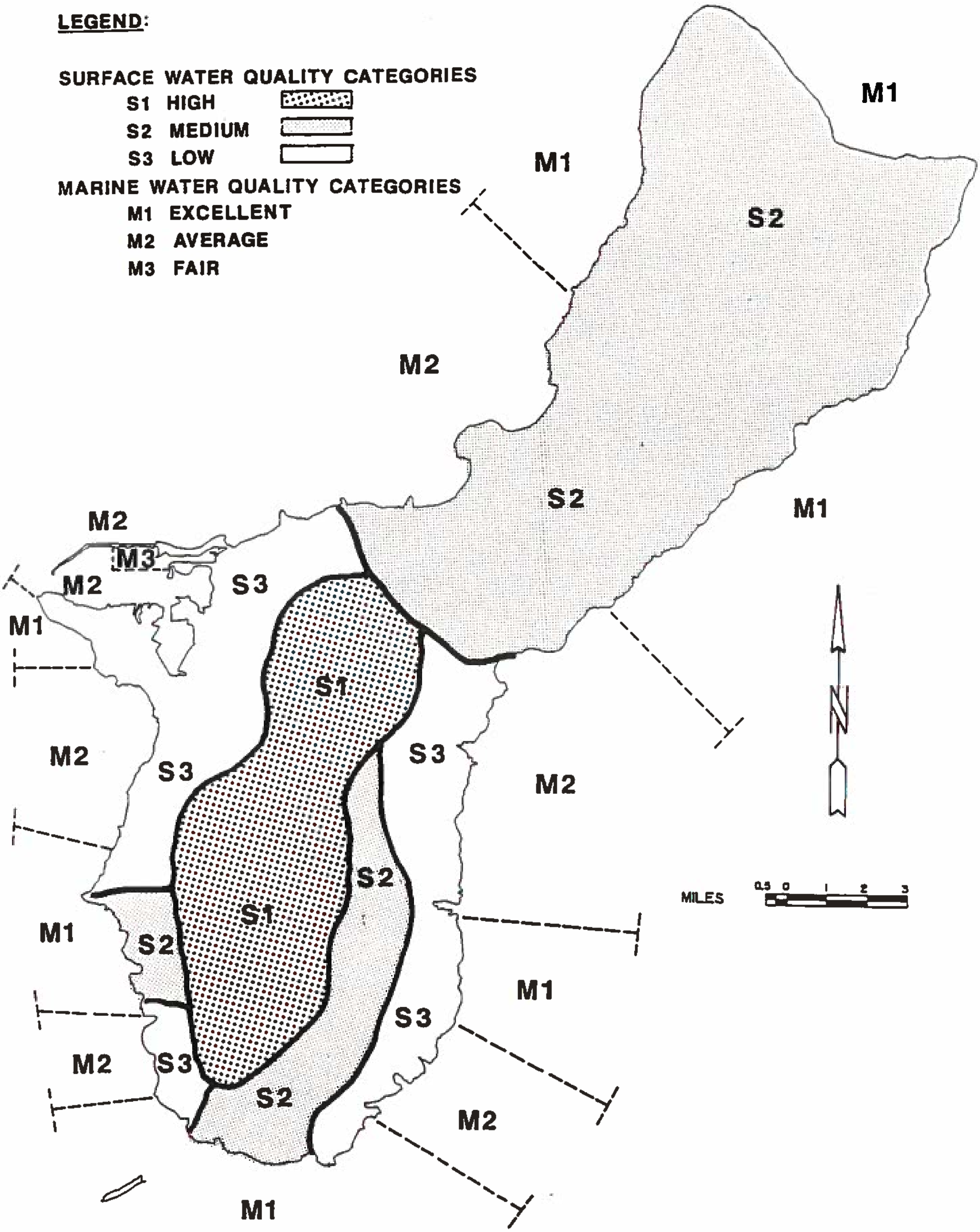
WHOLE BODY CONTACT: Any recreation or other use in which there is whole body contact with the water involving a risk sufficient to pose a significant health hazard either by contact with or ingestion of the water.

ZONE OF PASSAGE: Shall mean a continuous water route which joins segments of a river, stream, reservoir, estuary, or channel above, below, or around a mixing zone without going through the mixing zone. As a minimum no less than one-third of the cross-section of the water body shall be retained in compliance with the water quality criteria in Section II.

APPENDIX A

List of the 65 Toxic Pollutant designated under Section 307(a) (1) of the Clean Water Act

1. Acenaphthene
2. Acrolein
3. Acrylonitrile
4. Aldrin/Dieldrin
5. Antimony
6. Arsenic
7. Asbestos
8. Benzene
9. Benzidine
10. Beryllium
11. Cadmium
12. Carbon Tetrachloride
13. Chlordane
14. Chlorinated benzenes
15. Chlorinated ethanes
16. Chloroakyl ethers
17. Chlorinated naphthalene
18. Chlorinated phenols
19. Chloroform
20. 2-chlorophenol
21. Chromium
22. Copper
23. Cyanides
24. DDT
25. Dichlorobenzenes
26. Dichlorobenzidine
27. Dichloroethylenes
28. 2, 4-dichlorophenol
29. Dichloropropanes/ propenes
30. 2, 4-dimethylphenol
31. Dinitrotoluene
32. Diphenylhydrazine
33. Endosulfan
34. Endrin
35. Ethylbenzene
36. Fluoranthene
37. Haloethers
38. Halomethanes
39. Heptachlor
40. Hexachlorobutadiene
41. Hexachlorocyclohexane
42. Hexachlorocyclopentadiene
43. Isophorone
44. Lead
45. Mercury
46. Naphthalene
47. Nickel
48. Nitrobenzene
49. Nitrophenols
50. Nitrosamines
51. Pentachlorophenol
52. Phenol
53. Phthalate esters
54. Polychlorinated biphenyls (PCBs)
55. Polynuclear aromatic hydrocarbon
56. Selenium
57. Silver
58. TCDD (Dioxin)
59. Tetrachloroethylene
60. Thallium
61. Toluene
62. Toxaphene
63. Trichloroethylene
64. Vinyl chloride
65. Zinc



GUAM WATER CLASSIFICATION

MASTER MAP

SOURCE: GUAM WATER QUALITY STANDARDS, 1987

G

APPENDIX G

STATE OF HAWAII
DEPARTMENT OF HEALTH
EIGHT (8) CONDITIONS FOR NEW GOLF COURSE DEVELOPMENT

1. The owner/developer and all subsequent owners shall establish a groundwater monitoring plan and system which shall be presented to the State Department of Health for its approval. The groundwater monitoring plan and system shall minimally describe the following components:

   a. A monitoring system tailored to fit site conditions and circumstances. The system shall include, and not be limited to, the use of monitoring wells, lysimeters and vadose zone monitoring technologies. If monitoring wells are used, the monitoring wells shall generally extend 10 to 15 feet below the water table.

   b. A routine groundwater monitoring schedule of at least once every six (6) months and more frequently, as required by the State Department of Health, in the event that the monitoring data indicates a need for more frequent monitoring.

   c. A list of compounds which shall be tested for as agreed to by the State Department of Health. This list may include, but not be limited to the following: total dissolved solids; chlorides; pH; nitrogen; phosphorus; or any other compounds associated with fertilizers, biocides or effluent irrigation.

2. Baseline groundwater/vadose zone water data shall be established as described in this paragraph. Once the monitoring system and list of compounds to be monitored for have been determined and approved by the State Department of Health, the owner/developer shall contract with an independent third-party professional (approved by the State Department of Health) to establish the baseline groundwater/vadose zone water quality and report the findings to the State Department of Health. Testing of the analyses of the groundwater shall be done by a certified laboratory.

3. If the data from the monitoring system indicate the presence of the measured compound and/or the increased level of such compound, the State Department of Health can require the owner/developer or subsequent owner to take immediate mitigating action to stop the cause of the contamination. Subsequently, the developer/owner or subsequent owner shall mitigate any adverse effects caused by the contamination.

