# BASIC DESIGN STUDY REPORT
# ON
# THE PROJECT FOR IMPROVEMENT OF WATER SUPPLY SYSTEM
# IN
# THE REPUBLIC OF PALAU

MAY, 1990

JAPAN INTERNATIONAL COOPERATION AGENGY

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# PREFACE

In response to the request of the Government of the Republic of Palau, the Government of Japan has decided to conduct a basic design study on the Project for the improvement of the water supply system in the Koror and Airai areas and entrusted the project for the study to the Japan International Cooperation Agency (JICA). A study team headed by Minori Sano, Senior Assistant to the Managing Director of Grant Aid Planning and Survey Department, was sent to the Republic of Palau by JICA from December 1 to December 25, 1989.

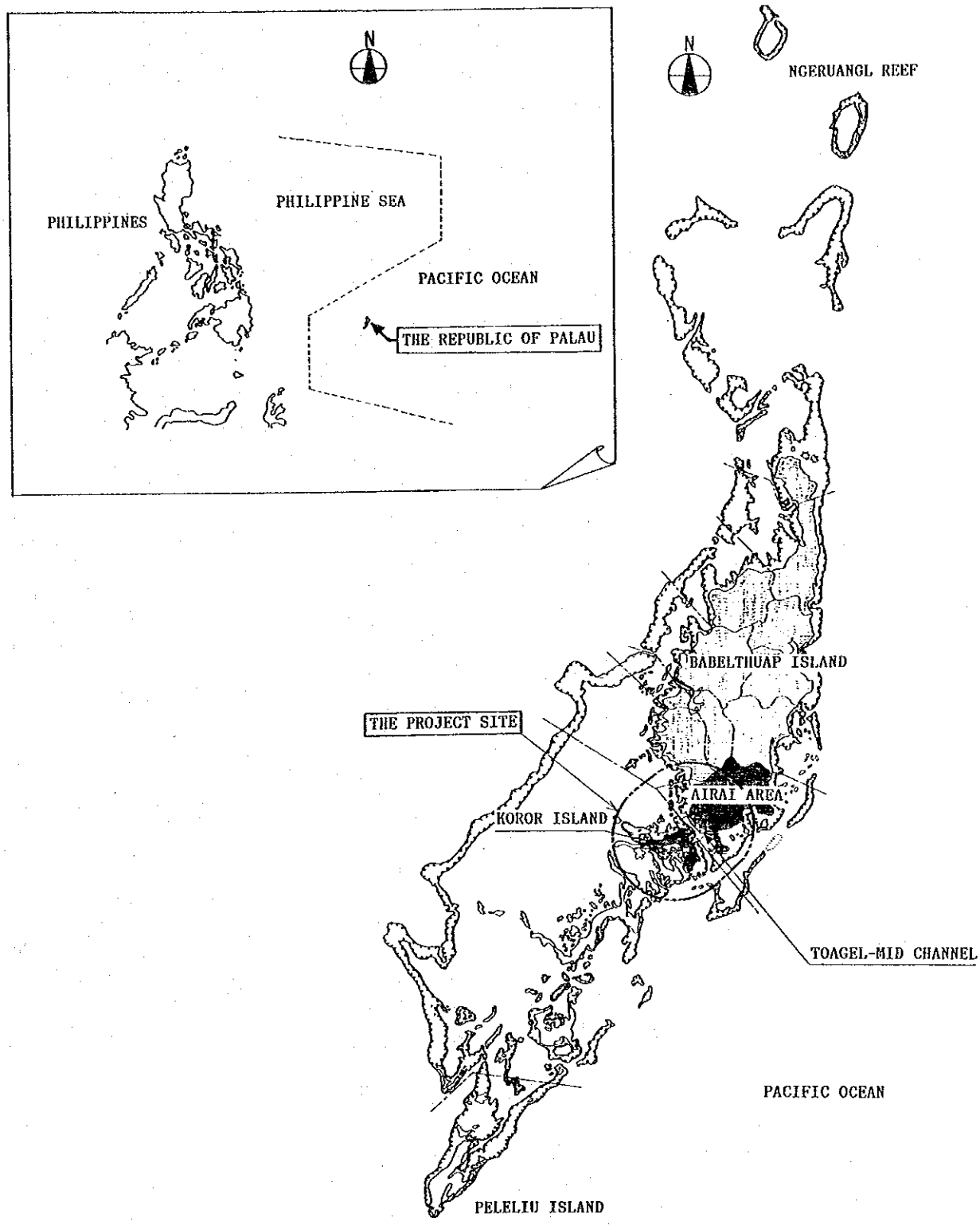
The team exchanged views with the officials concerned of the Government of the Republic of Palau and conducted a field survey in the Koror and Airai areas. After the team returned to Japan, further studies were made and a draft report was prepared. Then a mission headed by Yoshiaki Hata, Grant Aid Division, Economic Cooperation Bureau, the Ministry of Foreign Affairs, was dispatched to the Republic of Palau from April 16 to April 24, 1990 to discuss grant aid. As a result, the present report has been prepared.

I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

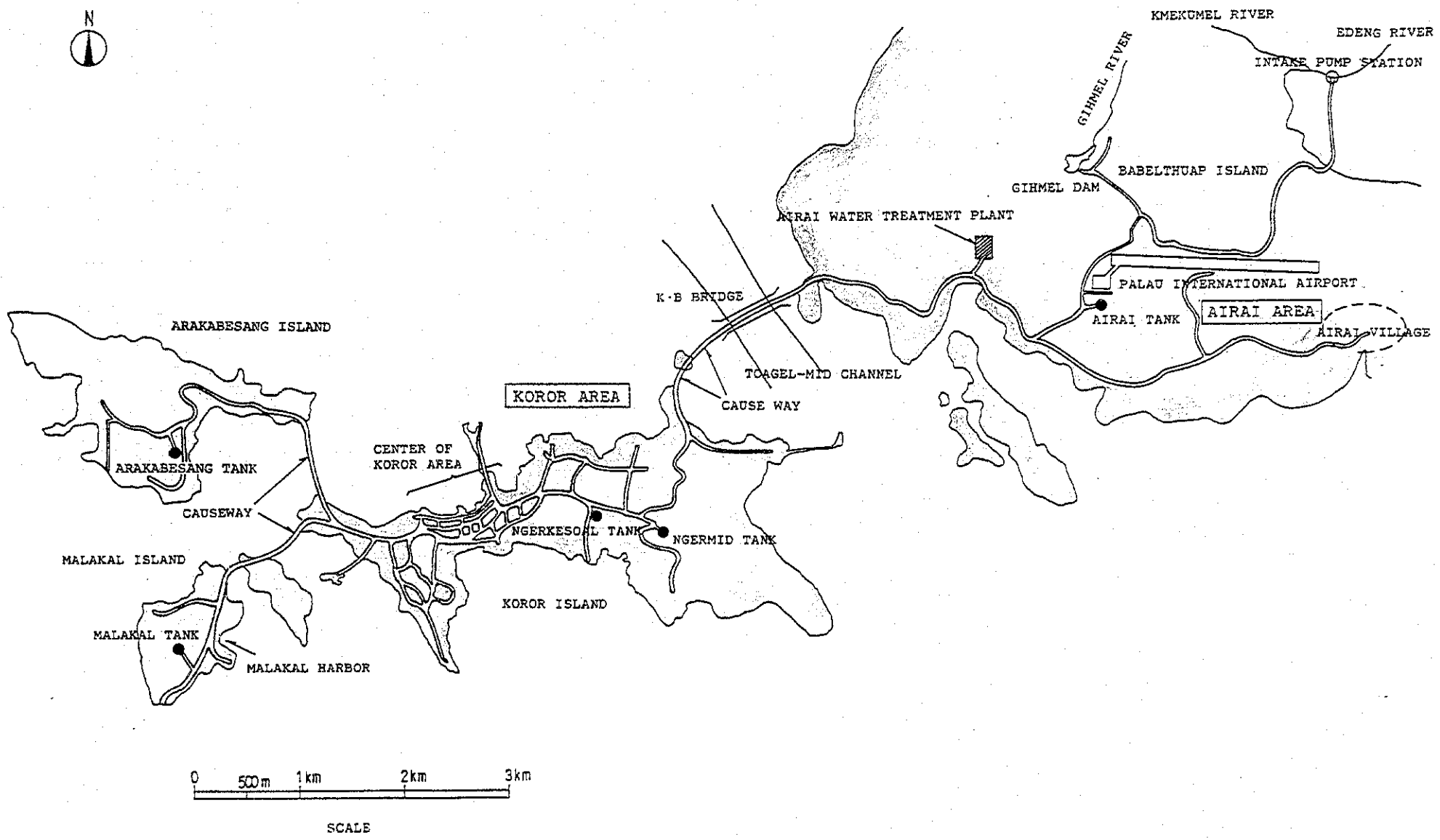
I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Palau for their close cooperation extended to the team.

May, 1990

Kensuke Yanagiya
President
Japan International Cooperation Agency




Map of the Republic of Palau




Project Site Location Map

# SUMMARY

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The metropolitan area of the Republic of Palau (hereinafter referred to as "Palau") is composed of the district centered around the Airai and Koror areas. Palau became the constitutional polity in 1981. The Koror and Airai areas have been highly developed as a center for politics, trade and tourism during the last several years. The population of these areas have sharply increased by the influx of laborers from foreign countries into these areas and tourists, and by 1986 the population reached 10,000.

However, water wasted by defects in the water supply facilities, insufficient maintenance and operation of these facilities, as well as an inefficient collection system, has led to insufficient water supply and pressure. Consequently, the water supply is shut off eight hours a day (from 21:00 to 5:00) throughout the year. However, only a small amount of water can be secured to the residential and commercial areas located in the higher areas even when water is supplied in the daytime, because of insufficient water supply quantity and pressure. Water supply is also restricted depending on the rainfall condition during the dry periods (from February to April, and from October to December).

The Government of Palau, with U.S. technical cooperation, has formulated the first five-year national development plan (1987-1991) to improve the water facilities. The improvement plan of the water supply system in the Koror and Airai area should raise the national living standard, promote hygiene, and foster industry and tourism development. However, the improvement work has not progressed as planned because of the worsening financial situation in Palau. Technical cooperation from the U.S. for the improvement plan will end in 1990.

Improvement of the water supply facilities in these two areas is a critical priority for the Government of Palau. And in June, 1988 the Government of Palau made a request to the Government of Japan for grant aid on the improvement of water supply system with the design target year set at 2000.

In response to the request, Japan International Cooperation Agency (JICA) conducted a preliminary study from September 4 - 14, 1989, on the significant impact of grant aid program and the contents of the improvement plan. And JICA dispatched a Basic Design Study Team to Palau from December 1 - 25, 1989.

In consultation with officials in Palau, the study team conducted a field survey which included 1) a survey of the present water supply condition in the Koror and Airai areas; 2) collection of relevant data and information on the Five-year National Development Plan and water supply facilities; 3) observation and evaluation of existing water supply facilities; 4) soil test excavation along the water supply pipeline route; 5) water quality tests and water pressure measurements; 6) study on the served areas and population, and the operation and maintenance of the existing facilities; and 7) a study on the local availability of construction equipment and materials. In Japan, the Study Team compiled the optimum basic design plan based on the results of the above field survey, JICA dispatched the draft final reporting team to Palau from April 16 to April 24, 1990 to explain the draft final report for improvement of water supply system.

The survey revealed that, although the average water supply quantity for the population of 13,600 is 8,000 $m^3$/day, the beneficiaries are not constantly supplied with enough water due to the defects in the water supply system. It is concluded that the Project for Improvement of Water Supply System (hereinafter referred to as the Project) is justifiable with design target year set at 2000. The study team formulated the optimum plan necessary for the implementation of the Project. An outline of the Project is as follows:

1) Raw water pipelines from the intake pump station to the Gihmel dam reservoir will be reinforced.

2) Since the existing pipelines are used both for water supply and distribution to each household, it causes excessive imbalance of the service water pressure and the water supply quantity among the served area. In the Project, new pipelines only for water supply use will be laid, and the existing pipelines will be used only for water distribution, so that water supply quantity and pressure will be equalized.

3) Water transfer pump will be installed.

This Project will rectify the defects in the system and actualize the water supply of 257 liter/day through 24 hours for each inhabitant, though the total water supply quantity will be diminished. The design criteria and an outline of the Project for Improvement of Water Supply System (by phase) is shown in the following page.

# Design Criteria and Outline of the Project for Improvement of Water Supply

## (1) Design Criteria

| | | |
|---|---|---|
| 1) Planned target year | : 2000 | |
| 2) Served population | : 10,600 | |
| 3) Total average water supply quantity | : | 5,300 $m^3$ (1.4 mil gallons/day) |
| 4) Average water supply quantity per person | : | 257 liters (68 gallons/day) |

## (2) Outline of the Project

| Construction Phase / Area / Item | PHASE I<br>Koror and Airai areas | PHASE II<br>Koror and Airai areas | PHASE III<br>Koror and Airai areas | Note |
|---|---|---|---|---|
| Water pipelines | | | | |
| 1) Planned length | 6.5 km | 7.0 km | 6.4 km | Total length: about 19.9 km |
| 2) Pipe diameter | 200 - 300 mm | 200 - 400 mm | 250 mm | |
| 3) Pipe material | Ductile cast iron pipe (DCIP) (material of aqueduct or pipeline along the wall fo causeway will be steel) | Same as left | Same as left | |
| 4) Other | Existing pipes installed along K.B.Bridge (DCIP: 300 mmø x 400 m) will be used. | | | |
| Control facilities for water tank | | | | |
| 1) Valve facilites | — | 3 sets | 1 set | Total: 4 sets |
| 2) Control facilities | — | 3 sets | 1 set | |
| Water transfer pump facilites | | | | |
| 1) Pump facilites | — | 1 (multi stage turbine pump, 1050 gpm (about 4.0 m3/min) x1) | — | |
| 2) Motor | — | 1 (100 Hp x 1) | — | |
| 3) Other | — | Removal of the existing pump 350 gpm (about 1.3 m3/min)) and replacement work of delivery pipes | — | |
| Painting of Arakabe-sang tank (inside and outside surfaces) | — | — | 1 | |

If the Project is implemented under Japan's grant aid program, the main works to be undertaken by the Government of Palau are as follows:

- Securing of sites for construction, material stockyard, temporary office, etc.
- Cleaning of the Project site area
- Installation work of water meters in houses and establishments

The cost to be undertaken by the Government of Palau for each phase is roughly estimated as follows:

| | |
|---|---|
| Phase I | US$36,000 |
| Phase II | US$36,000 |
| Phase III | US$36,000 |

The construction work period after signing of the construction contract shall be as follows:

| | |
|---|---|
| Phase I | 10.0 months |
| Phase II | 9.0 months |
| Phase III | 8.0 months |

The National Planning Council will be responsible for the proper implementation of the work to be carried out by the Government of Palau within a prescribed date, i.e., securing of sites required for all construction work related to the Project, material stock yard, and temporary office, etc. It will be important to smoothly implement the entire construction work of the Project in close communication and consultation between the Palau side and the Japan side. It is hoped that the implementation of the Project will achieve 1) the improvement of residents' daily life and health environment in the Koror and Airai areas, 2) a stable promotion for city planning, and 3) the construction of industrial and tourism facilities, therefore, contributing to the expansion of economic activities in Palau, the stabilization and improvement of citizens' livelihood. After the water is supplied for 24 hours a day and water meters are installed at every houses and establishments, a wasteful use of water will be avoided. Collection of appropriate water rates will lead to the improvement of financial condition for water works. It is significant and justifiable to construct water supply facilities and provide materials and equipment for the construction under Japan's grant aid.

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# CHAPTER 1 INTRODUCTION

# CHAPTER 1 INTRODUCTION

The Koror and Airai areas, under study for the Project for Improvement of Water Supply System, represent the metropolitan areas of Palau. The Koror area consists of Koror, Malakal and Arakabesang islands. Major public facilities such as government buildings, city halls, schools, hospitals, museums and post office, as well as residences and hotels are concentrated in Koror area. In the Airai area, located in the south tip of Babelthuap Island, there are international airport, houses and hotels.

The Koror and Airai areas are subjected to a rapid increase of population due to natural growth, the flow of population from the provincial area, the influx of labours from foreign countries in connection with the construction of urban facilities, and the increasing number of tourists to Palau. The population is especially concentrated in the Koror area, the political and economic center. About 1,000 houses, two thirds of the estimated total of 1,400 houses in the Koror and Airai areas are concentrated in the Koror area. The population, the number of houses and establishments in the Koror and Airai areas will increase in the future. Moreover, the infrastructure of the areas is still considered far from being in a satisfactory condition due to the shortage of construction funds.

The existing water facilities in the Koror and Airai areas, except for part of pipeline, was constructed between 1974 and 1990 under the U. S. assistance. However the capacity of those facilities is not sufficient for the demand of domestic use and industrial development, for quantity and quality. Further, it is difficult to secure a stable water supply in the narrow land space of the Koror area under the specific geographic conditions of having no rivers, lakes and ponds.

In the present water supply system, the water of the Edeng and Kmekumel rivers flowing through the south part of Babelthuap Island is used as raw water. The water is conveyed directly to the water treatment plant for purification, or conveyed via the storage reservoir. After purification, the water is supplied to each house and establishment by water transfer pumps directly.

The extreme shortage of water supply and pressure in the terminal areas of water distribution and highland areas is caused by the following reasons:

- the defect in the water facilities in which water is supplied from water mains to each house and establishment by water transfer pump directly.
- a wasteful use of water due to the insufficient installation of water meters, insufficient system of maintenance and insufficient system of water charge collection.

As a result, the water supply is normally restricted to 16 hours a day (from 5:00 to 21:00). Moreover, depending on the rainfall condition during the dry season, severe restrictions are imposed. For example, the water supply is shut off in the daytime.

