DOCUMENT 1. INTAKE WEIR

(A) Height of the Weir
Required water depth at intake mouth (H) is calculated from the follwing equation.

$Q = B \times H \times V \quad H = Q / (B^*V)$

Where:

Q: designed flow (m^3/sec)
B: Width of the intake mouth (m)
H: Depth of Water (m)
V: Velocity (m/sec)

Substituting, Q = 293,400 m^3/day, B = 1.5 m x 2 = 3.0 m, V = 1.3 m/sec, we get,

H = 3.4 /(3.0*1.3) = 0.872 (m) ~ about 0.9 m

Hence, required level of water at intake mouth is the level of intake mouth bottom plus H (0.9 m). ; 144.8 m + 0.9 m = 145.7 m.

Thus, required height of the intake mouth = 145.7 - level of the bottom of the intake weir (144.7 m) = 1.0 m:

(B) Maximum Flow Consideration at Intake Weir

The overflow water depth (H) for maximum flow at the weir is given by the follwing equation.

$Q = C \times B \times H^{3/2}$ Hence, $H = (Q/CxB)^{2/3}$

Where;

Q = Maximum Flow (22.0 m^3/sec)
C = Flow Coefficient (2.1 $m^{1/2}/sec$)
B = Width of the Weir (5.8 m)

Thus, H = 1.48 m

The total depth at the weir at the maximum flow becomes 2.5 m (= height of the weir (1.0 m) + overflow water depth (1.5 m)). Since the depth of the inflow channel is 2.7 m, there is still room (0.2 m) at the weir at maximum flow, and spill over will not occur at the weir at maximum estimated flow.

APPENDIX H

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

MANAGEMENT/OPERATION AND MAINTENANCE

CONTENTS

LIST OF TABLES

LIST OF FIGURES

I Management

1. Introduction

Water is one of the basic human needs (BHN) and water supply is a fundamental necessity for the population.

There are various management systems for water supply ranging from private enterprises to governmental entities. Each city can have its own type of management for water supply. Several relatively small cities can be managed by a single water supply system, because this could improve efficiency. These varieties can be explained from historical, social and political backgrounds. Therefore it would be rather difficult to convert one type of management to another in a short period, once it has been established in a city.

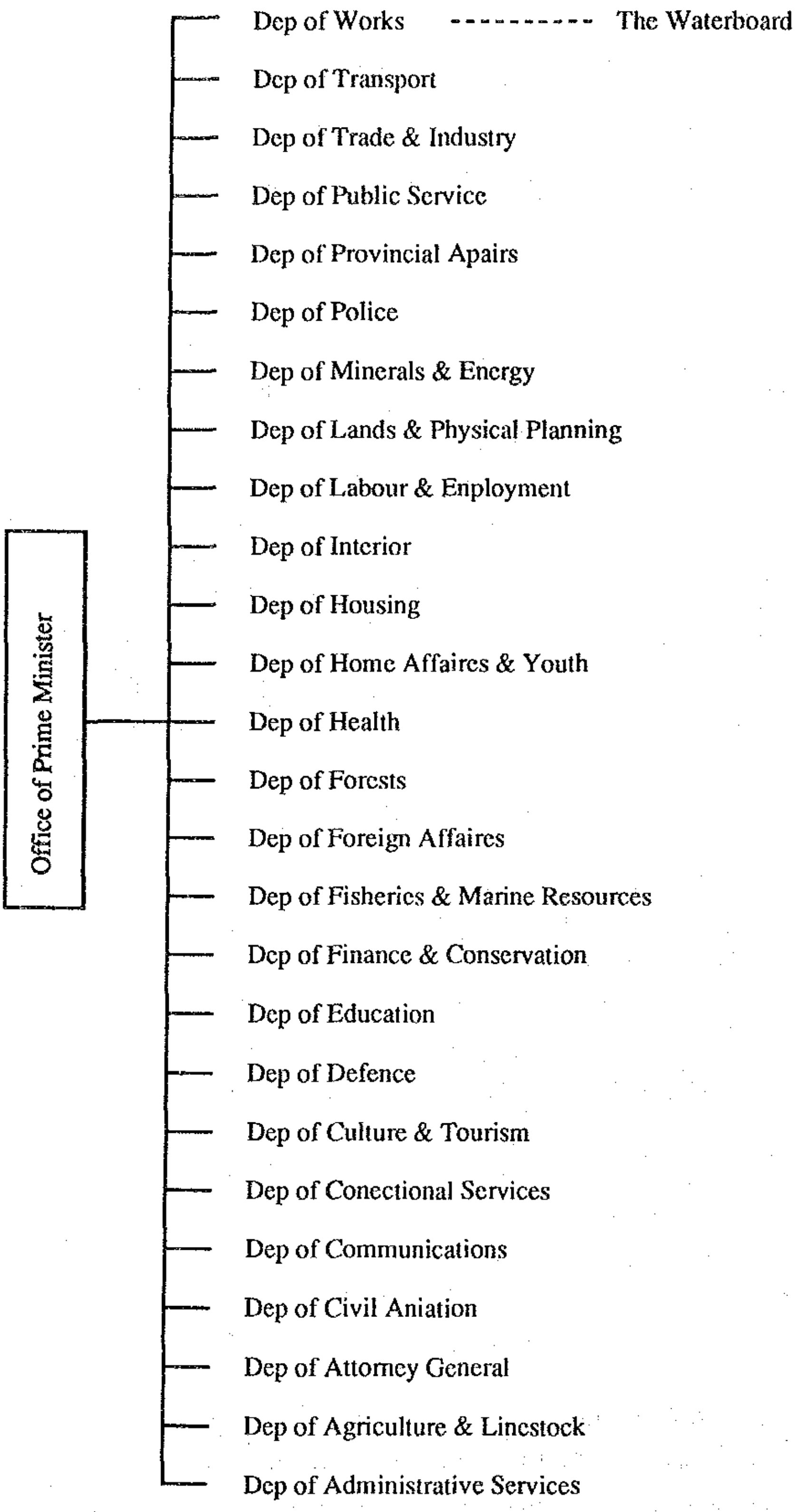
In Papua New Guinea there are three organizations responsible for water supply: NCDC, Waterboard and Department of Works. National Capital District Commission (NCDC) is responsible for water supply in Port Moresby, the capital of the country, while the Waterboard is responsible for water supply for other major cities. The Department of Works is responsible for small cities and towns/villages.

The water supply of Papua New Guinea was under the Commonwealth Department of Australia before the independence of 1975. It was transferred to Department of Works after independence. There have been several changes in the governmental organization. The present organization of PNG is shown in Fig. H-1.

The water supply service for the City of Port Moresby (named also as NCD = National Capital District) was transferred in 1976 from the Department of Works to the present National Capital District Commission (NCDC), then called the City Council of Port Moresby, as shown in Fig. H-2.

Projects to be financed by foreign funs need consultation with the Office of International Development Assistance (referred to as OIDA), Department of Finance and Planning. The procedures were following for this study.

There were disputes and problems over the ownership and control of the water and sewerage systems in NCD, between NCDC and the Waterboard. Both sides had claimed legal rights. However, the Supreme Court of Justice of PNG gave its final judgement on November 28, 1990 (SCA42 of 1990). According to the judgement the ownership and control of the water and sewerage systems in NCD rests with NCDC.



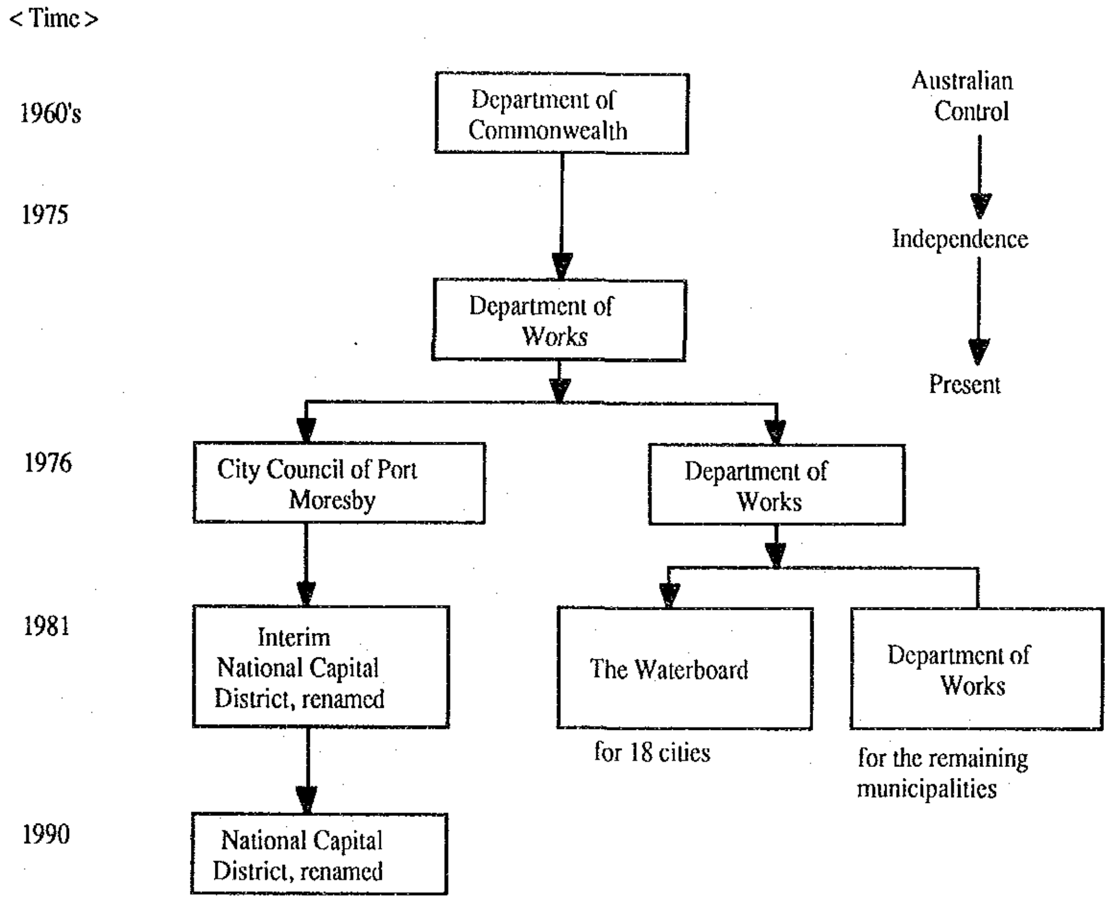
TITLE

GOVERNMENTAL ORGANIZATION OF PAPUA NEW GUINEA

Fig. No. **H.1**

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANS in association with PACIFIC CONSULTANTS INTERNATIONAL



TITLE

WATER SUPPLY SERVICE OF PAPUA NEW GUINEA

Fig. No. **H.2**

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

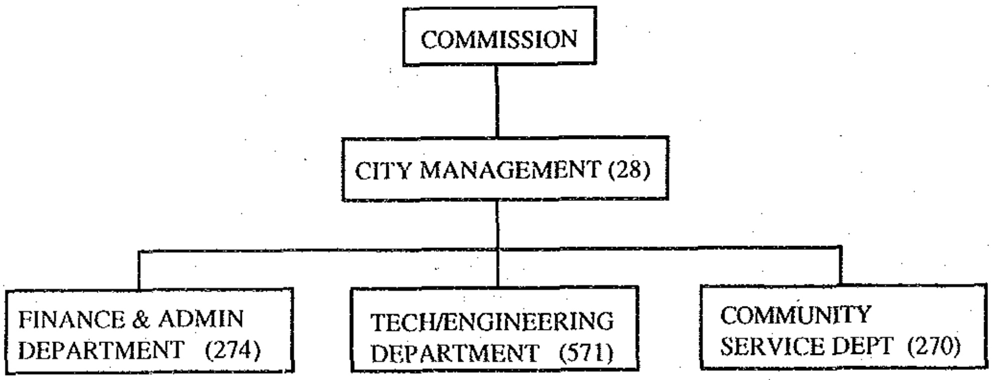
TOKYO ENGINEERING CONSULTANS in association with PACIFIC CONSULTANTS INTERNATIONAL

2. Organization of NCDC

The National Capital District Commission Act 1990 (No. 25 of 1990) was certified on August 29, 1990. The act specifies the functions, powers and composition of NCDC. The Commission consists of 24 members as given below.

a) 10 members elected by the Motu Koitabu people of NCDC,
b) 10 members elected by other inhabitants of NCDC,
c) 4 members of the National Parliament for NCDC (ex-officio members)

Under the Commission, there are Executive and Specialist Function Management (city management) sections consisting of eight executive and special staff: one General Manager, three Deputy Generals, and four Special Functional Managers, as shown in Fig. H-3.



Note: The number in ( ) indicates the number of staff.

Fig. H-3 Organization of NCDC

The four special functional managers include:

- Corporate Planner
- Principal Legal Officer
- Chief Internal Auditor
- Commission Secretary

The Corporate Planner is the counterpart for this study and has advisory functions with respect to the following five planners:

- Town Planner
- Social Planner

- Systems Development & Procedures Planner
- Transport Planner
- Water Supply & Sewerage Planner

(a) Structure of Finance & Administration Department

The structure of the Finance & Administration Department is shown in Fig. H-4. The Department has five divisions.

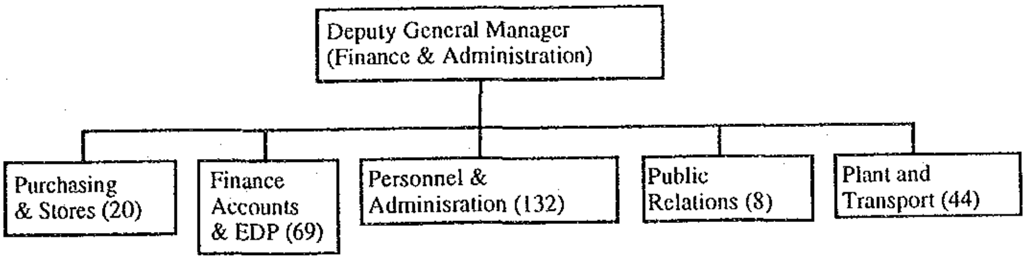


Fig. H-4 Structure of the Finance & Administration Department

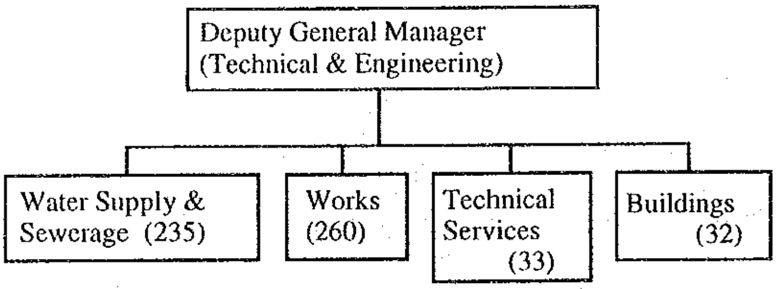
This Department has 19 functions mentioned below.

- EDP and Management Information *
- Budgeting *
- Purchasing *
- Payments *
- Receipts *
- Accounts*
- Property Maintenance *
- Security
- Housing
- Insurance
- Recruitment and Selection *
- Personnel and Salaries *
- Office Service
- Public Relations & Protocol
- Central Registry and Library
- Vehicles & Transport
- Workshop *
- Stores

As is clear from above, the Finance & Administration Department has a broad range of functions to control and monitor all activities of NCDC. The functions with * are directly related to water supply service.

(b) Structure of Technical & Engineering Department

The Department is responsible for technical jobs and is divided into four divisions as shown in Fig. H-5.



Note : The number in ( ) indicates the number of staff.

Fig. H-5 Structure of the Technical & Engineering Department.

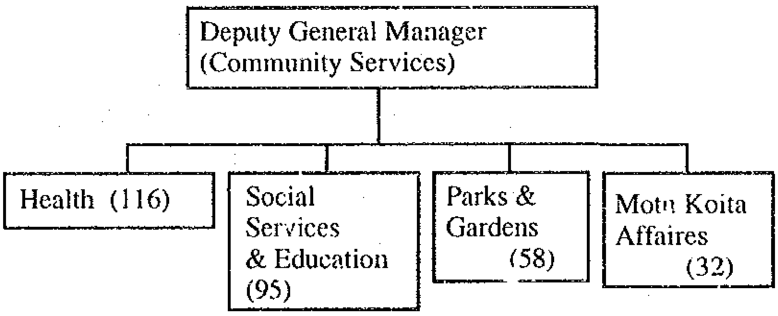
This Department has the following functions;

- Water Supply *
- Sewerage *
- Water Conservation *
- Water and Sewerage Design *
- Water Treatment *
- Road Maintenance
- Road Construction
- City Cleansing
- Architectural
- Building Authority
- Building Inspection
- Project Design and Construction
- Town Planning
- Traffic Management
- Land Administration
- Street Lighting
- Development Projects

The functions with * are directly related to water supply service.

(c) Structure of the Community Services Department

This Department has the duty of serving the population and is divided into four divisions shown in Fig. H-6.



Note : The number in ( ) indicates the staff number.

Fig. H-6 Structure of the Community Services Department

The Department has the following functions;

- Preventive Health
- Curative Health
- Inspection and Licensing
- Health Education
- Markets
- Youth
- Sports & Recreation
- Parks & Reserves
- Garbage and Sanitation
- Education
- Village Courts
- Women Affairs
- Probationary Service
- Religion
- Ward Administration
- Population Control
- Chemical Control
- Cemetery
- Community Law & Order and Welfare
- Motu Koitabu Projects/Administration
- Festival Co-ordination

The functions of this Department are not directly related to the water supply service. But in a broader sense, the Department should contribute to improved public relations.

The fundamental purpose of the water supply services is to provide the residents, commercial/industrial and other sectors with clean, abundant, and well-pressurized water.

- Clean water means water which is potable from water quality.
- Abundant water means water which is always sufficient and available.
- Well-pressurized water means water which has the requisite pressure to reach a certain height of building, based on the design criteria.

These are the three major duties of the water supply services.

Table H-1 shows the basic functions of water supply and the relevant sections of NCDC. Two problems were detected;

(A) the water supply organization of NCDC is rather fragmented.
(B) not all the functions required for water supply are covered by NCDC.

Table H-1 Basic Functions and Sections for Water Supply

Basic Function	NCDC Section
1. Planning/Design	Corporate Planner in Technical & Engineering Dep.
2. Survey	None (Consultants)
3. Detailed Design	Technical & Engineering Dep.
4. Bidding	Finance & Administration Dep.
5. Procurement	Finance & Administration Dep.
6. Construction	None (Contractors)
7. Supervision	None (Consultants)
8. Meter Reading/Collection	Finance & Administration Dep.
9. Operation & maintenance	Technical & Engineering Dep. (Water Supply and Sewerage Div.)

A solution to (A) is the establishment of a unified organization for water supply in NCDC. For a solution to (B), some new sections should be created to cover the relevant functions.

3. Technical Aspects

3.1 Present Status

The design valve for water consumption is reported as 225 l/c/d, while the actual figure is 750 l/c/d, or more than three times. This figure is considered to be very high and needs to be surveyed in the Study. The following are the explanations for the large difference:

- A large leaks
- Illegal connections
- Car washing
- Garden spray
- Others

It is reported that almost 100% of the residents in NCD are receiving correct water supply, but some areas have water shortages or low pressures. The present population in NCD is estimated to be about 200,000, based on the 1990 National Census. Water supply is different, depending on the income levels of residents; middle and high income groups have individual house taps, while low income groups are using community taps. Table H-2 summarizes the present status of water supply services in NCD.