4. Owner/developer shall provide sewage disposal by means of connection to the public sewer system; or by means of a wastewater treatment works providing treatment to a secondary level with chlorination. Effluent from this wastewater treatment works may be used for golf course irrigation, subject to Condition #3. The entire system shall be approved by the State Department of Health in conformance with Administrative Rules Title 11, Chapter 62, Wastewater Treatment Systems, effective December 10, 1988.

5. If a wastewater treatment works with effluent reuse becomes the choice of wastewater disposal, then the owner/developer and all subsequent owners shall develop and adhere to a Wastewater Reuse Plan which shall address as a minimum, the following items:

    a. Management Responsibility. The managers of the irrigation system using reclaiming wastewater shall be aware of the possible hazards and shall evaluate their system for public health, safety, and efficiency. They must recognize that contact with the reclaimed wastewater from treated domestic sewage poses potential exposure to pathogenic organisms which commonly cause infectious diseases (bacteria, viruses, protozoa, and helminths or worms.)

    b. General Recommendations

        1) Irrigated areas should be no closer than 500 feet from potable water wells and reservoirs.

        2) Irrigated areas should be no closer than 200 feet from any private residence.

3) Application rates should be controlled to minimize ponding. Excess irrigation tailwater in the reclaimed wastewater irrigation area shall be contained and properly disposed of. An assessment should be made of the acceptable time and rate of application based on factors such as type of vegetation, soil, topography, climate and seasonal variations.

4) Effluent holding/mixing ponds shall be designed to prevent the infiltration of the wastewater into the subsurface. The holding/mixing ponds shall be made impervious.

5) Irrigation shall be scheduled such that the public is not in the vicinity and the soil is sufficiently dry to accept the irrigation water.

6) Permanent fencing or barriers shall be erected around polishing or holding ponds to prevent public entry or stray feral and tame animals from gaining access to the ponds.

7) Adequate irrigation records shall be maintained. Records should include dates when the fields are irrigated, rate of application, total application and climatic conditions. Records should also include any operational problems, diversions to emergency storage or safe disposal and corrective or preventive action taken.

8) The holding/mixing ponds shall be periodically monitored for the purpose of detecting leakage into the subsurface. If leakage is detected, corrective action shall be immediately taken.

c. Adequate Notice. Appropriate means of notification shall be provided to inform the employees and public that reclaimed wastewater is being used for irrigation on the site.

1) Posting of conspicuous signs with sufficient letter size for clear visibility with proper wording should be distributed around the use areas.

2) Signs shall be securely fastened. Periodic surveillance shall be conducted to assure permanent posting at all times. Immediate replacements shall be made when necessitated by deterioration, vandalism or misuse.

d. Adequate Employee Education. Employees or users should be cautioned and warned of the potential health hazards associated with the ingestion of reclaimed wastewater being used at the site.

1) Employees should be warned that the ingestion of reclaimed wastewater is unsafe.

2) Employees should be protected from direct contact of the reclaimed wastewater. If necessary, protective clothing should be provided.

3) Employees should be informed of the following:

- The irrigation water is unsafe for drinking or washing.
- Avoid contact of the water or soil with any open cuts or wounds.
- Avoid touching the mouth, nose, ear or eyes with soiled hands, clothes or any other contaminated objects.
- Be aware that inanimate objects such as clothes or tools can transport pathogenic organisms.
- Always wear shoes or boots to protect feet from the pathogenic organisms in the soil or irrigation water.

6. Releases from underground storage tanks (USTs) used to store petroleum products for fueling golf carts, maintenance vehicles, and emergency power generators pose potential risks to groundwater.

Should the owner/developer/operator plan to install USTs that contain petroleum or other regulated substances, the owner/developer/operator must comply with the federal UST technical and financial responsibility requirements set forth in Title 40 of the Code of Federal Regulations Part 280. These federal rules require, among other things, owners and operators of USTs to meet specific requirements in the detection, release response and corrective action. Also, the owner/developer/operator must comply with all State UST rules and regulations pursuant to chapter 342-L 'Underground Storage Tanks' of the Hawaii Revised Statutes.

In consideration of the above-mentioned remarks, the Department of Health recommends that the owner/developer/operator implement facility plan alternatives that exclude the installation and operation of UST systems (e.g., the preferential use of electric golf carts, use of above-ground storage of fuel oil for emergency power generators, etc.), or, if USTs are utilized, that secondary containment be considered.

7. Buildings designated to house the fertilizer and biocides shall be bermed to a height sufficient to contain a catastrophic leak of all fluid containers. It is also recommended that the floor of this room be made waterproof so that all leaks can be contained within the structure for cleanup.

8. A golf course maintenance plan and program will be established based on "Best Management Practices (BMP)" in regards to utilization of fertilizers and biocides as well as the irrigation schedule. BMP's will be revised as an ongoing measure. The golf course maintenance plan will be reviewed by the State Department of Health prior to implementation.

H

PREFACE TO APPENDIX H

PRIORITY LIST THROUGH YEAR 2000
AND
PROPOSED ISLANDWIDE WATER SYSTEM
CAPITAL IMPROVEMENTS PROGRAM

The first three pages of Appendix H consist of the Capital Improvements Priority List which prioritizes the proposed capital improvements recommended for implementation to the year 2000. The remainder of Appendix H is a listing of capital improvements grouped by facility category, without priority, and includes <u>all</u> recommended capital improvements to meet projected year 2010 demands. These facility category groupings are as follows:

I. Water Main Improvements

II. Reservoir Improvements

III. Booster Pump Station Improvements

IV. Well Improvements

V. Surface Water Improvements

VI. Miscellaneous Improvements

APPENDIX H

PRIORITY LIST THROUGH YEAR 2000
PUBLIC UTILITY AGENCY OF GUAM
PROPOSED ISLANDWIDE WATER SYSTEM
CAPITAL IMPROVEMENTS PROGRAM

PRIORITY	PROJECT	LOCATION	Funding Source: $53 M Bond	Funding Source: Other	Funding Source: None Identified
1	*	Groundwater Exploration and Development Program			$470,000
	AW-1	Agafa Gumas Wells	$2,179,000		$2,021,000
	A-1	From Gayinero north along Rt. 1, north-west on Rt. 9 to Pott's Jct. then south along Rt. 3 to connection with Project A-5 at Ysengsong Rd. ($53 M Bond Project)	$7,796,000		$4,454,000
	AR-2	New Agafa Gumas, east of Pott's Junction ($53 M bond project).	$3,558,000		$2,682,000
2	A-5	From connection with Project A-1 at the intersection of Ysengsong Rd. and Rt. 3, south along Rt. 3 then west along Rt. 1 to connect to the 14-inch diameter main south of Haruna's restaurant and Project B-1. ($53 M Bond Project)	$6,480,000		$2,030,000
3	B-1	From connection to Project A-5 at Haruna's Restaurant, south on Rt. 1 to existing 12-inch main on Ypao Rd. ($53 M Bond Project)	$2,050,000		$740,000
4	B-7	From connection with Project B-4 at Rt. 10A, south on Rt. 16 to Rt. 10 with connections to proposed Rt. 16 Reservoir. (DOI Funded Project)		$2,145,000	$775,000
	BR-2	New Mongmong-Toto-Maite Reservoir. On Rt. 16 south of Barrigada Hts.			$4,680,000
	B-4	From Barrigada Reservoirs along Macheche Rd. to connection with Projects A-11 and B-5 at Rt. 16.			$2,450,000
5	B-8	From connection with Project B-6 at Rt. 15 south along Dairy Road approximately 4,000 ft. to Bull Cart Trail then west along Bull Cart Trail to Canada-Toto Loop Rd. and connection to existing 12-inch main on Rt. 8.	$1,078,000		$1,172,000
6	B-15, BPS-3	From connection to existing 18 inch main at Rt. 4 in Agana, south to Rt. 6 with connections to Asan Springs. From Asan, south along Rt. 1 to connection with B-16 at Rt. 6 in Piti. ($53 M Bond Project) Rt. 4 between Agana and Asan. Moves water from Agana to Asan Reservoir. ($53 M Bond Project)	$6,040,000		$920,000