In addition, some degradation and loss of function of water facilities are caused by the shortage of spare parts. Accordingly, an improvement in the water supply system is urgently required. The Project for improvement of water supply system in the Koror and Airai areas was proposed as a first priority under the category of the national projects in the Five-year Development Plan of Palau.

Under these circumstances, the Government of Palau has requested the Government of Japan for grant aid for the improvement of water supply system, with the target year set at 2000, for the purpose of solving the present severe water supply problems in the Koror and Airai areas. In response to the request from the Government of Palau, the Government of Japan sent a preliminary study team headed by Toru Imamura, Grant Aid Division, Economic Cooperation Bureau, the Ministry of Foreign Affairs, to the Republic of Palau from September 4 to September 14, 1989 to confirm the contents of the request and improvement policies.

The study team concluded that the improvement of water supply system with a design target year set at 2000 would be necessary. The Government of Japan has decided to conduct the basic design study. Based on this decision, JICA dispatched a basic design study team headed by Dr. Minori Sano, Grant Aid Planning and Survey Department, to the Republic of Palau from December 1 to December 25, 1989.

This study intended to evaluate the existing water supply systems, urgency and effects of the improvement of water supply system of the Koror and Airai areas requested by the Government of Palau.

In this study, the present-condition survey of water supply, water leakage, and soil test excavation along the planned route, as well as tests of raw water quality and water supply pressure were performed. The reason for the insufficient water supply was also investigated.

The study team also had discussions regarding the background of the request of the Government of Palau and objectives of the Project with officials of Palau.

After returning to Japan, the study team prepared a draft final report on the basic design study for the improvement of water supply system in the Koror and Airai areas, after examination of the present condition of water supply system, water service, operation and maintenance, and other projects related to this project. After the study team headed by Yoshiaki Hata, Grant Aid Division, Economic Cooperation Bureau, the Ministry of Foreign Affairs, explained a draft final report from April 16 to April 24, 1990 to officials concerned of Palau, the study team prepared this Basic Design Study Report on the Improvement of water supply system in the Koror and Airai areas.

The basic design study team and the draft final reporting team, study schedule, list of officials concerned of Palau and minutes of discussion are shown in the attached Appendix.

# CHAPTER 2 BACKGROUND OF THE PROJECT

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## 2-1 Outline of Palau

Palau, located in the south-west tip of Carolline Islands, about 1,000 km east off the coast of the Philippines, lies at 7°30' north latitude and 130°30' east longitude. Palau, well known for its scenic beauty, consists of the central Palau islands and four coral islands scattering in the south.

Palau's land area encompasses 492 $km^2$. Babelthuap Island (404 $km^2$), in Palau, is the largest island in Micronesia. Government offices are located in Koror area. Palau consists of more than 200 islands, of which eight are inhabited with the entire population. Except for three islands, Palau is located within a simple barrier reef, which allows for smooth exchanges within the regions and a homogeneous culture.

Palau has been ruled by four foreign countries since the 18th century, so different nationalities, manners and customs are intermixed in Palau.

Historically, Palau was a Spanish territory from 1885 to 1899 and then became a German territory from 1899 to 1914. After World War I, it was under Japanese trusteeship, and the Office of South Pacific of Japan was established. Since 1946, at the end of the World War II, it had been under U. S. trusteeship. In 1956 the national congress was established under the authority of the United States of America. The Micronesia Constitutional Establishment Committee was held in 1965, and the constitution of Palau was approved by the nation in 1980. Palau became a self-governing nation of constitutional polity in January, 1981, but foreign influence has been firmly established in the national consciousness.

(1) Socio-economic aspects

Palau's staple products include marine products, woodcraft products.

Palau's Gross Domestic Product (GDP) in 1975, 1977 and 1983 was US$15 million (about ¥2.17 billion), US$17.5 million (about ¥2.52 billion) and US$31.7 million (about ¥4.58 billion) respectively. The annual average rate of GDP growth was 9.2%. In particular, the annual average rate of growth from 1977 to

1983 was 10.5%. This rapid growth of GDP was caused by the rising prices of commodities.

Per capita GDP amount in 1983 was US$2,345 (about ¥340,000) per year. But foreign-affiliated companies are mostly involved in GDP. In particular, many Filipino seasonal workers have stayed in Palau. Therefore the actual per capita GDP amount of the nation is US$1,716 (about ¥240,000) per year. The revenue and expenditure of Palau are US$14.5 million (about ¥2.1 billion) and US$26.6 million (about ¥3.84 billion) respectively. A deficit in revenue has been covered by assistance from the U. S.

(2) Language

The main language spoken throughout Palau is the Palau language. The people on the islands speak different dialects of the Palau language. Approximately 500 people in the south-west islands speak a language similar to the language on Truk Island. Therefore the constitution of Palau has set both of these languages as the national language. English is widely spoken in Palau, and the older population who were residing during the Japanese trusteeship can speak Japanese.

(3) Population

According to the latest population census held in 1986, Palau's population, including 2,000 Palau nationals living abroad, was about 15,000. The population of the Koror and Airai areas was about 9,500 and 1,000, respectively. 70% of Palau's population is found in the Koror and Airai areas. In particular, Koror area has been developed as the center for politics, trade and tourism during the last several years. The population growth in Koror was high, at 3.5%, while that in Palau as a whole was 0.7%. This was attributed to the rapid influx of the population from rural areas and the increasing number of tourists.

## 2-2 Outline of the Related Projects

### 2-2-1 Outline of the national development plan

The Government of Palau has formulated the First Five-year Development Plan (1987-1991) as a great step for creating a society based self-determination and equality for achieving the long-term goal of self-reliance.

The national development objectives which provide the basis for this Plan includes the following:

- lay the foundations for achieving the long-term goal of self-reliance based on a free market economy
- develop the full potential of natural resources through controlled utilization, which will lead to the expansion of exports to earn foreign exchange and thus meet increased domestic demands for improved living standards
- develop, to the maximum extent possible, manpower resources through increased training programs and new jobs
- achieve a balanced growth and development among the States, as well as income generating opportunities for the population
- protect the environment and preserve the cultural heritage of country

The Government of Palau divided the first Five-year Development Plan into four sectors; economic development, infrastructure, social and government, to formulate the national development plan.

Development budgetary allocation/requirements by sector are shown in Table 2-1. The allocations and requirements by sector of development expenditure show that the existing infrastructure, including transportation, energy, water and sewerage, account for the largest share of expenditure (63.8% of the total planned development expenditure during the Plan period). Improvement of the infrastructure is heavily weighted in the First Five-year Development Plan.

Table 2-1 Development Budgetary Allocations/Requirements by Sector, FY1987-FY1991

(Units: US$1,000)

| SECTORS | 1987 | 1988 | 1989 | 1990 | 1991 | Total | Percent |
|---|---|---|---|---|---|---|---|
| ECONOMIC SECTORS | 2246 | 2038 | 1618 | 1368 | 1573 | 8843 | 9.3 |
| – Manpower Development | 30 | – | – | – | – | 30 | – |
| – Agriculture | 604 | 461 | 136 | 156 | 86 | 1443 | 1.5 |
| – Marine Resources | 640 | 590 | 345 | 30 | 105 | 1710 | 1.8 |
| – Mineral Resources | 125 | 50 | 50 | 50 | 50 | 325 | 0.3 |
| – Tourism | 327 | 187 | 187 | 132 | 132 | 965 | 1.0 |
| – Industry and Commerce | 20 | – | – | – | – | 20 | – |
| – Banking | 500 | 750 | 900 | 1000 | 1200 | 4350 | 4.6 |
| INFRASTRUCTURE SECTORS | 11337 | 9070 | 13500 | 12668 | 13865 | 60440 | 63.8 |
| – Transportation | 3979 | 1000 | 3250 | 5020 | 6450 | 19695 | 20.8 |
| – Telecommunication & Postal | 562 | 1645 | 250 | 398 | 165 | 3020 | 3.2 |
| – Energy | 1630 | 1625 | 3000 | 4500 | 5500 | 16255 | 17.2 |
| - Water and Sewer | 4600 | 3800 | 3800 | 2050 | 1050 | 15300 | 16.1 |
| – Government Facilities/Housing | 550 | 1000 | 3200 | 700 | 700 | 6150 | 6.5 |
| – Environm./Pollution Control | 20 | – | – | – | – | 20 | – |
| SOCIAL SECTORS | 6719 | 6705 | 6216 | 1780 | 1851 | 23271 | 24.6 |
| – Health Services | 5375 | 5365 | 4864 | 359 | 359 | 16320 | 17.2 |
| – Education | 1223 | 1296 | 1305 | 1374 | 1444 | 6642 | 7.0 |
| – Youth & Community Develop. | 20 | – | – | – | – | 20 | – |
| – Cultural Affairs | 101 | 46 | 47 | 47 | 48 | 289 | 0.3 |
| GOVERNMENT SECTOR | 1542 | 520 | 120 | – | – | 2128 | 2.3 |
| – Public Safety | 1197 | – | – | – | – | 1197 | 1.3 |
| – Legal and Judicial Service | – | 300 | – | – | – | 300 | 0.3 |
| – Civil Service | 45 | – | – | – | – | 45 | – |
| – Other Government Services | 300 | 220 | 120 | – | – | 640 | 0.7 |
| Total | 21,844 | 18,333 | 21,454 | 15,816 | 17,289 | 94,736 | 100 |

(Source: The Five-year Development Plan of Palau)

The national development plan by sector as shown in Table 2-1 is summarized below:

(1) Economic development

- Agricultural development
  US$1.44 million (about ¥208 million) is allocated to agriculture development to develop farms, train agricultural workers and supply food.

- Marine resources development
  The Government is paying particular attention to the marine resources development. The marine resources development budget accounts for 19.3% of the total expenditure for economic development sectors. US$1.71 million (¥250 million) is allocated to this marine resources development. The Government plans to educate personnel engaged in deep sea development and marine product industries.

- Mineral resources development
  Although the development of mineral resources is limited, the Government is attempting to establish working regulations for private sector employees who can collect phosphatic mineral and bauxite, promote assistance to landowners and foreign-affiliated companies and introduce new technologies.

- Banking
  The Government policy favors banks which finance the development of domestic industries, including, agriculture, industry, fishery, and tourism.

- Industry, commerce, and community development
  At present, the profitability of industry and commerce is unclear because of the small scale. However, the Government has set up policy to educate those who are engaged in particular businesses and encourages the advanced training and education for self-reliance.

(2) Infrastructure sectors

- Transportation
  The budget for roads (US$20.8 million (¥2.89 billion)) accounts for the largest expenditure (32.6%) for the infrastructure sectors. Road improvement is given high priority. The budget for road improvements has increased year to year.

The Government plans to improve the mooring facilities for marine transport at islands other than Koror Island.

- Telecommunication
  The budget for telephones accounts for only 5% of the total expenditure in the infrastructure sectors, but the Government plans to promote a more sophisticated telecommunication system.

- Energy
  The budget for energy (US$16.3 million (about ¥2.35 billion)) accounts for 26.9% of the total expenditure for the infrastructure sectors . This budget has increased annually. The improvement of transmission lines in Babelthuap Island, under Japan's grant aid, is one of the major projects in this area.

- Water and sewer
  The budget for water and sewerage projects (US$15.3 million (about ¥2.21 billion)) accounts for 25.3% of the total expenditure for infrastructure sectors. This project will improve the existing water supply and sewer facilities in the Koror and Airai areas and rural areas. The breakdown of the planned development allocations for water and sewerage is shown in the following table.

Year-to-year allocations planned for water supply facilities improvement projects in the Koror and Airai areas have declined from a high share in 1987, because of the water projects in rural areas and Malakal/Arakabesang sewerage treatment projects implemented between 1987 and 1989. Loss of water from wasteful use, bad water quality of Airai water treatment plant and insufficient storage capacity of Gihmel dam (raw water storage reservoir for the Koror and Airai areas) are pointed out in the Five-year Development Plan.

Planned Development Allocations for Water and Sewer, FY1987-FY1991

(Units: US$1,000)

| Project | 1987 | 1988 | 1989 | 1990 | 1991 | Total |
|---|---|---|---|---|---|---|
| WTP Modification | - | - | - | 450 | 450 | 900 |
| Koror/Airai Well Development | 300 | - | - | - | - | 300 |
| Koror/Airai Water System Modif I | 200 | - | - | - | - | 200 |
| Koror/Airai Water System Modif II | 300 | 300 | - | - | - | 600 |
| Rural Water System Project | 2000 | 1000 | - | - | - | 3000 |
| Malakal STP Expansion | - | 1000 | 2000 | 1000 | - | 4000 |
| Project I | 1500 | 1000 | - | - | - | 2500 |
| Arakabesang Sewer Project II | - | - | 1000 | - | - | 1000 |
| House Sewer Connection II | 200 | 200 | - | - | - | 400 |
| House Sewer Connection III | - | - | 500 | 300 | 300 | 1100 |
| Outdoor Sanitary Facilities Project | 100 | - | - | - | - | 100 |
| Rural Sanitation Project | - | 300 | 300 | 300 | 300 | 1200 |
| Sanitary Landfill (Modif & Expan.) | 30 | 35 | 40 | 45 | 50 | 200 |
| Total | 4630 | 3835 | 3840 | 2095 | 1100 | 15500 |

(Source: the Five-year Development Plan of Palau)

- Government facilities/housing

  The Government allocated US$6.15 million (about ¥890 million) for setting up a new capital in the 1989 budget and started a full-scale study. The Ministry of Housing has started to provide low-interest loans to finance housing for low-income earners.

- Environment/pollution control

  The Government plans to establish the Bureau of Environmental Preservation for protecting the environment and monitoring pollution, in cooperation with the Bureau of Public works which is responsible for sewer systems.

(3) Social sectors

- Health services

  The health services account for the largest budget allocation with a total of US$16.32 million (about ¥2.36 billion) or 70.1% of the total expenditures for the social sectors, of which US$14.5 million (about ¥2.1 billion) is allocated

for the establishment of a new hospital during the next three years. After the establishment of the new hospital, the Government will continue to study methods for improving health services in rural areas.

- Education
  The highest priority is given to the upgrading of schools in each state during the next three years.

2-2-2 Development project of rural area

The Government is planning a rural water project to develop the water system for all areas outside of the Koror and Airai areas, especially Babelthuap, Pelellu, Kayangel and the south-west islands. The population in these rural areas is about 5,000 which represents about 33% of the total population in Palau. This development project will improve the health of residents and local sanitation, as well as develop the rural economy.

2-2-3 Development project of the Koror and Airai areas

The Government is planning the large-scale developing of housings and hotels in the Koror and Airai areas, based on the long-term national plan (5 - 15 years from now.) The Government has already secured some land for developing, including land in Koror Island near K. B. Bridge and Arakabesang Island. Therefore the development project for hotels should proceed in the future.

## 2-3 Existing Water Facilities and Water Projects

### 2-3-1 Existing Water Facilities and Related Problems

#### 2-3-1-1 Outline of existing facilities

The water supply facilities for Koror and Airai areas, except for a 1.5 km length of pipe laid during the Japanese trusteeship, was constructed between 1974 and 1984 with U.S. assistance. New construction and further improvements were also undertaken between 1989 and 1990 with U.S. assistance.

The existing water facilities, including intake facilities, raw water storage reservoir (Gihmel Dam), water treatment plant, transfer pump station, pipelines, water tanks and water distribution facilities, are outlined below. Refer to Table 2-2 and Figure 2-1 for further details.

Raw water is supplied to the water treatment plant, by three submerged pumps (150 HP), installed at the intake pump station, via a 300-mm diameter asbestos cement pipeline. The intake pump station is located at the junction of Edeng River and Kmekumel River in the Airai area of Babelthuap Island. The water from the intake pump station can also be supplied to the raw water reservoir, Gihmel Dam, by operating the diverting valves on the asbestos-cement pipeline. Another 400-mm diameter asbestos cement pipeline, has been constructed from the higher elevation Gihmel Dam to the water treatment plant by gravitational flow. When Gihmel Dam reaches capacity during the rainy season, a 400-mm pipeline is used to supply raw water to the water treatment plant. In the dry season, raw water is supplied directly from the intake pump station to the water treatment plant by a 300-mm pipeline.

After treatment through 4 filters, raw water is supplied to the Koror and Airai areas by four transfer pumps, two rated at 1.3 $m^3$/ minute and two at 4.0 $m^3$/ minute. Originally, it was designed for water to be stored in two 3,800 $m^3$ and two 1,900 $m^3$ capacity tanks in the Koror area, and in a 3,800 $m^3$ tank in the Airai area, and then supplied to individual users.

Although the system is uncomplicated, the existing facilities are not fully utilized because of the problems outlined below.

- Water pumped directly from the water main to consumers
- Low water pressure

- Insufficient management and maintenance
- Insufficient billing and collection system
- Waste by individual houses and establishments

2-3-1-2 Improvement projects to date

Improvement projects for the existing water facilities to date are summarized below.

(1) 1976 - 1980 improvement projects

1) Installation of three automatic valveless gravity sand filters at the water treatment plant
2) Construction of water pipelines
   - From water treatment plant to Airai tank
   - From water treatment plant to Ngerkesoal and Ngermid tanks
   - From the above tanks to the entrance of the pipeline constructed around 1940
   - From the end of the above pipeline to Arakabesang and Malakal tanks
3) Installation of the following water tanks
   - Airai tank
   - Ngerkesoal tank
   - Ngermid tank
   - Arakabesang tank
   - Malakal tank

(2) 1983 - 1984 improvement projects

- Construction of intake pump station
- Construction of raw water pipeline (300 mm diameter) from intake pump station to Gihmel dam
- Construction of raw water pipeline (400 mm diameter) from Gihmel dam to the water treatment plant

(3) 1989 - 1990 improvement projects

- Installation of one additional intake pump, capacity 5.3 $m^3$/minute (1,400 gpm)

- Reinforcement of electrical transmission line to intake pump station
- Repairs of pipes at Gihmel Dam
- Installation of one additional automatic valveless gravity sand filter, capacity 2.65 $m^3$/minute (700 gpm)
- Construction of water pipeline for Ngesaol and Edeng areas

2-3-1-3 Future Improvement Plan

Future plans for the improvement of the water supply system based on the Five-year Development plan are described below.