Table H-2 Water Service Connections of Port Moresby

	Resident.	Comm/Ind	Stand pipe	Public	Str'ght pipe	Exempt	Total	Ratio
Metered								
Actual	8,030	811	10	4	17	1	8,873	46.5%
Estimated	5,205	281	32	1	14	1	5,534	29.0%
Subtotal	13,235	1,092	42	5	31	2	14,407	75.5%
Unmetered	2,765	341	1,558	3	12	4	4,683	24.5%
Total	16,000	1,433	1,600	8	43	6	19,090	100.0 %
(%)	83.8%	7.5%	8.4%	0.0%	0.2%	0.0%	100.0%	
Ratio								
Metered								
Actual	50.2%	56.6%	0.6%	50.0%	39.5%	16.7%	46.5%	
Estimated	32.5%	19.6%	2.0%	12.5%	32.6%	16.7%	29.0%	
Subtotal	82.7%	76.2%	2.6%	62.5%	72.1%	33.3%	75.5%	
Unmetered	17.3%	23.8%	97.4%	37.5%	27.9%	66.7%	24.5%	
Total	100.0%	100.0%	100.0%	100.0 %	100.0 %	100.0%	100.0%	

3.2 Meter Reading

The total number of connections is about 15,000, equal to the number of meters.

In the Finance & Administration Department there are 13 meter readers, who cover all the 15,000 connections every three months.

15,000 meters / 3 months / 25 days/month / 13 readers
= 15 meters/reader/day

Assuming that they spend 6 hrs a day for meter reading, they need 0.4 hrs (= 24 minutes) per meter for reading. This indicates that the meter readers have sufficient time, because they are reading the meters lot by lot in a short time. The meter readers maintain records and report to their supervisor. The records are processed by computer input.

They also report those meters that are stuck, broken or not available for investigation. Then the supervisor visits the same site to verify the report. If so, the Finance and Administration Department proceeds to replace the defunct meters with new ones.

It is reported that about 8% of the meters are defunct;

15,000 x 0.08 = 1,200 defunct meters

The number of defunct meters has been increasing. This is understandable, because the water supply system is aging without proper maintenance.

The JICA Study team found that the system of reporting from Finance and Administration Department to Technical and Engineering Department is not satisfactory. Reportedly about 3,000 new meters of different sizes are purchased by the Finance and Administration Department and used by the Technical and Engineering Department.

Since the water meter is sensitive, it gets stuck because of foreign matter or rust, or it may be inaccurate due to friction. Therefore, it is recommended that water meters be changed on a regular basis, regardless of whether they operate or not. In Japan, meters are renewed every 2 to 3 years free of charge.

Meter locations are unsuitable for meter reading, or not located within the private/public limits. Unsuitable locations of meters must be corrected for easy and safe access by meter readers. Water meters should be protected from traffic accidents and vandalism.

3.3 Record Keeping

(a) General

The main water supply system in NCD was designed and constructed in 1960's and 70's before the independence in 1975. City planning and design criteria for water supply were based on the Australian Standards, or British Standards. There is a colonial influence in design concepts. The original scheme of water supply in NCD was generous and provided water to widely spread areas.

In the last 20 years there has been no change nor investment in the water supply system. Minor constructions were made mainly for residential areas, but records have not been maintained systematically for updating the original system. Some are missing and others are not well organized.

The fundamental requirement of operation and maintenance is the upgrading of the existing system, so that the upgraded maps are available at any time for anybody. This was not done for NCD. There are two major reports for Port Moresby;

- Port Moresby Water Supply Study Report (Sept., 1992)

Volume 1 - Summary
Volume 2 - Technical Details

Prepared by Camp Scott Funy Pty Ltd.

- Report on Upgrading Raw Water Supply and Treatment Plant (May, 1987)
  Prepared by Beca Gure Pty Ltd.

(b) New Development

When a private company/citizen plans to develop a new area, the developer should follow the NCDC policy for land use and city planing, so that basic infrastructure like water, electricity, telephone etc. will be provided for the new development. NCDC prepared the following code for the purpose;

- National Capital District Interim Commission Submission Code (January, 1985) prepared by Camp Scott Furphy Pty Ltd.

The contents of the Subdivision Code are

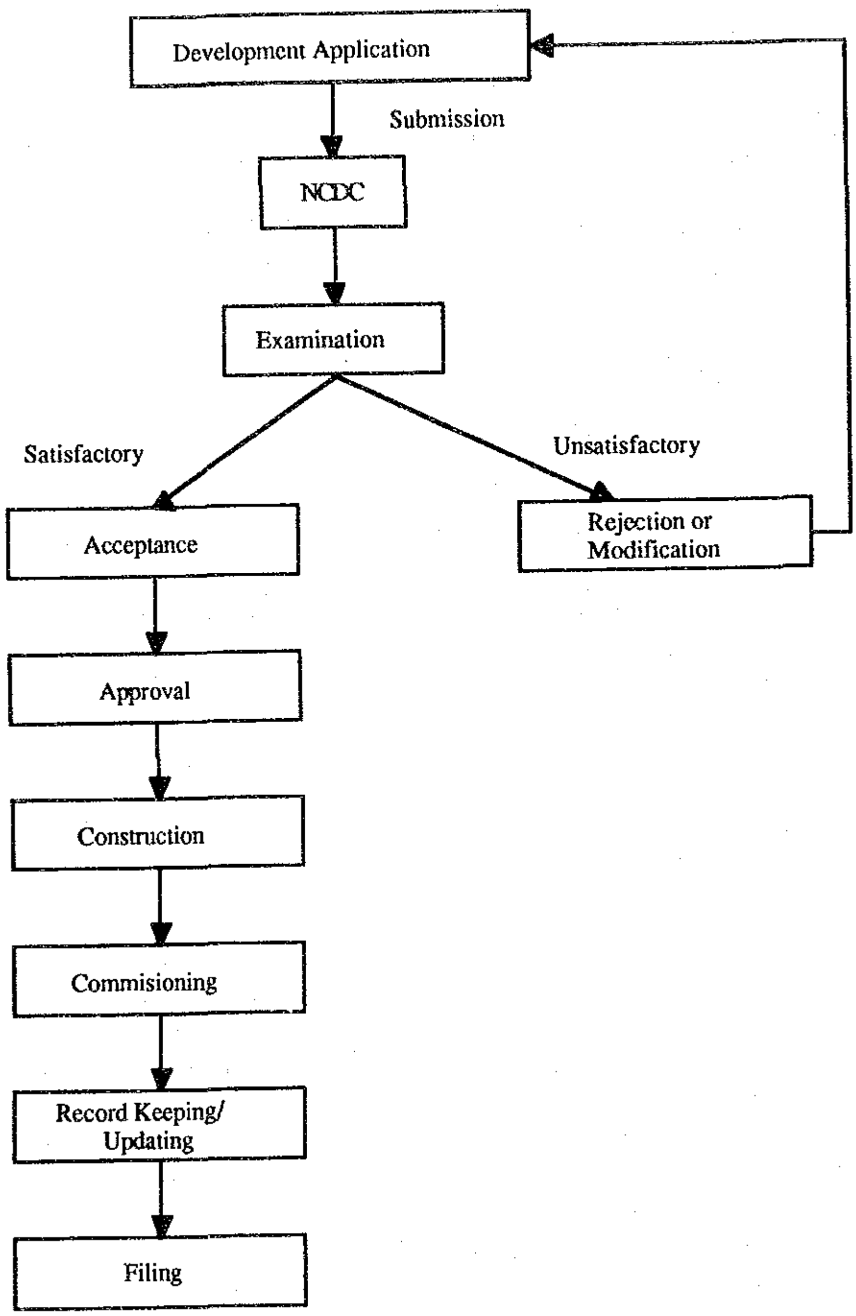
1. Introduction
2. General Requirements & Procedures
3. Roads
4. Drainage
5. Water Supply
6. Sewerage
7. Co-ordination of Other Services within Road Reserves

Water supply is further described as follows;

- General
- Water Demand & Pressure
- Basis of Hydraulic Design
- Alignment & Location of Mains
- Pipes
- Pipe Fittings
- Rubber Joint Rings
- Stop Valves
- Hydrants
- House Connection Services
- Main Construction
- Testing of Mains

- Connection to Existing Mains
- *Sterilizing & Flushing of Mains*
- Thrust Blocks
- Drainage Cutoffs
- Steep Water Mains - Special Requirements
- Special Requirements for Water Mains Crossing Other Services.

The general procedure for the application of a new development is shown in Fig. H-7, but a few problems exist, including the inadequate staffing of NCDC for examining and processing the procedure.



TITLE

APPLICATION PROCEDURES OF A NEW DEVELOPMENT

Fig. No.
H.7

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

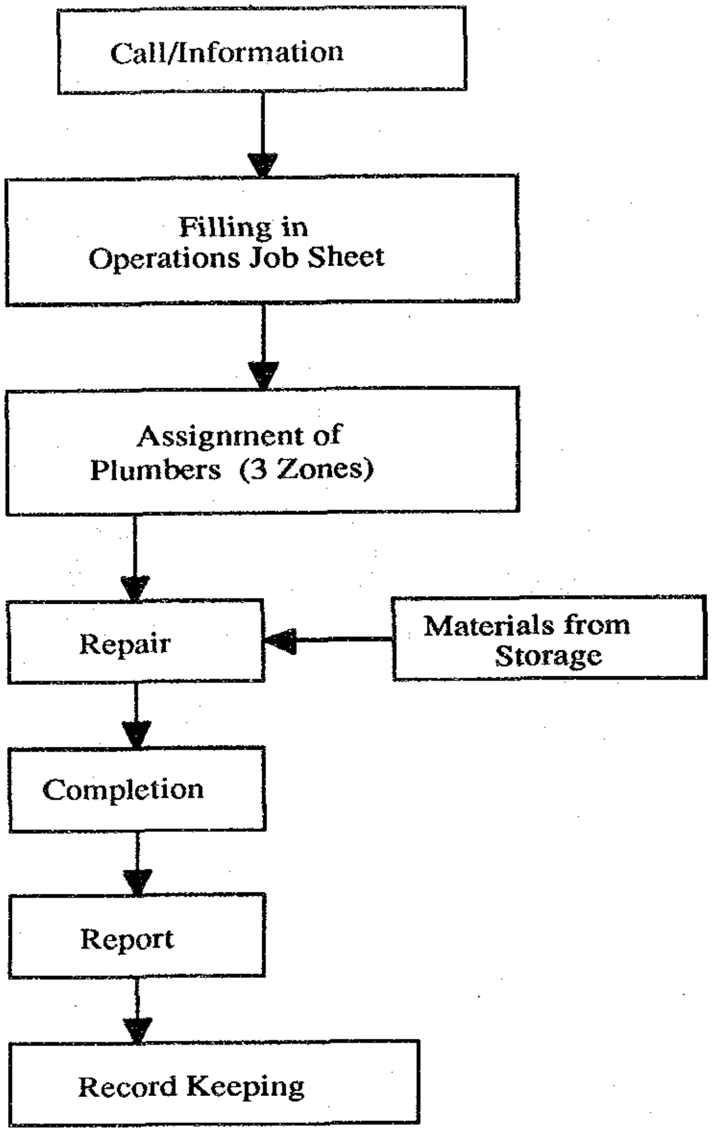
TOKYO ENGINEERING CONSULTANS in association with PACIFIC CONSULTANTS INTERNATIONAL

In the process the development engineer of Technical and Engineering Department examines the application based on the Subdivision Code. And after commissioning of the construction he is supposed to file all necessary documents. However the filing and updating system is not good. The JICA Study team requested the relevant documents required for the water supply study.

The most comprehensive drawings of the water supply system in Port Moresby are dated back to 1974. They were prepared by the Australian Dept. of Housing & Construction PNG before the Independence in 1975. The total length of the pipe system was estimated to be about 200 km. Since then only 10 km of new pipes were laid in the system. This is only a 5% increase of pipe length over a period of abcut 20 years, and only a 0.2% annual increase, compared to an annual population increase of 4.6%. This means that the original scheme was quite generous. Thanks to the generous system the population of Port Moresby was generally supplied with water with only minimum operation and maintenance, though there were cases of water shortage or low pressure.

(c) Repairs

There are two kinds of leaks: visible and invisible. A visible leak can be observed from the ground surface, while an invisible one is underground. If a visible leak is found by a resident, he will report it to Water Supply & Sewerage Division located at Shed 20. The procedure is as follows;



TITLE

JOB PROCEDURES

Fig. No.
H.8

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANS in association with PACIFIC CONSULTANTS INTERNATIONAL

Some of the problems recognized by the study team are;

- No systematic record keeping
- No asset correction
- No orderly storage of materials.
- Action taken only after call

Table H-3 Number of Service Calls

	Zone 1	Zone 2	Zone 3
1990	-	252	616
1991	756	1,700	1,372
1992	728	1,288	1,092
Average	742	1,080	1,026

Table H-3 shows that there are about 3 calls in each zone every day. But there is no record on how many days were required for each repair. It is assumed that almost all repairs are curative, not preventive, because plumbers are assigned to repair after a call. There is no system for preventing the potential leaks.

(d) Claims

Like repair calls, the affected residents call to report claims of water shortage or low pressure. The management of Water Supply and Sewerage Division assigns some plumbers to the site to identify the problem. They operate valves and try other measures to solve the problem. After finishing the job, they report to the management. There are some cases where a solution could not be found. However there are no systematic records.

3.4 Water Shortage

The residents living in some areas of the city, especially in Town, are suffering from a severe water shortage. An example indicating the situation is shown in Table H-4. A family of three persons in Town maintains records of water shortage.

Table H-4 An Example of Water Shortage in Town

Year/Month	Days with No Water Supply (Cumulative)	Rate (%)
1991 / 9	6.3	20.8
10	6.3	20.3
11	1.8	5.8
12	8.0 (estimated)	25.8
1992 / 1	0	0
2	0	0
3	0	0
4	0	0
5	0	0
6	1.8	6.0
7	16.4	53.0
8	7.0	23.3
9	4.9	16.3
10	26.2	84.5
11	18.6	61.9
12	10.3 (estimated)	33.3
Average	6.7	20.1

The table indicates that the average days of water shortage are 6.7 days per month, or 20.1% for a period from September 1991 to December 1992. However the worst water shortage occurred in October 1992, when water was stopped for 26.2 days, or 84.5%. The only relief measure is to install a water tank in the house to be filled by a water truck. However, private water trucks are quite expensive for the average residents. The installation of a water tank is a double investment. NCDC water trucks are few and very slow to respond to claim calls, because NCDC has only two trucks. NCDC contracted about 20 private water trucks in December 1992 to deliver water to houses suffering from water shortage.

3.5 Training

NCDC is providing its employees with local and overseas training. However, funs available are small and limited. NCDC is dependent on foreign funds for overseas training, and funds are sporadic and unreliable. The training can be divided into short and long terms. The next table shows the training situation from 1986 to 1991.

Table H-5 NCDC Truing

(persons)

Year	Local	Overseas
1986	16	3
87	22	5
88	12	0
89	2	2
90	7	1
91	9	0
Average	11.3	1.8

This table shows that on an average only 11.3 and 1.8 persons respectively, trained locally and internationally. The figures when compared with the total number of about 1000 NCDC employees, is only 1.3%. The training system of NCDC needs to be improved. There is no systematic training for new employees, especially at the lower level, in the Water Supply and Sewerage Division.

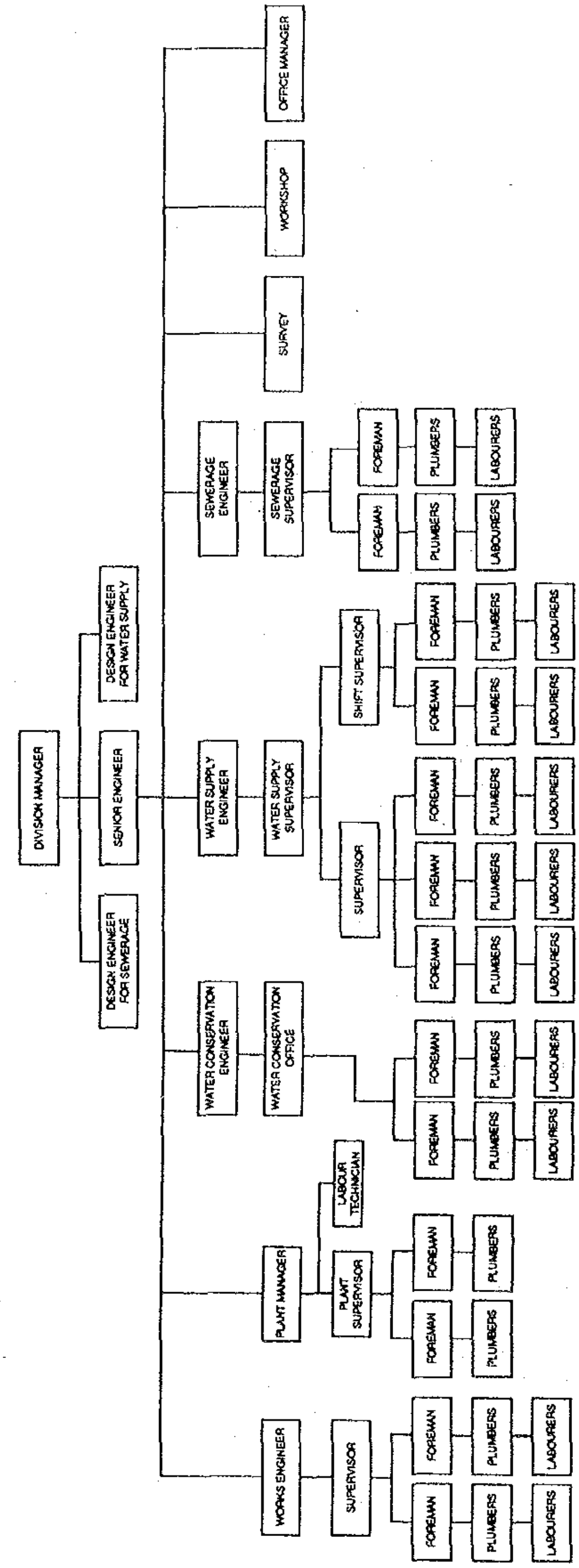
4. Organization of Water Supply and Sewerage Division

The existing organization of Water Supply and Sewerage Division is shown in Fig. H-9.
There are five major sections;

- Water Supply
- Water Conservation
- Treatment Plant
- Sewerage
- Works (Rezoning)

There are three minor subsections;

- Survey
- Workshop
- Office Management



TITLE	Fig. No.
EXISTING ORGANIZATION OF WATER SUPPLY AND SEWERAGE DIVISION	**H.9**

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANS in association with PACIFIC CONSULTANTS INTERNATIONAL

This organization consists of 235 staff, with 26% plumbers and 52% laborers, constituting about 80% of the total staff. There are about 13 meter readers and their supervisors in the Finance and Administration Department.

The existing organization is not designed for planning, but only for maint. It needs to be unified and strengthened. But this will be discussed later. An independent water supply organization has 12 major functions.

		Performance	
1)	Planning/Design	M	(T/E)
2)	Construction	¥	
3)	Plant Operation	M	(T/E)
4)	Facility Operation	M	(T/E)
5)	Repair/Overhaul	M	(T/E)
6)	Distribution	M	(T/E)
7)	Meter Reading	G	(F/A)
8)	Collection	G	(F/A)
9)	Purchasing/Warehouse	M	(F/A & T/E)
10)	Finance	M	(F/A)
11)	Public relations	M	(F/A)
12)	Administration	G	(F/A)

Note: T/E = Technical & Engineering Dept.
F/A = Finance & Administration Dept.
Performance : G (Good)
M (Moderate)
P (Poor)

Three alternatives are recommended for the water supply and sewerage organization.

Alternative I

Only minimum arrangements are made. The Water Supply & Sewerage Division is still dependent upon Finance & Administration Dept for meter reading, billing and collection. One of the disadvantages of the Alternative I is that the Division has no capacity to monitor and control financial aspects. The concept of cost-recovery is quite limited.

Alternative II

To avoid the above disadvantage, this alternative is recommended, with financial officers for meter reading and billing/collection.

Alternative III

In this alternative the Water Supply and Sewerage Division is upgraded to the Department level The Water Supply and Sewerage Department has more independence and a capacity for budgeting and planning. On the technical side the Department has given more capacity to plan the system comprehensively. This will be done in close consultation with other agencies like land use and city planning agencies. Actual arrangements need to be made also in consultation with electricity, telephone, gas companies etc. for sharing use of underground space.

5. Recommendations

The following are recommended for improved management:

a) Water Supply and Sewerage Division be reorganized and upgraded.

b) Frequency of meter reading should be increased to every two months for improving efficiency.

c) Systems of record keeping for repairs and claims should be developed.

d) Existing Water networks should be updated.

e) Proper training should be given to all levels of staff with necessary funds.