PUAG WATER MASTERPLAN
PROPOSED CAPITAL IMPROVEMENTS PROGRAM

I. Water Main Improvements

Service Area	Project	Location	Diameter (in)	Length (ft)	Estimated 1991 Project Cost
A	A-1	From Gayinero north along Rt. 1, north-west on Rt. 9 to Pott's Jct. then south along Rt. 3 to connection with Project A-5 at Ysengsong Rd. ($53 M Bond Project)	20	45,000	$12,250,000
	A-2	From connection with Project A-1 on Rt. 9 and proposed well fields to proposed Agafo Gumas Reservoir. ($53 M Bond Project)	12	4,400	$750,000
	A-3	From proposed Agafo Gumas Reservoir south to Astumbo Reservoir.	30	12,600	$5,490,000
	A-4	From Astumbo Reservoir to existing 12 and 16-inch mains feeding Barrigada Reservoir at Rt. 1.	24	18,000	$6,130,000
	A-5	From connection with Project A-1 at the intersection of Ysengsong Rd. and Rt. 3, south along Rt. 3 then west along Rt. 1 to connect to the 14-inch diameter main south of Haruna's restaurant and Project B-1. ($53 M Bond Project)	24	25,000	$8,510,000
	A-6	From connection with Project A-1 at Rt. 1 near Mataguac, west along existing 2-inch main to connect with Project A-3.	12	11,500	$1,960,000
	A-7	From Astumbo Reservoir outlet west to existing 12-inch main at Ysengsong Rd.	16	2,880	$650,000
	A-8	From connection to Project A-7 on Ysengsong Rd., south to the 12 and 14 inch diameter mains on Rt. 1.	16	12,500	$2,810,000
	A-9	Upgrade all sections along Swamp Road from Rt. 3 east to Ysengsong Rd.	12	450	$80,000
	A-10	From connection to Project A-5 at Rts. 1 and 3 junction, east on Rt. 1 to connect with Dededo's 12-inch diameter main on north Fatima St.	12	2,000	$340,000
	A-11	From connnection to existing 12-inch diameter main on Rt. 16 at south Fatima Street, north to connection with Project A-5, and from connection to the existing 12-inch main west of Ft. Muna, east along Rt. 16 to connection with Projects B-4 and B-5.	12	3,400	$580,000
	A-12	Upgrade Macheche/Adacao distribution lines. ($53 M Bond Project)	8 6	15,000 18,200	$1,640,000 $1,860,000

PUAG WATER MASTERPLAN
PROPOSED CAPITAL IMPROVEMENTS PROGRAM

I. Water Main Improvements

Service Area	Project	Location	Diameter (in)	Length (ft)	Estimated 1991 Project Cost
A	A-13	From PUAG's Mt. Santa Rosa Reservoir, north along Rt. 15 to Andersen Elementary School then west along Andersen's boundary to connection with Project A-1 on Rt. 9. (Mt. Santa Rosa to School, Locally Funded)	16 12	1,300 4,950	$300,000 $850,000
	A-14	From connection to Project A-15 in Gayinero, south along Rt. 15 to connection with Project B-6 at Carnation Rd. ($53 M Bond Project)	12	18,880	$3,210,000
	A-15	From connection with Project A-1 on Rt. 1 southeast, through Takanao Subdivision to connection with Project A-14 at Rt. 15. This project is in addition to the 16-inch main now under construction along the same route.	12	6,000	$1,020,000
	A-16	From Project A-13 west to Route 3.	16	6700	$1,510,000
B	B-1	From connection to Project A-5 at Haruna's Restaurant, south on Rt. 1 to existing 12-inch main on Ypao Rd. ($53 M Bond Project)	24	8,200	$2,790,000
	B-2	From Japan Plaza along San Vitores Rd. to connection with Project B-3 on JFK Rd.	12	7,200	$1,230,000
	B-3	From connection to Project B-2 on San Vitores Rd. along JFK Rd to connection Project B-1 on Rt. 1.	16	2,400	$390,000
	B-4	From Barrigada Reservoirs along Macheche Rd. to connection with Projects A-11 and B-5 at Rt. 16.	24	7,200	$2,450,000
	B-5	From connection to Projects A-11 and B-4 at Rt. 16 to proposed Airport Reservoir then west along Rt. 10 A to connect with Project B-1 on Rt. 1.	16	12,600	$2,830,000
	B-6	From connection to Project A-14 at Carnation Rd., south along Rt. 15 to connect with Projects B-10 and B-14 at Rt. 10. (DOI Funded Project; under construction)	24	25,000	$8,510,000
	B-7	From connection with Project B-4 at Rt. 10A, south on Rt. 16 to Rt. 10 with connections to proposed Rt. 16 Reservoir. (DOI Funded Project)	16	13,000	$2,920,000
	B-8	From connection with Project B-6 at Rt. 15 south along Dairy Road approximately 4,000 ft. to Bull Cart Trail then west along Bull Cart Trail to Canada-Toto Loop Rd. and connection to existing 12-inch main on Rt. 8.	12	13,200	$2,250,000
	B-9	From connection to existing 12-inch main at Rt. 8 in Mongmong, west to connection with existing 12-inch main on Rt. 1.	12	3,600	$620,000

PUAG WATER MASTERPLAN
PROPOSED CAPITAL IMPROVEMENTS PROGRAM

I. Water Main Improvements

Service Area	Project	Location	Diameter (in)	Length (ft)	Estimated 1991 Project Cost
B	B-10	From Agana Springs along existing power right of way to connection with Project B-9 at Rt. 8 in Mongmong.	12	12,000	$2,040,000
	B-11	From Mangilao Reservoir to connection with Project B-6 on Rt. 15--inlet and outlet.	16	5,600	$1,260,000
	B-12	From Mangilao Reservoir to connection with Project B-13 and existing 12-inch main at Rt. 10 via Corten Torres and Guam Community College.	16	1,400	$320,000
	B-13	From connection to Project B-12 on Rt. 15, south along Rt. 10 to connect to existing 16 and 12-inch mains at Rt. 4.	16	12,000	$2,700,000
	B-14	Upgrade Sinajana/Agana Hts. distribution main between connections at Route 4 and Agana Hts. Reservoir.	8	5,810	$640,000
	B-15	From connection to existing 18 inch main at Rt. 4 in Agana, south to Rt. 6 with connections to Asan Springs. From Asan, south along Rt. 1 to connection with B-16 at Rt. 6 in Piti. ($53 M Bond Project)	16 20	11,000 15,000	$2,470,000 $4,090,000
	B-16	From connection with Project B-15 on Rt. 1 west along Rt. 6 to new Nimitz Hill Reservoir, then west on Rt. 6 to connection with Project B-15 at Rt. 1 at at Adelup. Also distribution main from new Nimitz Hill Reservoir, west along Rt. 6 to connection with Project B-15 at Piti.	16	35,000	$7,860,000
C	C-1	From existing 12-inch main from Sinifa BPS west along Rt. 17 to connection with the 12-inch Santa Rita main.	12	11,000	$1,870,000
	C-2	From connection with the existing 12-inch on Rt. 2 near Magpo Beach, south along Rt. 2 to Pagachao Reservoir. ($53 M Bond Project)	16	5,000	$1,130,000
	C-3	Upgrade Agat-Santa Rita distribution system. ($53 M Bond Project)	6 8 16	40,000 15,000 11,500	$3,540,000 $1,640,000 $2,590,000
	C-4	From Pagachao Subdivision to Umatac with connections to the proposed Agat/Umatac Reservoir. ($53 M Bond Project)	12	15,000	$2,550,000
	C-5	From connection to Project D-5 on Rt. 17 at proposed Cross Island Reservoir to Sinifa Reservoir.	14	10,500	$2,150,000

PUAG WATER MASTERPLAN
PROPOSED CAPITAL IMPROVEMENTS PROGRAM

I. Water Main Improvements

Service Area	Project	Location	Diameter (in)	Length (ft)	Estimated 1991 Project Cost
D	D-1	From Ugum Reservoir, north on Rt. 4 to Rt. 4A then west along Rt. 4A to connection with Windward Hills Reservoir. (To be funded by the Talofofo Water System Project).	16	26,000	$5,840,000
	D-2	From Pago Bay BPS along Rt. 4 to connect to the existing 12-inch Pulantat main.	16	8,500	$1,910,000
	D-3	From Rt. 4 connection to Project D-2, west to Pulantat Reservoir.	20	9,500	$2,590,000
	D-4	From Rt. 4 north to proposed Ija Reservoir with outlet back to Rt. 4.	12	8,250	$1,410,000
	D-5	From Windward Hills Reservoir to connection with Project C-5 at proposed Cross Island Reservoir via Windward Hills Booster Pump Station.	14	14,500	$3,260,000
		TOTAL WATER MAIN IMPROVEMENTS			$125,790,000

NOTE: Project costs include standard valves, and PRV's and PSV's as noted in Appendix I, Figures A through D.