(1) The Government of Palau's request for Japan's grant aid to improve the water supply system of Palau (hereinafter referred to as the project)

(2) Future conception
The following are under consideration for the future

- Removal of the accumulated soil from the Gihmel dam reservoir and increase the capacity of the reservoir
- Installation of a pre-treatment facility such as a clarifier to improve the quality of supplied water

2-3-1-4 Problems of Existing Facilities

(1) Intake facilities
Intake facilities include diversion weir, intake pumps and raw water pipeline. The existing problems for each facility are listed below.

1) Diversion weir
The diversion weir can intake water from the Edeng River and Kmekumel River. The diversion weir, constructed of stone (2 m high by 10 m long) was built in 1989, 40 meters downstream from where the two rivers merge to increase the amount of raw water intake. There are no problems either in the scale or functioning of the diversion weir.

2) Intake pump station
The intake pump station was constructed between 1983 and 1984, 300 m upstream from where the Edeng and Kmekumel Rivers merge on the Edeng River side. One additional intake pump was installed in January, 1990 to

increase the capacity of the raw water intake. However, the following problems exist at the facility.

a. River discharge

The daily average discharge at the intake pump station of the Edeng and Kmekumel Rivers was measured and found to be 65 times greater than the target year plan of 5,300 $m^3$ (approximately 1.4 million gallons) per day water supply, according to discharge statistics from the past 8 to 14 years. Even with flow fluctuations, the river flow amount seems more than adequate. However, in 1983 an unusual situation occurred where the maximum discharge was only 60 % of the planned water supply quantity. If this unusual situation reoccurs, there is a possibility that the planned water supply quantity can not be drawn from Edeng and Kmekumel Rivers for a short period of time.

The average discharge from the rivers at the intake pump station is estimated at 99,600 $m^3$ (26 million gallons) a day, according to actual discharge survey data collected by the U.S. for 14 years at Edeng River and 8 years at Kmekumel River.

Edeng River Average Discharge

Q1 = 31.7 $ft^3$/second x 60 x 60 x 24

= 2,739,000 $ft^3$

= 77,600 $m^3$ (20.5 million gallons)/day

Kmekumel River Average Discharge

Q2 = 8.96 $ft^3$/second x 60 x 60 x 24

= 774,000 $ft^3$

= 22,000 $m^3$ (5.8 million gallons)/day

Average discharge = Q0 = Q1 + Q2 = 99,600 $m^3$ (26 million gallons)/day

The minimum discharge of these rivers is estimated at 3,130 $m^3$ (0.83 million gallons)/day, according to the above discharge observation data.

Minimum discharge of Edeng River during April 15 - 17, 1983, according to discharge data of 14 years

Q1' = 1.1 $ft^3$/second x 60 x 60 x 24
= 95,000 $ft^3$
= 2,690 $m^3$ (0.7 million gallons)/day

Kmekumel River's minimum discharge during April 14 - 17, 1983, according to five-year discharge data

Q2' = 0.18 $ft^3$/second x 60 x 60 x 24
= 15,500 $ft^3$
= 440 $m^3$ ( 120,000 gallons)/day

Minimum discharge = Q0' = Q1' + Q2' = 3,130 $m^3$ (830,000 gallons)/day

b. Intake pump

- An additional pump, capacity 5.3 $m^3$ (1,400 gallons)/ minute, was installed in January, 1990, bringing the total to three pumps, which can intake the quantity of raw water necessary to meet the target year's water supply.

- The electrical power for the intake pump station is supplied by overhead electrical transmission lines, which run 20 km through dense jungle and hill areas. When these transmission lines were cut by trees that fell during strong winds, 20 to 30 hours were required for power restoration.

c. Raw water pipeline

At the intake pump station site, the daily average discharge is 65 times the planned supply. However, the existing water pipelines are mainly used to supply raw water from the intake pump station directly to the water treatment plant. There is no pipeline to supply raw water from the intake pump station to the reservoir, Gihmel Dam, so the water is wasted as discharge.

(2) Raw water reservoir (Gihmel Dam)

1) Water from Gihmel, Edeng and Kmekumel rivers is stored at Gihmel Dam, a gravity-type concrete dam. The planned water storage capacity of 94,6000 $m^3$ (25,000,000 gallons) decreased to 75,000 $m^3$

(20,000,000 gallons) because of accumulated soil and damage to a rubber dam.

2) A rubber dam (height 60 cm, length 15.2 m), was constructed at the top part of the tailrace in 1969 to increase the reservoir potential of Gihmel Dam, but was removed after it was damaged.

3) Various water sources are necessary to secure a sufficient water supply. U.S. assistance project was extended in 1989 - 1990 to secure a stable water supply from groundwater. Three wells, capable of 0.23 $m^3$ (60 gallons)/ minute, were dug at the Gihmel dam site.

(3) Water treatment plant and water transfer equipment

1) At the water treatment plant, four automatic valveless gravity filters have been installed. The filters should not be a problem because they require minimal electricity, are simply constructed, function well and are easily operated and maintained.

2) Since there is no pre-treatment facility, such as a settling basin, water is sent directly from the intake pump to the filters. Particularly during the rainy season, the water combines with silt from the Edeng and Kmekumel river beds and becomes muddy. When water is sent directly from the intake pump to the filters, the filters frequently clog with soil. The filters must be cleaned by backwashing with much water, consequently the water supply drops. In the dry season, filters are backwashed once or twice a day for five minutes, so the water wasted through discharge is small.

3) Inadequate Water Storage Reservoir

The reservoir which stores water for the transfer pump has a capacity of only 300 $m^3$, so it cannot function as a storage reservoir, leading to the problems listed below.

- The amount of supplied water is limited to the capacity of the filter.
- A decline in filtering capacity leads to a drop in the water supply.

- Supplying water to meet morning and evening peak water usage is difficult.

4) The filter's treatment capacity is 2.65 $m^3$/ minute (700 gallons/ minute) for each of four machines. But, for the reasons stated above, they are only functioning at 70% of its designed capacity. At present, American filter sand is used. Filter sand cannot be supplied domestically since Palau Island is largely formed of laterite, aged and weathered basalt. Consequently, filter sand is not sufficiently replaced because of a shortage in maintenance funds.

5) The four existing water transfer pumps, two large (4.0 $m^3$ (1,050 gallons) / minute) and two small (1.3 $m^3$ (350 gallons)/ minute) have the following problems.
   - The functioning of the two small pumps has decreased because of deterioration and abrasion from continuous operation.
   - Since the total head and capacity for the large and small pumps differ, standard operation of the pumps is difficult.
   - The actual capacity of the pumps is reduced because of a lack of spare parts and maintenance tools. Damaged water meters are left unattended and water supply data is incomplete.
   - Since the water transfer pump has no automatic control function, so it must be operated manually over three shifts for continuous 24-hour service.
   - Since a daily operations record is kept by operating personnel, water supply quantity can be estimated from the discharge pressure of the pump and summarized as follows. The discharge pressure of the pump is rated at 125 psi, but operates from 100 psi during the day time to 145 psi at night.

     a) From 9 p.m. to 5 a.m.,
     operating pumps: two 1.3 $m^3$/ minute, two 4.0 $m^3$/ minute

     b) From 5 a.m. to 9 p.m.,
     operating pumps: two 1.3 $m^3$/ minute, one 4.0 $m^3$/ minute

(4) Water transfer-distribution pipelines

1) Water is transferred and distributed by one pipeline. The capacity of the booster pump for the water tank is insufficient, leading to the problems described below.

- In the served area near the treatment plant, the water supply and water pressure are sufficient. However, since water is freely used by the residents and establishments of the served area near the treatment plant, it has caused an imbalance leading to extreme shortages of water supply and pressure insufficiencies for areas distant from the treatment plant.

- Water cannot be stored at Malakal and Arakabesang tanks, located at the edge of the served area, because of the insufficiency in supply and pressure.

- The water supply and distribution pipeline valve for the Airai area, located in the center of the served area, is closed between 9 p.m. and 5 a.m. During the suspension, water is transferred to Ngerkesoal and Ngermid tanks to meet the peak morning water use. However, since the capacity of the booster pump for Ngermid tank is insufficient, water is supplied to Ngerkesoal at 50%, and to Ngermid at 15% of their respective capacities. Thus water supply for the morning peak demand is insufficient.

An anticipated increase in future construction of public facilities and housing in the upstream area will aggravate the already imbalanced water supply condition.

(5) Water Tank

1) Water tank operation

Although five water tanks for distributing water were originally planned for water distribution, only Ngermid and Ngerkesoal tanks are partially functioning, and the other three tanks are not functioning.

a) Arakabesang tank

This tank has not been able to store water since its construction due to insufficient water pressure.

b) Malakal tank

Since the water supply quantity and pressure is insufficient, this tank has never stored water at the water supply facilities. There is a nearby concrete tank constructed during the Japanese trusteeship, which temporarily stored water from the mountain riverbed, and water was transferred from this concrete tank to Malakal tank. However, this facility has deteriorated so it can no longer be utilized. Since the Malakal tank valve has been closed, water remains in the tank.

c) Ngerkesoal tank

Water is transferred to the Ngerkesoal tank by suspending water supply to residents in the Koror Island urban area, Arakabesang, Malakal Islands and Airai area from 9 p.m. to 5 a.m. However, the tank is filled only to half of its capacity.

d) Ngermid tank

As in above, water is transferred to Ngermid tank between 9 p.m. and 5 a.m. However, since the tank is about 80 meters above sea level, the water transfer pump pressure is insufficient, so a booster pump is used to send water. However, since the capacity of the booster pump is relatively smaller than that of the tank, water is stored at only 15% of the tank's capacity.

e) Airai tank

Because the tank is near the water treatment plant, water supply pressure is high and for a short time the tank is filled. However, the tank valve remains closed for the following reasons, and the tank cannot be used.

- Generally, the inlet valve to the tank is automatically opened and closed according to the water level in the tank. However, the Airai tank valve is manually operated so it continuously supplies water even when it is full, leading to overflow.

- The valve needs to be opened and closed manually, according to the water level of the tank. It is very difficult to operate the valve everyday, so the valve for the Airai tank remains closed.

2) Condition of Water Tanks

All the tanks are made of steel. The steel plate and anchor bolts have not been damaged. However, since construction (1974 - 1975) touch-up painting for the inside and outside has not been done, so spot corrosion is evident on the surface. Furthermore, a 2 meter-stretch from the ground and along the edge of the roof has shown some damage. If it is left as it is, corrosion on the outside will progress rapidly. To prevent corrosion and maintain Arakabesang tank as a safe tank for high water quality, it is necessary to repaint. The interior of the tank needs to be repainted before storing water to prevent corrosion and maintain Arakabesang tank as a safe tank for high water quality. Since the area around the tank is profuse with weeds and trees, it needs to be cleared and maintained to prevent damage and maintain safety..

3) Condition of Tank Valve

The sluice valve in the distribution pipeline to the five water tanks is the same kind of manually operated device as found at the Airai tank. To improve the water supply system it is necessary to change to an automatic valve, which opens and shuts according to the water level.

(6) Condition of Water Supply Pressure

Water pressure has been measured at 22 points along the water pipelines between the treatment plant to the edge of the served area. The measurement locations and results are contained in the appendix, "Field Report", Table AN-1 and Figure AN-3 (1/2), (2/2). The maximum water pressure near the water treatment plant is about 7.0 kg/cm$^2$ (100 psi). However, at the minimum pressure, no water flows to the highland area of Koror Island. This water pressure imbalance is caused by the defective water supply system which allows water to be taken from the upstream area and water waste. In addition, the water pressure is insufficient for the difference in ground elevation. For these reasons, a drop in the water pressure occurs in areas far from the water treatment plant. Thus, water cannot be stored at the

water tanks, and the water supply condition on Arakabesang and Malakal Islands is poor.

(7) Condition of Water Supply Quantity

Since the actual water supply quantity cannot be directly measured, the water transfer pump discharge pressure and pump operation data is taken from the daily operation record of the water treatment plant, and data from two flow meters on the Airai side of the K.B. Bridge are used to estimate the water supply quantity at the water treatment plant in the Airai area. From this data, the amount of supplied water fluctuates between 4,500 $m^3$ (1.2 million gallons) to 8,300 $m^3$ (2.2 million gallons)/day, according to the filtering capacity, (number of machines in operation, time) water transfer pump capacity and the number of times the filter is backwashed.

(8) Water Leak Condition

Inspection for leakage has been carried out along the water pipelines from the water treatment plant to the edge of the served area. For the reasons described below, leakage is minimal.

1) The existing water pipelines in Koror Island, except for a 1.5 km pipeline constructed during Japanese trusteeship in 1940, was constructed between 1974 and 1980 and are not thought to have worn out or been damaged. Construction periods for the existing water pipelines are shown in Figures 2-2 and 2-3.

2) Sections of the pipeline constructed during the Japanese trusteeship were removed and abandoned in a field in the K.B. bridge area. After inspection, they do not appear to have been worn out or damaged at all.

3) Since the soil quality of the project site area is clay-like, permeability is low. If a leak were to occur, water would normally come to the ground or road surface. However, in this area, there is no evidence of leakage points on the road or slope.

4) A geological survey conducted along the existing water pipeline, with test holes at 21 sites revealed no leakage.

5) The leakage condition for the pipeline, which links each island in the Causeway area, was examined at low tide when the entire foundation was visible, but no leakage was found.

6) Since construction, there have only been six minor leaks from 1980 to 1987, all of which were repaired soon after detection. The source of the leak are shown in Figure 2-4.

7) Only minor damage to the rubber connecting hoses of the distribution branch pipes to individual houses and businesses was found, and leakage was minimal.

8) The Bureau of Public Works repairs leaks soon after detection.

9) Each household has a small water tank installed, and during water supply time, water is stored for personal use. Since water is not being supplied continuously, it is troublesome to open and close the valve, so the valve is left open and the water tank eventually overflows. Palau is trying to prevent such waste, but has yet to find an effective solution.

10) Leakage can be measured by existing flow meters installed in the water pipelines. An investigation using the two methods described below found almost no leakage. Locations of the existing flow water meters are shown in Figure 2-5 and Figure 2-6.

    a) Comparison of metered flows of both sides of the K.B. Bridge

    To detect possible water leakage in the pipelines, actual measurements of flow meters installed on both sides of the K.B. Bridge were taken at 9 a.m., when water transfer to Ngermid and Ngerkesoal tanks begins, and at 5 a.m., at the completion of the water transfer. The average difference of this data for 8 hours is 85 $m^3$ (22,500 gallons), approximately 3% of the water transferred. Refer to Figure 2-3 for details.

    Since water in this area is utilized for different purposes including, residential, business, industrial and agricultural, different quantities

of water need to be supplied to the consumers. There is little leakage in this area. The actual amount of water supplied can not be measured at homes and businesses without flow meters.

b) Comparison of metered flows and the water stored at Ngermid and Ngerkesoal tanks

The actual measurements of flow meter (Inabo flow meter) installed on Koror side of the K.B. Bridge were taken at 9 a.m. and at 5 a.m to detect possible water leakage in the pipelines. The average difference of the measurements of flow meter and the water quantities stored at Ngermid and Ngerkesoal tanks for 8 hours is 33 $m^3$ (8,900 gallons). Refer to Figure 2-4 for details.

Since there are about 30 residences, businesses and farms in this area, different quantities of water needs to be supplied to these consumers. There is very little leakage evident. The actual amount of water supplied can not be measured for consumers without flow meters.

(9) Condition of Water Quality

1) Water quality testing standards

Raw water is supplied from the Edeng and Kmekumel Rivers. There are few people in these river basins, and during the dry season, the water is clear and the water quality is good. However, the water quality deteriorates when laterite soil enters the water during the rainy season. The water supply facility is not adequately supervised. After filtering, a gravitational infuse of hypochlorite disinfects the water. However, the quality of the water is not fully controlled.

A wide sampling of raw water, filtered water and water supplied to households (12 samples) was gathered just before returning to Japan for the testing of quality in accordance to Japanese water quality standards, as specified in the Waterworks Law of Japan. Sampling sites for testing are shown in Figure 2-7.

2) On-site testing results of raw and water quality

Electric conductivity (EC) was measured by a simple electric conductivity meter to determine the salt concentration and contents of organic matter. The water quality was determined to be good because the measurement values were small and of little variance. The sampling locations, test purpose and electric conductivity data are listed below.

| Sampling site | Test purpose | EC value |
|---|---|---|
| Junction of Edeng and Kmekumel Rivers: 1 sample | Intake site water quality | 84 µs/cm |
| Gihmel Dam (Storage reservoir): 1 sample | Storage reservoir water quality | 96 µs/cm |
| Existing treatment plant: 1 sample | Existing treatment plant purification capacity | 85 µs/cm |
| Households: 9 samples | Existing water supply system water quality* | 90 - 100 µs/cm |

*including whether groundwater or dirty water has entered the pipeline

3) Results of raw and processed water quality testing conducted in Japan

The same samplings described above were also tested in Japan.

Common germs and colon bacillus were detected in the raw and filtered water samplings, but were not detected in the chlorinated water.

Some metal contents were detected in the raw and filtered water because the existing water treatment plant is insufficient. Iron (0.38 mg/l) and zinc (0.05 mg/l) were present in the filtered water. The water tasted and smelled of iron because iron is present in the laterite of the intake river area. A pre-treatment facility, such as a clarifier should be installed at the water treatment facility, since these microscopic metal bits can pass through the filter. A chlorination device, which can automatically infuse a chlorine proportionally to the water level, should also be installed.

(10) Condition of installed water meters

Although water is distributed to 2,054 locations, functioning water meters are only installed at 50% (1,037) of the these locations, as shown below. Since the number of installed meters is insufficient, the wasting of water by households and establishments is neither supervised nor prevented, and water cannot be billed according to use. Furthermore, the inhabitants do not understand the need for water conservation. These factors have led to an insufficient water supply for the Koror Island urban district hills, Arakabesang and Malakal islands.