II Operation and Maintenance

1. Introduction

The water system of Port Moresby has been operated and maintained by the citizens of Papua New Guinea since Independence of 1975. Inadequate knowledge of the water supply system and inappropriate operation and management have caused a serious deterioration of the system, since the population has been increasing at a higher rate of about 5%. The present population for water supply is estimated to be about 210,000, or 100% of service ratio.

There have been severe droughts in the Port Moresby area in recent years. In 1992, there was almost no rain from April to November in the city. These factors have caused severe problems such as water shortage and low pressure in many areas, especially in Town.

The residents of the adversely affected areas have to install storage tanks and facilities, and call at NCDC or private companies for water delivery. Charges of private companies for water delivery, are expensive and only rich people can afford it. If they have to install water facilities at home, the costs are a duplication of investment. Poor people can not afford these options. The situation is likely to force them to buy water or at high prices make illegal connections.

2. Major Problems of Current Operation and Maintenance

There are many problems in the current operation and maintenance of the water supply system in Port Moresby. Improvements will be recommended later in the Master Plan, because they are fundamental. A certain amount of funds will be required for improvements. The present organization needs to be reorganized. Qualified staff need to be recruited for management: the salaries for this staff must be decided. There are also training requirements. More sophisticated techniques should be developed to monitor the whole system properly.

2.1 Inefficient Meter Reading

The number of water supply service connections are estimated as 19,090, of which 75.5% are metered and 24.5% are not metered. About 60% of the metered connections are read every three months. Consumption of the remaining are estimated, because they are broken or cannot be located. Estimated readings are surprisingly high. The details are shown in Table H-6.

There are at present 13 meter readers in the Dep. of FA who read about 15,000 meters every three months. This means that each meter reader should read only 15 meters every day. More efficient meter reading is possible by zoning or selecting routes.

Table H-6 Water Service Connections of Port Moresby

	Resident	Comm/Ind	Stand Pipe	Public	Str'ght Pipe	Exempt	Total	Ratio
Metered								
Actual	8,030	811	10	4	17	1	8,873	46.5%
Estimated	5,205	281	32	1	14	1	5,534	29.0%
Subtotal	13,235	1,092	42	5	31	2	14,407	75.5%
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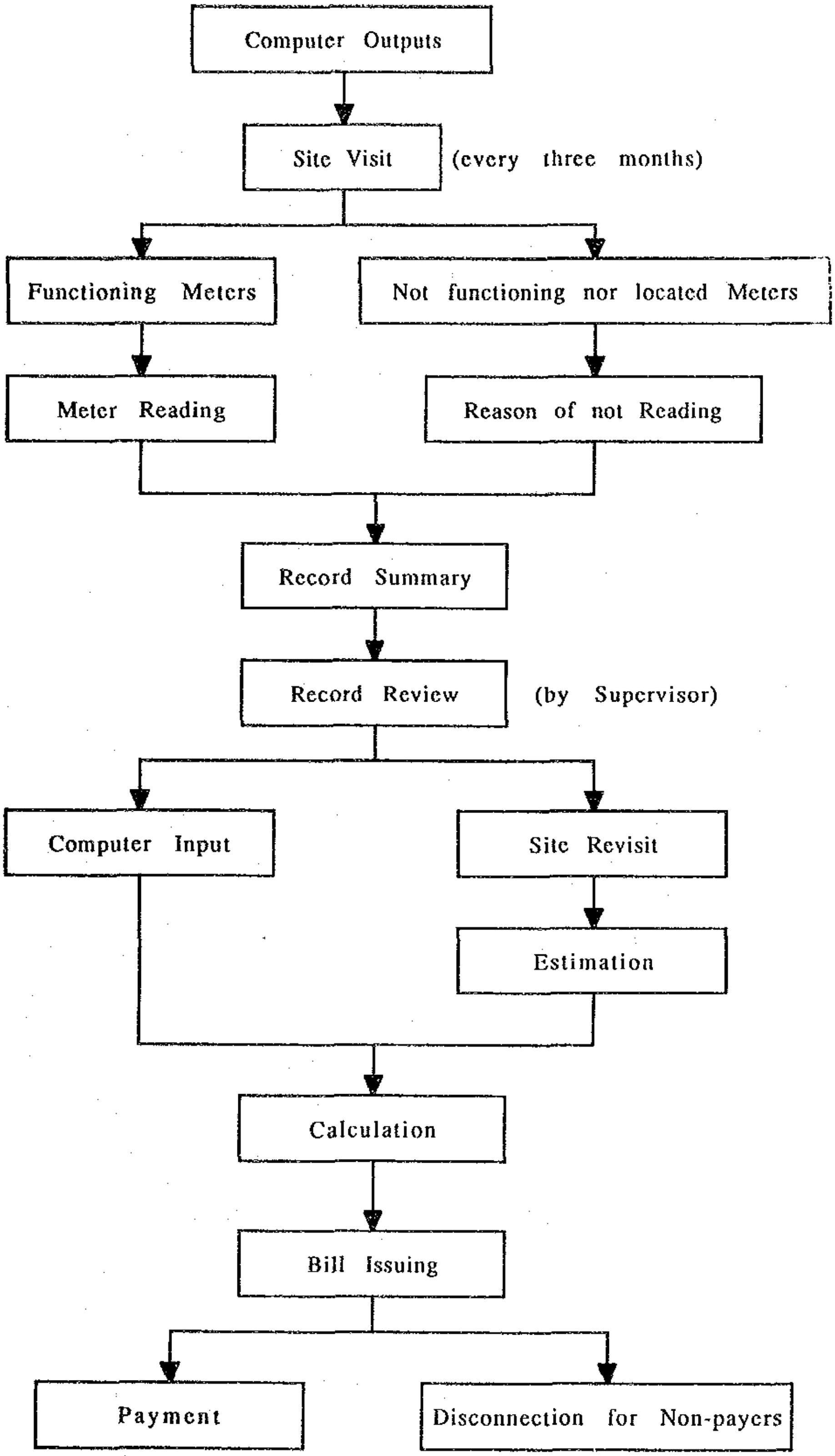
Total	16,000	1,433	1,600	8	43	6	19,090	100.0 %
(%)	83.8%	7.5%	8.4%	0.0%	0.2%	0.0%	100.0%	
Ratio								
Metered								
Actual	50.2%	56.6%	0.6%	50.0%	39.5%	16.7%	46.5%	
Estimated	32.5%	19.6%	2.0%	12.5%	32.6%	16.7%	29.0%	
Subtotal	82.7%	76.2%	2.6%	62.5%	72.1%	33.3%	75.5%	
Unmetered	17.3%	23.8%	97.4%	37.5%	27.9%	66.7%	24.5%	
Total	100.0%	100.0%	100.0%	100.0 %	100.0 %	100.0%	100.0%	

Simplified procedures for meter reading done presently, are shown in Fig. H-10. The city of Port Moresby is divided roughly into three areas for meter reading. The meter readers are using two mini-vans with 10 seats including the driver. This means that there are two teams with a total of 13 meter readers. They go to the designated area with a computer output showing the last readings. They visit site by site to read the meters. They enter the readings in the record book. In some cases, however, meters are broken or damaged due to traffic or vandalism. If so, they write down the reason for not reading. Other cases include meters covered with some heavy object or meters that cannot be located. Or sometimes there are guard dogs only in houses so meter readers cannot access the meters. In such cases they write down the reasons for not reading the meters.

After reading meters one day, the meter readers report to their supervisor. He reviews the records and inputs data in the computer. For non-read meters the computer makes an estimate based on the past trend. The supervisor explained to JICA study team that an effort would be made to avoid two continuous estimates. In case of doubtful readings, the supervisor visits the site to verify the record. After the computer processing, NCDC issues the bills to the consumers every three months. They are obliged to pay the bill within two weeks. If they fail to comply with the deadline, their water supply may be disconnected.



TITLE

METER READING PROCEDURES

Fig. No. **H.10**

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANTS in association with PACIFIC CONSULTANTS INTERNATIONAL

2.2 Incomplete Coverage by Meters

The total bill units are estimated to be about 23,000, considered equivalent to the number of registered households. There are illegal settlers or unregistered residents. NCDC installs about 19,000 connections for water supply. This means there are some households who share a connection. The metered connections being read are low as 46.5%, as shown in Table H-7.

Inaccurate estimations are causing frustrations and claims among water consumers. Therefore all connections should be metered and all houses connected as soon as possible. If a connection is shared by several households, the collecting the charge is difficult, and may cause inconveniences for the users. For this reason, all straight pipes should be metered. Exempted users should also be metered, though they are exempted from paying bills. This is because their consumption needs to be monitored by NCDC.

2.3 Illegal Connections

Meter readings are taken every three moths and bills are sent to the users. The payment is due within two weeks. Overdue payments are subject to disconnections. The Finance & Administration Dept is responsible for disconnections. When a disconnected user pays the bill and additional surcharge, his house will be reconnected for service resumption. The reconnection charge is K 20. When a new house is constructed, the owner can apply for a new connection with K 20. These relationships are shown in Table H-7.

According to the Table, the annual increase in connections is estimated to be 1,200. However it is estimated that half of the disconnected services have been converted to illegal connections. They are not charged, but are still using the same or more water free of charge through illegal connections. This situation is deteriorating the financial status of NCDC and must not be tolerated.

NCDC should take quick action to investigate the illegal connections and stop the water supply, unless they pay the bills. All the users be metered, regardless of whether they are paying the bills or exempted for social welfare, because the total water consumption as well as leakage must be monitored to ensure system operation.

Table H-7 Disconnections, Reconnections and New Connections

Month	Disconnect	Reconnect.	Illegal Conn (estimated)	New Connc.	Total
'1991					
Jan	0	140	0	38	178
Feb	480	306	240	30	96
Mar	510	220	255	11	-24
Apr	570	268	285	36	19
May	570	337	285	62	114
Jun	480	231	240	182	173
Jul	540	232	270	60	22
Aug	540	267	270	22	19
Sep	480	307	240	31	98
Oct	570	314	285	43	72
Nov	510	312	255	12	69
Dec	360	117	180	3	-60
Subtotal	5,610	3,051	2,805	530	776
Ave 1	467.5	254.3	233.8	44.2	64.7
'1992					
Jan	0	64	0	14	78
Feb	480	226	240	29	15
Mar	540	306	270	23	59
Apr	540	278	270	23	31
May	480	251	240	25	36
Jun	540	218	270	29	-23
Jul	540	286	270	43	59
Aug	510	183	255	133	61
Sep	540	236	270	96	62
Oct	510	208	255	14	-33
Nov	510	287	255	46	78
Dec					
Subtotal	5,190	2,543	2,595	475	423
Ave 2	471.8	231.2	235.9	43.2	38.5
Total	10,800	5,594	5,400	1,005	1,199
Average	469.6	243.2	234.8	43.7	52.1

2.4 Problem of Stand Pipes

Stand pipes are generally constructed for low-income group and are found in planned or unplanned settlements. There are many illegal connections from stand pipes, according to JICA observations.

Water is a social commodity, which should be provided to poor people at a lower price. All users should pay for it. However it is practically difficult to collect money for water and use of stand pipes, because they are too poor, and can not pay. Therefore it is recommended that the number of stand pipes be reduced gradually to the minimum level, unless absolutely necessary for welfare. The following table shows that the water consumption amounts to 3.2%.

Table H-8 Water Consumption by Category

(m^3/d)	Resident.	Commer.	Stand P.	Public	Str'ght P.	Exempt*	Total
Quaters							
2nd Q/92	45,241	34,781	2,590	141	32	16	82,800
1st Q/92	52,235	31,170	2,688	174	36	18	86,322
4th Q/91	39,848	34,781	2,545	91	34	17	77,316
3rd Q/91	44,942	31,170	2,517	214	34	17	78,895
2nd Q/91	41,570	32,660	2,505	192	37	18	76,983
Total	182,266	131,902	10,340	620	136	68	325,332
Ratio (%)	56.0%	40.5%	3.2%	0.2%	0.0%	0.0%	100.0%
Average	45,566	32,975	2,585	155	34	17	81,333
Gr Rate(%)	108.83%	106.49%	103.39%	73.29%	86.46%	86.46%	107.56%

The next table shows the water consumption per connection by category. It is seen that water consumptions are 356, 81 and 99 l/c/d for residents, stand pipe and straight pipe users, respectively. These figures are almost similar to those found in the survey.

Table H-9 Water Consumption per Connection

	Resident	Commer/ Ind.	Stand Pipe	Public	Straight Pipe	Exempt	Total
Connect.	16,000	1,433	1,600	8	43	6	19,090
Water Con (m^3/d)	45,566	32,975	2,585	155	34	17	81,332
Per Con. ($m^3/d/c$)	2.85	23.01	1.62	19.38	0.79	2.83	
No of HH	8		20		8		
Water Con (l/c/d)	356		81		99		

2.5 Low Water Prices

The water rate is the only resource for running the system by covering the following costs:

- Administration
- Operation
- Maintenance
- Depreciation
- Loan repayment

NCDC has the water tariff shown below, but what costs are covered by the water tariff, and how much is covered, is unclear.

Table H-10 Water Tariff of NCDC

Domestic Premises	from	to	unit		Unit
	0	40	m^3	0.125	$K/m^3/month$
	40	140	m^3	0.500	$K/m^3/month$
	140	over	m^3	1.000	$K/m^3/month$
minimum				5	K/month
Commercial/Indust./ Instit. Premises	from	to	unit		
	0	200	m^3	0.150	$K/m^3/month$
	200	over	m^3	0.600	$K/m^3/month$
minimum				30	K/month
Public Premises	from	to	unit		
	0	250	m^3	0.100	$K/m^3/month$
	250	over	m^3	0.150	$K/m^3/month$
minimum				12	K/month
Unmetered Domestic Premises					
Inside water				5	K/month
Stand pipe				2	K/month
Other Charges - Water from Hydrant					
Daily Permit				8	K/day
Weekly Permit				30	K/week
Monthly Permit				100	K/month
Vessels per 10 m^3 or part there of					
Coastal				2.5	K/month
Overseas				3.0	K/month
minimum					
Coastal				2.5	K/V/month
Overseas				25.0	K/V/month

2.6 Weak Asset Management

The water supply system is a typical heavy capital business and asset management is very important. However NCDC has not managed its assets properly, nor maintained necessary records. This management needs to be strengthened urgently, because it affects the operational costs.

2.7 Insufficient Bill Collection

NCDC is reading the meters and sending the bills to the account holders every three months. Then they start paying the bills. The payment is due within two months. However the efficiency of bill collection is as low as 60% (see Table H-11). The bill collection system needs to be improved.

Table H-11 Efficiency of Bill Collection

	Billing Amount (K) Min	Excess	Subtotal	Collected Amount (K)	Subtotal	Rate
Month						(%)
'1991						
Jan				1,041,605		
Feb				357,326		
Mar	439,113	1,676,225	2,115,338	146,465	1,545,396	
Apr				683,838		
May				524,496		
Jun	442,119	1,676,300	2,118,419	126,162	1,334,496	63.1%
Jul				485,059		
Aug				699,237		
Sep	442,107	2,179,659	2,621,766	23,694	1,207,990	57.0%
Oct				911,467		
Nov				626,331		
Dec	445,137	2,298,270	2,743,407	131,913	1,669,711	63.7%
Subtotal	1,768,476	7,830,454	9,598,930	5,757,593		
Ave 1	147,373	652,538	799,911	479,799		61.3%
'1992						
Jan				682,419		
Feb				669,057		
Mar	446,166	2,637,402	3,083,568	294,631	1,646,179	60.0%
Apr				386,160		
May				835,427		
Jun	446,660	2,395,063	2,841,723	477,815	1,699,402	55.1%
Jul				639,386		
Aug				582,564		
Sep	444,651	2,696,995	3,141,646	220,988	1,442,938	50.8%
Oct				1,000,674		
Nov						
Dec						
Subtotal	1,337,477	7,729,460	9,066,937	5,789,193		
Ave 2	148,609	858,829	1,007,437	578,919		55.3%
Total	3,105,953	15,559,914	18,665,867	11,546,786		
Average	147,903	740,948	888,851	577,339		58.3%

2.8 Inappropriate Location of Meters

It is recommended that water meters be located on the boundary line between public and private premises and protected properly from damage. Correct meter reading is essential for proper operation. However there are quite a few examples of inappropriate meter locations in Port Moresby. They are damaged by vehicles or vandals. This is why many meters, or 38% of total meters, are not read but estimated. This is quite a high figure.

Water meters should be located appropriately so that meter readers can access them easily. This will improve the efficiency of meter reading. All present locations must be located at appropriate places and recorded in the "Book of Meters". If the locations are not appropriate, they should be relocated immediately at usser's cost or NCDC.

2.9 Poor PR Activities

It is important to inform and educate the population the high costs incurred for producing water and the correct mode of usage. They should be informed regularly about the following:

- Present situation of water supply
- Measures for saving water ,
- Prevention of illegal connections,
- Price of water (ex, per m^3 of water)

In this context, the "Water Patrol" should be strengthened by educating them, and illegal consumptions must be found. Mass media are also important. A budget for this must be allocated.

2.10 Improper Record Keeping

There are no systematic records of operation and maintenance, such as numbers of repairs or claim calls. If records are kept in a systematic way, NCDC can monitor equipment affected by the old system or water shortage.

NCDC has divided Port Moresby into three zones for services and operation/maintenance, as shown in Fig. H-5.

The three service zones are divided as follows:

Table H-12 Water Service Zones of Port Moresby

Zone No.	Area Names
Zone 1	GEREHU, UNIVERSITY, WAIGANI, MORATA, ENSISI VALLEY, TOKARA, WAIGANI GOVERNMENT OFFICES
Zone 2	HOHOLA, GORDONS 5, GORDONS, ERIMA, BOROKO, SARAGA/AIRPORT, BOMANA, 8 MILE SETTLEMENT, 9 MILE SETTLEMENT
Zone 3	KOROBOSEA SABAMA, KAUGERE, KILAKILA/VABUKORI, GABUTU, BADILI/KOKI, TOWN, HANUABADA, BARUNI/TATANA, IDUBADA

A person detecting a leak makes a call to Shed 20 Water Supply & Sewerage Div. Shed 20 will send a repair team to the site and repair the leak with necessary materials and hired equipment. These calls are maintained in "Record Book or Repairs". A person affected by water shortage for low pressure, calls Shed 20. Shed 20 will send a staff to the caller and try to supply water by operating the valves. These calls are recorded in the "Book of Claim Calls".

However these records are unsystematic and improper. There are no records for a couple years ago. There are only incomplete or no records on the materials that were used, types of repairs, and number of man-days required for the repair. The system of record keeping should be improved urgently.

The following table though incomplete, gives a rough idea of repairs and claim calls.

Table H-13 Repair and No Water Calls to NCDC

	Repairs Calls 1	2	3	Subt 1	No Water Calls 1	2		Subt 2
Year/Mon								
'1991								
May	39			39				0
Jun	83			83				0
Jul	106			106				0
Aug	88			88				0
Sep	73			73		19	95	114
Oct	127			127	57	67	86	210
Nov	94			94	6	22	90	118
Dec	81	75		156	4	22	89	115
Subt 1	691	75		766	67	130	360	557
Ave 1	86.4	75.0		161.4	16.8	26.0	72.0	114.8
'1992								
Jan	72	113		185	5	12	120	137
Feb	95	138		233	14	13	138	165
Mar	114	124	48	286	9	18	115	142
Apr	40	106	93	239	5	14	128	147
May	68	96	82	246	8	21	130	159
Jun	77	138	101	316	16	10	126	152
Jul	128	157	172	457	22	15	132	169
Aug	116	159	128	403	8	13	125	146
Sep	98	146	116	360	3	10	132	145
Oct	123	144	133	400	4	8	140	152
Nov	97	137	95	329	3	7	129	139
Subt 2	1,028	1,458	968	3,454	97	141	1,415	1,653
Ave 2	85.7	121.5	96.8	287.8	8.1	11.8	117.9	137.8
Total	1,719	1,533	968	4,220	164	271	1,775	2,210
Average	90.5	127.8	96.8	315.0	10.3	15.9	104.4	130.6
Annual calls	1,086	1,533	1,162	3,780	123	191	1,253	1,567

This table shows that there are 3,780 calls for repair each year, or about 10 calls daily . The calls are spread out almost equally in three zones. This means that the existing system has deteriorated all over the city. It is also observed that there are 1,567 calls for no water each year, of which about 80% are concentrated in Zone 3. This Zone includes the major business and commercial areas of Town. This means that supplied water cannot reach the downstream end of the system.