PUAG WATER MASTERPLAN
PROPOSED CAPITAL IMPROVEMENTS PROGRAM

II. RESERVOIR IMPROVEMENTS

Service Area	Project	Location	Yr. 2000 Volume (Million Gallons)	Estimated 1991 Project Cost	Yr. 2010 Volume (Million Gallons)	Estimated 1991 Project Cost
A	AR-1	Site of present Yigo Reservoir.	5.0	$6,240,000	-	-
	AR-2	New Agafa Gumas, east of Pott's Junction ($53 M bond project).	5.0	$6,240,000	-	-
	AR-3	Site of present Astumbo Reservoir.	3.0	$4,680,000	2.0	$4,160,000
	AR-4	Site of present Dededo Reservoir ($53 M bond project).	5.0	$6,240,000	-	-
B	BR-1	Site of present Mangilao Reservoir ($53 M bond project).	5.0	$6,240,000	-	-
	BR-2	New Mongmong-Toto-Maite Reservoir. On Rt. 16 south of Barrigada Hts.	3.0	$4,680,000	3.0	$4,680,000
	BR-3	North end of Airport Industrial Park. Alternate: Across Rt.16 on Perez lot.	3.0	$4,680,000	3.0	$4,680,000
	BR-4	Site of present Agana Hts. Reservoir.	-	-	2.0	$4,160,000
	BR-5	Site of present Chaot Reservoir.	-	-	2.0	$4,160,000
	BR-6	Near site of Present Asan Springs.	-	-	1.0	$1,560,000
	BR-7	Site of present Piti Reservoir	-	-	1.0	$1,560,000
	BR-8	Near site of Navy's present Nimitz Hill Reservoir.	1.0	$1,560,000	-	-
C	CR-1	Site of present Sinifa Reservoir.	-	-	1.0	$1,560,000
	CR-2	Near Torres School in Santa Rita. Below present Santa Rita Reservoir.	1.0	$1,560,000	-	-
	CR-3	GovGuam site in Pagachao subdivision. Alternate: Rt. 4 near Ascola Sita.	1.0	$1,560,000	-	-
	CR-4	East of Route 2 above Sella Bay	0.5	$990,000	-	-
D	DR-1	Near site of present Pulantat Reservoir.	2.0	$3,640,000	3.0	$4,680,000
	DR-2	Site of present Windward Hills Reservoir.	-	-	1.0	$1,560,000
	DR-3	Rt. 17 near East Lookout Tower.	-	-	1.0	$1,560,000
	DR-4	Standpipe at site of present Malojloj Reservoir.	0.2	$310,000	-	-
	DR-5	Site of present Inarajan Reservoir.	-	-	1.0	$1,560,000
	DR-6	Near Ija Rd. at elev. 196 ft. 500 ft. access rd.	0.5	$1,040,000	0.5	$940,000
	DR-7	Rt. 4 at Mt. Jumullong Manglo pass.	0.5	$940,000	-	-
		TOTAL RESERVOIR IMPROVEMENTS		$50,600,000		$36,820,000
		Year 1990 to 2010 Entire Guam Total:		$87,420,000		

PUAG WATER MASTERPLAN
PROPOSED CAPITAL IMPROVEMENTS PROGRAM

III. Booster Pump Station Improvements

Service Area	Project	Location	Capacity(1) (gpm)	Estimated 1991 Project Cost	Number Pumps	Pump Size (gpm)
B	BPS-1	Rt. 6 below Nimitz Towers. Nimitz BPS No. 1 moves water from Piti Reservoir to proposed Nimitz BPS No. 2.	700	$380,000	2	700
	BPS-2	Rt. 6 above Nimitz Towers. Nimitz BPS No. 2 boosts water from Nimitz BPS No. 1 to proposed Nimitz Hill Reservoir.	700	$380,000	2	700
	BPS-3	Rt. 4 between Agana and Asan. Moves water from Agana to Asan Reservoir. ($53 M Bond Project)	700	$400,000	2	700
C	CPS-1	On Rt. 17 between proposed Cross Island and Sinifa reservoirs. To move water from Cross Island to Sinifa reservoirs.	2,000	$750,000	2	2000
	CPS-2	On Rt. 2 near Tumag. Moves water from Agat/Santa Rita to the proposed Sella Reservoir. ($53 M Bond Project)	1,000	$520,000	2	1000
	CPS-3	On Rt. 2 near Sella River. Moves water from proposed Sella Reservoir to proposed reservoir at Jumollong Mangilao Pass.	1000	$520,000	2	1000
D	DPS-1	Existing Pago Booster Pump Station. Upgrade existing 2000 gpm capacity to accomodate Year 2010 flows. Moves water from north to Pulantat Reservoir.	6,500	$1,800,000		
	DPS-2	On Rt. 4 between Ylig River and Yona. Moves water from Ugum to Pulantat Reservoir.	1,400	$570,000	2	1400
	DPS-3	Existing Windward Hills BPS. Upgrade existing 400 gpm capacity to move water to proposed Cross Island Reservoir.	2,000	$750,000	2	2000
	DPS-4	On Rt. 4 near Rt. 4A intersection. To Move water from Ugum Reservoir to Windward Hills Reservoir. (Funded under Talofofo Water System Project).	3,500	$590,000	3	1750
	DPS-5	Existing Pigua BPS. Upgrade existing 300 gpm capacity to accommodate Year 2010 demands.	1,100	$420,000	2	1100
	DPS-6	Existing Umatac BPS No. 3. Upgrade existing 35 gpm capacity to meet Year 2010 demands.	350	$150,000	2	350
		TOTAL BOOSTER PUMP STATION IMPORVEMENTS		$7,230,000		

(1) Represents maximum day capacity demand requirements. Pumps will satisfy demand with pump out of service. Final design capacity may be larger due to specific project requirements.