Water supply consumers and installed water meters

| Area | No. of water service consumers | No. of installed water meters | Unmetered water supply* |
|---|---|---|---|
| Koror area | 1,754 | 1,037 | 717 |
| Airai area | 300 | 0 | 300 |
| Total | 2,054 | 1,037 | 1,017 |

*This figure includes installed but damaged meters

(Source: Bureau of Public Works)

(11) Condition of administration and maintenance

1) Insufficient water meters

As explained in (10), functioning water meters are not installed at all houses and businesses.

2) Deficiencies in billing system

Since functioning water meters are only installed at 50% of homes and businesses, a billing system for collecting the charges from consumers based on the amount of water used has not been organized. The present water billing system is as follows.

- Basic charge: $5.00/month
- Water meter charge: $0.50/1,000 gallons

The inspection of water meters and collection of payment are under the jurisdiction of the utility collection agency in the Ministry of

Administration. However, the rate of collected charges is only 54% of total water usage. Only payment for the basic charge, and not for the corresponding use of water, can be collected from homes and businesses where no meter is installed. The total amount of charges collected in the most recent three years, is shown below. If bill collection based on water usage was complete, the National Treasury would expect an annual revenue of $300,000. However, at present annual revenue is $110,000.

Results of water payment collection

(Unit: US$)

| | 1987 | 1988 | 1989 |
|---|---|---|---|
| Basic charge payment collection | 22,205 | 21,790 | 236,315 |
| Meter charge payment collection | 88,611 | 98,581 | 82,609 |
| Total: | 110,816 | 120,381 | 108,924 |

(Source: Bureau of Public Works)

3) Wasted water

When water supply is available in the daytime, individual households and businesses store water in personal tanks, so these tank valves are usually kept open and the tanks overflow, leading to a waste of water. In the evening, when water supply is normally suspended, each household and business use water which has been stored in the tanks.

The detection and prevention of wasted water by monitoring individuals known to waste water, conservation campaign and education activities have proven ineffective.

4) No vehicle is available for the inspection, maintenance and repairs of the water facilities, or the monitoring and education to prevent water waste.

Table 2-2 Summary of Existing Water Facilities

| | Equipment | Quantity | Measure |
|---|---|---|---|
| (1) Intake facilities | | | Average flow: 99,600 $m^3$ (26 million gallons)/day |
| | Raw water intake pump | 3 | Pump capacity: 5.3 $m^3$ (1,400 gallons)/minute<br>Motor: 150 HP<br>(one standby machine) |
| | Raw water pipe between intake and Gihmel Dam | 5,100 m | Pipe diameter: 30 cm (12-inch) asbestos cement pipe |
| (2) Raw water storage reservoir (Gihmel Dam) | Gravity Dam | 1 | Planned storage capacity: 94,600 $m^3$ (25 million gallons)<br>Present storage capacity: 75,700 $m^3$ (20 million gallons) |
| | Raw water pipe between Gihmel Dam and water treatment plant | 1,800 m | Pipe diameter: 40 cm (16-inch asbestos cement pipe) |
| | | 1,800 m | Pipe diameter: 30 cm (12-inch asbestos cement pipe) |
| (3) Water treatment plant | Filter | 4 | Diameter: 6 m (20 feet)<br>Type: automatic valveless gravity filter<br>Capacity: 2.65 $m^3$ (700 gallons)/minute |
| | Filter supply pump | 3 | Pump capacity: 2.65 $m^3$ (700 gallons)/minute<br>Motor: 15 HP |
| | Generator | 2 | Rated output: 300 kVA |
| | Water transfer pump | 2 | Pump capacity: 1.3 $m^3$ (350 gallons)/minute<br>Motor: 40 HP |
| | | 2 | Pump capacity: 4.0 $m^3$ minute (1,050 gallons)/minute<br>Motor: 100 HP |
| (4) Water transfer pipe | Between water treatment plant and Airai tank | 1,800 m | Pipe diameter: 20 cm (8-inch) asbestos cement pipe |
| | Between water treatment plant and Arakabesang and Malakal storage tanks | 6,700 m | Pipe diameter: 20 cm (8-inch) asbestos cement pipe |
| | | 8,400 m | Pipe diameter: 30 cm (12-inch) asbestos cement pipe |

continued

| | | | |
|---|---|---|---|
| | Section installed along K.B. Bridge | 400 m | Pipe diameter: 30 cm (12-inch) ductile cast-iron pipe |
| (5) Water tanks | Airai tank | 1 | Capacity: 3,800 $m^3$ (1.0 million gallons) Diameter: 22.5 m, height: 9.6 m |
| | Ngermid tank | 1 | Capacity: 3,800 $m^3$ (1.0 million gallons) Diameter: 20 m, height: 12 m |
| | Ngermid tank booster pump | 1 | Pump capacity: 0.95 $m^3$ (250 gallons)/minute Motor: 10 HP |
| | Ngerkesoal tank | 1 | Capacity: 3,800 $m^3$ (1.0 million gallons) Diameter: 22.5 m, height: 9.6 m |
| | Arakabesang tank | 1 | Capacity: 1,900 $m^3$ (0.5 million gallons) Diameter: 17.0 m, height: 8.4 m |
| | Malakal tank | 1 | Capacity: 1, 900 $m^3$ (0.5 million gallons) Diameter: 17.0 m, height: 8.4 m |
| (6) Well | Gihmel Dam area | 3 | Pump capacity: 0.23 $m^3$ (60 gallons)/minute, each |
| | Water treatment plant area | 1 | Pump capacity: 0.25 $m^3$ (65 gallons)/minute |
| | Ngerias area | 1 | Pump capacity: 0.32 $m^3$ (85 gallons)/minute |
| | Arakabesang area | 3 | Pump capacity: 0.09 $m^3$ (25 gallons)/minute, each |

Table 2-3 Flow meter measurements and net measurements between Airai and Inabo flow meters

(units: gallons)

| Date | Time | Airai diacharge | | Inabo discharge | | Net discharge |
|---|---|---|---|---|---|---|
| | | Integrated meter reading | Discharge ① | Integrated meter reading | Discharge ② | ① - ② |
| 12/27/89 | 9:00 p.m. | 243,553,000 | 873,000 | 184,268,000 | 843,000 | 30,000 |
| 12/28/89 | 5:00 a.m. | 244,426,000 | | 185,111,000 | | |
| 12/28/89 | 9:00 p.m. | 245,348,000 | 865,000 | 186,028,000 | 841,000 | 24,000 |
| 12/29/89 | 5:00 a.m. | 246,213,000 | | 186,869,000 | | |
| 12/29/89 | 9:00 p.m. | 247,900,000 | 691,000 | 188,421,000 | 678,000 | 13,000 |
| 12/30/89 | 5:00 a.m. | 248,591,000 | | 189,099,000 | | |
| 12/30/89 | 9:00 p.m. | 249,899,000 | 770,000 | 190,320,000 | 747,000 | 23,000 |
| 12/31/89 | 5:00 a.m. | 250,669,000 | | 191,067,000 | | |
| 12/31/89 | 9:00 p.m. | 251,989,000 | | 192,294,000 | | |
| | | | 799,750 (average) | | 777,250 (average) | 22,500/8 hours = 2,813/hour (10.6 $m^3$/hour) |

Table 2-4 Discharge measurement values and net discharge measurement between Inabo and Ngermid and Nberkesoal tanks

(units: gallons)

| Date | Time | Inabo flow integrated meter reading | Inabo measured flow ① | Ngermid flow integrated meter reading | Ngermid measured flow ② | Inflow to Ngerkesoul tank ③ | Residual water in pipeline ④ | Net flow ① - (② + ③ + ④) |
|---|---|---|---|---|---|---|---|---|
| 12/27/89 | 9:00 p.m. | 184,268,000 | 843,000 | 203,333,000 | 149,000 | 505,916 | 40,292 | 148,512 |
| 12/28/89 | 5:00 a.m. | 185,111,000 | | 203,482,000 | | | | |
| 12/28/89 | 9:00 p.m. | 186,028,000 | 841,000 | 203,534,000 | 141,000 | 577,367 | 40,292 | 82,341 |
| 12/29/89 | 5:00 a.m. | 186,869,000 | | 203,675,000 | | | | |
| 12/29/89 | 9:00 p.m. | 188,421,000 | 669,000 | 203,688,000 | 150,000 | 443,025 | 40,292 | 45,683 |
| 12/30/89 | 5:00 a.m. | 189,099,000 | | 203,838,000 | | | | |
| 12/30/89 | 9:00 p.m. | 190,320,000 | 747,000 | 203,,901,360 | 157,640 | 541,281 | 541,281 | 17,787 |
| 12/31/89 | 5:00 a.m. | 191,067,000 | | 204,059,000 | | | | |
| 12/31/89 | 9:00 p.m. | 192,294,000 | | 204,126,000 | | | | |
| | | | 775,000 (average) | | 149,410 (average) | 541,217 (average) | | 71,081/8 hours = 8,885/hour (33.6 $m^3$/hour) |

## 2-3-2 Organization, Personnel and Budget

### (1) Organization for Operation and Maintenance

The organization in charge of the water supply project is shown in Table 2-5. The Bureau of Public Works is under the Ministry of National Resources as shown in Figure 2-8. The Bureau of Public Works manages the facilities for the water system, sewer system, telephones, and electricity, as well as the promotion of construction of roads, ports and harbors. The Bureau of Public Works employs 156 people, as shown in Figure 2-9.

The construction, operation and maintenance of the existing water facilities is administered and managed by the departments shown in Table 2-5. The Ministry of National Planning, which is directly under the president, is in charge of the construction. The Water Supply Branch of the Division of Utilities, which is under the Bureau of Public Works, is in charge of the operation and maintenance of the water system. The Ministry of Administration is in charge of bill collection. The Water Supply Branch is composed of 20 personnel, including 18 who are in charge of the Koror and Airai areas, as shown in Table 2-6. However, since only three personnel are knowledgeable about the existing water system and facilities, the water facilities specialist personnel are insufficient. Presently, two American supervisors, who have the necessary technical knowledge, are staying to provide technical advice for maintenance and operation. Furthermore, since the budget of the Bureau of Public Work is managed by the government, the financial self-sufficiency of the water project is difficult to achieve.

Table 2-5 The Division of Construction, Operation, and Management

| | Construction | Operation and Maintenance | Sales |
|---|---|---|---|
| Charged section | Bureau of National Planning | Bureau of Public Works Water Supply Branch, Division of Utilities | Ministry of Natural Resources Billing Department |
| Work | Planning, design and execution of work | Water facilities, operation and maintenance | Meter inspection<br>Bill Collection |

Table 2-6 Water System Branch Personnel (as of 1989)

| Name | Position |
|---|---|
| 1. A. Remoket | Trades Specialist |
| 2. U. Debelot | Plumber Foreman |
| 3. M. Moses | Plumber |
| 4. N. Senardo | Plumber |
| 5. I. Ngelwong | Plumber |
| 6. S. Rechirikl | Plumber Foreman |
| 7. L. Antonio | Plumber |
| 8. M. Petrus | Plumber |
| 9. J. Ngieraklang | Plumber |
| 10. D. Ngiraibai | Plumber |
| 11. H. Renguul | Plumber |
| 12. M. Daniel | Plumber |
| 13. T. Tesei | WTR P. Operator |
| 14. N. Blesoch | Equipment Operator |
| 15. J. Meledang | Equipment Operator |
| 16. T. Rengiil | Mechanic |
| 17. R. Isaac | Tradesman |
| 18. M. Telei | Plumber |
| 19. J. Belibei | WTP Operator (Angaur State Water System) |
| 20. H. Eungel | WTP Operator (Melekeok State Water System) |

(2) Budget

The operation and maintenance budget of the water facilities is described as follows. Although $223,614 (¥34,200,000) has been budgeted for 1990, a large share of this is taken up in personnel expenses, so little remains for the operation, maintenance, and the purchasing of tools and spare parts for the facilities. The Government of Palau is making a substantial cuts in the budget requested by the Bureau of Public Works, since the National Budget is insufficient. However, budget improvements need to be made for the organization of the operation and maintenance of the water facilities after the implementation of this project.

The Water Facilities Operation and Maintenance Budget

| Year | 1988 | 1989 | 1990 |
|---|---|---|---|
| Annual budget | US$164,312 (¥24.9 million) | US$228,987 (¥34.3 million) | US$223,614 (¥34.2 million) |

(Source: Bureau of Public Works)

## 2-4 Details and Contents of the Request

(1) Details of the Request

Koror area, the capital of Palau, has been the center for politics, trade and tourism and over the last several years. Development in this area has led to an influx of foreigners, which has increased the population by 3.5% annually, while the national population has only risen by 0.7%. Airai area has also shown the same kind of growth, and the population of both areas is anticipated to increase from 10,000 people in 1986 to 20,000 by the year 2000, including seasonal workers and residents.

At present, water supply is suspended from 9 p.m. to 5 a.m. throughout the year. However, water is still wasted because of defects in the water facilities, insufficient maintenance and operation of the facilities, and an inefficient system of billing and collections. In the higher elevation residential and commercial areas very little water can be secured even when the water supply is available during the daytime because of insufficient water supply and pressure. Water supply is also restricted during the dry season depending on the rainfall, when water supply and pressure develop into a serious problem. The ordinarily high temperatures and humidity makes the daily

life of residents harsh, and seriously affects the development of business and tourism.

Palau's current First Five-year Development Plan (1987 - 1991) has progressed in the development of the Koror and Airai areas. However, by the target year 2000, the estimated water supply will be seriously insufficient. The Government of Palau has requested to the Government of Japan for grant aid on the improvement of the water supply system to meet the target year 2000.

In response to the Government of Palau's request, the Government of Japan dispatched a study team to conduct a preliminary study on the feasibility, impact and necessity for the water supply improvement plan. The study team concluded that the grant aid for the implementation of this plan would provide a stable water supply for the Koror and Airai areas, contribute to hygienic environment for the residents, and lead to an anticipated expansion of the society and economy.

(2) Contents of the request

The request involves correcting the water supply condition of the Koror and Airai areas, by improving the existing water facilities, as described in detail below.

1) Construction of emergency power generators for the intake pumps
   Two 300 kW machines

2) Construction of a water pipeline from the intake pump station to Gihmel Dam.
   Ductile cast-iron pipe: diameter: 400 mm, length: 6,200 m

3) Construction of water transfer pipeline under the sea from the water treatment plant to Koror area
   Ductile cast-iron pipe: diameter: 400 mm, length: 5,000 m
   Steel pipe (under the sea): diameter: 400 mm, length: 500 m

4) Construction of water transfer pipeline for Koror area
   Ductile cast-iron pipe: diameter: 400 mm, length: 3,380 m
   Ductile cast-iron pipe: diameter: 300 mm, length: 7,430 m