2.11 Poor Water Supply Service

The service level of water supply by NCDC is low and needs to be improved. The minimum requirements of water supply are as follows:

- Safe water
- Continuous supply
- Low cost

For those who are suffering from water shortage, there are two options to get water:

- call NCDC (free but slow)
- call a private company (fast but expensive)

NCDC is contracting about 20 water carts, or trucks for water delivery. NCDC has two water trucks. In case someone calls NCDC for water delivery, it will assign one of the trucks for delivering water. It will get water from a fire hydrant or a filling station and deliver it to the caller's house. This delivery is free of charge except the normal tariff, but is usually very slow. This operation may be subject to corruption. Those who want water urgently call one of the private companies for water delivery. They are fast, but expensive and charge about K400 ~ 600 per a tank. There are two problems:

- Low tariff for private companies
- No control over water quality

There is a water tariff for truck delivery, but it is quite low. Financial viability is largely ignored. This tariff needs to be increased. A private company can not assure water quality. It may fetch water from a source where the water quality is not assured.

For both cases the users have to install a storage tank and additional facility at their own cost, which is waste of investment or duplication. It is difficult to keep the storage tanks clean. Water in the tank has a risk of corrosion, insects or others. The tanks need to be maintained on a regular basis by the owner. But in most cases this is very difficult.

2.12 Poor Training System

At present NCDC is sending several upper level staff overseas mainly for graduate courses, based on funds from available outside the country. It is also sending some staff to short term courses organized by universities or academic organizations. However the budget for training is quite small K120,000 for all NCDC staff for local and overseas training.
There is no training for water supply staff, especially for low level staff. The low level staff also need to be trained. The training can be on-job or off-job training. Some low level staff are

not literate and they have joined NCDC when there was a vacancy, but this is why they need training. Fundamental problems are as follows:

- Insufficient funds
- No lecturers
- No materials
- No facilities

However the present situation of water supply in Port Moresby offers the best opportunity for training high and low level staff, to investigate why many people are suffering from water shortage, or why the system is not working well. JICA reports can be used for understandings the system.

2.13 No Maintenance Plan

Any system needs to be maintained properly on a regular basis. This is preventive maintenance. But what NCDC has been doing is only bandage maintenance. There is no maintenance plan. Wherever a repair is needed, it is repaired temporarily. If the same site needs repair again, it repeats the same repair without understanding the reason.

Therefore, a maintenance plan should be developed for the long tern. For this a specific budget will be required, and above all the system must be understood thoroughly.

3. Recommendations

The following are recommendations for improved operation and maintenance:

a) All connections must be metered as soon as possible.

b) Illegal connections must be inspected and eliminated quickly.

c) Problems of stand pipes must be identified and solved.

d) Water pricing must be studied and established from social and economic view points.

e) All assets must be registered and their values assessed urgently.

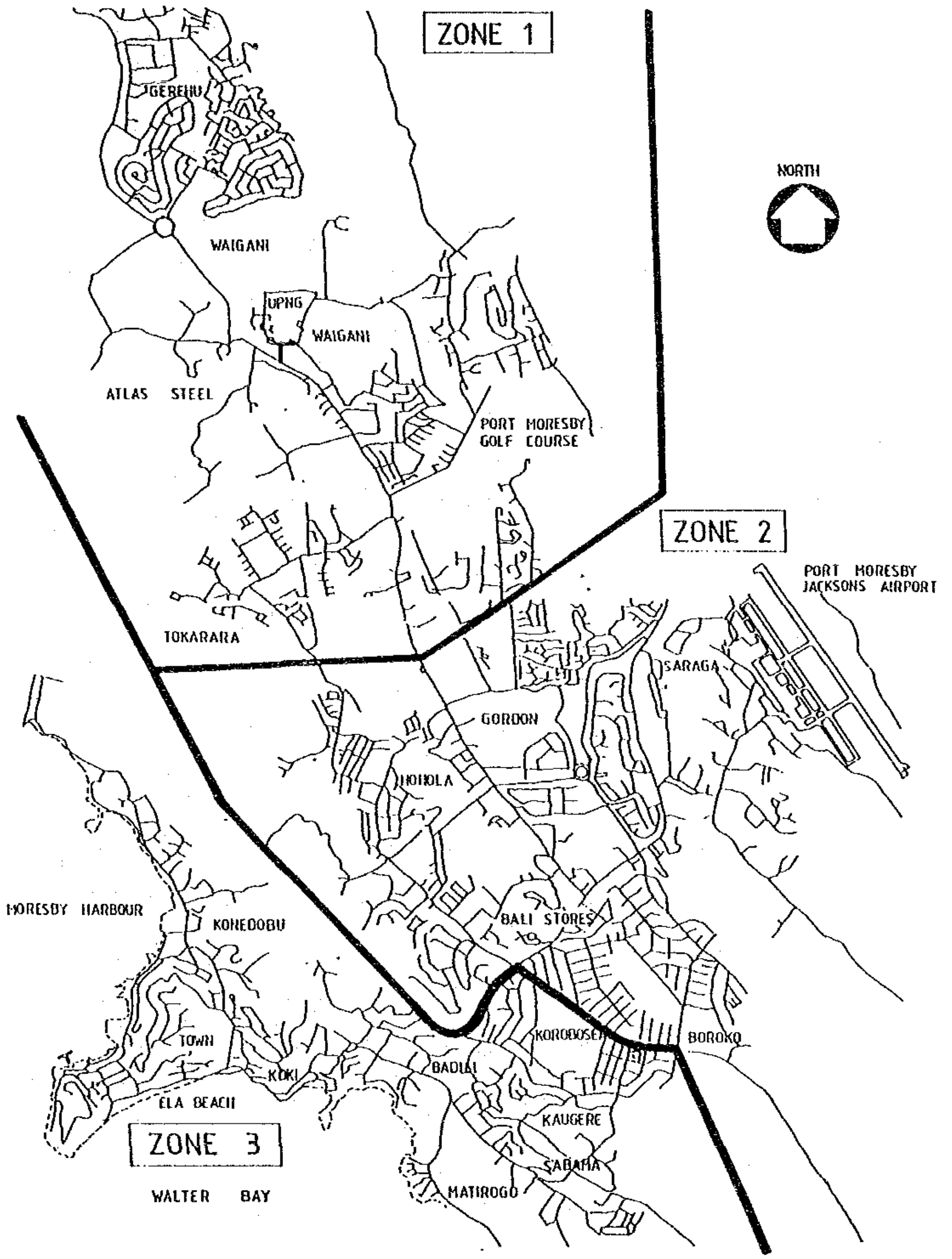
f) Efficiency of bill collection must be improved.

g) Inappropriate locations of meters must be identified and tariff collected as soon as possible.

h) PR activities must be intensified.

i) Urgent maintenance plan must be established.

j) Leak prevention measures must be implement.



TITLE

SERVICE ZONES OF WATER SUPPLY IN PORT MORESBY

Fig. No. H.11

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANS in association with PACIFIC CONSULTANTS INTERNATIONAL

APPENDIX I

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

FINANCIAL ANALYSIS

CONTENTS

Page

LIST OF TABLES

1. INTRODUCTION

The explanations of the following tables are described in Chapter 10, Master Plan, and only the tables are attached here for reference.

TABLE I.1 FINANCIAL STATEMENTS OF THE NCDC

Kina: current

	1987	1988	1989	1990
Fixed Asset : WS&S	3,918,590	4,025,5 43	4,282,644	5,230,135
Fixed Asset : General	5,934,715	6,561,505	6,547,159	6,381,976
Investments	510,880	10,880	1,010,880	1,010,880
Debtors : WS	4,683,514	7,696,106	8,327,648	11,271,351
- : Bad D Provision: WS	-1,170,879	-1,682,000	-2,214,696	-2,817,838
Debtors : Sewerage	471,262	2,162,376	2,415,189	2,665,522
- : Bad D Provision : WS	-393,392	-590,987	-759,950	-838,840
Debtors : Others	6,542,235	6,116,453	7,524,982	8,638,604
- : Bad D Provision : O	-661,265	-909,649	-938,201	-1,019,431
Stock : WS&S	588,720	430,487	533,435	498,545
- : Obsolate S Prov: WS&S	-58,958	-21,524	-26,672	-24,927
Stock : Others	266,955	295,872	207,117	364,273
- : Obsolate Prov: O	-26,735	-14,794	-10,356	-18,213
Cash	800	700	700	800
Adjustment	0	0	0	0
ASSETS : TOTAL	20,606,442	23,080,968	26,899,879	31,342,837
Loans : WS&S	6,382,533	5,794,920	5 ,394,712	5,059,731
Loans : General	418,032	418,032	0	33,334
Loan Repayment	878,042	767,705	1,473,991	2,298,584
Sundry Creditors	1,112,412	1,511,595	1,026,053	1,094,106
Bank Overdraft	1,382,594	822,218	2,397,694	2,055,753
Provision for Leave	1,003,696	939,536	1,173,763	1,145,122
Project Fund : WS	112,000	112,000	0	0
Project Funds : Others	134,788	485,000	153,154	153,620
Deferred Income : Sewer	784,875	811,578	821,665	827,840
Reserved Funds : WS&S	8,138,213	10,972,412	13,611,555	18,724,607
Reserved Funds : General	259,257	445,472	847,392	-49,860
Adjustment	0	0	0	0
Liabilities :	20,606,442	23,080,968	26,899,979	31,342,837

Income : WS	4,075,729	5,964,641	6,672,692	8,900,123
Reconnection	13,176	66,958	50,513	84,581
Income : Sewerage	1,532,639	1,657,196	1,740,054	1,639,150
Prov: Doubt. Debts	-330,270	0	0	0

Expend : WS&S, Administer	1,330,258	2,654,527	4,094,222	3,387,493
Expend : WS, Mt.Eriama	539,453	645,106	599,139	795,646
Expend : WS, Distribution	1,019,475	1,138,510	839,416	904,365
Expend : Sewer, Operation	430,977	402,992	291,339	423,298
Balance : WS&S	2,631,651	2,847,660	2,639,143	5,113,052

Income : General	11,857,322	14,471,408	16,982,977	18,978,603
Expenditure : General	12,387,521	13,480,551	16,581,057	19,813,026
Balance : General	-530,199	990,857	401,920	-834,423

TABLE I.2 (A) NCDC WS EXPENDITURE

Kina: current

WS&S : ADMI+WS	4909010	1990	1991	1992
201 Salaries		161,049	187,807	190,850
203 Overtime		17,911	18,513	24,147
241 Power & Light		506,673	722,742	896,082
244 Equipment		4,203	4,631	0
245 R&M : Office		2,669	2,405	0
246 R&M : AC, Elc		1,968	4,030	0
247 R&M : Office		5,428	20,345	
652 Tech Fee		11,620	71,511	
747 Tools		1,484		
928 Interest		-30,752		222,003
929 Provision : Bad Debt		603,142	600,000	675,000
935 Depn : Ld&B1		310		
942 Depn : El Fit		274		
943 Depn : Off Eq		256	768	
944 Depn : Other			310	
945 Water of : Stock		-1,299		
949 Transfer Expn		1,004,874	1,200,000	0
950 Depn : WS ply			275,603	
951 Depn : WWork			155,638	
Administration Total	4909020	2,289,810	3,264,303	2,008,082
201 Salaries		164,925	154,366	138,261
203 Overtime		14,905	10,192	12,078
745 Hire : Tipper Truck		14,296	8,928	7,839
747 Tools		12,009	17,174	16,758
748 Minor Works				13,553
749 Materials		365,914	496,586	385,415
902 Pen Stock Maintenance		147,535	62,616	37,500
903 Repair & Maintenance		75,870	56,724	18,786
Plant Operation Total	4909040	795,454	806,586	630,190
-749 Materials (4909030)		193		
201 Salaries		333,867	365,485	358,216
203 Overtime		45,442	68,547	82,655
745 Hire : Tipper Truck		24,207	19,152	30,821
746 Hire : Heavy Equipment		144,093	334,455	537,896
747 Tools		12,854	24,954	12,699
748 Minor		0	0	141,534

749 Materials	269,399	335,802	306,757
903 R&M	1,964	9,919	35,357
905 Settlements WS	100	0	695,213
907 River Intake Fees	72,189	39,538	0
Management & Operation Total 4989985	904,115	1,197,852	2,201,148
555 Pressure Re-zoning	5,038	30,641	1,087
556 Reservoir Improvement	0	1,965	4,000
557 Reticulation : New Work	108,789	64,919	48,245
558 Upgrade : Village Supply	31,478	132,284	10,455
559 Conservation : Meters	235,364	0	120,666
562 Pipe Line : BO/GE/ERM	47,640	0	334,627
564 Settlement Supplies	17,136	28,590	0
565 Eriama Plant : Upgrade	0	0	2,669
574 Raw Water Main Upgrade	0	0	4,500
575 Nazareth School WS		75,893	31,713
576 Gordons Ridge WS		1,031	0
577 Upgrade : Settlement WS		980	53,136
578 Water Tanks			17,328
579 Weed Eradication			26,500
581 Free Washer Service			14,062
Development Works Total 4999997	445,445	359,115	668,988
777 Repayment	355,122	0	32
783 Air Con	1,740		
787 Shed20 : Off Bld Dev	0		7,977
791 Eri : Store	1,304		
792 Eri : Bulk	1,100		
Loan Payment Total	359,266	0	8,009
Water Supply Total	4,794,283	5,627,856	5,823,173

TABLE I.2 (B) NCDC SEWERAGE EXPENDITURE

Kina: current

	4909010	1990	1991	1992
930 Provision : Bad Debt		78,890	300,000	225,000
952 Depn : Work		0	60,044	0
Administration Total	4959510	78,890	360,044	225,000
201 Salaries		168,054	170,733	131,610
203 Overtime		13,550	15,186	16,941
745 Hire : Tipper Truck		12,393	48,606	23,369
746 Hire : Heavy Equipment		90,540	25,902	5,996
747 Tools		13,882	61,280	2,363
748 Minor Works				41,219
749 Materials		68,235	69,621	9,838
903 R&M		55,700	0	0
Management & Operation Total	4989985	422,354	391,328	231,336
566 Sewerage		135	0	0
567 Sewerage		22,398	1,033	15,079
568 Sewerage		14,236	1,117	0
569 Sewerage		4,211	20,808	0
572 Sewerage		55,131	3,246	0
Development Plan Total		96,111	26,204	15,079
Sewerage Total		597,355	777,576	471,415
Grand Total		5,391,638	6,405,432	6,294,588

TABLE 1.3 (A) NCDC WS BUDGET

Kina: current

WS&S : ADMI + WS 4909010	1990	1991	1992	1993
201 Salaries	180,000	175,000	169,750	203,000
203 Overtime	10,000	15,000	14,550	25,000
241 Power & Light	200,000	300,000	291,000	1,000,000
244 Equipment	5,000		0	
245 R&M : Office	1,000	1,000	0	
246 R&M : AC, Elc	1,500	5,000	0	
247 R&M : Office	6,000	8,000	0	
652 Tech Fee	50,000	65,000	0	
928 Interest	327,000	296,000	296,000	296,000
929 Provision : Bad Debt	300,000	600,000	900,000	1,500,000
931 Discount Allowed	250,000	200,000	200,000	200,000
949 Transfer Allowed	1,360,000	1,200,000	1,164,000	1,200,000
Administration Total 4909020	2,690,500	2,865,000	3,035,300	4,424,000
201 Salaries	208,000	187,000	181,390	151,000
203 Overtime	5,000	10,000	9,700	12,000
745 Hire : Tipper Truck	11,000	10,000	9,700	10,000
747 Tools	10,000	9,000	9,700	20,000
748 Minor Works			97,000	0
749 Materials	450,000	400,000	388,000	450,000
902 Pen Stock Maintenance	50,000	50,000	48,500	48,500
903 Repair & Maintenance	35,000	90,000	0	50,000
Plant Operation Total 4909040	769,000	756,000	743,990	741,500
201 Salaries	325,000	340,000	329,800	390,000
203 Overtime	30,000	60,000	58,200	80,000
745 Hire : Tipper Truck	30,000	30,000	58,200	30,000
746 Hire : Heavy Equipment	40,000	160,000	155,200	400,000
747 Tools	10,000	10,000	9,700	15,000
748 Minor Works	0	0	97,000	100,000
749 Materials	150,000	270,000	261,900	500,000
903 R&M		0	0	100,000
905 Settlements WS		0	100,000	100,000
907 River Intake Fees	50,000	50,000	48,500	48,500
Management & Operation Total 4989985	635,000	920,000	1,118,500	1,763,500
555 Pressure Re-zoning	10,000	50,000	50,000	100,000
556 Reservoir Improvement	50,000	50,000	1,000,000	100,000

557 Reticulation : New Work	330,000	130,000	100,000	200,000
558 Upgrade : Village Supply	20,000	45,000	200,000	200,000
559 Conservation : Meters	100,000	200,000	200,000	250,000
561 Reservoir Siting	0	10,000	100,000	100,000
562 Pipe Line : BO/GE/ERM	650,000	800,000	100,000	0
564 Settlement supplies	20,000	20,000	0	0
565 Eriama Plant : Upgrade	150,000	0	150,000	600,000
574 Raw Water Main Upgrade	50,000	500,000	1,200,000	0
575 Nazareth School Ws		100,000	50,000	0
576 Gordons Ridge WS		20,000	0	0
577 Upgrade : Settlement WS		15,000	100,000	100,000
578 Water Tanks		25,000	25,000	25,000
579 Weed Eradication			40,000	80,000
580 Standby Generator			500,000	0
581 Free Washer Service			100,000	0
582 Porebada WS			1,000,000	800,000
583 Chemical Shed			0	400,000
584 Bomana Pumps			0	1,500,000
585 General Improvement			0	600,000
Development Works Total 4999997	1,380,000	1,965,000	4,915,000	5,055,000
777 Repayment	511,000	664,000	664,000	664,000
779 Plt, Equip.	0		0	130,000
780 Vehicles	0		0	50,000
781 Hardware	0		0	20,000
782 Software	0		0	20,000
783 Air Con	5,000		0	0
784 Communic	0		0	5,000
785 Safety Equipment	0		0	5,000
786 Office Equipment	0		0	10,000
787 Shed 20 : Off Bld Dev	0		50,000	0
791 Eri : Store	75,000		0	0
Loan payment Total	591,000	664,000	714,000	904,000
Water Supply Total	6,215,500	7,440,000	10,788,690	13,388,000

TABLE I.3 (B) NCDC SEWERAGE BUDGET

Kina: current

WS&S : Sewerage 4909010	1990	1991	1992	1993
930 Provision : Bad Debt	240,000	300,000	300,000	300,000
932 Discount Allowed	80,000	100,000	100,000	0
Administration Total 4959510	320,000	400,000	400,000	300,000
201 Salaries	180,000	180,000	174,600	140,000
203 Overtime	15,000	16,000	15,520	15,000
745 Hire : Tipper Truck	10,000	20,000	19,400	20,000
746 Hire : Heavy Equipment	20,000	50,000	58,200	10,000
747 Tools	13,000	15,000	29,100	100,000
748 Minor Works			38,800	100,000
749 Materials	47,000	25,000	58,200	50,000
903 R&M	0	0	0	100,000
Management & Operation Total 4989985	285,000	306,000	393,820	455,000
566 Sewerage	230,000	0	0	0
567 Sewerage	0	50,000	400,000	400,000
568 Sewerage	100,000	15,000	0	50,000
569 Sewerage	12,000	12,000	0	0
570 Sewerage	50,000	50,000	0	0
571 Sewerage	140,000	0	400,000	400,000
572 Sewerage	350,000	200,000	0	150,000
573 Sewerage	50,000	75,000	75,000	0
Development Plan Total	932,000	402,000	875,000	2,367,000
Sewerage Total	1,537,000	1,108,000	1,668,820	3,122,000
Grand Total	7,752,500	8,548,000	12,457,510	16,510,000

APPENDIX J

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

ENVIRONMENTAL ASPECTS

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1. Introduction

The important environmental aspects of potential long term negative impacts identified with respect to future expansion of potable water supply scheme, according to this master plan until the year 2015 for NCD area, are grouped into the following three(3) categories.