PUAG WATER MASTER PLAN
PROPOSED CAPITAL IMPROVEMENTS PROGRAM

IV. Well Improvements

Service Area	Project No.	G.W. Zone	Location	Number of Wells by Size (GPM) IG	100	200	350	500	750	Estimated 1991 Cost
A	AW-1	16	Agafa Gumas. East of Pott's Jct., south of Rt. 9.	--	--	--	--	12	--	$4,200,000
	AW-2	29	Along Ysengsong Rd. North of and including the D-series wells.	--	--	1	--	1	4	$2,200,000
B	BW-1	9	Adacao, adjacent to Rt. 15.	--	--	--	--	2	1	$1,090,000
A	AW-3	10	Sabanan Pagat, along Rt. 15.	--	--	--	1	1	--	$660,000
B	BW-2	21	West of Mt. Barrigada in upper Macheche.	--	--	--	1	2	--	$1,010,000
A	AW-4	28	Yigo, expansion of existing Y-series wells.	--	--	1	--	--	4	$1,830,000
	AW-5	25	East Yigo, expansion of Y-series wells.	--	--	1	--	3	--	$1,340,000
	AW-6	19	East Finegayan north of Callon Tramojo.	--	--	1	--	2	--	$990,000
	AW-7	26	Along Rt. 1, north of Yigo Village.	--	--	--	1	1	--	$670,000
	AW-8	27	Mataguac, adjacent to Rt. 1 .	--	--	--	--	2	--	$700,000
	AW-9	44	Dededo, along Rt. 3 north of D-16/18 wells.	--	--	6	--	--	--	$1,670,000
B	BW-3	3	Nimitz Hill, along Rt. 6.	--	1	3	4	1	--	$2,590,000
A	AW-10	14	Lupog, adjacent to Rt. 15, south of Andersen.	--	--	--	--	9	--	$3,150,000
B	BW-4	32	Agana Swamp between Afami and Agana Springs.	--	--	3	5	--	--	$2,330,000
A	AW-11	18	Between Callon Tramojo and Rt. 3.	--	--	3	--	--	--	$820,000
B	BW-5	4	Anigua near Rt. 1.	--	--	4	--	--	--	$1,040,000
	BW-6	31	Toto area.	--	--	3	--	--	--	$780,000
	BW-7	46	Macheche and Airport .	--	--	5	--	--	--	$1,300,000
	BW-8	8	Mangilao North, Carnation Road.	--	--	--	1	1	--	$660,000
	BW-9	34	Manaca, Rt.8 east of Rt. 10 Jct.	--	--	5	5	--	--	$2,850,000
	B-10	37	Sasajyan, along Rt. 15.	--	2	--	--	--	--	$570,000
	B-11	2	Chalan Pago.	--	--	1	--	--	--	$260,000
A	AW-12	24	Marbo North, on Anderson South Annex.	--	--	5	--	--	--	$1,410,000
	AW-13	11	Janum, east of Mt. Santa Rosa.	7	--	--	--	--	--	$2,680,000
	AW-14	22	Mogfog, near existing M-series wells.	--	--	--	2	--	--	$620,000
	AW-15	47	Yigo, along Rt. 1 in Asatdas area.	--	--	1	2	--	--	$890,000
B	BW-12	30	Barrigada, near Rt. 16.	--	--	2	--	--	--	$520,000
A	AW-16	43	Along north Ysengsong Road.	--	17	--	--	--	--	$4,490,000

PUAG WATER MASTER PLAN
PROPOSED CAPITAL IMPROVEMENTS PROGRAM

IV. Well Improvements

Service Area	Project No.	G.W. Zone	Location	Number of Wells by Size (GPM) IG	100	200	350	500	750	Estimated 1991 Cost
B	BW-13	36	Taguan, near Rt. 15.	--	4	--	--	--	--	$1,130,000
A	AW-17	45	South Dededo, expansion of D-series well fields.	--	--	2	--	--	--	$520,000
B	BW-14	5	South of Mt. Barrigada near Rt. 16.	--	--	2	--	--	--	$520,000
A	AW-18	42	Finegayan West, east side of Rt. 3.	--	3	--	--	--	--	$850,000
	AW-19	20	Pott's Junction.	--	--	--	--	1	--	$350,000
B	BW-15	35	Asbeco, along Rt. 15.	--	--	14	--	--	--	$3,660,000
			TOTAL WELL IMPROVEMENTS	7	27	63	22	38	9	$50,350,000

* * * * *

1) Well projects include the following improvements:

- o Mobilization
- o Access Clearing
- o Drilling
- o Reaming
- o Pump Testing
- o Casing
- o Screen
- o Gravel
- o Cement Grout
- o Well Pad
- o Pump
- o Chlorination
- o Chlorination Building
- o Fluoridation
- o Standby Power

2) Wells are arranged in priority of development after NGLS recommendations. This priority is tentative. Final priority and capacity of each well field may vary subject to further analysis of test well data and Northern Lens productivity.

PRIORITY LIST THROUGH YEAR 2000
PUBLIC UTILITY AGENCY OF GUAM
PROPOSED ISLANDWIDE WATER SYSTEM
CAPITAL IMPROVEMENTS PROGRAM

PRIORITY	PROJECT	LOCATION	Funding Source: $53 M Bond	Other	None Identified
	A-14	From connection to Project A-15 in Gayinero, south along Rt. 15 to connection with Project B-6 at Carnation Rd. ($53 M Bond Project)	$2,509,000		$701,000
	B-5	From connection to Projects A-11 and B-4 at Rt. 16 to proposed Airport Reservoir then west along Rt. 10 A to connect with Project B-1 on Rt. 1.			$2,830,000
	BR-3	North end of Airport Industrial Park. Alternate: Across Rt.16 on Perez lot.			$4,680,000
	BR-1	Site of present Mangilao Reservoir ($53 M bond project).	$1,513,000		$4,727,000
7	C-2	From connection with the existing 12-inch on Rt. 2 near Magpo Beach, south along Rt. 2 to Pagachao Reservoir. ($53 M Bond Project)	$825,000		$305,000
	CR-3	GovGuam site in Pagachao subdivision. Alternate: Rt. 4 near Ascola Sita.	$780,000		$780,000
	C-3	Upgrade Agat-Santa Rita distribution system. ($53 M Bond Project)	$4,472,000		$3,298,000
	CR-2	Near Torres School in Santa Rita. Below present Santa Rita Reservoir.			$1,560,000
	C-4	From Pagachao Subdivision to Umatac with connections to the proposed Agat/Umatac Reservoir. ($53 M Bond Project)	$1,569,000		$981,000
	CPS-2	On Rt. 2 near Tumag. Moves water from Agat/Santa Rita to the proposed Agat-Umatac Reservoir. ($53 M Bond Project)	$200,000		$315,000
	DR-7	Rt. 4 at Mt. Jumullong Manglo pass.	$145,000		$795,000
	B-10	From Agana Springs along existing power right of way to connection with Project B-9 at Rt. 8 in Mongmong.			$2,040,000
8	M-7	Oka Point Service Areas			$310,000
9	A-11	From connnection to existing 12-inch diameter main on Rt. 16 at south Fatima Street, north to connection with Project A-5, and from connection to the existing 12-inch main west of Ft. Muna, east along Rt. 16 to connection with Projects B-4 and B-5.			$580,000
10	AR-4	Site of present Dededo Reservoir ($53 M bond project).	$1,779,000		$4,461,000

PRIORITY LIST THROUGH YEAR 2000
PUBLIC UTILITY AGENCY OF GUAM
PROPOSED ISLANDWIDE WATER SYSTEM
CAPITAL IMPROVEMENTS PROGRAM

PRIORITY	PROJECT	LOCATION	Funding Source: $53 M Bond	Funding Source: Other	Funding Source: None Identified
	B-2,B-3	From Japan Plaza along San Vitores Rd. to connection with Project B-3 on JFK Rd. From connection to Project B-2 on San Vitores Rd. along JFK Rd to connection Project B-1 on Rt. 1.			$1,610,000
	AR-3	Site of present Astumbo Reservoir.	$1,779,000		$2,901,000
11	A-7	From Astumbo Reservoir outlet west to existing 12-inch main at Ysengsong Rd.			$650,000
	A-8	From connection to Project A-7 on Ysengsong Rd., south to the 12 and 14 inch diameter mains on Rt. 1.			$2,810,000
12	A-3	From proposed Agafo Gumas Reservoir south to Astumbo Reservoir.			$5,490,000
	A-4	From Astumbo Reservoir to existing 12 and 16-inch mains feeding Barrigada Reservoir at Rt. 1.			$6,130,000
13	A-12	Upgrade Macheche/Adacao distribution lines. ($53 M Bond Project)	$2,223,000		$1,277,000

PUAG WATER MASTERPLAN
PROPOSED CAPITAL IMPROVEMENTS PROGRAM

V. SURFACE WATER IMPROVEMENTS

Service Area	Project	Location	Yield (MGD)	Storage Volume (Billion Gallons)	Estimated 1991 Project Cost
D	DD-1	Ugum River	9.3	1.0	$45,700,000
	DD-2	Inarajan River	6.3	1.0	$45,700,000
		TOTAL RESERVOIR IMPROVEMENTS			$91,400,000

* * * * *

1) Surface water projects include the following improvements:

- o Land and Damages
- o Care and Diversion of Water
- o Reservoir
- o Dam
- o Spillway
- o Outlet Works
- o Access Road
- o Water Treatment Facilities
- o Construction Facilities
- o Engineering and Design
- o Supervision and Administration

2) Storage volumes required to provide indicated yield are taken from Appendix D of the "Ugum River Draft Interim Report and Environmental Impact Statement", 1979; USACOE. These yields include flows required to maintain 90 % frequency streamflow. Storage is for minimum development of respective river to meet average day demands.