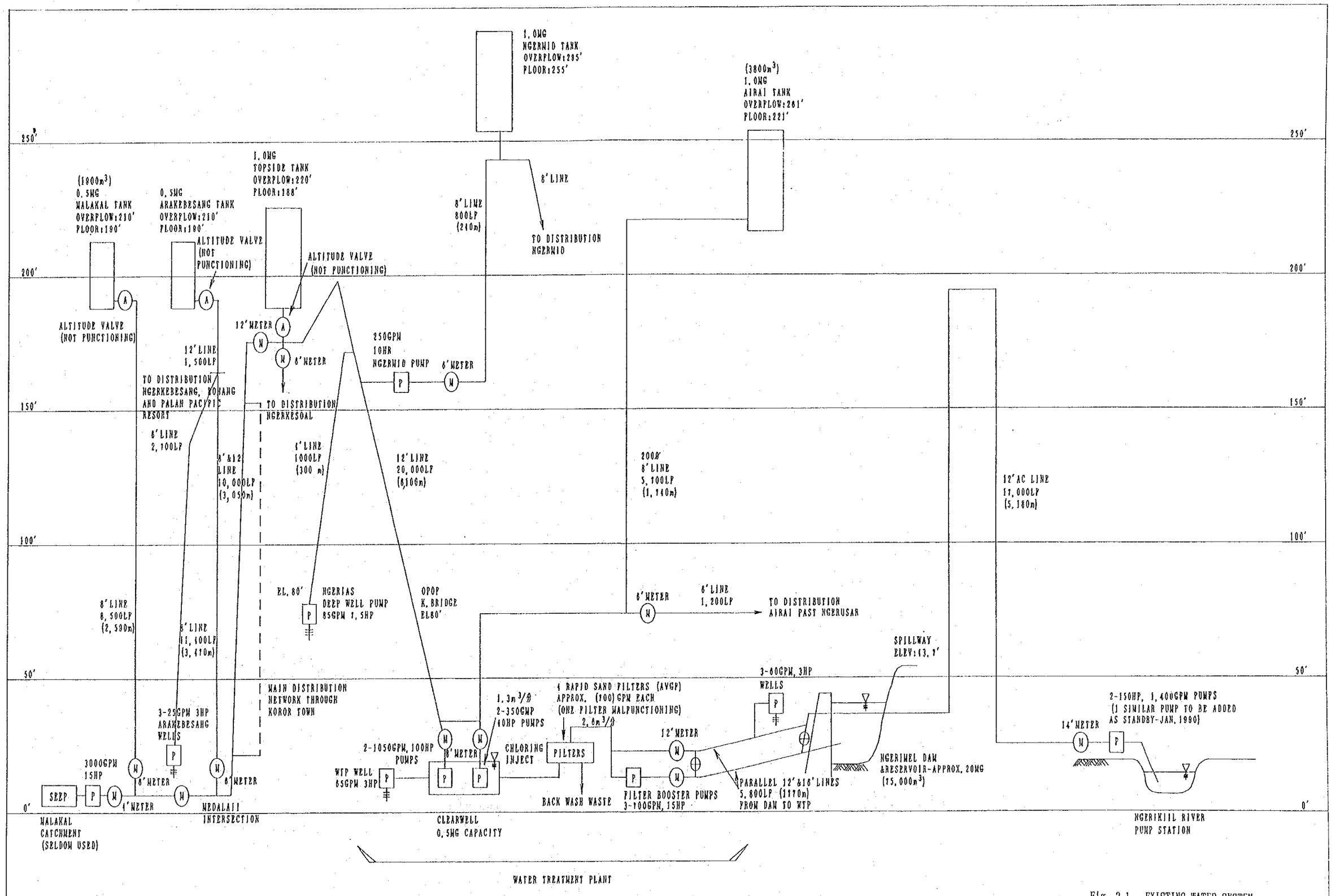


Fig. 2-1 EXISTING WATER SYSTEM

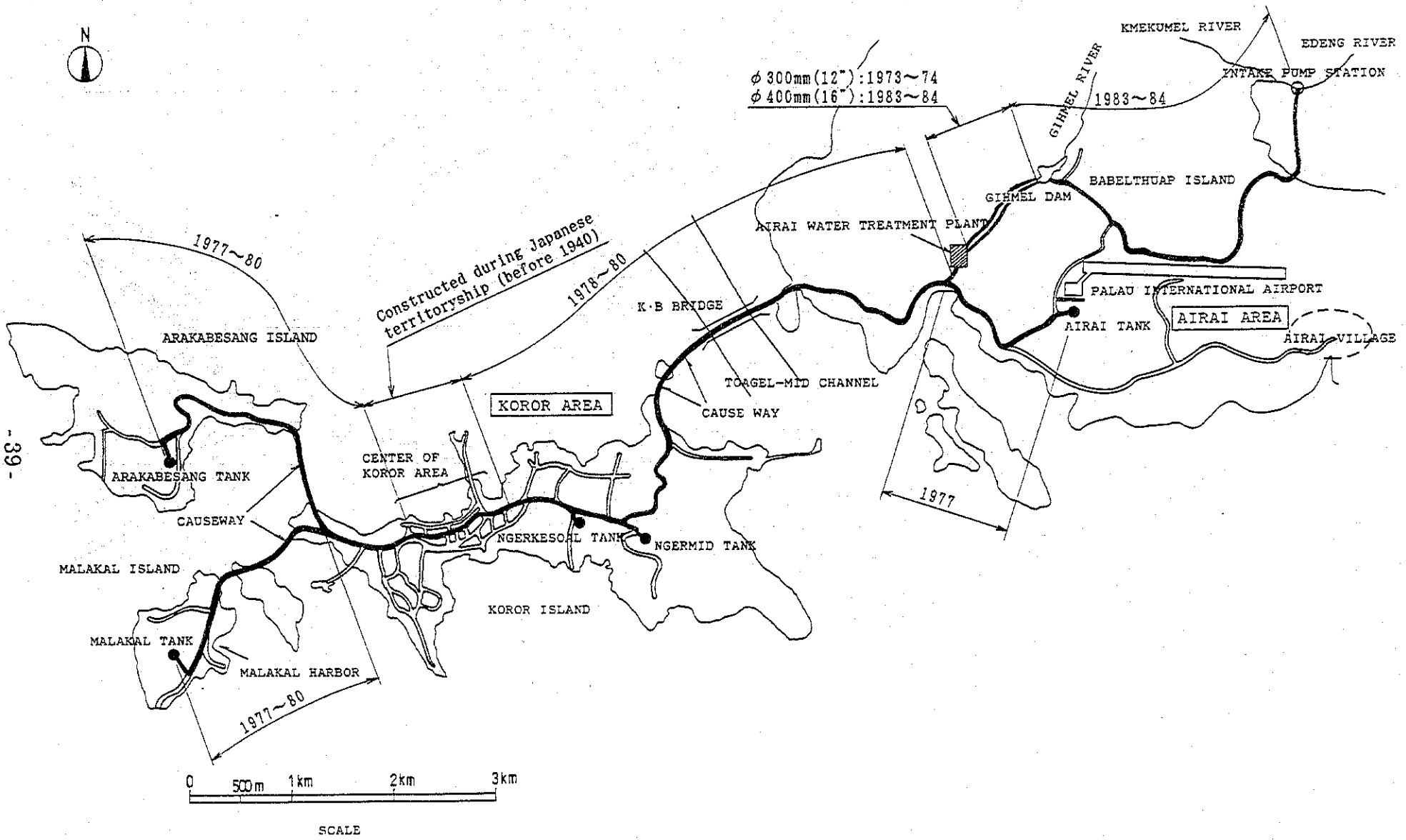


Fig. 2-2 Construction period of pipeline and water tanks

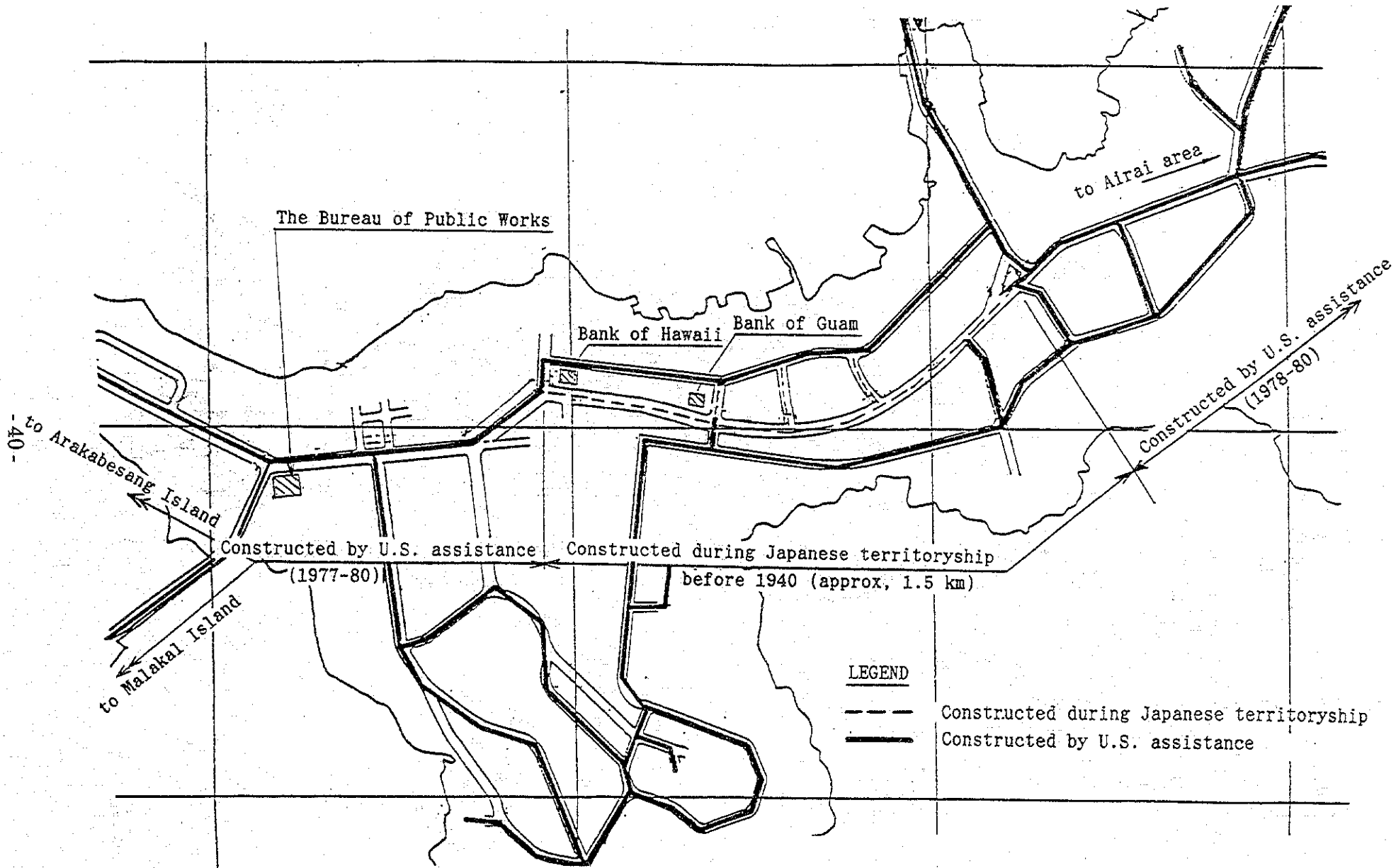


Fig. 2-3 Service section of water pipes laid during the Japanese trusteeship

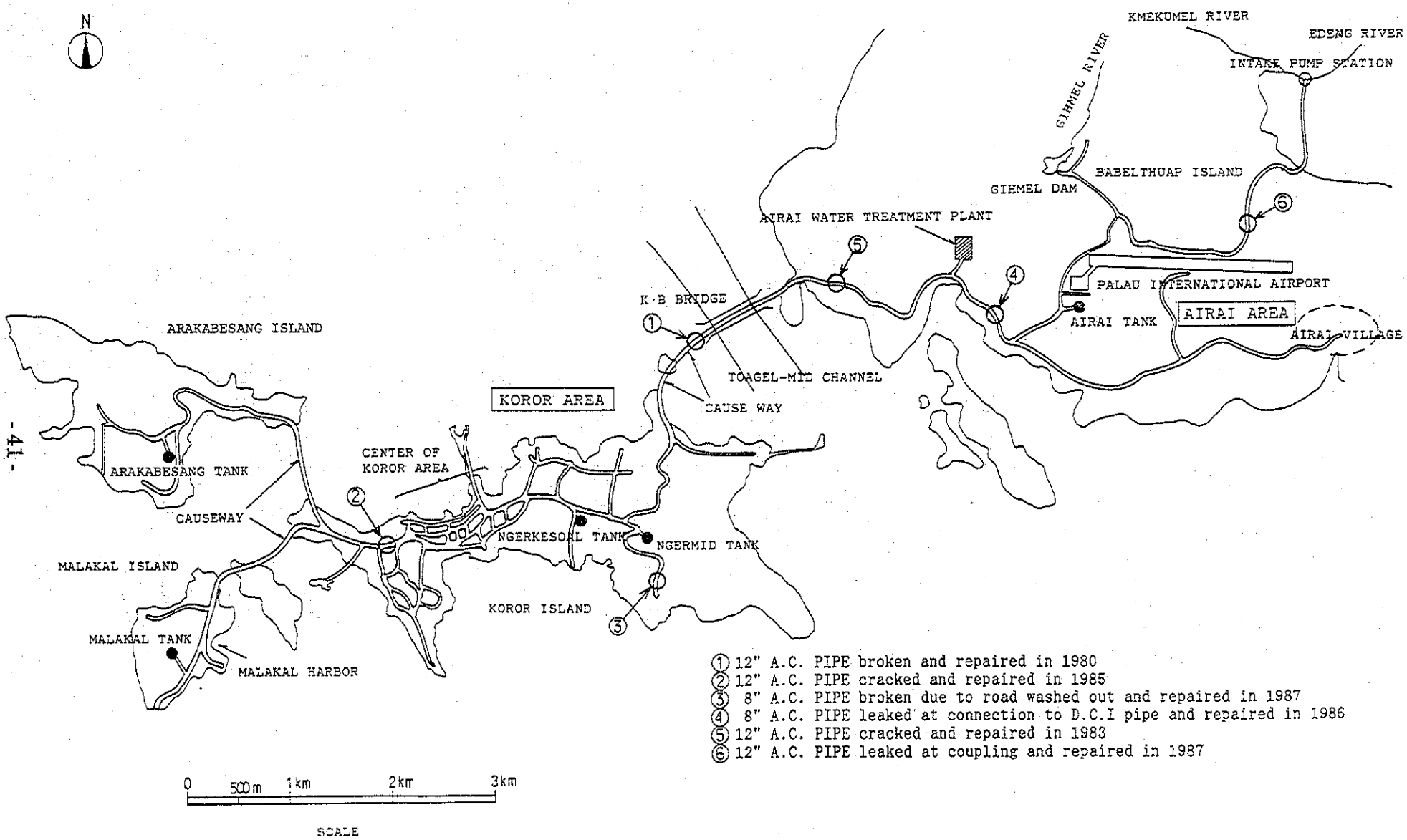


Fig. 2-4 Leakage and repaired locations of existing water mains

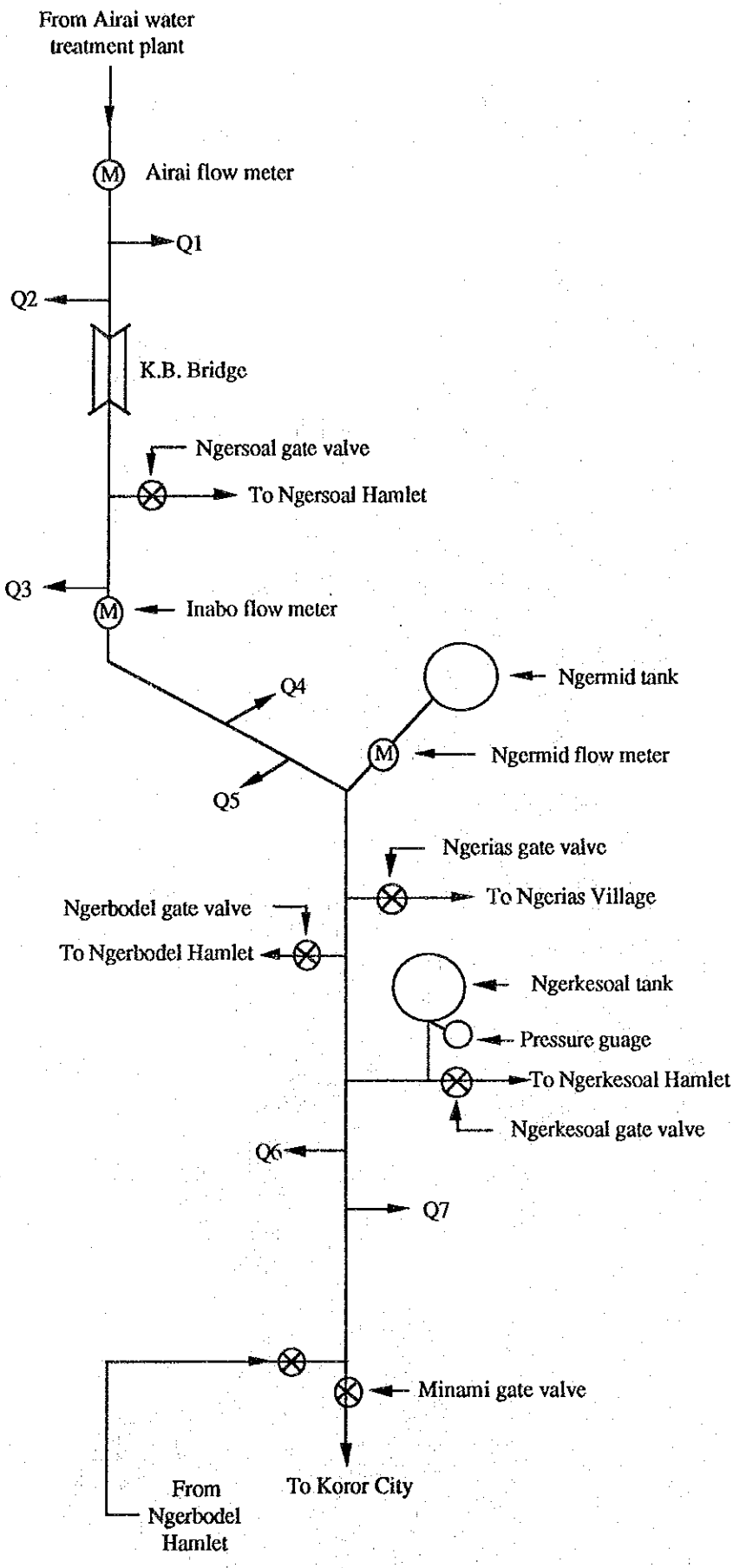


Fig. 2-5 Flow Meter Map

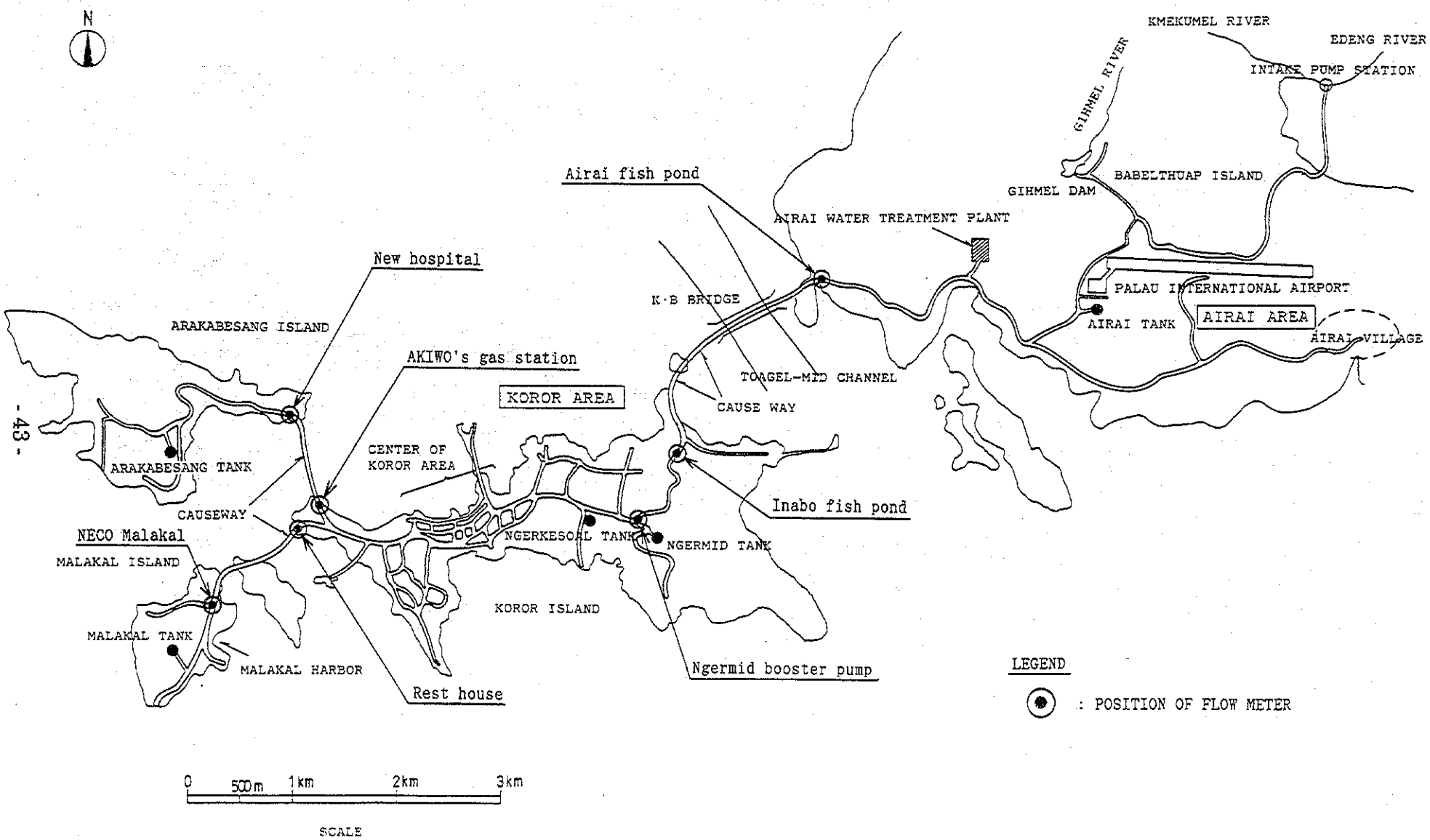


Fig. 2-6 Location of measured water meters and water tank level

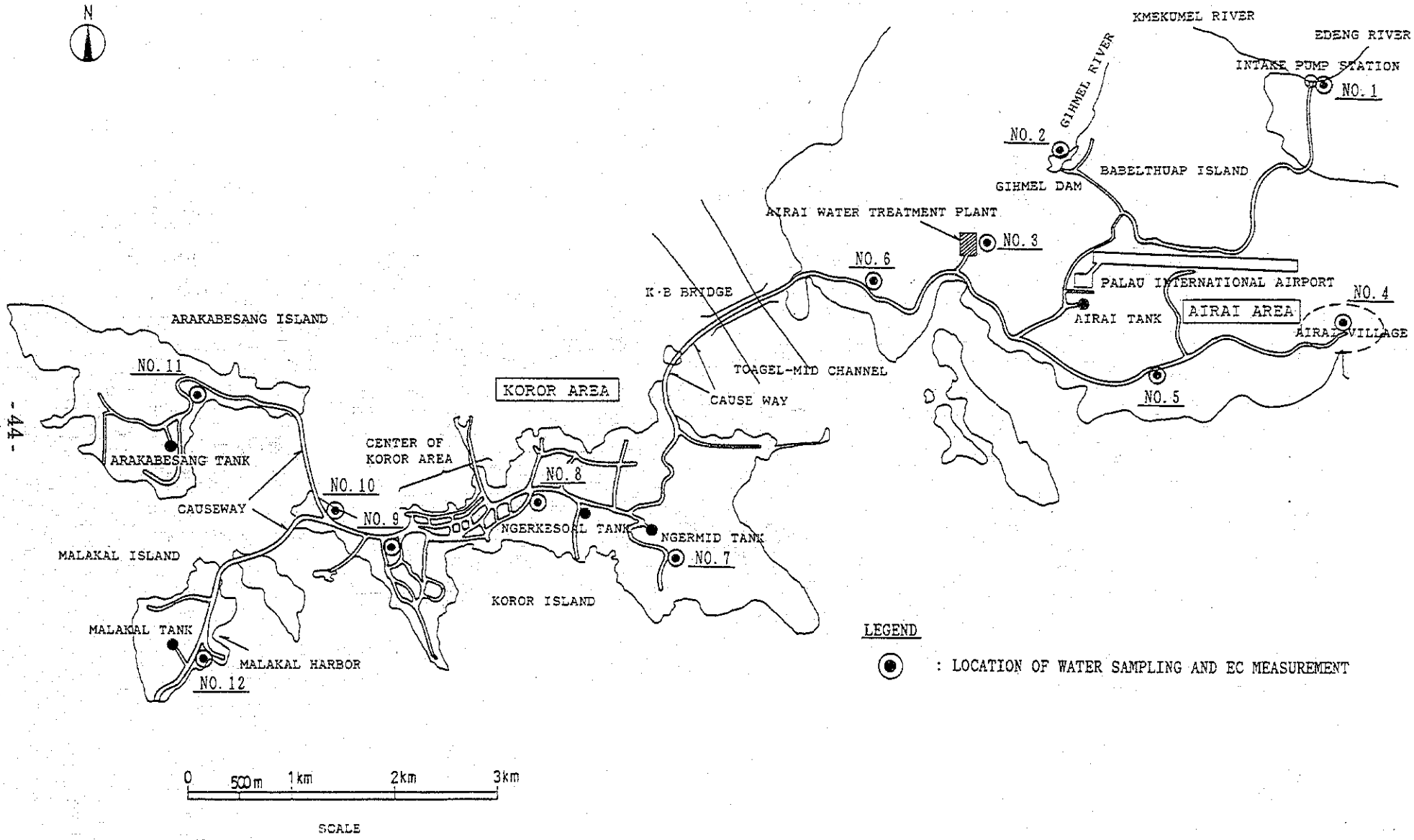


Fig. 2-7 Location of samples collected for water quality test

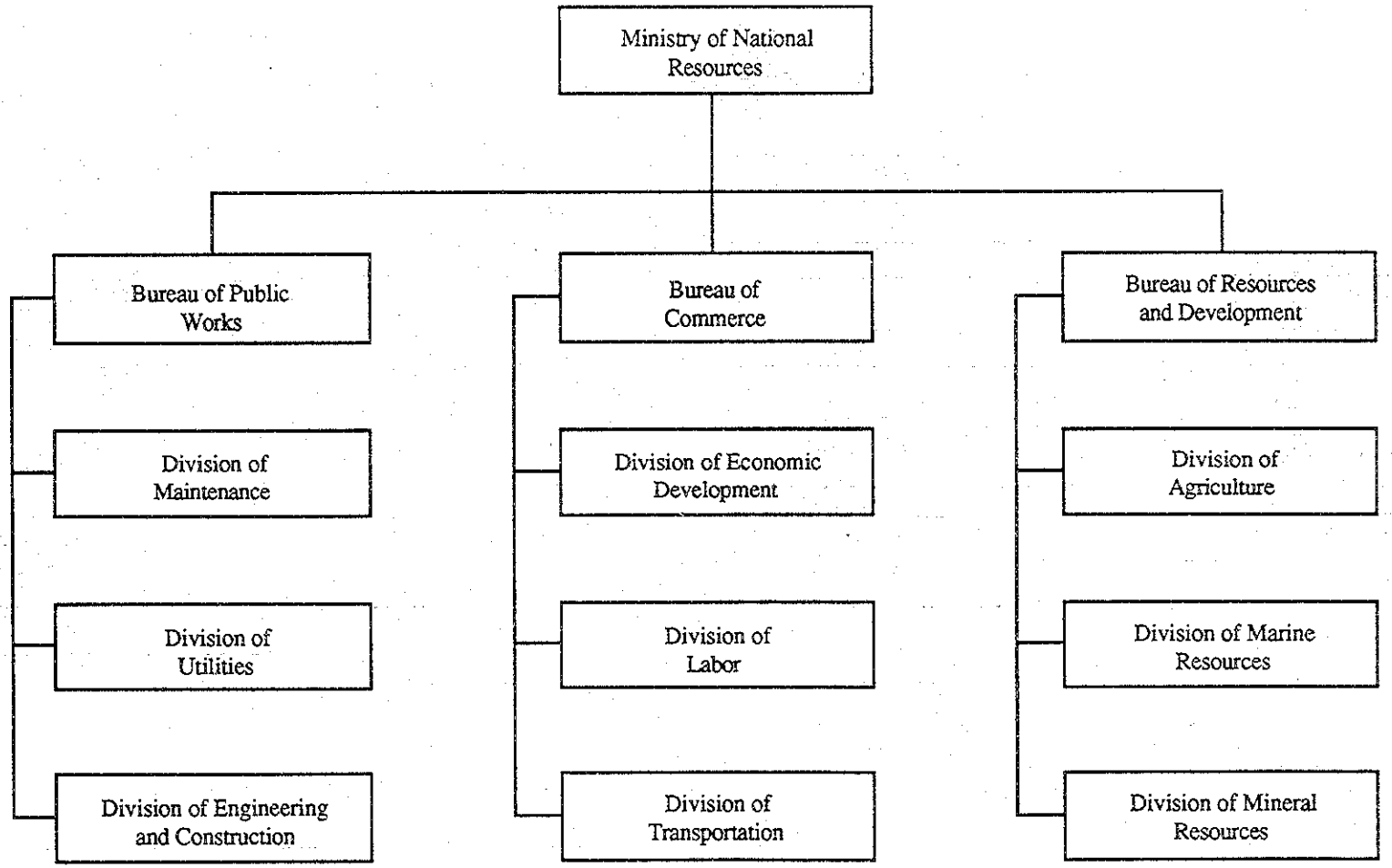


Fig. 2-8 Organization Chart of Ministry of National Resources

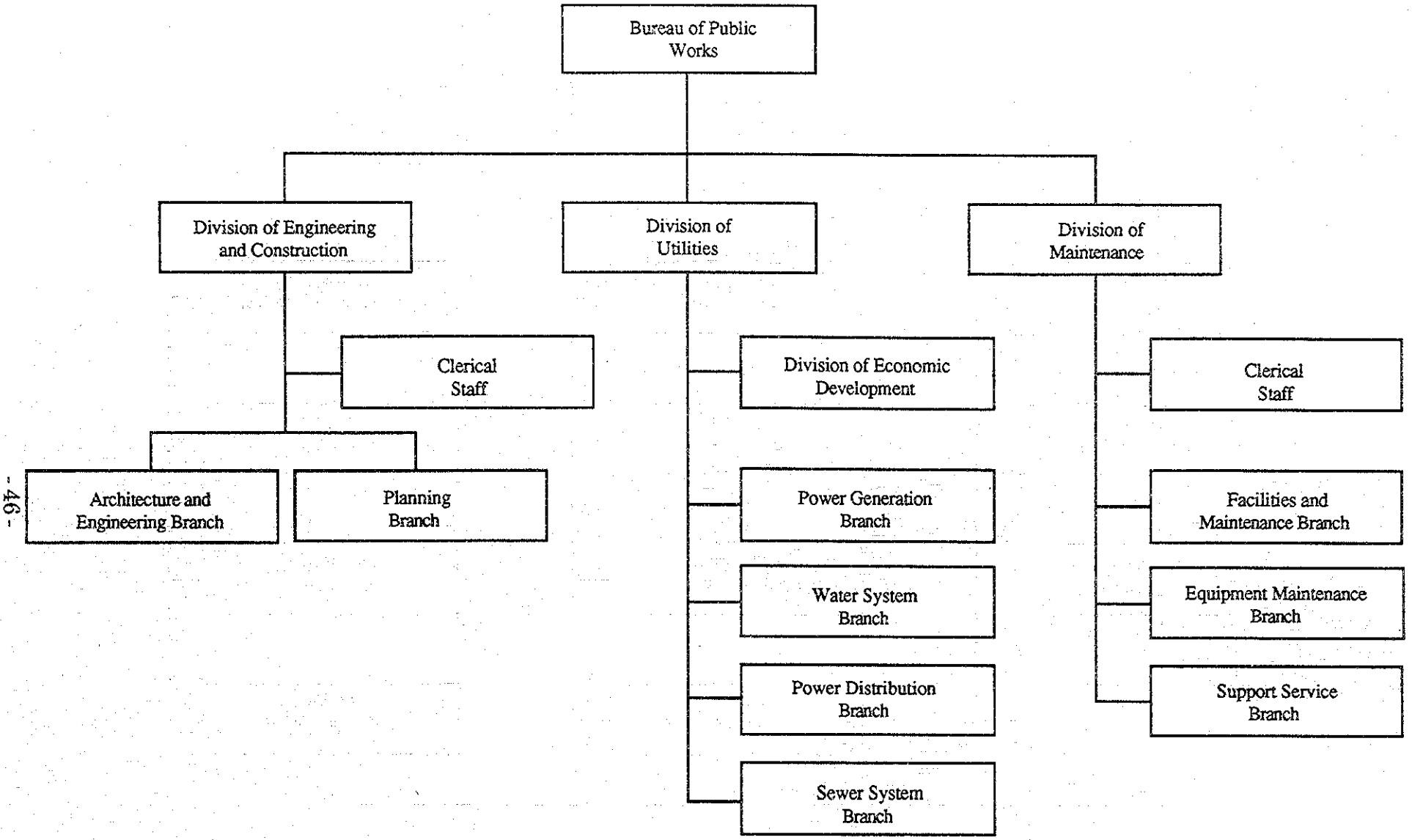


Fig. 2-9 Organization Chart of Bureau of Public Works

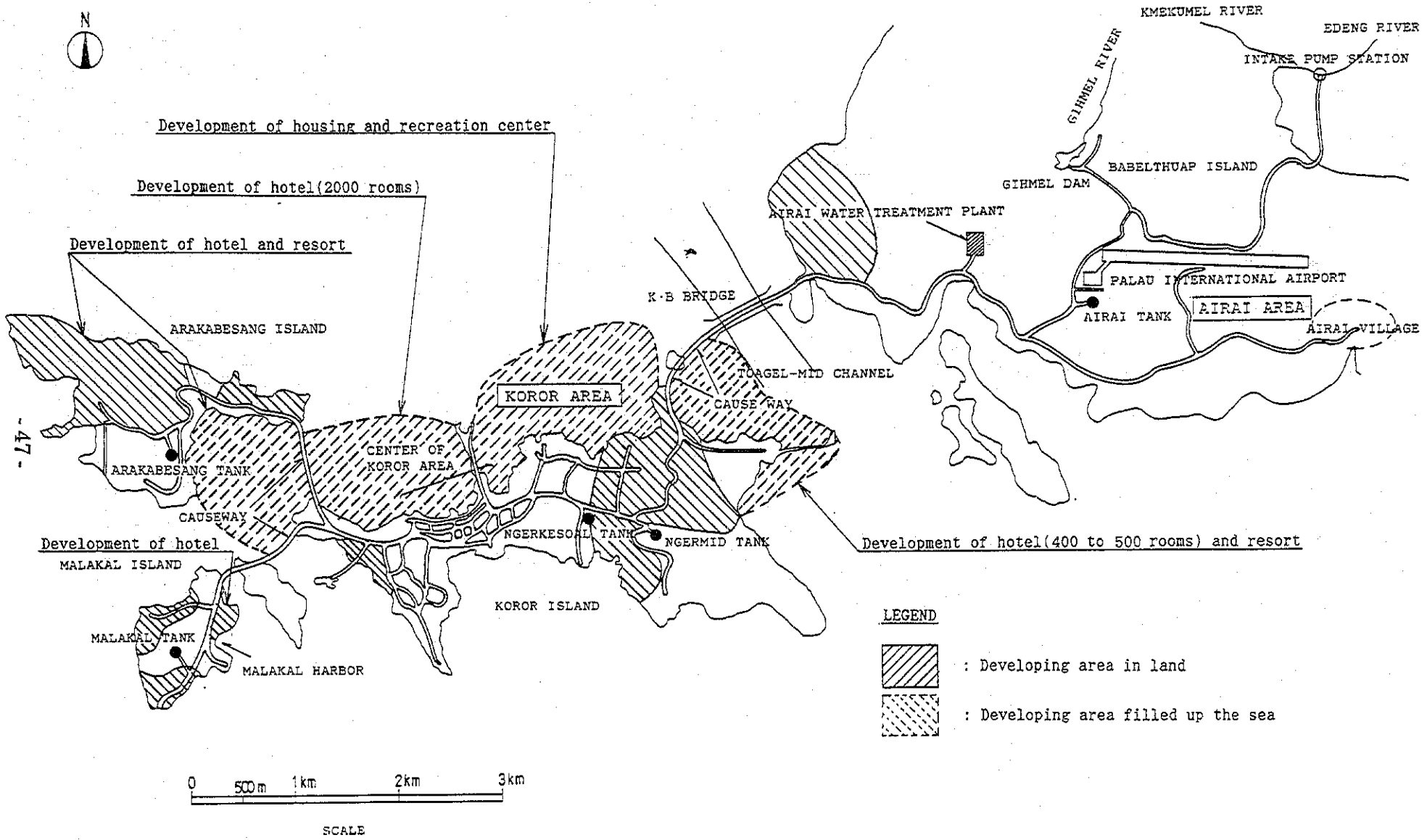


Fig. 2-10 Koror and Airai areas development plan

# CHAPTER 3 OUTLINE OF THE PROJECT SITE

# CHAPTER 3 OUTLINE OF THE PROJECT SITE

## 3-1 General Conditions

### 3-1-1 Topography

The Koror area is composed of Koror, Arakabesang and Malakal islands, which are linked by a causeway, to form a 10 $km^2$ (2,471 acres) area of land. The area has rolling hills, which is convex-shaped, with little plain area, as typically found on Arakabesang Island. The development on suitable flatland areas is concentrated on Koror Island and one part along the coastline of Malakal and Arakabesang islands.

The residential and commercial development of Palau is concentrated in the center of Koror Island, a 6 km-long, narrow island, on an elevated plateau, which runs down to the coastal flatlands.

Since there are very few flat areas along the coastline on Malakal Island, Palau's developing industrial area is concentrated in Malakal Port.