1. Surface Water Intake

Major effects of decrease in natural river discharge downstream of the raw water intake location at Rouna 1/3 pond in Laloki river.

2. Water Treatment Plant

Adverse effects due to operation of water treatment plant on its immediate vicinity, with the generation of raw water sludge for disposal being the major effect.

3. Wastewater Generation

Generation of wastewater, as a consequence of water supply, that requires conveyance and disposal in a sanitary and environmentally acceptable method.

The existing water supply facilities that draw its entire raw water from Laloki river with conventional water treatment plant of capacity 136 mld at Mt. Eriama, are described in Chapter 3 of Main Report.

The NCD area has a sewerage system for the inland service areas in which the collected sewage is either treated in oxidation ponds before final disposal into Waigani Swamp or discharged into sea with no treatment, ocean outfall, for the coastal town areas of Port Moresby city *ref. Fig. J.1)

The proposed master plan until the year 2015, that would draw the entire raw water from the Laloki river, with two(2) conventional water treatment plant at Mt. Eriama and a hill at Nine Mile near Airport, the new plant, is described in Chapter 7 of Main Report.

The baseline environmental conditions for three(3) aspects mentioned above, related to the existing water supply facilities and future implications of this proposed water supply master plan, were evaluated on a preliminary basis and are described in subsequent sections.

It is noted that potable water supply is a basic human need. Therefore, this is essentially an environmental improvement project aimed at enhancing the quality of life of the NCD residents. Beneficial environmental effects are the basic aims of project planning, and are not considered under these environmental aspects.

2. Surface Water Intake

2.1 Existing Condition

Thought there are two(2) potable water intake locations in Laloki river, namely the gravity intake at Rouna 1/3 pond and the pump intake at Bomana, the bulk of the raw water accounting for 85% of total abstraction, is from the Rouna intake.

The quantity of total water abstracted from Laloki river is about 1.2 m^3/s, while the probable drought discharge of a 20-year return period is estimated as $8m^3/s$. Hence, the abstraction for potable use is about 15% of the 20-year drought discharge. The effect of this water abstraction on other beneficial usage downstream, and on river ecology is not significant, under the existing conditions.

Moreover, as the bulk of the water is drawn by gravity with no pumping facilities, other than that of the Bomana intake, the system is very economical and also free from noise nuisance. Even in case of Bomana pump intake, the effect of noise nuisance is not significant considering its remoteness from residential areas. Both the water intake locations, and the treatment plant at Mt. Eriama are remote from residential areas.

The treatment plant at Mt. Eriama is also free from noise nuisance, as treated water is distributed by gravity, making use of the unique topographical advantage of this water supply scheme.

2.2 Future Condition

As per this master plan until 2015, the Rouna 1/3 and Rouna 4 gravity intake of Laloki River will become the only location for raw water abstraction to meet the estimated future demand of $4.3m^3/s$. This future abstraction is 54% of the 20-years drought discharge of $8.0m^3/s$ and 43% of the normal dry weather river flow of $10m^3/s$. Even with the reduction due to potable water intake, a minimum river discharge of about $6m^3/s$ will be ensured under normal dry weather flow conditions. Under extreme drought condition, the water abstraction will have to be limited, resulting in rationing of water supply.

This reduction in river discharge downstream of Rouna 1/3 pond intake, though a significant irreversible effect, is not anticipated to cause adverse effects on the aquatic fauna, flora in the downstream Laloki river reaches. A 15 km reach of Laloki river between the Rouna 1/3 pond and its confluence with Goldie river at Bomana, would be subjected to a reduction in discharge.

The effect downstream of the Goldie-Laloki river confluence is evaluated to be insignificant, considering the contribution of an additional $7m^3/s$ of the 20-year drought discharge into Laloki river from Goldie River.

There is no significant irrigation off-take or large scale water abstraction for other beneficial uses in this critical river reach between Rouna 1/3 pond and Bomana, under the existing conditions.

Any future significant water abstractions for beneficial use like irrigation in this 15 km Laloki river reach will be planned giving due consideration to the reduction in river discharge due to this master plan.

The Bureau of Water Resources(BWR), the organization responsible for allocation of water resources for beneficial uses, must consider this reduction in discharge when permitting future water abstractions in this critical 15 km reach, so that conservation of river ecology, including aquatic flora and fauna is ensured.

The entire future raw water intake will be from either Rouna 1/3 pond or Rouna 4 pond by gravity, with boosting pump facilities. The existing Bomana pump intake will be abandoned. However, boosting station is remote from the residences and will be from noise nuisance.

3. Water Treatment Plant

3.1 Existing Condition

The existing sole water treatment plant at Mt. Eriama, as emphasized in the previous section, distributes the treated water by gravity with no pumping facilities, hence it is free from noise nuisance.

The unit operations/processes used in the treatment plant are conventional for a surface water source. The treatment involves essentially coagulation, flocculation/ sedimentation, followed with rapid gravity filtration and disinfection. The treatment plant utilizes chlorination, using chlorine gas for disinfection.

The treatment plant has been in operation since 1917. The plant is well operated to produce fine potable water for consumption. Accordingly, the experience gained over the years, including the handling of dangerous chemicals like chlorine gas, to ensure a proper operation and maintenance o the treatment plant is assessed as adequate.

The sludge produced in the treatment plant during the process of sedimentation/
clarification and backwashing of filters, is discharged by gravity to a series of earthen settling basins located at the base of Mt. Eriama.

The settled/clarified effluent is apparently very clear and used for irrigation. Though, this effluent quality was never determined for confirming its suitability for irrigation purpose, no noticeable adverse effects on the irrigated plants were reported. Hence, the effluent quality may be assumed suitable for irrigation use. Nevertheless, the treatment plant must conduct at least some monitoring of this clarified effluent quality, as well sludge characteristics.

The sludge settled in the pond is allowed to remain to become landfill material for the pond, an appropriate practice.

At present, a vast land area is available for creating new settling ponds. Two(2) new sludge settling ponds are being constructed as of December 1992.

Based on the above considerations, the existing sludge management practice in the Mt. Eriama water treatment plant is assessed as satisfactory. Yet, determination of the clarified effluent as well as the settled sludge characteristics is recommended to ensure their appropriateness for the existing usages. Exploration of other more profitable alternative uses is also recommended.

3.2 Future Condition

The proposed master plan envisages a new water treatment plan in addition to the existing one at Mt. Eriama to satisfy the design maximum daily demand in the year 2015. The Mt. Eriama plant will also be expanded from its existing capacity of 136 mld to the maximum permissible capacity of 200 mld. No more expansion at this site is possible due to the space limitation. The remaining capacity requirement will be met by the new treatment plant.

The intake as well as distribution after treatment for both the treatment plants will be by gravity. The Bomana pup intake will be abandoned. Accordingly, the whole system in future will be entirely by gravity, for conveyance and distribution with one pump facilitys . In addition to being economical with simplified operation and maintenance, this will result in an improved environmental condition in future around the Bomana pump facility.

The design static head of gravity water distribution at the existing Mt. Eriama plant is about 163 m, while that of the Rouna 1/3 gravity intake of Laloki river is about 273 m. These elevations will be the same for the future expansion of this existing plant, as well.

The location of the proposed new water treatment plant is closer to the service area of NCD and located on a hill near the Airport at Nine Mile (ref. Chapter 7 of Main Report). The design static head of water distribution of this new plant is about 100m, less in comparison to 163m for the Mt. Eriama plant.

The new plant near the Airport will use similar unit operations/processes for treatment, and the management of raw water sludge, as that of the existing one at Mt. Eriama. Very similar hilly topography of both plant locations in turn facilitates similar considerations for design, operation and maintenance of both plants. This would also allow for easy extension of the required operation and maintenance skill acquired at Eriama plant.

The sludge generated in the new plant will be settled in a series of ponds located at the base of the hill. The clarified effluent could be utilized for irrigation, as in the case of Eriama plant. The settled sludge could also be utilized as soil conditioner.

The land for the proposed new treatment plant is an uninhabited open area belonging to the Government of PNG. No social issues such as land acquisition, house compensation and resettlement are involved.

Based on the above considerations, it is concluded that the anticipated adverse effects of the new treatment plant and the existing one at Mt. Eriama on the surroundings, are not significant.

4. Wastewater Generation

4.1 Existing Condition

The wastewater generated as a consequence of the existing water supply scheme for the NCD area, is collected and disposed with and without treatment by the city sewerage system as ocean outfall and disposal after treatment in oxidation ponds (lagoon system).

The sewerage system comprises a number of independent collection, treatment and disposal systems as shown in Fig. J.1.

4.1.1 Ocean Outfall

As evident from Fig. J.1, there are a number of ocean outfalls along the coastal areas with small service areas. Out of these outfalls, the Paga outfall serving the Town area of Port Moresby is the largest outfall..

All outfalls discharge raw sewage with no pretreatment. Most outfalls, with Koki outfall being the worst, are not satisfactory from a sanitary view point, because the locations of final disposal of sewage are near the sea coast.

Visible coastal degradation including foul odor is detected along the coast of Koki outfall. Not only is the distance of outfall into the sea very short, (only about 100m), but also the discharge location is a bay that hinders active diffusion and dispersion of wastewater, unlike the open sea.

Even Paga, the longest and largest outfall has long term effects such as rock coloration with peculiar odor of sewage in the coastal areas. However considering the remoteness of this rocky, coastal terrain below Paga hill, the outfall may be considered satisfactory from the sanitary aspects, if not from the environmental aspects.

It is recommended that the development of ocean outfall as the means of final disposal of sewage be discontinued in future. The distance of existing outfalls into the sea may be extended, based on the monitoring of coastal sea water quality, or if it should be terminated and subsequently integrated into the inland sewage collection system, described below.

Under the existing conditions, the ocean outfalls are not satisfactory even from sanitary aspects, except Paga Outfall.

4.1.2 Lagoon System

The bulk of the wastewater generated in the inland water service areas, other than the above mentioned coastal areas, are collected and treated in three(3) lagoon (oxidation pond) treatment systems. They are Waigani Lagoon, Morata Lagoon and Gerehu Lagoon (ref. Fig. J.1).

All treated effluents of these three lagoon systems are discharged into the vast wetland and lake area, known as Waigani Swamp, with an area of about 500 ha.

The Waigani Lagoon is the largest wastewater treatment system with two (2) large service areas that cover highly developed and developing areas like Boroko and Waigani. The Waigani lagoon system covers an area of about 30 ha with four(4) parallel initial anaerobic ponds, and a single large facultative pond.

The Lagoon treatment system is shown in Fig. J.2.

This Waigani Lagoon treatment system does not produce acceptable effluent. Design, operational, and maintenance deficiencies are responsible for this. As of December 1992, both the anaerobic ponds No.3 and No.4 (ref. Fig. J.2) are not in operation. Moreover, an uneven influent wastewater distribution between ponds No.1 an No.2 was noted.

Extensive foaming at the final treated effluent outlet of the facultative pond in the Waigani Swamp area clearly indicated the inefficiency of wastewater treatment of the pond system.

The other two(2) smaller lagoon systems, the Morata and Gerehu lagoons seem to be functioning satisfactorily.

The final receiving water body from all three(3) pond systems, the vast lake of Waigani Swamp, is observed to be in the hypereutrophic condition. This could be due to accumulation of nutrients in the lake which contains the treated effluent discharged from the above treatment plants, principally the Waigani treatment system.

The lake of this Waigani Swamp remains enclosed during dry season, when the lake inflow is mostly sewage, and discharges into Laloki River mostly during the rainy season from December to March, when the lake inflow is both sewage and storm water run-off.

The lake is rich in freshwater fishery resources, with Tilapiya(Tilapiya mossambicus) being the dominant fish species. This species is very tolerant to high algae concentration as well as low DO, and can breed even in sewage ponds.

Professional/semiprofessional fishing boats with fish nets are widely used in this lake, Waigani Swamp.

No serious health risk due to improper sewage treatment and subsequent bacterial contamination of fish, are anticipated by consuming this fish as it is customary in PNG to cook the fish before consumption. No complaints of food poisoning due to fish have been reported in the NCD area.

Nevertheless, from the environmental and usage aspects, the water quality of the large Waigani Swamp requires improvement. The improved water quality will enhance the diversity of fishery resources in the lake. This condition can be achieved by ensuring proper treatment of influent wastewater in lagoon treatment systems, particularly the Waigani Lagoon.

As an immediate step toward enhancing the treatment efficiency of the Waigani Lagoon system, all four(4) primary anaerobic ponds must be put into operation. Moreover, the influent and effluent water quantities and qualities, including those of intermediate effluents must be regularly monitored for at least the following water quality parameters, namely, pH, temperature, BOD, COD, total and fecal coliforms.

Based on the evaluation of treatment efficiency reconfiguration of the treatment system is necessary to increase the number of ponds in series prior to final disposal, either by redirecting the effluents of the first two(2) anaerobic ponds as influent to the other two(2) anaerobic ponds, or division of the large facultative pond into small units in series, or by provision of additional ponds or a combination of the above could be instituted to enhance the treatment efficiency.

It has been verified that an oxidation pond system with a number of ponds is series produces superior effluent quality, than a single large pond system of the same capacity.

Although the existing treatment system of Waigani Lagoon occupies a vast area of 30 ha, it utilizes only two(2) series systems with four(4) parallel anaerobic ponds, out of which two(2) are out of order, and the discharge is into one single large facultative pond. For a large treatment system of this nature, three(3) or more serial flows before final disposal are preferred.

The main advantage of an oxidation pond treatment system is that it requires only periodic maintenance by unskilled labor, though it requires large land area. No security or guard service is provided ever for the large Waigani Lagoon System, and it remains virtually neglected. NCDC must ensure the presence of at least one(1) security personnel, who could also handle the periodic maintenance work at the lagoon treatment plant site.

This will prevent illegal dumping of wastes like night soil, into the treatment system, as noted during the site visit.

Based on the above considerations, the final disposal with lagoon treatment, especially in case of the largest Waigani Lagoon System, is judged as unsatisfactory from the environmental, if not sanitary, aspects, under the existing conditions.

4.2. Future Condition

The wastewater generation will increase almost in proportion to the increase in water supply from 1.2m^3/s, currently to 4.3m^3/s in 2015, as per this master plan.

Assuming no further expansion of the ocean outfall system for waste water disposal, considering the proximity, low land topography and vast expanse of area facilitating multitude of final effluent receiving locations, the Waigani Swamp will continue to be the logical choice for the final receiving water body for the additional wastewater generated.

Increased waste water generation necessitates expansion of sewer collection system as well as subsequent treatment systems prior to final disposal into the Waigani Swamp.

Accordingly, a sewerage rehabilitation and development master plan study must be carried out by NCDC as the follow-up of this water supply master plan, to ensure disposal of generated wastewater in a sanitarily and environmentally acceptable manner. Under the existing conditions, as illustrated in the previous section, the final disposal even after treatment in Waigani Lagoon is judged as environmentally unsatisfactory.

Moreover, the appropriate rehabilitation/improvement measures for the existing ocean outfall systems, including necessary sanitation improvement measures for areas with no sewerage, will be studied as a component of this sewerage master plan.

5. Conclusion

Surface water intake, treatment plant for treating the abstracted water, and generation of wastewater, are three(3) major aspects of potential long term adverse environmental effects requiring evaluation due to this potable water supply rehabilitation master plan until the year 2015.

All potential negative environmental effects related to the three(3) aspects mentioned above are manageable and insignificant. The environmental effects are summarized in Table. J.1.

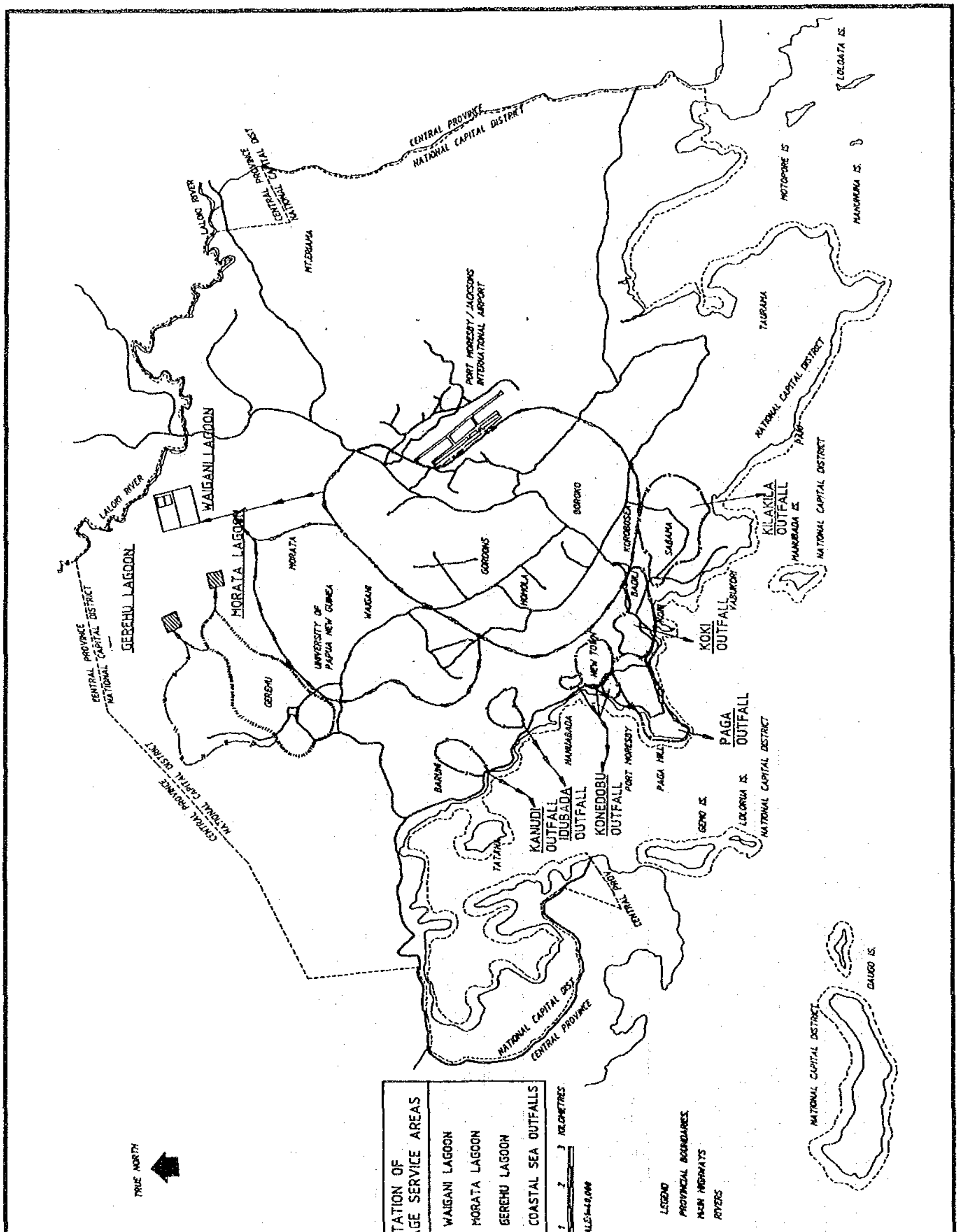
Reduction of the Laloki river discharge in a 15 km of river reach between the proposed Rouna 1/3 gravity intake location and the confluence with Goldie river, accounts for a significant 43% of the normal dry weather flow of $10m^3/s$. Although this is an irreversible long term effect, the potential adverse effects on river ecology, including adverse effects on aquatic flora and fauna, are negligible.

Wastewater generation, as a consequence of water supply, and its subsequent disposal in a sanitarily and environmentally acceptable manner, is a major problem that requires appropriate management. This is not just due to the anticipated future increase of wastewater generation, but due more to the deficiencies in existing wastewater management systems.

A master plan study of sewerage rehabilitation and development in NCD area must be conducted by NCDC as a follow-up to this water supply master plan.