3) Improvement costs are based on a cost per storage gallon rate derived from project costs presented in the Ugum River study cited above. Costs were adjusted upward to present day, Guam costs. The project costs presented in this table are order of magnitude estimates only. Thorough and updated Engineering studies for each site, which is beyond the scope of this report, must be completed for more accurate estimation of project costs.

PUAG WATER FACILITIES MASTER PLAN
PROPOSED CAPITAL IMPROVEMENTS

VI. Miscellaneous Improvements

Project	Description	Estimated 1991 Project Cost
M-1	Repair inoperable pump control valves at PUAG's existing 89 wells	$570,000
M-2	Construct emergency standby generator hook-ups at 43 pump stations and purchase 22 portable generators.	$1,370,000
M-3	Construct stationary emergency power generators in typhoon-proof buildings at 8 key well clusters.	$750,000
M-4	Replace existing water meters at 12 production wells.	$60,000
M-5	Improve approximately 730 existing fire hydrants (40% of estimated total).	$690,000
M-6	Enclose approximately 40 production well chlorination and fluoridation facilities in typhoon-proof buildings for protection from sunlight and vandalism.	$1,050,000
M-7	Provide valving in existing Oka Point distribution system to create two separate distribution networks.	$310,000
	TOTAL MISCELLANEOUS SYSTEM IMPROVEMENTS	$4,800,000

I

APPENDIX I

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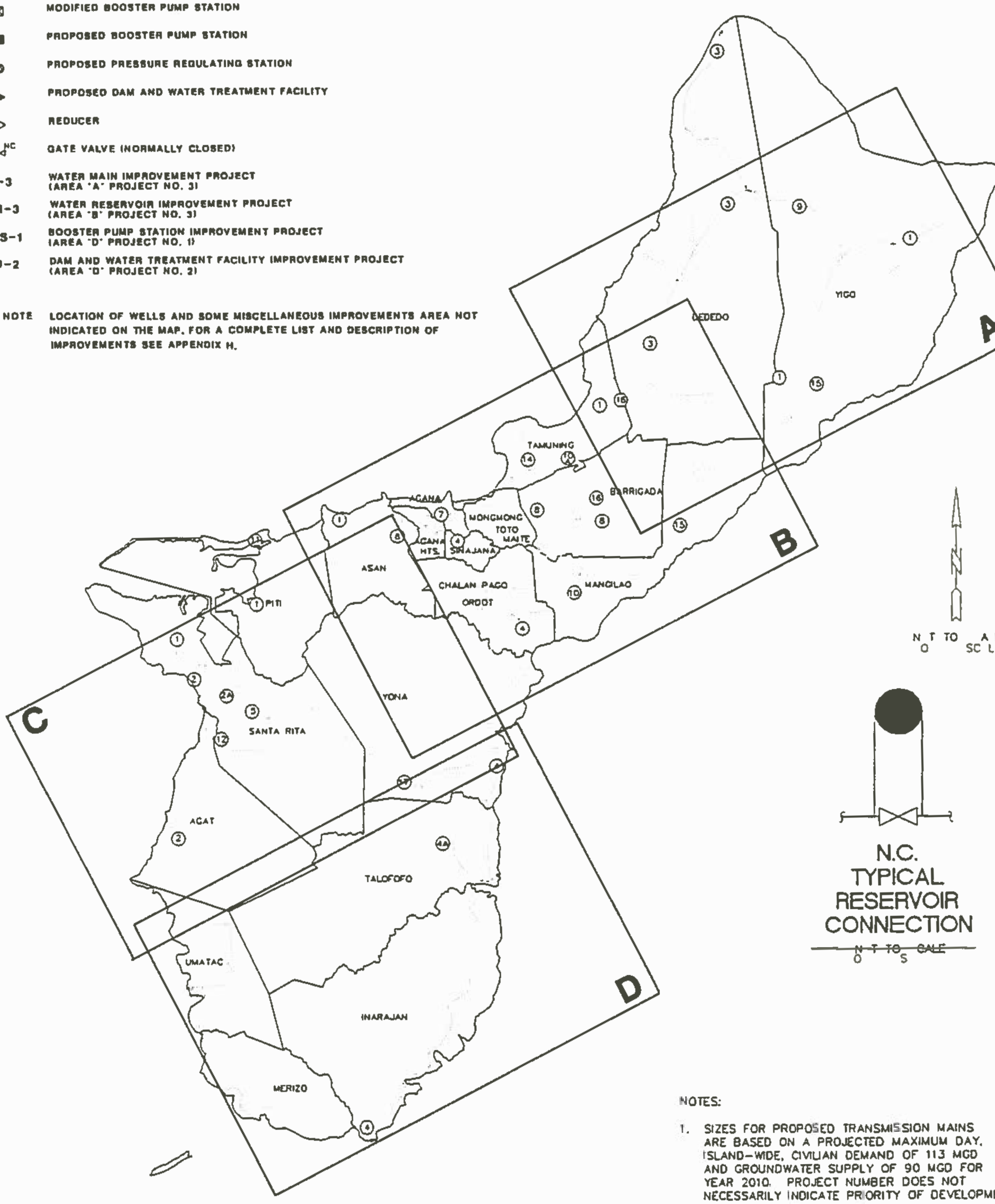
PROPOSED CAPITAL IMPROVEMENTS

LEGEND

- 8" (dotted line) — EXISTING WATER TRANSMISSION MAIN (SIZE INDICATED)
- 12" (solid line) — PROPOSED WATER TRANSMISSION MAIN (SIZE INDICATED)
- (0.2 MG) ○ — EXISTING WATER STORAGE RESERVOIR (SIZE IN MILLION GALLONS INDICATED)
- 7 MG ● — PROPOSED WATER STORAGE RESERVOIR (SIZE IN MILLION GALLONS INDICATED)
- □ — EXISTING BOOSTER PUMP STATION
- ⊠ — MODIFIED BOOSTER PUMP STATION
- ■ — PROPOSED BOOSTER PUMP STATION
- ⊙ — PROPOSED PRESSURE REGULATING STATION
- ▶ — PROPOSED DAM AND WATER TREATMENT FACILITY
- ▷ — REDUCER
- ⋈ NC — GATE VALVE (NORMALLY CLOSED)
- A-3 — WATER MAIN IMPROVEMENT PROJECT (AREA "A" PROJECT NO. 3)
- BR-3 — WATER RESERVOIR IMPROVEMENT PROJECT (AREA "B" PROJECT NO. 3)
- DPS-1 — BOOSTER PUMP STATION IMPROVEMENT PROJECT (AREA "D" PROJECT NO. 1)
- DD-2 — DAM AND WATER TREATMENT FACILITY IMPROVEMENT PROJECT (AREA "D" PROJECT NO. 2)

NOTE LOCATION OF WELLS AND SOME MISCELLANEOUS IMPROVEMENTS AREA NOT INDICATED ON THE MAP. FOR A COMPLETE LIST AND DESCRIPTION OF IMPROVEMENTS SEE APPENDIX H.



N.C.
TYPICAL
RESERVOIR
CONNECTION

NOT TO SCALE

NOTES:

1. SIZES FOR PROPOSED TRANSMISSION MAINS ARE BASED ON A PROJECTED MAXIMUM DAY, ISLAND-WIDE, CIVILIAN DEMAND OF 113 MGD AND GROUNDWATER SUPPLY OF 90 MGD FOR YEAR 2010. PROJECT NUMBER DOES NOT NECESSARILY INDICATE PRIORITY OF DEVELOPMENT.