Since Arakabesang Island is characterized by rolling hills, with little flatland, the Presidents Office and residents are located on the elevated plateau area.

The Airai area, located on the southern tip of Babelthuap Island, Palau's largest island (404 $km^2$), characterized by rolling hills, is linked to Koror Island by K.B. Bridge. The international airport and wide areas of empty space are on Babelthuap Island, and the future development of housing and tourism is expected here.

### 3-1-2 Population

The population for the Koror and Airai areas in 1986 was 10,463. 9,432 (90%) people were residents of Koror area, with 8,100 (86%) people residing on Koror Island (6.7 $km^2$), including in the hill areas.

Under these present conditions, demand for housing in the highlands, outside of the city limits is unavoidable. 810 (9%) people of the population of Koror area are living on a steep slope of the narrow highlands on Arakabesang Island. Since the Koror and Airai areas have very little flat areas, this condition will become even more aggravated in the future.

The population of the Koror and Airai areas from the 1986 national census, is shown below.

| Year | 1986 |
|---|---|
| Koror area | 9,442 |
| Airai area | 1,021 |
| Total: | 10,463 |

## 3-2 Natural Features

### 3-2-1 Topography and Geography

The area of this project site is generally 30 - 90 meters above sea level, with rolling hills. However, the southern part of Koror Island is a flat area, 2 - 3 meters above sea level.

Except for one part near the K. B. Bridge, the geology of the area is mainly formed of laterite, weathered basalt . When laterite becomes wet it dissolves. Water retention is high so it does not dry out properly. Since in one part of the area near the water treatment plant mangrove swamp was reclaimed to construct a road, the soil includes mangrove humus. There is coral rock (2.0 km) near one part of K.B. Bridge on Koror Island. Accordingly, special measures are needed for construction in this area, such as shoring work and breaking bedrock.

### 3-2-2 Meteorology, Hydrology and Oceanography

(1) Meteorology and Hydrology

Palau is a tropical country with a yearly average temperature of 27 degrees centigrade, and a maximum temperature of 30 degrees centigrade. The temperature never drops below 20 degrees centigrade. Throughout the year, the temperature changes very little, so in one day, the temperature varies no more than 5 degrees centigrade. The average humidity is high at 80%, however, trade winds and squalls slightly moderate the temperature and humidity.

Rainfall is heavy, with annual average rainfall at 3,800 mm. During the year, January, and May to September, is generally considered the rainy season, while February to April, and October to December, have been observed as the dry season, though these seasons are not clearly distinguished. Rain falls many times in one day, but usually for a short duration (30 minutes to an hour). It often rains hard and typhoons usually occur throughout the year, though big typhoons are extremely rare.

Since the frequency of rainfall is great and the probability of heavy rain is high, the clay-soil dissolves in water, so its viscosity is not very good for pipeline construction, thus it is necessary to keep rainwater from entering the excavated trenches.

(2) Oceanography

From year-round observation data of the Malakal Harbor in 1987, the greatest change between low and high tide was recorded at 2.2 meters.

The velocity of the biggest tide is about 5 -6 knots.

## 3-3 Infrastructure

### 3-3-1 Residential

Housing in Palau is largely concentrated in the Koror and Airai areas. Most housing is one-story, however, in the Koror Island urban district, some 3 and 4-story apartments and office buildings have been constructed recently.

There are also large (38 to 100-room) hotels on each of the islands.

### 3-3-2 Water Facilities

The existing water facilities was built with U.S. assistance. The main pipeline is constructed from asbestos cement and the service pipes from PVC pipe. The main pipes and service pipes run in an intricate network throughout the Koror Island urban area . The existing main pipeline is generally buried 90 cm under the ground.

### 3-3-3 Sewer Facilities

Except for raw water pipelines from the intake pump station to the Airai water treatment plant, sufficient number of sewer pipelines have been installed along the water pipelines of the project site area. Sewage is treated at the sewer treatment plant on Malakal Island and then discharged to the sea.

### 3-3-4 Rainwater Drainage

In the Koror and Airai areas, V-shaped side gutters have been installed for rainwater drainage along one side of the paved road. Rainwater is discharged through a gutter to a drainage pipeline below the road. However, the capacity of the gutter and drainage pipe is small, and after a 10-minute squall, the roadway becomes flooded.

In Airai area, a concrete pipe (diameter: 900 mm, earthcovering: 0.5 m) and two culverts (width: 2.1 meters, height: 2 m, earthcovering: 0.6 m) for discharging rainwater have been installed underneath and perpendicular to the road .

### 3-3-5 Harbor

Shipping companies from Japan, the U.S.A., Australia and other far east countries, have been servicing Palau for the transporting of food, construction material and machinery and general cargo, but the number of ships is small.. There is only one sailing scheduled per month from Japan. Cargo can be unloaded only at Malakal Port on Malakal Island for the Koror and Airai areas.

Malakal Port's wharf facilities are summarized below.

- Commercial wharf length: 155 m (510 feet)
- Ship side wharf depth: 8.9 m (29 feet)
- Concrete block warehouse: Two 15.2 m x 30.5 m (50 feet x 100 feet)
- Channel width: 91.4 m (300 feet)
- Channel length: 5,850 m (19,200 feet)
- Channel depth: 8 m (26.1 feet)

Cannisters and rhomboid buoys indicate the course in the channel.

- Possible anchoring sites near the channel entrance exist
- Ferry service: available
- Distance from anchoring point: 5,850 m (19,200 feet)
- Water supply facilities: wharf alongside ship
- Fuel oil supply facilities: wharf alongside ship
- Pilot: available
- Crane lifting capacity: 30-ton (Crawler crane)
  20-ton (Mobile crane)
- Wharf height: 104 cm above sea level (3 feet 5 inches)

There is sufficient capacity for unloading construction equipment and material necessary for this project at Malakal Port, since the pier can handle 5,000 - 8,000 ton class transport ships for transporting containers.

### 3-3-6 Electric Power, Telephone

#### (1) Electric Power

A diesel power station (generating capacity: 12,800 kW), located on the west coast of Babelthuap Island, supplies all the electricity required for the Koror and Airai areas. The transmission lines, constructed by Japanese grant aid, are all overhead lines and provide a reliable electricity supply. The high voltage cable is rated at 34.5 kilovolts/13.8 kilovolts, and the low voltage cable at 210 volts/120 volts. The charges for electricity costs are outlined below.

| | |
|---|---|
| Less than 2,000 kWh: | US$0.09/kWh |
| 2,000 kWh and over: | US$0.10/kWh |

Unless power is cutoff in an accident, such as falling trees knocking down power lines, the power station and existing transmission facilities have sufficient capacity.

(2) Telephone

Worldwide telephone service from Palau is available via a communications satellite linkup to O'ahu Island in Hawaii. However, the use of telephones has not spread across Palau, making international calling difficult from hotels. International calls should be placed through the communication center at Arakabesang Island. All telephone lines are overhead.

3-3-7 Roads

The main roads in the Koror area have already been paved with U.S. assistance, leaving just 4.0 km stretch (2.5 miles) of secondary roads unpaved. In Airai area, only one part of the road from K.B. Bridge to the airport and Airai village has been paved. The two-lane main road from Malakal Port, passing K.B.Bridge to the Airai Airport has been paved. Thus there should be no problems for transporting construction machinery and materials to the project site of this plan. The access road from the main road to Gihmel Dam is 5 meters wide, with a 15 - 20 degree steep grade for 300 meters. Coral sand unevenly covers the laterite. And when it rains, construction machinery and vehicles could slip. Some improvement of the road surface is necessary to ensure the safety for the construction work of the project.

The road from the airport to the intake station is in a similar condition as the road described above, so similar measures need to be taken.

3-3-8 Bridges

(1) K.B. Bridge

Construction of K.B. Bridge was completed in two years, in April, 1977 . The longest span is 241 meters (790 feet), making it the world's longest pre-stressed concrete box-typed bridge at the time.

The design for this bridge was conducted by Alfred A. Yee and Associates, Inc., a Hawai'i-based company. Construction was performed by Socio Construction Co. of Guam. Before construction was completed, this company declared bankruptcy. However, with governmental assistance, the bridge was finally constructed. The bridge was built by the Dywidag method, but the center of the bridge sags. However,

since the bearing capacity of the bridge is sufficient for heavy vehicle-use, there should be no problem for constructions for this project.

(2) Other Bridges

There is a 20-meter long bridge on the way to the intake pump station. The steel girders of the bridge have corroded, so necessary precautions should be taken. From Koror Island to Malakal Island there are many 5 - 6-meter long concrete bridges, which should not pose any special problems.

# CHAPTER 4 OUTLINE OF THE PROJECT

# CHAPTER 4 OUTLINE OF THE PROJECT

## 4-1 Objectives and Contents

Even with an abundant average rainfall, measuring 3,800 mm annually, the water supply for the residents of the Koror and Airai areas is suspended from 9 p.m. to 5 a.m. year-round because of defects in the existing water facilities. Despite these measures, water supply and pressure at mid-day are still insufficient for elevated areas.

Since 1974, improvements to the water facilities have progressed under a U.S. assisted plan which ends in 1990. However, there are many problems with the existing water facility, as summarized in section 2-1 Chapter 2. If these problems are left unresolved, the living conditions for the residents will become increasingly harsh. This project would improve the existing water facilities by the target year 2000 and secure a clean water supply for the Koror and Airai areas for 24-hours a day.

The objective of this water facility improvement plan is to advance the health and welfare of the residents of Koror and Airai areas, promote industrial growth and contribute to the stability of the civil administration of Palau. The Government of Japan will extend Japan Grant Aid to attain these objectives..

## 4-2 Evaluation of the Request

The study team conducted a field survey to study the condition of the water supply and the existing water facility based on the request made by the Government of Palau. The study concluded that the improvement plan, summarized in the following, is necessary to secure the water supply. The existing water facilities, the improvement plan submitted by Palau and the improvement plan proposed by the study team are all shown in Table 4-1. At the time of the field survey, the study team submitted a draft proposal for improvement of the water supply facilities to the Palau officials for their consideration. (refer to Appendix 9, Field Report)

The effectiveness, urgency, appropriateness, safety, economy and term of work should not just be studied, but actually integrated in accordance to the related improvements of the existing water and sewer systems and road made under U.S. assistances, in determining this improvement plan.

4-2-1 Adequacy and Necessity of the Plan

(1) Installation of intake generator (for emergency-use)

The electrical power for the intake pumps is supplied by transmission lines which run for 20 kilometers through dense jungle and hill areas. During strong winds, trees have fallen over, cutting the power transmission lines, and at least 20 to 30 hours are required to restore power. During this time, water from Edeng River cannot be utilized. From the basic study, one 300 kw emergency generator is determined to be necessary. However, after a detailed review in Japan, it was determined not to be a major priority for the following reasons.

- The capacity of the present storage reservoir is 14 times the water supply quantity for the plan's target year, and 36 times the present water supply quantity.
- Accidents which sever the power transmission lines are rare.
- During the restoration of power, water from the storage reservoir at Gihmel Dam can be utilized, avoiding any decline in the water supply.

(2) Construction of raw water pipeline

The daily average discharge of Edeng and Kmekumel rivers at the intake pump station is 65 times the planned supply. However, since there is no pipeline to supply raw water from the intake pump station to the storage reservoir, Gihmel Dam directly, the water is wastefully discharged.

Water can be stored effectively at the storage reservoir, Gihmel Dam by constructing a raw water pipeline (diameter: 250 mm, length: 5.1 km) . It is appropriate to construct a main raw water pipeline to increase the quantity and stability of supplied water.

(3) Installation of a rubber dam at Gihmel Dam

The storage capacity of Gihmel Dam has decreased from 94,600 $m^3$ (25 million gallons) to 75,700 $m^3$ (20 million gallons) because of accumulated sand and damage to the surplus discharge rubber dam. However, after followed review in Japan, the restoration of the rubber dam (height: 60 cm, length: 15.2 meters) was determined not to be a major priority for the following reasons.

- The capacity of the present storage reservoir is 14 times the water supply quantity for the plan's target year, and 36 times the present water supply quantity.

(4) Construction of water transfer pipeline

Water is pumped directly to houses and establishments through the existing water pipelines. Consumers in the upstream area near the water treatment plant freely use and waste large quantities of water, leading to insufficient water supply and pressure at the edge of the supply area of Arakabesang and Malakal islands. Since an increase in future construction of public facilities and housing in the upstream area is anticipated, insufficiencies of the water supply in the downstream area will accelerate as the target year approaches.

The construction of a new water transfer pipeline would correct this situation by changing the function of the existing pipeline from supply and distribution to only distribution.

Water supply quantity and pressure would increase by replacing one water transfer pump, and installing water pipeline. The four tanks could then be utilized to distribute a stable and uniform supply of water to the planned supply area.

The new water transfer pipeline, running from the water treatment plant transfer pump to Ngermid and Ngerkesoal tanks will be 300 mm in diameter. The pipeline diameters in Koror urban area will be 250 mm, and the pipeline diameter from the water transfer pump to Airai tank will be 200 mm.

Palau requested the construction of a water transfer pipeline under the Toagel mid channel. However, since the water is too deep (30 - 36 meters), the current is too rough (5 -6 knots) and there are undetonated bombs left over from the second world war at this site, construction in this area should be avoided.

The existing pipeline (diameter : 300 mm, Ductile cast iron pipe) to K.B. Bridge has no problem, and it will be used for water transfer. Therefore the pipeline to K.B. Bridge is not included in this project.

(5) Installation of water level control facility for the water tanks

Automatic valves, which operate according to the water level, should be installed at Airai, Ngermid, Ngerkesoal and Arakabesang tanks to prevent water waste.

(6) Installation of water treatment facility

The capacity and the numbers of the existing filters are sufficient for water supply at the plan's target year since, out of the existing four filters, three will operate at the working ratio of 70% and one as a spare.

(7) Installation of water transfer pump

The existing water transfer pumps include two large pumps and two small pumps. The two small pumps, which have been regularly used, have become extremely old and worn out. Since the discharge and head of the large and small pumps differ, operation is difficult and complex. Without an automatic control function, operators for 3 shifts are necessary for uninterrupted 24-hour manual operation of the facility.

The installation of one new large pump to replace the old small pump will increase the supply water capacity to meet the target year, by securing the designated head, so water can be pumped to the water tanks. Since the new transfer pump has the same specifications as the existing large pumps, operation and maintenance would be simple.

The water supply quantity and pressure for the target year can be secured by installing one large pump.

(8) Painting of Arakabesang water tank

All of the water tanks, constructed of steel plates and bolts, have received little corrosion damage. However, since the inside and outside touch-up painting has not been done, spot corrosion is evident on the entire surface, and along the edge of the roof, some damage is evident. In particular, since Arakabesang water tank has much damage, it is necessary to paint the outside and inside surfaces of this tank.

(9) Maintenance truck with one ton crane and patrol car with communication equipment

The Bureau of Public Works has one truck (pick-up type). Therefore it is possible to execute the scheduled inspections, repair work or contract for maintaining the safety and functioning of the water facility by using this truck. Therefore, supply of a maintenance truck and a patrol car is not considered a high priority.

(10) Water meters

Water meters have been installed at 50% of all residences and businesses. Leaving 50% of residences and businesses where water meters have not been installed,leading to the wasteful use of water.

Installing water meters is an effective way to reduce water shortages, at a comparatively low cost by supervising the water usage of consumers. This is one of the means to improve the condition of the water facility by establishing a water charge collection system.

The Government of Palau is progressing the installation works of water meters to each residence or business by the U.S. assistance from February, 1990. And after the completion of the installation works of water meters, all residences and businesses will have water meters. Therefore the provision of water meters from Japan Grant Aid is not necessary.

4-2-2 The Contents of the Government of Palau's Request and the Improvement Plan

The contents of the improvement plan were changed after careful consideration of the effect, urgency and economics as well as the coordination and use of existing facilities. The comparison is shown in Table 4-1.

Table 4-1 Contents of the Government of Palau's Request and the Study Team's Improvement Plan

| Item | Contents of request | Improvement plan | Net increase/decrease |
|---|---|---|---|
| 1. Water supply system | Supply system is not changed.<br>Existing pipelines are replaced.<br>Existing pipelines are not used. | Supply system is changed. Supply-distribution pipelines are split and used according to their function. New pipelines are installed as water transfer pipes, and existing pipelines are used for distribution. | |
| 2. Intake pump generator for emergency use (300 kVA) | 2 | 0 | 2 (-) |
| 3. Pipeline (Ductile cast-iron) | | | |
| (1) Raw water pipeline between transfer pump station and Gihmel Dam | diameter: 400 mm, length: 6.20 km | diameter: 250 mm, length: 5.10 km | 400-mm diameter: length: 14.98 km (-)<br>300-mm diameter: length: 2.23 km (-)<br>250-mm diameter: length: 11.90 km (+)<br>200-mm diameter: length: 2.40 km (+) |
| (2) Water transfer pipline between water treatment plant, Airai tank and K.B. Bridge | diameter: 400 mm, length: 5.50 km<br>diameter: 300 mm, length: 0.40 km | diameter: 400 mm, length: 0.10 km<br>diameter: 300 mm, length: 2.20 km<br>diameter: 200 mm, length: 1.80 km | |
| (3) Pipelines to every tank on Koror, Malakal and Arakabesang islands | diameter: 400 mm, length: 3.38 km<br>diameter: 300 mm, length: 7.43 km | diameter: 300 mm, length: 3.30 km<br>diameter: 250 mm, length: 6.80 km<br>diameter: 200 mm, length: 0.60 km<br>(except Malakal Island) | Total pipe length: 3.01 km (-) |
| 4. Existing tank water level control device | — | 4 | 4 (+) |
| 5. Water transfer pump (capacity: 3.97 $m^3$/min.) | — | 1 | 1 (+) |
| 6. Painting of Arakabesang water tank (outside and inside surfaces) | — | 1 | 1 (+) |

## 4-3 Outline of the Project

### 4-3-1 Implementation of the project

The National Planning Council is responsible for the implementation of the work under this project, and will operate and maintain the facilities after completion.