Table J.1 Environmental Effects of Proposed Master Plan

ITEM	ENVIRONMENTAL EFFECT		EVALUATION
	EXISTING(1993)	FUTURE(2015)	
Surface Water Intake	1)Pump intake at Bomana is a source of noise pollution, though effects are very significant.	Entire intake from Rouna 1/3 pond must be by gravity. Bomana intake to be terminated. No significant noise generation.	Simplified and economical operation and maintenance of gravity intake in future with no pump and noise generation. Improved future intake environment compared to existing condition.
	2)Reduction in discharge downstream of Rouna 1/3 intake of Laloki river is not significant	Abstraction from the Rouna 1/3 gravity intake would be a significant 43%(4.3m3/s) of normal Laloki river dry weather flow of 10 m3/s. An irreversible long term effect.	Effect on downstream aquatic flora and fauna including river ecology due to discharge reduction, is not significant. Future abstraction for other uses in reduced discharge reaches to regulated by Bureau of Water Resources(BWR).
Water Treatment Plant	*Operation and Maintenance (O/M) including* sludge management at Mt.Eriama treatment plant is satisfactory with no significant adverse effects on the surrounding environment.	*O/M of both the existing existing and future* new plants at Nine Mile will be very similar to the existing one at Mt.Eriama. The location of new plant at Nine Mile(a hill) is uninhabited state land. No house compensation and resettlement is involved.	Very similar O/M of both treatment plants located at similar hilly topography ensures easy extension of skills acquired at Mt.Eriama plant. As in the case of existing plant no significant impact is anticipated in future.
Wastewater Generation	For final disposal of generated wastewater due to existing water supply, both the ocean outfall with no treatment and lagoon system with treatment, require rehabilitation.	Increased wasterwater generation increases demand for sewage collection and treatment system.	A sewerage rehabilitation and development master plan study is recommended for addressing both existing and the anticipated future wastewater disposal problems.



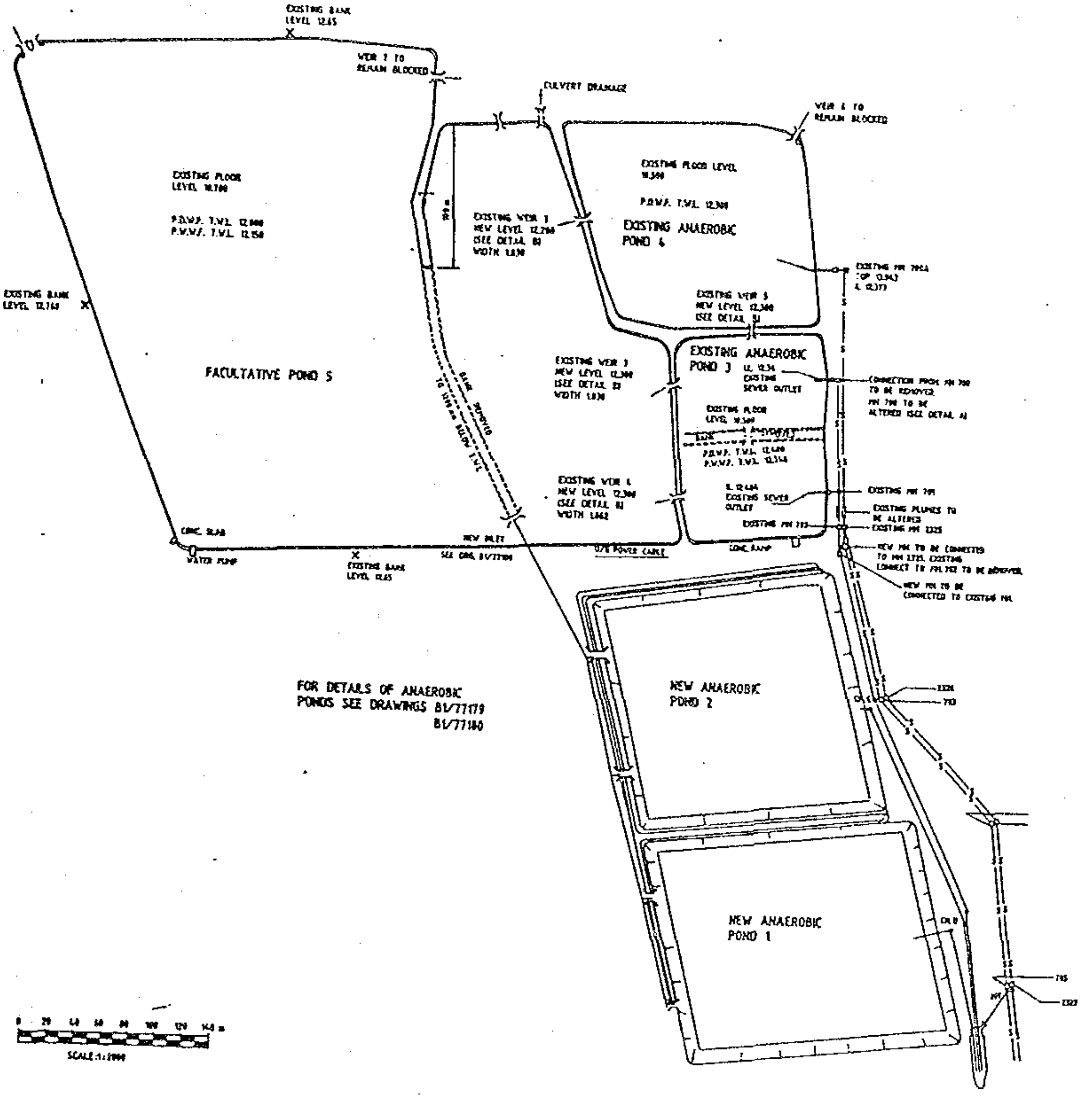
TITLE

EXISTING SEWERED AREAS AND DISPOSAL SYSTEMS

Fig. No. **J.1**

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANS in association with PACIFIC CONSULTANTS INTERNATIONAL



TITLE

WAIGANI LAGOON TREATMENT SYSTEM

Fig. No. **J.2**

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANS in association with PACIFIC CONSULTANTS INTERNATIONAL

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

COST ESTIMATION

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APPENDIX K COST ESTIMATION

1. INTRODUCTION

Cost of materials and labour cost for the construction works are shown in this appendix. Most of the construction materials or machines for water supply facilities are available locally, but they are not locally made. They are imported from neighboring countries such as Australia or New Zealand. Prices for the related materials, machines, and labour costs were obtained from several local construction companies, department of labour and employment, and related local companies.

In this project, the following items are to be imported directly from neighboring countries and Japan, and the rest purchased at Port Moresby.

Pipes & Valves
Filter Materials
Electrical & Mechanical Equipment
Chemicals

In estimating the construction cost of the facilities, first the unit costs for laborers, material, electrical & mechanical equipment, and transportation costs were established, then the construction cost for component works such as concrete works, excavations, etc., were estimated. Some unit costs were directly obtained from NCDC and local companies.

The following sections mainly show the local market prices, which were obtained during second on-site job (July to August, 1993).

2. RELATED COST

2.1 Labour Cost

In Papua New Guinea, national minimum wages are established by the national Minimum Wages Board, which says "a single national minimum of 22.96 per week for all employees, applicable irrespective of location (1992). This shall apply to all new entrants to wage employment as of 15 September 1992. Wage above K22.96 is subject to negotiation between the employer and the employee." The minimum Wages Board Determination No. 1 of 1992 is as follows:

Table K.1 MINIMUM WAGES

Area	Alotau, Arawa, Goroka, Kavieng, Kieta, Lae, Madang, Mout Hagen, Popondetta, Port Moresby, Rabaul, Wewak.		Bulolo, Bwagaoia, Daru, Kainantu, Kerema, Lorengau, Samarai, Vanimo, Wau, Mendi, Kimbe, Kundiawa, Wabag.	
Classifications	Minimum Weekly Rates (Kina)	Minimum Fortnightly Rates (Kina)	Minimum Weekly Rates (Kina)	Minimum Fortnightly Rates (Kina)
Youth under 22 years of age	31.40	62.80	26.51	53.02
General Laborers & Married Youths				
Class 1	62.83	125.66	53.02	106.04
Class 2	66.68	133.36	57.00	114.00
Class 3	71.04	142.08	61.52	123.02
Class 4	76.63	153.26	67.18	134.36
Class 5	83.34	166.68	83.34	166.68
Qualified Tradesman (B1 and B2)	90.05	180.10	90.05	180.10
Class 6 Qualified Tradesman (A)	96.79	193.58	96.79	193.58

Source: Department of Labour & Employment

Job description and classifications are also determined by the Minimum Wages Board. In practice, the cost for major labourers is estimated as shown in the following Table.

Table K.2 LABOUR COST ESTIMATION

Classifications	Hourly Rates (Kina)
General Labour	2.00
Class 1	2.00
Class 2	2.50
Class 3	2.75
Class 4	3.50
Class 5	4.00
Class 6	4.50
Machine Operator	12.00
Plumber	12.00
Form Worker (skilled)	5.0 K/m^2
Form Worker (normal)	2.5 K/m^2

2.2 Material Cost

Table K.3 shows material costs at Port Moresby as of July 1993.

Table K.3 MATERIAL COSTS

Type of Material	Cost
Concrete Aggregate	K 25.03 / m^3
Premix	K 33.32 / m^3
Road Base (Base)	K 23.93 / m^3
Road Base (sub-base)	K 22.27 / m^3
Crusher Dust	K 19.22 / m^3
Diorite	K 15.99 / m^3
Soil	K 15.99 / m^3
Sand	K 24.88 / m^3
Bagged Cement	K 220.00 / ton
Concrete (10 MPA)	K 96.00 / m^3
Concrete (20 MPA)	K 107.00 / m^3
Concrete (30 MPA)	K 118.00 / m^3
Concrete (40 MPA)	K 133.00 / m^3
Timbering hire rate	K 11 /m^2/week
Formboard hire rate	K 5 /m^2/week
Plywood (2.4x1.2x4 mm)	K 15.80
Plywood (2.4x1.2x6 mm)	K 19.29
Plywood (2.4x1.2x9 mm)	K 33.50
Plywood (2.4x1.2x12 mm)	K 40.64
Plywood (2.4x1.2x15 mm)	K 49.35
Plywood (2.4x1.2x18 mm)	K 67.22
Reinforcing Bar (10 mm x 6 m)	K 2.77 /m
Reinforcing Bar (12 mm x 10 m)	K 5.85 /m
Reinforcing Bar (16 mm x 10 m)	K 10.40 /m
Reinforcing Bar (20 mm x 10 m)	K 16.24 /m
Reinforcing Bar (24 mm x 10 m)	K 23.40 /m
Reinforcing Bar (28 mm x 10 m)	K 31.83 /m
Reinforcing Fabric=2.4 m x 6 m sheet	
Reinforcing Fabric (4 mm x200 mm)	K 13.67
Reinforcing Fabric (5 mm x200 mm)	K 21.35
Reinforcing Fabric (6.3 mm x200 mm)	K 33.90
Reinforcing Fabric (7.1 mm x200 mm)	K 43.05
Reinforcing Fabric (8 mm x200 mm)	K 54.66

Table K.4 COST OF DUCTILE IRON CEMENT LINED PIPE

Nominal Diameter	Effective Length (m)	Prices (A$/m)
100 mm	5.5 m	21.90
150 mm	5.5 m	31.65
200 mm	5.5 m	44.40
250 mm	5.5 m	58.15
300 mm	5.5 m	75.10
375 mm	5.5 m	104.10
450 mm	5.5 m	132.30
500 mm	5.5 m	152.40
600 mm	5.5 m	201.79
750 mm	5.5 m	283.45

Note; Country of origin : Australia
CIF at Port Moresby

Table K.5 COST OF MILD STEEL PIPE

Classification	Price (CIF at Port Moresby)
762 mm OD x 6.4 mm WT x 10 m long	K 220 / m
914 mm OD x 6.4 mm WT x 10 m long	K 270 / m
1016 mm OD x 6.4 mm WT x 10 m long	K 320 / m
1219 mm OD x 8.0 mm WT x 10 m long	K 400 / m
1524 mm OD x 10. mm WT x 10 m long	K 590 / m

Note; Country of origin : New Zealand
Pipe is concrete lined and polyken tape coated.

2.3 Unit Construction Cost

Unit construction costs are estimated for normal conditions, and any work to be carried out under special conditions are not considered. Table K.6 shows these costs. Port charges are also shown in Table K.7.

Table K.6 UNIT CONSTRUCTION COST

Type of Work	Unit Cost
Excavation -- sand	K 10 / m^3
Excavation -- rock, with partially blasting	K 40 / m^3
Backfilling	K 10 / m^3
Removal of surplus soils (short distance)	K 4.0 / m^3
Removal of surplus soils (long distance)	K 8.0 / m^3
Form work	K 90 / m^2
Concrete work	K 160 / m^3
Reinforcing work	K 1500 / ton
Waterproofing work	K 50 / m^2
Filter media -- sand	K 400 / m^3
Filter media -- gravel	K 400 / m^3
Welding work	
900 mm (diameter)	K 450 / joint
1000 mm	K 475 / joint
1100 mm	K 500 / joint
1200 mm	K 525 / joint
1350 mm	K 550 / joint
1500 mm	K 625 / joint
1600 mm	K 675 / joint

Table K.7 PORT CHARGES AND HANDLING CHARGES

Items	Cost
Wharf charge	K 3.75 / m^3
Pilot charge	LOA (m) x K 1.3 x movement
Berth charge	LOA (m) x 0.65 t / hour
Storage charge	K 0.75 /m^3/day
Stevedoring	K 3.65 m^3/ton
Handling in Yard	
Yard onto Trucks	K 6.85 m^3/ton
Documentation	K 0.9 m^3/ton
Customs Clearance	
Preparation of Entry	K 100
Second & Subsequent pages	K 60 / page
Agency and attendance	K 25
Permits	K 75
Cartage (40' semi-trailer Load)	
to Sirinum	K 500
to Rouna	K 350
to 14 Mile & all other areas	K 250

Note: LOA: Length of Alongside

Next Table K.8 shows plant hiring rates.

Table K.8 PLANT HIRING RATES

Description	Rates
2 x D7 caterpillar dozer	K 90 /hour
3 x D6 caterpillar dozer	K 70 /hour
1 x D4 caterpillar dozer	K 50 /hour
Excavator 215 caterpillar dozer	K 70 /hour
Excavator 225 caterpillar dozer	K 90 /hour
F.E Loader 916 caterpillar	K 50 /hour
F.E Loader 955 L track	K 60 /hour
Grader 140B	K 75 /hour
Grader 130B	K 80 /hour
Komatsu Grader	K 75 /hour
2 x Pacific Roller 11 ton	K 60 /hour
1 x Multi type Roller	K 40 /hour
6 x tipper truck 8 - 9 m^3	K 70 /hour
4 x tipper truck 3 - 4 m^3	K 40 /hour
2 x tipper truck 5 - 6 m^3	K 55 /hour
Crane 10 ton	K 85 /hour
Crane 20 ton	K 120 /hour
Crane 60 ton	K 200 /hour

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

WATER RATIONING PLAN FOR PORT MORESBY

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APPENDIX L Water Rationing Plan for Port Moresby

1. Introduction

Water demand in Port Moresby is increasing annually. In 1990, the daily maximum demand was 155,900 m^3/d. This is projected to increase to 201,300 m^3/d in 1995. However, the treated water supply to Port Moresby is constant at 125,000 m^3/d and will not increase until early 1997, when the expansion of the existing Mt. Eriama plant is completed. This demand-supply imbalance is causing reduced pressure or non-availability of water at certain locations in the distribution system during the dry months. Among the worst affected areas are Town, Konedobu, Hanuabada, and the elevated areas of Hohola and Tokarara.

The additions to the treatment capacity are expected to operational by late 1996. However, in the period between 1994 to 1996, there are no possible sources of augmentation to the existing supply of 125,000 m^3/d. It is therefore proposed that water supply be rationed on a day-to-day basis in Port Moresby during the problematic dry season, so as to ensure that all parts of the system are equitably served by the limited water supply.

Water rationing would entail the stoppage or cut-off of water supply to a certain area of the system for a period of time (e.g. one day), and diversion of this water cut off to other areas of the system, to improve pressures during that time period. At the end of this period, water service will be restored to the cut-off area and service to another area will be cut. In this way, the water stoppage is rotated to all parts of the city so that every part of the system will be without water for a small period of time. In return, better service (pressures and flow) will be available during other times. Water rationing would also serve to distribute water equitably to all parts of the system, including the shortage areas where water is presently available only for a few hours after midnight at best and not at all at worst.

Port Moresby is divided into census divisions and units; The water demands from 1990 to 2015 was derived, as already been explained in previous chapters. Table L.1 gives the area-wise daily minimum, average and maximum water demand between 1990 and 2000, which roughly corresponds to the demand during the wet season, the early dry season (between June and September) and the late dry season (between October and December), respectively.

A significant part of the water demand is due to watering lawns, gardens and patches for vegetables and fruits. This gardening demand is mainly responsible for the water shortage in the city. This gardening demand varies with the season and is practically non-existent during the wet months. With the onset of the dry season, this demand begins to rise, with *the increase directly proportional* to the progress of the dry season. During the early months of the dry season, especially if there have been abundant rains during the preceding rainy season, the gardening demand is moderate, therefore, the demand-supply deficiency is moderate. During the later months of the dry season (October to December), the water shortage becomes more acute.

From Table L.1, it can be seen that while the daily average and maximum demands exceed the supply for all years, the daily minimum is less than the supply, indicating that water shortages are essentially phenomena of the dry season. Therefore, water rationing is required as an administrative measure during the dry season only.

It is proposed that Port Moresby initiate water rationing as early as possible. Given the various administrative, technical and public/consumer relation measures that have to be adopted prior to implementation, it is proposed that water rationing be started from the dry season of 1994. A water rationing plan, based on area-wise demand and the hydraulics of the distribution system, is presented here for 1994 and later, for alleviating the water scarcity in the drought-prone areas and uniform distribution of water within the network.

For preparing a water rationing plan, trial rationing experiments are necessary to gain better understanding of the operational aspects of rationing, - particularly administrative, technical and public relations/reactions, - and to evaluate its effectiveness in distributing water to water-scarce, far-flung areas of the system. Such trial rationing exercises would also serve to evaluate the manpower requirements and shed light on the areas of the present administrative set-up that need bolstering for successful implementation of water rationing from 1994 onwards.

Hence, water rationing experiments were conducted in June 1993, and water supply was stopped to certain areas. The resultant flows and pressures were monitored in various parts of the system, and valve operations, problems encountered, and system improvements needed to enhance the effectiveness of the rationing plan were analyzed.

2. Trial Water Rationing Experiments

Trial water rationing experiments were conducted between June 23 & 25. At the beginning of the dry season, the demand-supply shortfall is moderate and the demand is the daily average demand. As seen from Table L.1, the 1993 daily average base supply shortfall was about 16,000 m^3/d. For effective rationing, water must be stopped to an area in the city which has a daily average demand of about 16,000 m^3/d. By stopping water supply to this block for a period of time, the rest of the city would be better served during that time period. By appropriately selecting the area for which water supply is stopped, the effects of the stoppage on problematic areas of the city, such as the elevated areas of Town, Hanuabada, Konedobu, hilly areas of Tokarara and Hohola can be evaluated.

The experiments were carried out by coordination between the JICA study team and NCDC. The administrative set-up and functions for the trial water rationing experiments are given in Fig. L.1. The number of people involved in each step is also given.

2.1 Planning

2.1.1 Period of Stoppage

Stoppage of water supply to an area involves shutting off the valves on the pipelines that bring water to the area. Subsequently, when the rationing period is over, the valves are restored to their original positions. To decide the optimal period for cutting water to an area, three factors must be considered. The first is the inconvenience to the consumer, the second is the work load on the operations staff, who close the valves at the start and reopen them at the end period. The third factor is the area to be selected for cutoff, since there is diurnal variation, as well as hourly variation in demand.

From the consumers' point of view, any stoppage is inconvenient and the greater the duration, the more the inconvenience. The consumer has to store water before the period of stoppage, and this requires time, effort and storage space. From the operational point of view, valve closing or opening require moving to each valve and closing or opening it. The greater the number of valves and the greater the distance between the valves, the greater is the effort required.