2. LOCATION OF WELLS AND SOME MISCELLANEOUS IMPROVEMENTS ARE NOT INDICATED ON THE MAP. FOR A COMPLETE LIST AND DESCRIPTION OF IMPROVEMENTS SEE APPENDIX H.

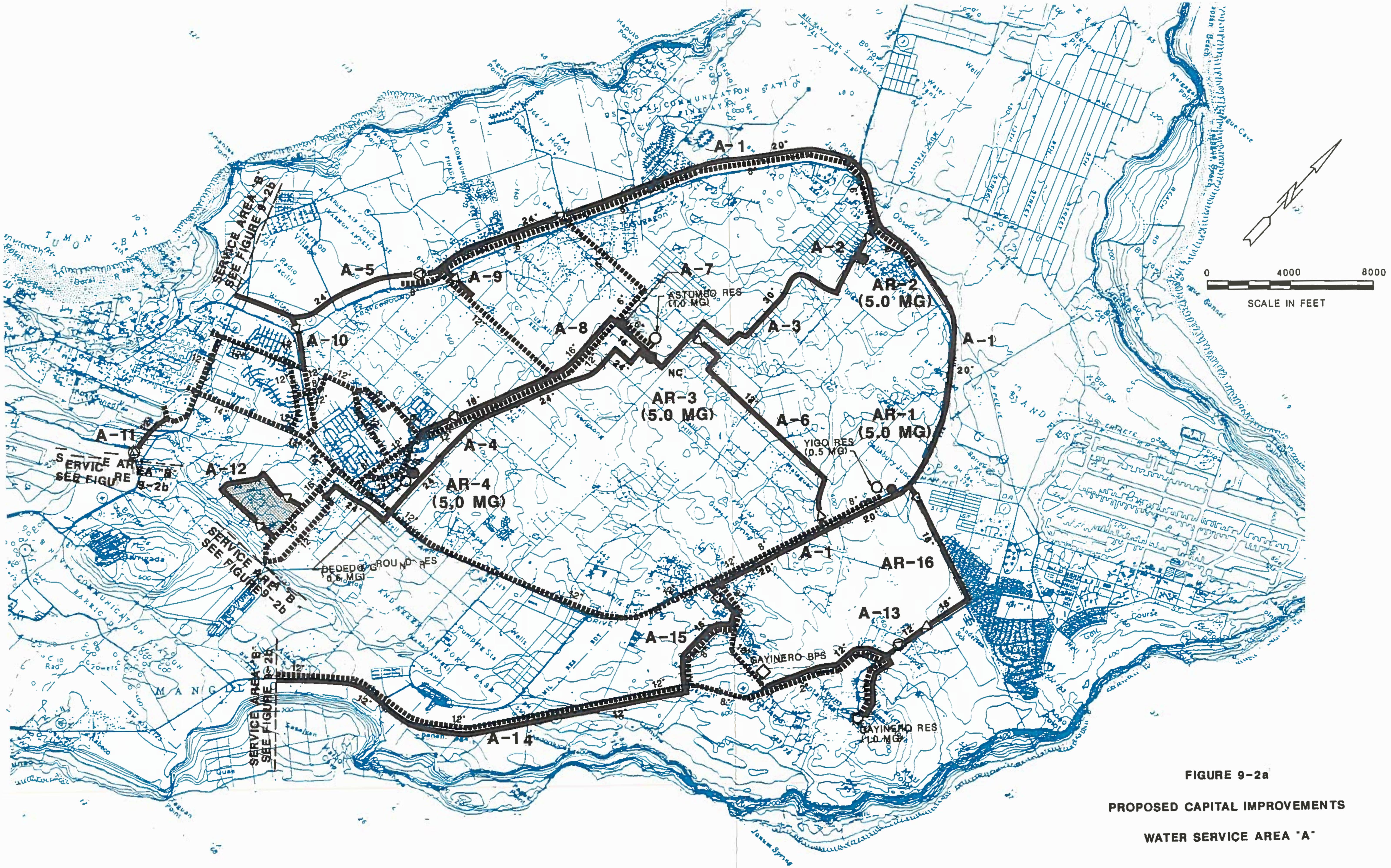


FIGURE 9-2a

PROPOSED CAPITAL IMPROVEMENTS

WATER SERVICE AREA "A"

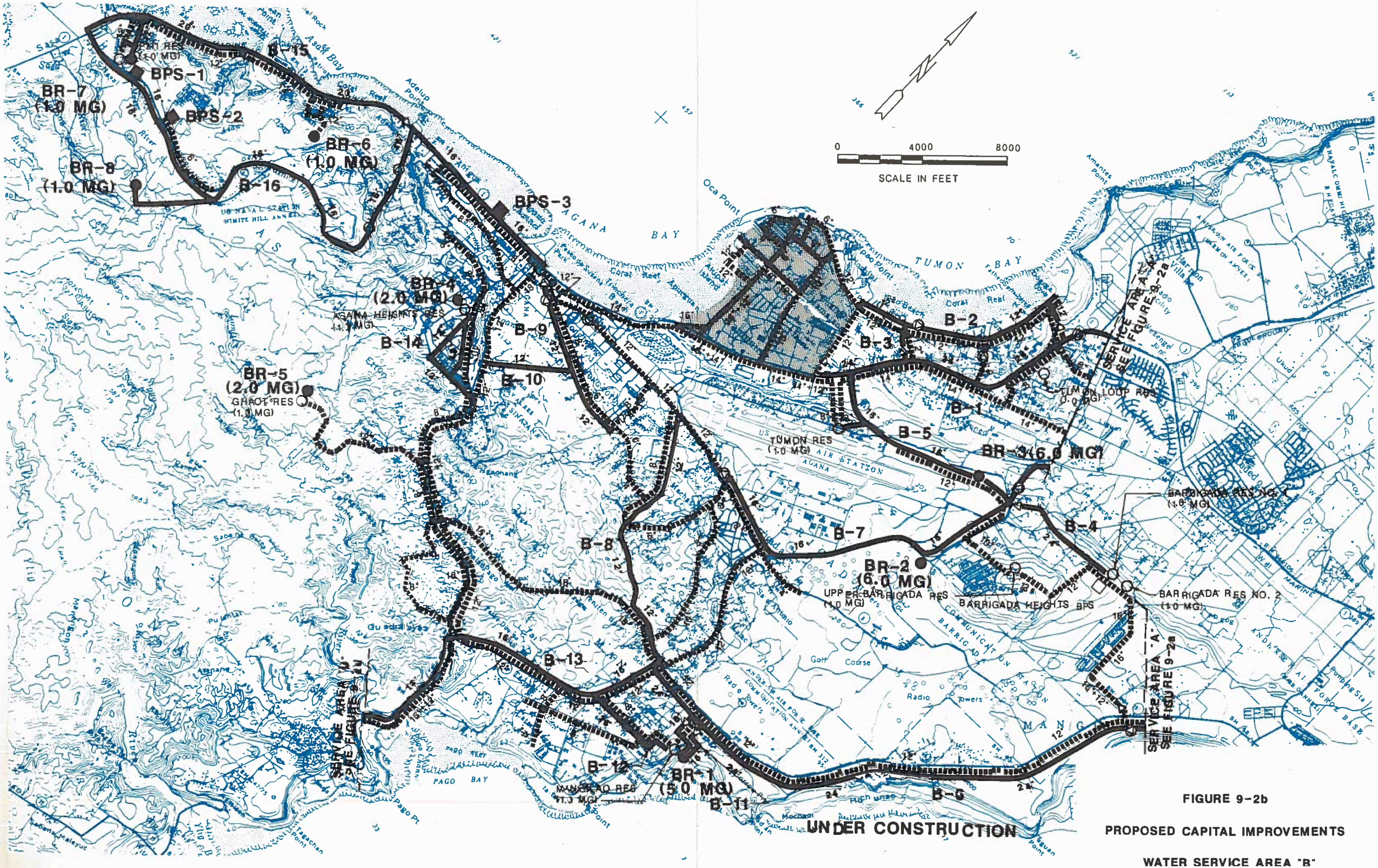


FIGURE 9-2b

PROPOSED CAPITAL IMPROVEMENTS

WATER SERVICE AREA "B"