### 4-3-2 Basic Schemes for the Plan

Basic schemes for the improvement plan of the water facility are described as follows.

(1) The design target year is set at 2000.

(2) The planned served area is the Koror and Airai areas.

(3) In the target year, water supply capacity will be 5,300 $m^3$ (1.4 million gallons)/day.

1) In the designed target year, the served population will be 20,600 people.

2) In the designed target year, the average per capita water supply will be 257 liters (68 gallons).

(4) The water supply system will be changed, additional pump and pipelines will be installed under Japan's grant aid to improve the existing facilities equipment.

(5) Improvements in operation, management, and charge collection will be made to improve the administration of the existing facilities.

### 4-3-3 Project summary

Improvements planned for the water facility of Palau are summarized below.

| Summary of the Project |
|---|
| 1) Installation of raw water pipeline<br>— Ductile cast-iron pipe, diameter: 250 mm, length: 5.1 km<br>2) Installation of water transfer pipeline<br>(excluding the existing 300 mm pipeline installed to K.B. Bridge also used for water transfer pipeline)<br>— Ductile cast-iron pipe, diameter: 400 mm, length: 0.1 km<br>— Ductile cast-iron pipe, diameter: 300 mm, length: 5.5 km<br>— Ductile cast-iron pipe, diameter: 250 mm, length: 6.8 km<br>— Ductile cast-iron pipe, diameter: 200 mm, length: 2.4 km<br>3) Installation of water level control device<br>— Installation of water level control facilities with automatic valves at the four existing tanks<br>4) Installation of fresh water transfer pump<br>— One multi-stage turbine pump [3.97 $m^3$ (1,050 gallons)/min.]<br>(Same as the existing large multi-stage turbine pump)<br>— One motor and control device<br>— Partial improvement of the discharge pipe of existing large multi-stage pump<br>5) Painting of Arakabesang water tank (outside and inside surfaces) |

# CHAPTER 5 BASIC DESIGN

# CHAPTER 5 BASIC DESIGN

## 5-1 Basic Design Philosophy

The study of the contents of the request made by the Government of Palau and the results of the field survey revealed that significant regional imbalance between the water supply quantity and water supply pressure was caused by defects of the existing water supply facilities, insufficient number of water meters installed, and insufficient maintenance.

The main objectives of the Project for Improvement of Water Supply System includes: 1) eliminating the above imbalance, 2) securing the design target year's water supply quantity, 3) supplying water continuously for 24 hours a day to residents in the Koror and Airai areas, 4) improving the existing water supply facilities, and 5) enhancing their function. The achievement of these objectives will lead improve the living standards of the residents in the Koror and Airai areas, as well as the industrial facilities.

The basic design for this project was conducted, emphasizing functionality, durability and economic efficiency, in line with the contents of this project described in Chapter 4, and according to the following policies.

(1) The planned served area for this project will be the Koror and Airai areas.

(2) The new water pipelines for this project will be used exclusively to transfer water to water tanks. The existing pipelines will continued to be used for the distribution of water to individual households. Therefore the pipelines for water distribution and water transfer can be separated.

(3) This project will be planned to make the most effective use of the existing water supply facilities.

(4) The existing pipes (pipe diameter: 300 mm, material: ductile cast iron pipe) installed along K.B. Bridge sidewalk will be used for water transfer pipeline.

(5) Since the present project is for the improvement of the existing facilities, efforts will be made to coordinate machine types, specifications, standards and other relevant aspects, by taking into consideration operation and maintenance, as well

as the interchangeability of parts and components. Japanese design standards and products will be used, unless comparative products are found in Palau.

The service life the existing facilities is taken into consideration in the design of this project.

(6) Areas in the South Pacific Ocean, including Palau, were greatly affected by a drought in 1983. This project is planned to minimize the effect of such a drought.

(7) The maintenance of the existing water supply facilities is being carried out by the Bureau of Public Works with cooperation from the U.S.A. However, the necessary technical skill, knowledge and the financial resources are insufficient. Therefore, the adoption of a system or facilities which include sophisticated automatic equipment must be avoided. Equipment which is simple, easy to operate and inexpensive to maintain should be installed, so that the facilities can be repaired by the technical personnel of Palau.

(8) This project will be executed ensuring the safety of the existing infrastructure, including water supply, sewerage and electricity, buildings and residents, and causing minimum interference with the daily life of residents, commercial activities and traffic.

(9) The cost of this project will be minimized.

(10) The construction work period will be minimized.

(11) Efforts will be made to obtain the understanding and cooperation from residents in the project area for the execution of the construction work under the implementation of this project.

(12) This project will be planned to utilize locally available construction equipment and materials, as well as increase the employment opportunities for workers in Palau.

(13) This project will be planned to utilize public land areas to minimize the use of privately-owned land.

(14) Since much rain falls in Palau, this project will be planned to prevent rainwater from entering trenches excavated for the laying of pipelines during the construction work.

(15) Since 80% of the population for the Koror and Airai areas is concentrated on Koror Island, urgent improvements for the water supply, including the laying of pipelines from the water treatment plant to the two water tanks on Koror Island will be planned for the Phase I construction work.

Phase II construction work includes the laying of a raw water pipeline from the intake pump station to Gihmel Dam and water transfer pipeline from the water treatment plant to Airai tank, and the water transfer pump. This phase of construction will secure the water supply quantity for the target year 2000, improve the water supply condition for the Airai area located near the water treatment plant and prevent water waste. Under Phase III construction work, a water supply pipeline will be laid from the Ngerkesoal tank to the Arakabesang tank, at the edge of the served area, to improve the water supply condition for Koror Island urban district and Arakabesang and Malakal islands .

## 5-2 Study of Design Conditions

The design conditions for this project are studied considering the water supply improvement project which has been implemented under the U.S. assistance, the functions of the existing facilities, natural conditions, and the present condition of operation and maintenance. These conditions are as follows:

(1) Basic design conditions

Table 5-1 shows the basic design conditions.

Table 5-1 Basic Design Conditions

| Item | | Design conditions | Note |
|---|---|---|---|
| 1. | Design target year for the project for improvement of water supply system | 2000 | |
| 2. | Water supply quantity for the target year | 0.257 x 20,600 = 5,300 $m^3$<br>(1.4 million gallons)/day | |
| | 1) Planned population | 20,600 | |
| | 2) Per capita planned daily average water supply | 257 liters (68 gallons)/man-day | Refer to 5-2 (2) for the base of setting up. |
| 3. | Water supply quantity for design of water facilities | 5,300 x 1.5 = 7,950 $m^3$<br>(2.1 million gallons)/day | |
| 4. | Pipeline system | The existing water transfer and distribution pipelines will be used exclusively for distribution to each household, and new pipelines will be used exclusively for transfer of water to the water tanks. | |
| 5. | Pipe material | Ductile cast iron pipe (Pipes around water transfer pump, and aqueduct : steel pipe) | Refer to Table 5-8 for the base of setting up. |
| 6. | Pipe diameter | 200 - 400 mm | |
| 7. | Design flow velocity | 0.75 - 1.5 m/sec. | |
| 8. | Thickness of earth covering | the sloped area = 0.7 m<br>the flat area = 0.9 m | |
| 9. | Air valve | Single-type air valve. | Air valves will be installed at ridge portions on main line. |
| 10. | Wash-out valve | Sludge-discharge pipe's diameter will be 1/2-1/4 of the main pipe's diameter. | Several wash-out valves will be installed at valley sections on main line. |
| 11. | Stop valve | Sluice valves will be installed. | Sluice valves will be installed at diverting points of the main pipes. |
| 12. | Pipe installation | Pipe will be buried into underground except for aqueduct and the wall of Arakabesang causeway. | |

(2) Planned served population

The planned population in both the Koror and Airai areas up to the target year is shown in Table 5-2, as obtained through the 1986 census and the survey by the Basic Design Team:

Table 5-2 Planned Served Population

| Year | 1986 | 1988 | 1989 | 1990 | 1992 | 1994 | 1996 | 1998 | 2000 |
|---|---|---|---|---|---|---|---|---|---|
| Palau Nationals | 10,463 | 11,200 | 11,600 | 12,000 | 12,900 | 13,800 | 14,800 | 15,800 | 17,000 |
| Foreign Nationals (workers, etc.) | — | — | 2,000 | 2,100 | 2,350 | 2,600 | 2,900 | 3,250 | 3,600 |
| Total | 10,463 | 11,200 | 13,600 | 14,100 | 15,250 | 16,400 | 17,700 | 19,050 | 20,600 |

The population increase of Palau nationals is estimated at 3.5%, the same as the present level.

The population based on the 1986 census only included Palau Nationals, and did not include long-term foreign workers who came from the Phillipines, Taiwain, Korea and other foreign countries. In projecting the population figures for the Koror and Airai areas, it is necessary to include these long-term foreign workers which are increasing each year due to the growth in the number of construction workers and employees for the service industry. Although the actual number of foreign workers was not included in the 1986 census, according to estimates for 1989, there were 2,000 foreign workers, of which approximately 1,500 were Filipino. Construction of housing and hotels is currently under planning as part of the large-scale development for the Koror and Airai areas. Therefore, the influx of long-term foreign workers is expected to increase from the Phillipines and other neighboring countries.

Accordingly, the total population in the Koror and Airai areas is estimated to be 20,600 in the target year of 2000. In Saipan, whose population was 12,000 roughly equal to that of Palau in 1976, an explosive increase of population was seen as the tourism development was started. In 1988, it numbered 36,000, three-fold over the above year. It may well be predicted that the total population will reach 20,600 in 2000 in Palau, where large-scale development is planned through Japanese and U.S. investments. The secured water supply at the target year will be 100%, although there are no rivers nor lakes to supply water for these areas.

(3) Planned served population by area at the target year

The planned served pupluation at the target year in Airai area and Koror, Malakal and Arakabesang islands are shown in Table 5-3.

Table 5-3 Projected population

| Served area | Airai area | Koror Island | Malakal Island | Arakabesang Island | Total |
|---|---|---|---|---|---|
| Served Population | 5,000 | 11,000 | 1,500 | 3,100 | 20,600 |

(4) The planned served population and water supply by water tank at the target year

The planned served population and water supply by water tank at the target year are shown in Table 5 -4.

Table 5-4 The Planned Served Population and Water Supply by Water Tank at Target Year

| Water tank for distribution | | Airai tank | Ngermid tank | Ngerkesoal tank | Arakabesang tank | Total |
|---|---|---|---|---|---|---|
| Served area | | Airai area | East area of Koror Island | West area of Koror Island and a part of Malakal Island | Arakabesang Island and a part of Malakal Island | |
| Served population | | 5,000 | 2,100 | 9,900 | 3,600 | 20,600 |
| Daily average water supply | ① | 1,290 | 530 | 2,560 | 920 | 5,300 |
| | ② | 0.34 | 0.14 | 0.68 | 0.24 | 1.4 |
| Water supply for design of water facilities | ① | 1,930 | 800 | 3,840 | 1,380 | 7,950 |
| | ② | 0.51 | 0.21 | 1.01 | 0.37 | 2.1 |

① : $m^3$/day ② : million gallons/day

(5) Per capita water consumption at the target year (2000)

The large-scale tourism and industrial development programs under way in the Koror and Airai areas in line with the Koror Master Plan and Airai Development Plan, are mainly composed of housing and hotel construction, as shown in Fig. 2-10. Since land for some projects near K.B. Bridge on the Koror Island and Arakabesang Island have already been secured, future development should progress rapidly. The projected daily average water consumption at the target

year is 257 liters/person, for industrial use, and 200 liters/person for housing and residents, as shown in Table 5-5. This figure is considered a reasonable projection in comparing it with the planned unit water consumption in cities throughout the world, as shown in Table 5-6, and in view of the increase in water consumption by the growth in population, development of industry and tourism, and the people's higher living standard in the Koror and Airai areas.

The unit water consumption for the design of water facilities is 386 liters/person, 1.5 times the average water consumption taking into account seasonal variations, as well as daily and hourly changes.

Table 5-5 Water Consumption at Each Sector

| | Per capita water consumption to served (lit./person) | Served population (persons) | Total water consumption to served ($m^3$) |
|---|---|---|---|
| ① Resident and housing | 200 | 20,600 | 4,120 |
| ② Industry (present) | | | 960 |
| - Office | 80 | 1,800 | 150 |
| - School (primary to high school: 12 years) | 50 | 4,200 | 210 |
| - Hotel (330 rooms x 0.75 (occupation rate) = 248 persons) | 200 | 248 | 50 |
| - Restaurant | 20 | 1,500 | 30 |
| - Factory, store | 70 | 2,000 | 140 |
| - Harbor, marine product | - | - | 150 |
| - Construction | - | - | 230 |
| ③ Industry (at the target year) | | | 230 |
| - Office | 80 | 500 | 40 |
| - School (primary to high school: 12 years) | 50 | 1,200 | 60 |
| - Hotel (400 rooms x 0.75 (occupation rate) = 300 persons) | 200 | 300 | 60 |
| - Restaurant | 20 | 500 | 10 |
| - Factory, store | 70 | 600 | 40 |
| - Hospital (79 beds) | 250 lit.bed | 79 beds | 20 |
| TOTAL (① + ② + ③) | | | 5,300 (1.4 million gallons) |
| Total served water consumption per capita | | | 257 lit./person |

Table 5-6 Specific Consumption of Potable Water in Urban Areas All Over the World

| Country and City | Average consumption per capita (lit./capita• day) | Survey year | Remarks |
|---|---|---|---|
| England & Wales | 175 | 1971 | Urban area |
| West Germany | 180 | 1971 | Maximum consumption with toilet and 50% with bath |
| Ghana | 57 | 1963 | |
| Ghana | 189 | 2000 | Forecast |
| India | 116 | 2000 | Forecast (urban area no flush toilet) |
| Rumania | 130 | 1971 | Areas without hot water supply facilities |
| Venezuela | 190 | 1956 | |
| Malaysia | 90 | 1964 | |
| Phillipines | 115 | 1964 | |
| Indonesia | 87 | 1964 | |
| Singapore | 94 | 1972 | |

Source: WATERWORKS ANNUAL '86

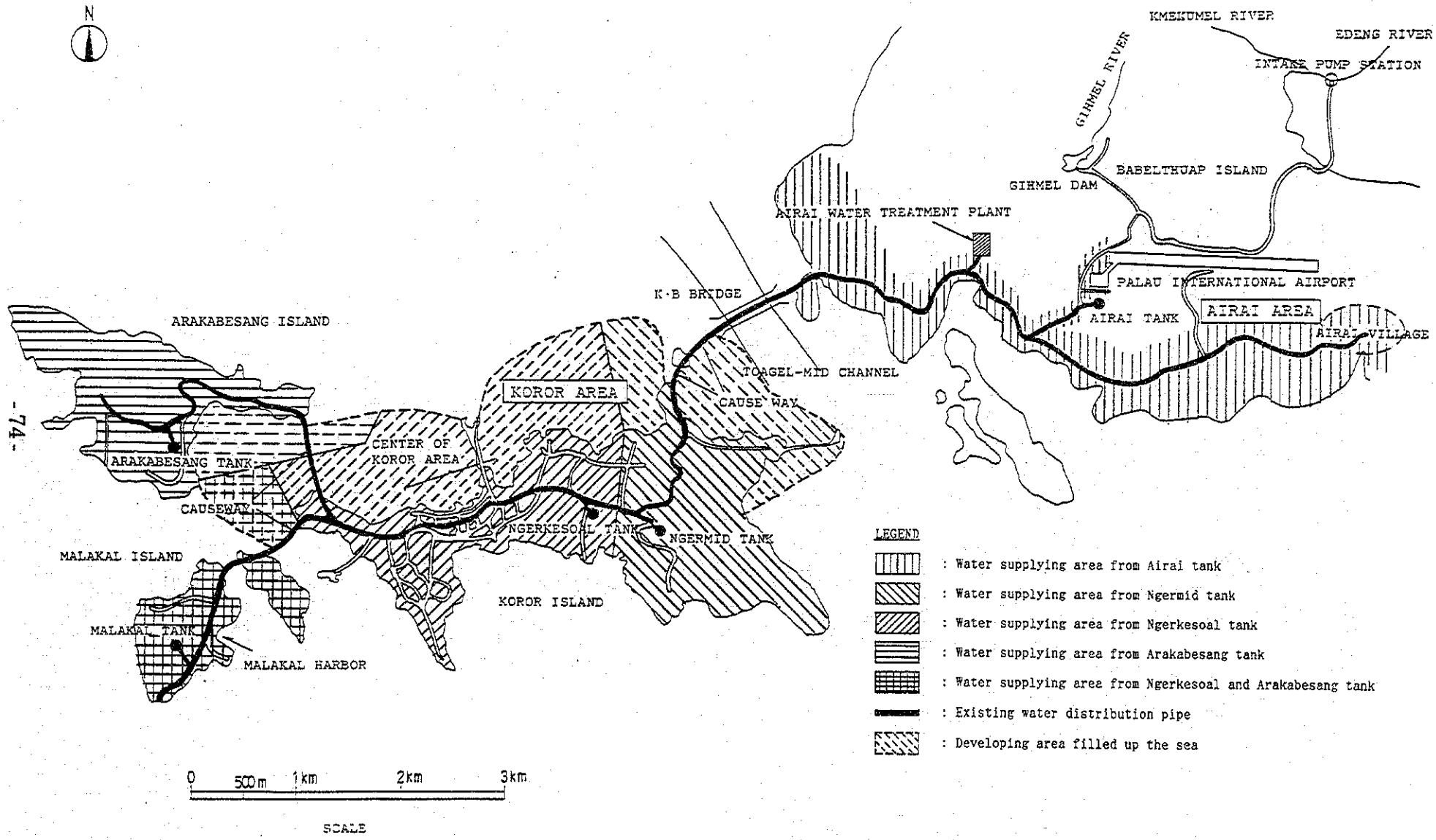


Fig. 5-1 Served areas by individual water tanks