Stopping the supply during the night only, after the evening peak and before the morning peak hours, would cause least inconvenience to the consumer. However, this is also the period when demand is minimum, therefore, the water saved by rationing will not be of such quantity as to effectively increase supply to problematic areas.

Port Moresby is a city spread out thinly over a large area, because of topography, consisting of numerous relatively inhabitable hills interspersed by flat, habitable land. The water supply network is also laid out over this large area. The distance between valve locations for a given volume of demand is much higher than more densely populated, flat urban areas of Asia. Furthermore, the distribution system has not been designed such that a small number of primary valves can control supply to large blocks. Consequently, even a geographically contiguous area like the Boroko/Korobosea block would require control by about 30 valves. Given the work involved in opening and closing valves and the need to operate numerous valves to hydraulically isolate an area or block, it is felt that the optimal period of time for stoppage would be 24 hours. This will also account for the diurnal demand variation over a 24-hour period. A period less than one day would increase the work of opening and closing valves beyond reasonable limits and may necessitate employment of an unusually large staff for the purpose.

2.1.2 Dates of Experiments and Determination of "No shut-off" Consumers

Given the sensitive nature of water rationing and the fact that it was to be implemented the first time with only about two weeks of advance publicity, it was felt that disruption of water supply would be kept to the minimum during trial water rationing experiments. Activities that contribute to the economic well-being of the country, such as industries, were not affected. Government offices, hospitals, hotels, foreign embassies, schools and universities were also not affected. The annual vacations for schools and universities started on 19th June; hence water rationing experiments were scheduled between 23rd and 25th June. The experiments were conducted according to the following schedule, with one day before and one day after also included as days for control of water supply.

Date and day	Time	Area
22nd June (Tuesday)	1430	
		Control experiment
23rd June (Wednesday)	1430	
		Stop supply to Block 1
24th June (Thursday)	1430	
		Stop supply to Block 2
25th June (Friday)	1430	
		Control experiment
26th June (Saturday)	1430	

2.1.3 Blocks for water rationing

As mentioned earlier, rationing exercises should evaluate its effectiveness to the worst affected areas - Town, Hanuabada, Konedobu, and Tokarara and Hohola. Hence, it was decided that rationing would be enforced on two days. On each day, one block would have the water supply stopped. Of two blocks, one would be a block that would improve supply in Town further downstream and the other block would improve supply to Tokarara and Hohola. Furthermore, being the first time rationing tests were conducted on such a large scale in Port Moresby, it was decided that pipelines on which valves would be closed would be as small as possible in diameter, since doing so on the larger pipelines would require greater precautions in reopening them to avoid water hammers and pipe bursts. Air valves are not available on all large diameter pipes (i.e. pipes greater than 400 mm). Therefore, it was decided that valves would be closed, in principle only on pipes below 250 mm.

Water supply to Town and further down to Konedobu and Hanuabada are primarily through the 450, 600 and 250 mains along the Hubert Murray highway originating from the reservoirs at the Mt. Eriama water treatment plant, via Three-mile Koki and Town reservoirs. Water supply would be cut off to some areas en route to Town from the WTP from among the following : Gordons, Boroko, Korobosea, Kilakila, Kaugere for increasing the water supply to reach the water-deficient areas. There are a large number of factories and industries in the Gordons area, and to a lesser degree in Kilakila and Kaugere area. Hence, rationing these areas would require ensuring supply to the industries as exceptions. This would require numerous valve closings and make the exercise needlessly complex. On the other hand, the Boroko and Korobosea areas are largely residential with only the Port Moresby General Hospital within the area to which water supply has to be ensured during the cut-off day. Hence, the Boroko/Korobosea areas were selected as the second block for the water rationing experiment.

Supply to the hilly areas Tokarara and Hohola is through 375 mm AC main taken off from the 525 mm main to the Gerehu/Waigani area. Due to supply to Gerehu and Waigani blocks, which are at lower elevations than the water-deficient areas of Tokarara and Hohola, water does not reach the latter areas. Therefore, the other water rationing experiment involved cutting-off supply to Gerehu and Waigani.

Since approximately 16,000 m^3/d of daily average water demand had to be cut-off each day, and since the Gerehu and Waigani blocks has a total demand of about 26,300 m^3/d, some areas of Waigani were excluded from the areas to be rationed, based on the ease of valve operations. These include Morata, the University of Papua New Guinea, and the central government buildings east of Waigani Drive. By doing so, the daily average demand cut-off is about 17,500 m^3/d. This is shown in Table L.2.

Similarly, in the Boroko/Korobosea area, the distribution system is so designed that the need to ensure continuous water supply during the rationing experiment day to only the Port Moresby General Hospital required closure of 30 - or so valves to seal the area. Of these valves more than a third had to be closed to seal residential areas around the General Hospital between the Korobosea drive, Hubert Murray highway and Taurama road. Therefore, the area around the hospital was excluded from water rationing. However, to compensate for this, water supply to the Horse camp area in the neighboring Kilakila census division was cut-off.. By doing so, the total cut-off daily average demand is about 17,000 m^3/d. This is also shown in Table L.2. The actual areas where water was shut-off during the experiments are shown in Fig. L.2. These two blocks do not include major industrial areas. Also supply to government offices, embassies and other important institutions, discussed earlier are not affected.

2.1.4 Monitoring during Experiments

During trial rationing experiments, flow and pressure measurements were taken at various critical points all over the city to evaluate the effectiveness. 19 points were selected all over the city for pressure measurements. Two types of pressure measurements were carried out - continuous measurements over 24 hours at 3 places and spot measurements for measuring pressure twice a day - at 0830 hours and at 1700 hours, at the remaining 16 locations. In spot measurements, pressures were also measured at 6 places at 0000 hours. Continuous flow measurements were recorded at 2 locations. Details of the flow and pressure measurements, locations, pipe details, etc. are given in Table L.3 and the exact locations are shown in Fig. L.3.

2.2 Preparatory Activities and Operations

In the week prior to the experiments, a variety of preparatory activities were undertaken.

2.2.1 Testing of Valves

All valves that had to be controlled during the experiment in Boroko/Korobosea and Gerehu/Waigani, were located and tested to confirm normal operation. In some places, valves were not readily visible and required digging. In some other places, valves given in the plans could not be located and hence alternative valves were identified and checked.

2.2.2 Pit Digging / Drilling / Tapping

Digging around a few pipelines to attach flow meters and drilling pressure monitoring taps on pipes with no fire hydrants (pressure in pipes with fire hydrants were measured through the hydrants) were other preparatory activities implemented.

2.2.3 Announcements in the Mass-media

Announcements were made in the mass-media (newspapers, radio and TV) to inform the public about the need for water rationing experiments and the areas that would be affected. Advertisements from the City Manager of NCDC were published in the Post-Courier newspaper on the following days - 10th, 16th, 17th, 18th, 21st, 22nd and 23rd June '93. A news article regarding the trial water rationing experiments was published on 18th June 1993. The articles and advertisements are given in Appendix 3. In addition, announcements were made on the national MTV television network during the weekly NCDC news program at 2030 hours on Saturday 19th June, in which one senior engineer of the NCDC familiar with the trial water rationing experiment personally appeared on TV and explained the need and the nature to the water rationing exercise. Announcements were also made on radio. It was further planned that on the day prior to the experiment, pamphlets would be distributed of all houses in the affected areas. Other plans included operating vehicles equipped with loudspeakers in affected areas, informing residents in English, Pidgin and Motu languages about the exercise. However, due to time limitations the distribution of pamphlets and loudspeaker announcements had to be skipped.

2.2.4 Complaints Desk

A complaints desk was organized for the water rationing test to receive complaints from the public. A special telephone line was provided. This telephone line was also publicized in the mass-media announcements.

2.2.5 Spares Availability

Availability of spare pipes of different diameters and materials was checked, in case pipes burst during the trial water rationing experiment. Some spares had been held up at the Port Moresby customs, and the intervention of higher officials of NCDC was needed to get them cleared.

2.2.6 Vehicle / Manpower Deployment

Four vehicles with 2-way radios that could communicate with the control room (Shed 20) and with each other, were set apart for the experiments. During the experiments, three cars were actually used for the opening and closing valves of and spot pressure measurements. The fourth vehicle was a stand-by for maintenance work. The other three were also on maintenance stand-by when not used for valve operations and pressure measurements.

2.2.7 Stand-by Water Trucks

Two water trucks (capacity : 11 m^3 each) were kept as stand-by during the experiments to provide water to consumers who request emergency supply by phone.

2.3 Analysis of Results

2.3.1 Valve Operations

Water supply to Boroko, Korobosea and parts of Kilakila was cut off at 1430 hours on 23rd June. This required control of 17 valves and the work was divided among three teams, each covering 6 valves. On the 24th afternoon, the supply to this area was restored and that to Gerehu and parts of Waigani was cut off. Cutting off supply to Gerehu and Waigani required control of 6 valves. All teams were provided a route map they were asked to follow and log sheets for recording the exact times they reached each valve. It was found that operating 6 valves took an average of about 30 minutes by a crew of three - a technician, a driver and a worker - and the entire operation went off smoothly.

2.3.2 Pressure

Detailed records of spot measurements at all 16 locations in Port Moresby between 22nd June and 26th June are given in Appendix, Table 1. In this table, the actual time of morning, evening and night measurements, as well as the ground elevations are also given. A detailed record of the 24-hour continuous pressure measurements at 3 locations - 150 mm pipe on Ela Beach Road in Town, 200 mm pipe at Lawes Road outside the premises of the Post-Courier newspaper company in Konedobu, and the fire hydrant off the 150 mm pipe on Gaibodbu Road in Tokarara - are given in Appendix, Table 2.

Fig. L.4 gives the effective pressure variation obtained from continuous pressure measurements at the three above-mentioned locations. At Ela Beach, while pressures could be measured round the clock for the control days (22nd-23rd June and 25th-26th June), measurement are available only between 3 pm and mid-night on 23rd June, the day water supply to the Boroko/Korobosea/Kilakila area was stopped. However, it was seen that during this nine hour period, there was a 5-8 m increase in available pressure over normal times.

For Lawes Road, it is seen that the pressure dramatically rises over normal days when supply to the Boroko area is stopped. This increase is about 20 m during the evening peak hours and about 5-8 m during the morning peak hours. However, during the late night and early morning hours, there is no change from normal times. This shows that by rationing supply in areas upstream, high pressures are available during the peak demand hours. But during the night-time, due to minimal demand upstream, pressures reach their peak even during normal times.

At Gaibodbu road, Tokarara, which is another water-scarce area, it is observed that when water supply was stopped to Gerehu and parts of Waigani on 24th-25th June, there is an effective pressure increase between 6-20 m over normal times. This increase is critical, since water supply to this and surrounding areas, normally available only intermittently during late night-early morning hours normally, changed to a 24-hour supply during the day.

Fig. L.5 gives the pattern of variation of spot pressure measurements at 9 locations between June 22 - 26. Airvos Road (elevation - 70 m MSL) and Douglas street (elevation - 14 m MSL) are in Town. The latter, due to its low elevation, normally gets good supply, even during the Boroko stoppage. At Airvos road, where water is normally supplied through the Town reservoir, pressures normally do not rise sufficiently to fill the reservoir. To correct this, NCDC artificially fills up the reservoir at night, by stopping supply to other areas in Town every two days. On the 23rd morning, this was the reason for the 30 m pressure reading. However, when the Boroko water supply is stopped, as seen in Fig. L.5, water pressure rises naturally (NCDC was asked to discontinue artificial reservoir filling from the day before the experiment) on the following day. This is because water could flow into Town reservoir on the night of 23rd June, and this is reflected as higher pressures in Airvos the following day.

It can also be seen that the pressures at Gordons industrial area and NCDC Westpac office increase when Boroko water supply is cut off, as expected, due to the diversion of water to the 150 mm CICL pipe on Waigani drive. At Nuana street in Gordons, there was increased pressure on 23rd-24th and also on 24th night. The former is due to increased water available in the network by stoppage of the Boroko supply, but the water cannot go down to Town and other locations downstream, therefore, flows back into the Gordons area.

When water supply was stopped to Gerehu and parts of Waigani on June 24-25, it is seen in the same figure, that pressures increase dramatically along the Baruni road. At Erupi Place, which is at an elevation of 70 m in the problematic area of Hohola and which normally has water only during nighttime, water was available round-the-clock on 24th-25th. Hohola reservoir fills up partially and this makes water available to this area until 26th morning even after the Gerehu/Waigani supply was resumed on the 25th afternoon. It is interesting to note that at Boevagi street in Hanuabada, water pressure rises about 18-20 m higher than normal times the night of 23rd, when Boroko supply was stopped, and also on the 24th night when Gerehu/Waigani supply was stopped. The former is due to increased flow along the 300 & 375 mm in Koki due to diversion of water from the Boroko area. However, the latter is due to increased pressures at Baruni, which flows further down to Boevagi and other parts of Hanuabada. There is marginal improvement in pressure at the junction of Spring Gardens and Wards Road in Hohola when Gerehu/Waigani supply is stopped, due to the increased pressure at Erupi place.

2.3.3 Flow

A detailed record of the hourly flow measurements at two locations - on the 250 mm main off Pascal avenue in Badili which carries flow through to Ela Beach in Town and off the 375 mm main along Waigani Avenue that conveys water to Tokarara / Hohola - are given in Appendix, Table 3. A graph of the same is shown in Fig. L.6.

At the Badili location, it is seen that when supply to the Boroko area is stopped, flow marginally increases during the evening peak hours on 23rd and the morning peak hours on 24th June. However, during both these periods, there is a marked flattening of the curve visible between 6 and 9 pm on 23rd and again between 7 and 9 am on 24th. This shows that pipe capacity is a restraining factor and had more pipe capacity been available, the curve would have risen during those hours. However, at other hours, it is seen that flow is marginally greater all through the day when the Boroko water supply is stopped. The total daily flow increases by only about 5 % over the normal day, indicating that capacity of this pipe is a factor limiting greater flow.

On the other hand, as shown in Fig. L.6, when water supply was stopped to Gerehu and parts of Waigani on 24th-25th June, water flow in the 375 mm AC main increases almost

100 % over normal times throughout the 24-hour period. The flow rate through the 375 mm pipe to Tokarara and Hohola over the whole day when Gerehu and Waigani supply was stopped, is 12,500 m^3/d, as compared to 6,000 m^3/d normally. This indicates that pipe capacity is not a limiting factor in this case. The Hohola reservoir started filling up on 24th-25th, resulting in water pressures at the far end of Hohola (Erupi Place) even on the following day, well after the trial water rationing experiment was completed.

2.3.4 Service Reservoir Levels

The levels at all the 7 service reservoirs in Port Moresby - Boroko, Korobosea, Three-mile, Waigani, Koki, Hohola and Town - in the morning, evening and late at night between 22nd and 26th June were recorded and are given in the Appendix, Table 4. Fig. L.7 gives the variation in the levels in Hohola, Koki and Town reservoirs during this period. The other reservoirs did not show any difference from the normal level - which was zero - during this period.

As seen from Fig. L.7, Town reservoir was about a quarter full before the water supply to the Boroko area was stopped. This was because of the artificial filling of this reservoir before the experiment. During the experimental period, NCDC was requested not to fill up the reservoir, so as to enable assessment of the natural flow conditions to the reservoir and the network at higher elevations. Between midnight and 9 am on the 24th, water level rose in the Town reservoir and filled up half the tank, due to the stoppage of supply to Boroko area. This tank has a capacity of 2,270 m^3. However, as will be discussed in the next section, the water levels rose at the Mt. Eriama water treatment plant during this period, indicating that although excess water was made available in the system, it could not completely fill up the Town reservoir because of the limitation in capacity of pipe between Mt. Eriama and Koki. The level at Koki also did not rise significantly during the experimental period.

When water supply was stopped to Gerehu and parts of Waigani on 24th-25th, water started flowing into the Hohola reservoir during the early hours of 25th and reached a level about 15 % of its capacity. Water normally does not enter the Hohola reservoir.

2.3.5 Mt. Eriama Water Treatment Plant - Inflow and Outflow

The detailed hourly records of inflow from the Rouna 1-3 pond into the Mt. Eriama water treatment plant and the variation of storage levels in the two reservoirs at the plant between 22nd and 26th June are given in Appendix, Table 5. During this period of time, two of the three pumps at the Bomana pumping station were operating continuously at an average flow rate of 8,000 m^3/d each, except between 1 pm and 7.30 pm on 24th, when the operators at the treatment plant observed that the reservoirs could overflow, and stopped one pump.

The variation of the storage levels in the two reservoirs at the plant and the inflow to the plant are graphically shown in Fig. L.8. It is seen from this graph that during the stoppage of water supply to the Boroko area, the water stored in the reservoir # 2, which has more than 84 % of the storage capacity of the two reservoirs, started rising to dangerous limit of 9400 m^3 (which is its overflow level) at about 3 am on 24th and hovered between 8500 m^3 and 9000 m^3 until 1 pm on 24th. The operator then shut off one pump for water from Bomana into the plant until 7.30 pm, which caused the level to drop. This implies that when supply to the Boroko area was stopped, some of the water available flowed into the downstream sections of the network - Town, Konedobu, Hanuabada. Water did rise in the Town reservoir during the early morning of 24th. However, it did not rise above the halfway mark, nor did it rise significantly in Koki, or rise at all in other reservoirs. Despite availability of demand (reservoir filling up) right through the early morning hours, water storage at the plant started increasing beyond normal levels. This again confirms that it is pipe capacity in the downstream areas that limits flow into these areas and causes back pressure at the plant. It is important to note from the lowest graph in Fig. L.8 that the inflow from the Rouna 1-3, which is without control at present, did not vary over the four-day period, nor did the pumping rate from Bomana, vary except what was mentioned previously.

2.3.6 Summary of Results

Rationing of water supply to certain areas of the city is effective in diverting water to problematic areas of the network - Town and Hanuabada, by stopping water supply to Boroko, Korobosea and Kilakila, and improved water supply to elevated locations at Tokarara and Hohola, when water supply was stopped to Gerehu and parts of Waigani. While the latter stoppage enhanced flows to Tokarara and Hohola by 100 %, the former caused a total flow increase to Town on the 250 mm at Badili by only about 5 %. Continuous pressure measurements indicate that pipe capacity limits the increased flow. The latter stoppage caused increased pressures at Baruni as expected and also at Hanuabada, connected to Baruni, which was unexpected. It also enabled a 24-hour supply to areas in Tokarara and Hohola which normally have water only between midnight and 4 or 5 am. The Hohola reservoir filled up partially, and ensured water availability during the day following the stoppage, when the system was restored to its pre-rationing condition. The reservoir at Town was filled to half the capacity during the stoppage of water supply to the Boroko area, but during this period, back pressure occurred at the Mt. Eriama plant, indicating pipe capacity limitation en route from the plant to Town and further downstream.

Valve closures and openings were handled smoothly by the NCDC staff and on each day, the entire operation was completed in about half an hour. Care was exercised to ensure that, hydrants on major pipes were opened beforehand to bleed the air when valves were reopened. The same crew also handled spot pressure measurements three times a day over the four day period, without any major hitches. Each crew consisted of 3 members - a driver, a technician and a worker. However, it was felt that even if the crew were reduced to two members (driver and technician), as it inadvertently happened with some crews on some days, no problems were encountered in valve operations. Therefore, there will not be any problem in implementing water rationing as a regular feature from manpower deployment and logistics.

Due to the regular publicity given to the water rationing exercise during the two weeks before the experiment, no complaints were received during the period of stoppage. Only a few calls were received from Gerehu in the afternoon of the 25th of June, because reopening valves in the area was delayed by about half an hour. There were also no acts of vandalism during the experiments. In the past, when water supply was cut off to some areas like Gerehu, residents have been known to break open fire hydrants. However, good publicity given to the exercise and the background for the experiment prevented any such untoward incidents. There were also no incidents of pipe bursts, except one on Airvos Road in Town during the experiments, though 4 maintenance crews were on standby during the day time and one during the night.