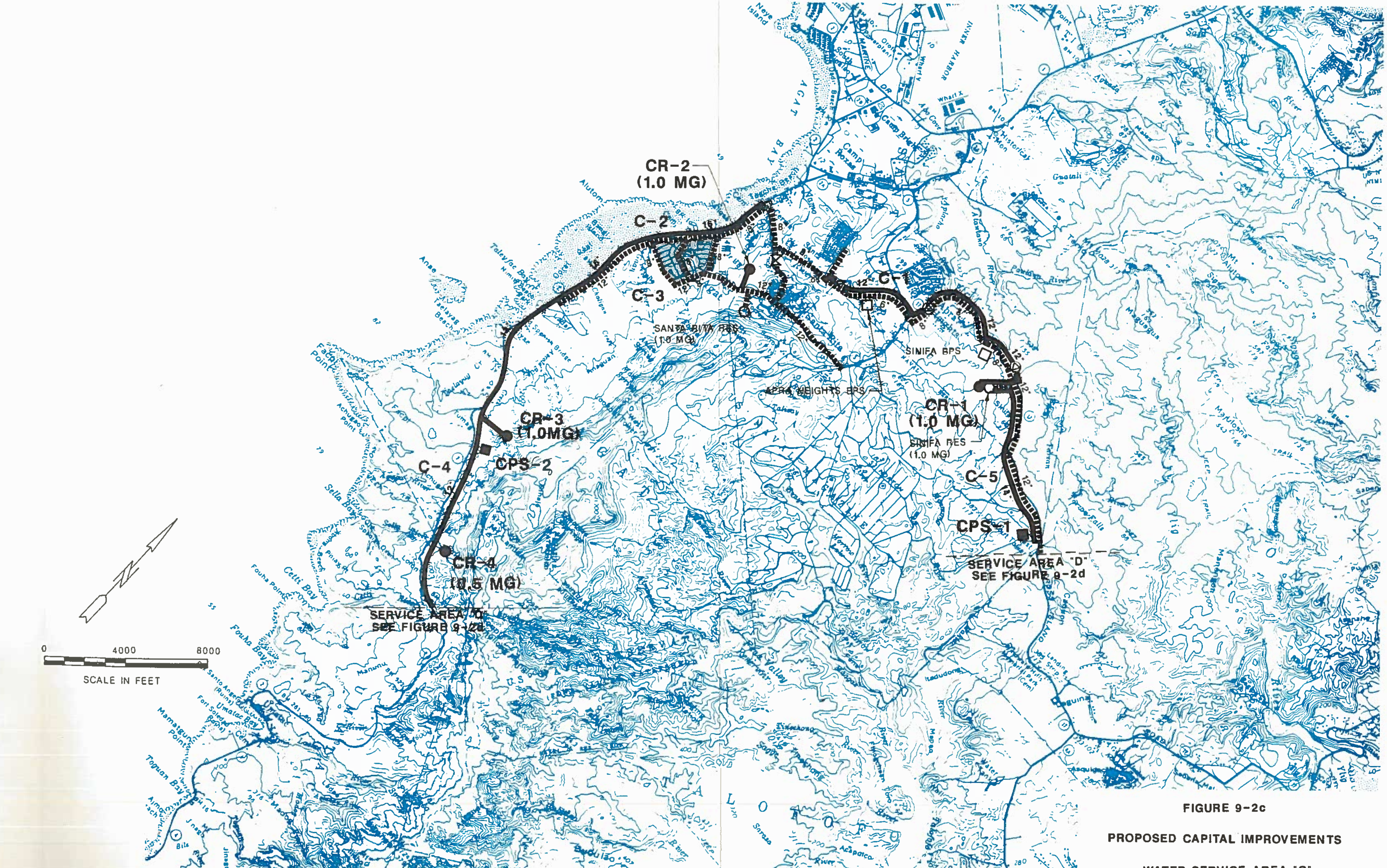


FIGURE 9-2c

PROPOSED CAPITAL IMPROVEMENTS

WATER SERVICE AREA "C"

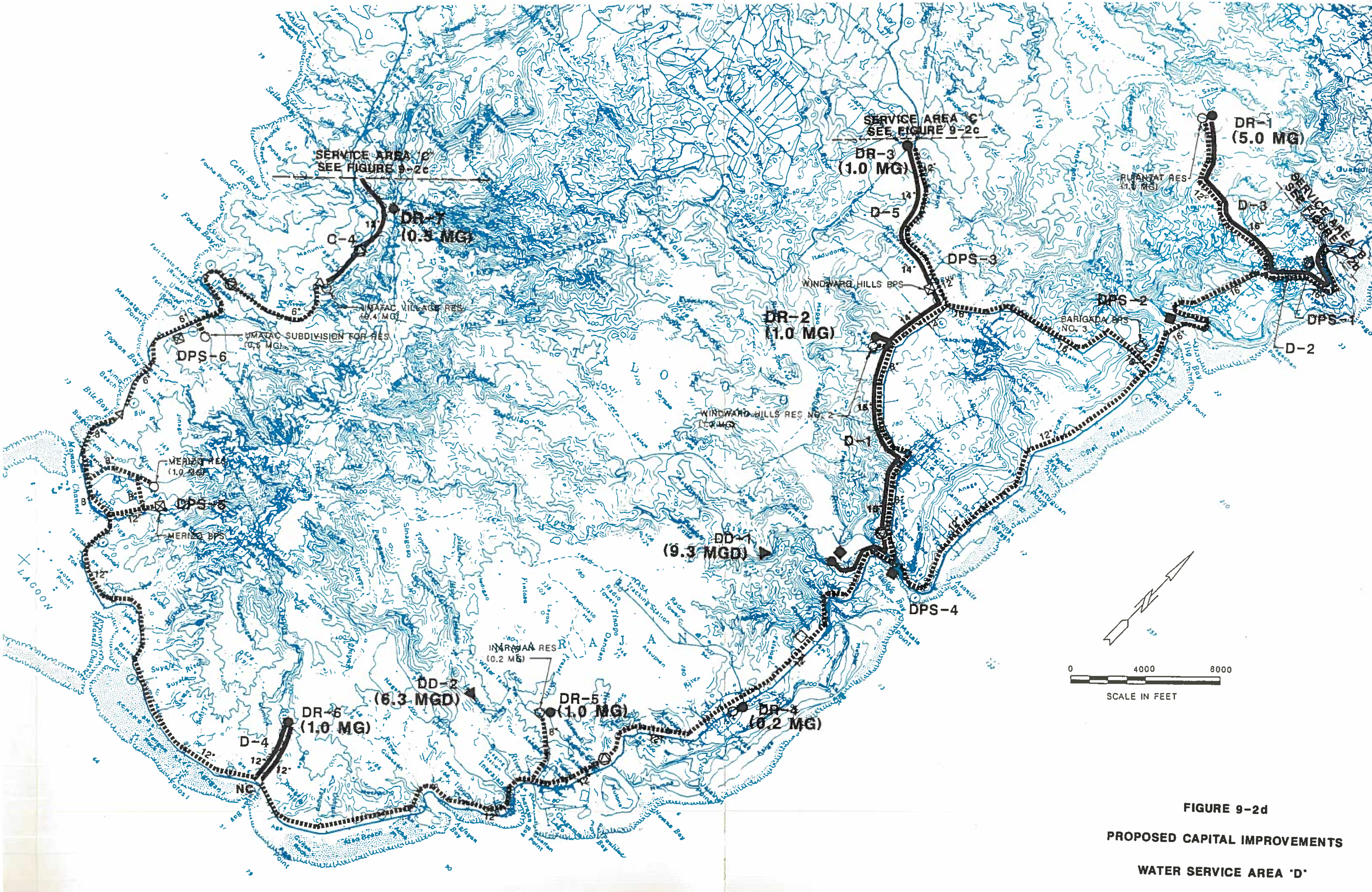


FIGURE 9-2d

PROPOSED CAPITAL IMPROVEMENTS

WATER SERVICE AREA 'D'