In conclusion, while there is a problem with pipe capacity for conveying water to Koki and Town, the experiments have showed that water rationing can be effective in diverting water even to tail end areas of the network and can improve water supply to the city of Port Moresby in a more equitable manner. Installation of the planned 600 mm pipeline from the Mt. Eriama water treatment plant to the reservoir at Koki should serve to circumvent the problem of pipe capacity and enhance the effectiveness of water rationing in the Town, Konedobu and Hanuabada areas.

Announcements in the mass-media were continuously provided for a week prior to the experiment as well as on the week of the experiment, and on the whole the experiment went off smoothly, with the populace in the affected areas making sufficient alternative arrangements for the one-day stoppage. This shows that if the city is given adequate notice and public awareness campaigns are vigorous, people are cooperative as long as they understand what is going on and how they will benefit from it.

3 Future Water Rationing Plan

The demand for water is increasing every year, while the supply is constant at 125,000 m^3/d for the next few years. It is expected that additional treatment capacity will come on line in late 1996 or early 1997. Until then, the demand-supply imbalance will continuously increase year by year, and water rationing is the only answer for an equitable supply of water to the city. As mentioned in the beginning of this chapter, water shortages occur during the dry season, and even within the dry season, the water shortage gradually increases as the dry season progresses from May to December. Therefore, two water rationing plans are proposed - a moderate plan that should be put into effect early in the dry season, and a severe rationing plan which should be enforced when the water shortage becomes very acute, towards the end of the year. The time for the transition from the moderate to the severe rationing plan should be determined based on the amount of rainfall in the previous year and the severity of the summer predicted from pressure and flow patterns in the network. The setting up of a monitoring program is discussed later.

Water rationing should be initiated as a regular feature of water supply in Port Moresby in the middle of 1994. The water supply-demand balance from 1994 to 1996 is given in Table L.4. The shortfall in 1994, based on the daily average demand, corresponding to the earlier part of the dry season, is about 23,000 m^3/d. To correct this deficit, a moderate rationing plan, that would cut off about 23,000 m^3/d of demand from the distribution network every day, is required. This would require the city to be divided into 6 blocks of about 23,000 m^3/d of daily average demand. Rationing would cause water supply to be stopped to each block once every 6 days. It is proposed that for the convenience of consumers, a weekly water supply stoppage cycle be established, so that water is stopped to a given area in the city on the same day every week. Sunday can be kept as the day off for water rationing, thereby forming a full 7-day water rationing cycle.

The deficit based on the daily maximum demand in 1994, corresponding to the later part of the dry season, is about 67,000 m^3/d. To correct this deficit, a more severe rationing plan that would cut off about 67,000 m^3/d of demand from the distribution network every day, is required. This would require that the city be divided into 3 blocks of about 67,000 m^3/d of daily maximum demand. Rationing would cause water supply be stopped to each block once every 3 days, i.e. twice a week. Here again, it is proposed that water supply be stopped to a given block on the same two days of every week, and Sunday be made the day without rationing, enabling a full 7-day rationing cycle to be formed.

The number of institutions exempt from water rationing should be minimized to enable easy valve operations, and to prevent increase in the non-rationed demand. For humanitarian and economic reasons, the following institutions are proposed for exemption:

1. Major industries (esp. water-intensive industries)
2. General Hospital
3. Airport

All other institutions - university, schools, government offices, embassies, etc. - should install storage tanks on their premises to cope with a one-day water supply cut. In dividing the city into blocks, the primary consideration is hydraulic, and the secondary consideration is obtaining nearly equal-sized demand blocks approximately equal to the required cut-off volume..

The method of how to deal with the presently problematic areas of Town, Hanuabada, Konedobu and elevated locations in Tokarara and Hohola in the rationing plan so that these locations do not have further water stoppages than at present, needs to be considered. Water supply to Town, Hanuabada and Konedobu can theoretically be increased, by increasing pipe capacity, by stopping water supply to locations that draw water from mains along the Hubert Murray highway, i.e. Gordons, Saraga, Boroko, Korobosea, Kilakila, Kaugere, Murray barracks area of Tokarara/Hohola census division, and areas with a large population which contribute to about 50 % of the demand.

On the other hand, water supply to water scarcity areas of Tokarara and Hohola can theoretically be increased by stopping water supply to areas that get supply from the 525 mm mains to Waigani - Gerehu, Morata, Waigani, Baruni - areas which contribute to about 25 % of the demand. This means that equal stoppage of water supply to all areas, Town and Konedobu would get double the increase of water supply that the problematic areas of Tokarara and Hohola can expect. One method for approximate equalization would be to exempt the problematic areas of Tokarara and Hohola from rationing. This will not completely reduce the number of days this area would have to go without water, compared to other areas, but would be a step in that direction. This is because under any water rationing plan this area would have to go without water for a number of days anyway. It should be noted that Gerehu, Morata, Waigani and Baruni should be divided over 2 days to ensure that some supply reaches the Tokarara / Hohola area on these two days. Reservoir filling on these two days will ensure supply for another two days. However, the demand in these four areas (Gerehu, Morata, Waigani and Baruni) cannot by themselves satisfy two full rationing blocks in size, and hence adjustments with some part of another CD are necessary. This additional area would not contribute to flow diversion to Tokarara/Hohola, however.

Based on these and hydraulic considerations, two water rationing plans for the city of Port Moresby have been drawn up - a moderate rationing plan and a severe rationing plan. In the moderate plan, the city has been divided into six blocks as given below. Please refer to Fig. 1 in Appendix for the exact locations of the census division units in Bomana and Laloki/Napanapa census divisions in the following description. The division into six blocks is also shown in Fig. L.9.

Block 1 -	Entire Gerehu census division (CD) Morata and Rainbow village of Waigani CD Units 1,2 3 and 5 (north) of Laloki/Napanapa CD
Block 2 -	Remaining parts of Waigani CD Erima in Gordons CD, bounded by Cameron Road & Geauta Drive Baruni/Tatana island of Town/Hanuabada CD Areas beside Waigani drive in Tokarara CD upto Wards road Units 4 and 9 of Laloki/Napanapa CD
Block 3 -	All areas in Tokarara/Hohola CD south of Spring gardens road Entire Bomana CD Units 5 (south), 6,7 and 8 of Laloki/Napanapa CD
Block 4 -	Part of Gordons CD enclosed by HM Highway & Geauta drive Saraga area of Gordons/Saraga CD Boroko area of Boroko/Korobosea CD upto Taurama Road.
Block 5 -	Korobosea, Taurama barracks & Pari in Boroko/Korobosea CD Kilakila, Kaugere, Gabutu & Horse Camp in Kilakila/Kaugere CD
Block 6 -	All parts of Town/Hanuabada CD except Baruni/Tatana Koki area of Kilakila/Kaugere CD

While the division of the city into blocks has been made on the basis of the demand in 1994, it can be seen from Table L.5 that as the shortfall increases in 1995 and 1996, the demands in the blocks also increase proportionately. Therefore, these block divisions can be used for rationing until 1996.

The details of demands in the constituent areas of each of these 6 blocks are given in Table L.5. The effect of the moderate plan on the water supply situation in each block on different days of the week, and in the Tokarara-Hohola problem area (which is not subject to intentional water rationing) is given in Table L.6.

It can be observed from Table L.6 that despite non-rationed supply to the problem areas of Tokarara/Hohola CD, the area can only have supply for 4 days a week, while other areas generally get supply on five days (plus Sunday). Supply to the Town/Hanuabada CD would be limited by the problem of pipe capacity. Once the 600 mm pipeline to 3-mile from Mt. Eriama is laid, supply will improve. The total cut-off volume in each block is less than the 23,000 m^3/d required. This is due to dividing the demand after excluding almost a sixth of the daily average demand which falls in the exempt (non-rationed) category. However, during the water rationing experiments, it was observed that the stored water levels in the reservoirs at the Mt. Eriama water treatment plant rose significantly during the rationing exercise when pipe capacity limited flow to Town and further downstream. Since the new 600 mm pipe is to laid by early 1996, the last year of water rationing, it is expected that this condition would continue until then. Therefore the cut-off volumes may be reduced during rationing, since the excess will return to the Mt. Eriama water treatment plant.

While this moderate water rationing plan would suffice for the earlier parts of the dry season, a more severe rationing plan would be needed to ensure equitable supply during the later parts of the dry season. In this severe plan, the city is divided into 3 blocks. These three blocks are formed by combining two blocks from the moderate plan. Block 1 and 4 of the moderate plan are combined, as also blocks 2 and 6. Block 3 and 5 make up the last block under the severe rationing plan. The division of the city into blocks under the severe plan is given in Fig. L.10. The effects of this plan on different blocks in the city as well as on the problematic areas of Tokarara/Hohola CD (which again is not intentionally subjected to water rationing) are given in Table L.7.

It can be seen from Table L.7 that each block would get increased water supply during the four days of the week they are not subjected to rationing, and on Sundays, the supply would be as is currently available. The areas in Tokarara and Hohola CD would get water supply six days a week, one more than in other blocks. However, the supply would be less on Tuesdays and Fridays because the cut-off in areas (Waigani, Baruni, Laloki 4/9) on these two days is much less than on Monday and Thursday (Gerehu-Morata-Laloki 1,2,3,5).

4 Measures Recommended Prior to Water Rationing

Water rationing measures should be implemented from the dry season of 1994. However, it is recommended that some preparatory measures be undertaken as soon as possible to ensure smooth implementation.

4.1 Administrative Body for Water Rationing

There should be one senior NCDC official appointed as the overall overseer of all aspects of water rationing - preparation, operations, publicity, etc. - who would then delegate work under different categories to other officials. Appointment of such a central authority figure is necessary to ensure that the operation is focused and problems with several leaders, without established lines of authority and responsibility are prevented. The leader, together with the heads of different sub-groups (operations, publicity, etc.) would form a core group, and direct the necessary arrangements.

4.2 Valves

Valves are important components of the system particularly for water rationing. Critical valves that control flow to rationing blocks must be proper working order and capable of opening and closing fully. Therefore, regular maintenance of valves should be carried out.

At the start, valves should be considered one block at a time. Their locations must be verified in some cases, this may require digging. The valves must be tested to check how well they open and close. This will identify faulty valves that need to be repaired or replaced. Since there are valves that open both clockwise and counter-clockwise, and the number of turns between the fully closed and fully open positions vary, a valve database should be prepared containing this information, locations, and pipe size and material, for use when regular water rationing is implemented. The valve locations must be updated on the distribution maps, since it was noticed that some were shown on the maps. At some other locations, valves had been removed and the pipes capped, and these were not shown in the maps. A system for regular updating of information must be maintained.

When one block is finished, another can be taken up. Checking, repairing, replacing and creating the database of the valves in all the blocks will need at least two months of work. Therefore this work should be started immediately. Morata is one area in the city that does not have sufficient valves to control flow from the 525 mm mains from which it draws water. There are 9 offtakes from the 525 mm mains in Morata, and the control valves are located near the offtake point at one of these offtakes only. Most cannot be effectively controlled. Valves should be installed on all these offtakes, as near the offtake point as possible. Since the offtake is directly off the mains, pressure reducing valves can also be installed at the same time.

4.3 Flow and Pressure Monitoring

It is recommended that permanent pressure and flow measurements be made at critical points in the system, with the equipment properly housed in rain-proof and vandal-proof shelters. By doing so, an ongoing record of the performance of the system, which can identify flow and pressure deficiency at various locations, will be available based on which rationing measures can be adopted. This will enhance the effectiveness of rationing and help identify minor modifications for improvements. It will also identify the period for starting rationing and when to switch over from moderate to severe rationing. Quantitative records are also useful for convincing the public on the need for rationing and the effectiveness of rationing.

During the water rationing experiment, pressure measurements were taken at 19 points and flow measurements at 2 points. These points must be made permanent measurement points. In addition, the following points are recommended :

1. 600 mm pipe near Three-mile reservoir, where a tapping already exists (Pressure and Flow)
2. 300 mm pipe on Hubert Murray highway near Guitana road (Pressure and flow)
3. 375 mm pipe from Koki reservoir (Pressure and flow)
4. 450 mm pipe from Koki to Town (Pressure and flow)
5. One of the offtakes at Morata (Pressure)

4.4 Public / Consumer Relations

Since there was a vigorous publicity campaign in the mass-media in the weeks prior to the experiments, there were hardly any complaints from consumers during the rationing tests. The people had taken measures to store water for the period the stoppage. There were no requests for water through water trucks and no acts of vandalism on fire hydrants, etc. All this goes to show that if the public is made aware of the reasons behind water rationing and if they are properly informed of the exact time and period of water stoppage, they are cooperative.

The importance of proper publicity for rationing in future cannot be understated. It is recommended that one senior official of the NCDC be appointed to oversee all aspects of publicity and public relations. The services of a public relations company to chalk out a well-planned public relations campaign over a period of a few months, may be considered also.

Since water rationing will be continuous in the medium-term, a vigorous publicity campaign should start as early as possible. Firstly, the reasons for water rationing (fixed supply, increasing demand, shortfall in supply, equitable distribution of available water, emergency, vagaries of the weather, etc.) should be publicized, months before the actual rationing starts. The example of acute water shortage in 1991-92 should be highlighted, preferably with pictures. The aim is to make people understand that given the present condition, there is no choice until additional treatment facilities become operational stream in late 1996 or late 1997. People are reasonable and willing to undergo hardships, if tangible results may be expected, and if the water supply cut-off and restarting times are announced in advance and strictly adhered to.

Campaigns in conventional mass-media should also include announcements in languages other than English, viz., Pidgin and Motu, since the lower sections/populace in settlements may not be fully conversant in English. Apart from advertisements in newspapers, newspapers and magazines should be requested to write feature articles on the topic. News releases on water rationing should be circulated regularly. Apart from these, there should also be announcements/advertisements on television at other times, during game broadcasts, movies, etc. This will ensure wider publicity.

Apart from the conventional mass-media (newspaper, radio and television) whose importance cannot be understated, it is also important to get cooperation from local council representatives, circulate pamphlets, use loudspeaker announcements, place posters in market places and other public gatherings, etc. Information should be given to school teachers, who can discuss the merits of water rationing with children in high school, so that this information reaches the children's houses. Telling children when they are young about the value and need to conserve water, will be an additional, permanent asset of the water rationing program.

As organized during the experiment, a complaints cell should be set up, but on a more permanent basis within NCDC. This cell should be manned by people who are well-versed with the operational details of the water rationing program and who can therefore explain to callers in detail which areas will be affected on which days, why it is being done, etc.

4.5 Control of Wasteful Usage of Water

The gardening demand in Port Moresby is more than 30 % of the total demand during the dry months. This is a very large portion and since this is not part of the demand essential to human survival and existence, it is more responsive to external factors like price, etc. While some amount of greenery is essential, over-indulgence and excess consumption for gardening should be curtailed. If it is possible to curtail gardening by 50 %, the need for water rationing during the early dry season (the moderate rationing plan) can be eliminated. In practice it may not be possible to curtail it to this extent. However, efforts must be made regularly for cutting down water demand for gardening.

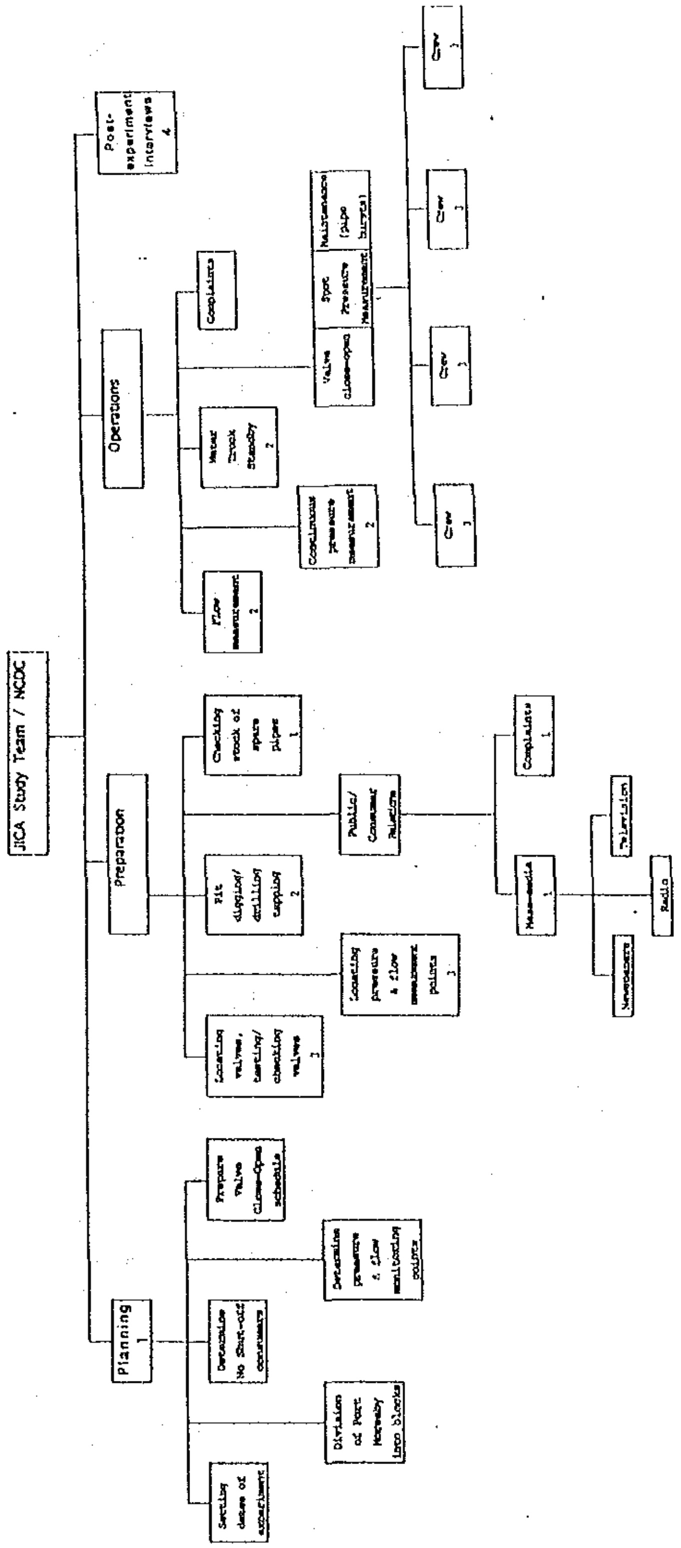
One method of control is by designating days when certain parts of the city may use water for gardening, and patrolling the city to enforce this method. This has been tried out in Port Moresby and, while it has been partially successful, it has not been continued over the medium and long term. It has also been observed in the past that some members of the public resort to tricks to circumvent this by spraying their gardens at late night/early morning or building walls around their premises to avoid the gaze of the inspectors. However, such cases have and will necessarily be an exception rather than the rule.

Another method is by the water tariff, since gardening normally shows high price elasticity. The tariff was revised, recently whereby the minimum charge of Kina 5 was revised down from the first 40 m^3 to the first 25 m^3, with consumption upto 40 m^3 charged a flat rate of Kina 11. 25 m^3 per month. This is a fair estimate of the water required to satisfy basic human needs as well a reasonable surplus for a family of 8, and should affordable for all sections of the population. Further consumption should be subjected to higher tariff to control wasteful consumption like excessive gardening. Collection efficiency is also important for ensuring the effectiveness of this graded tariff structure.

However, one of the advantages of water rationing is that it is a surefire method of ensuring reduction in gardening demand and leakage (which is estimated to be around 30 %) to zero on the rationed day. This would translate to a 16 % reduction in gardening demand and leakage, during the moderate rationing period and a 33 % reduction during the severe rationing period. While increased water pressures in other areas would lead to slightly higher leakage and gardening usage, the experience in cities that have rationed supplies show that the savings by the former is much greater than the losses by the latter. Apart from ensuring more equitable distribution of water to all parts of the city, this is another justification for implementing water rationing.

4.6 Full-fledged Trial Water Rationing

It is recommended that a trial be conducted for about 2 weeks before actually initiating a water rationing program in Port Moresby city, covering the trial areas. This would firstly serve to familiarize the populace with rationing. It would also assist in orienting the NCDC staff to full-fledged rationing. After this trial, detailed analysis and discussions on the results, shortcomings and possible modifications are necessary to achieve the desired results.



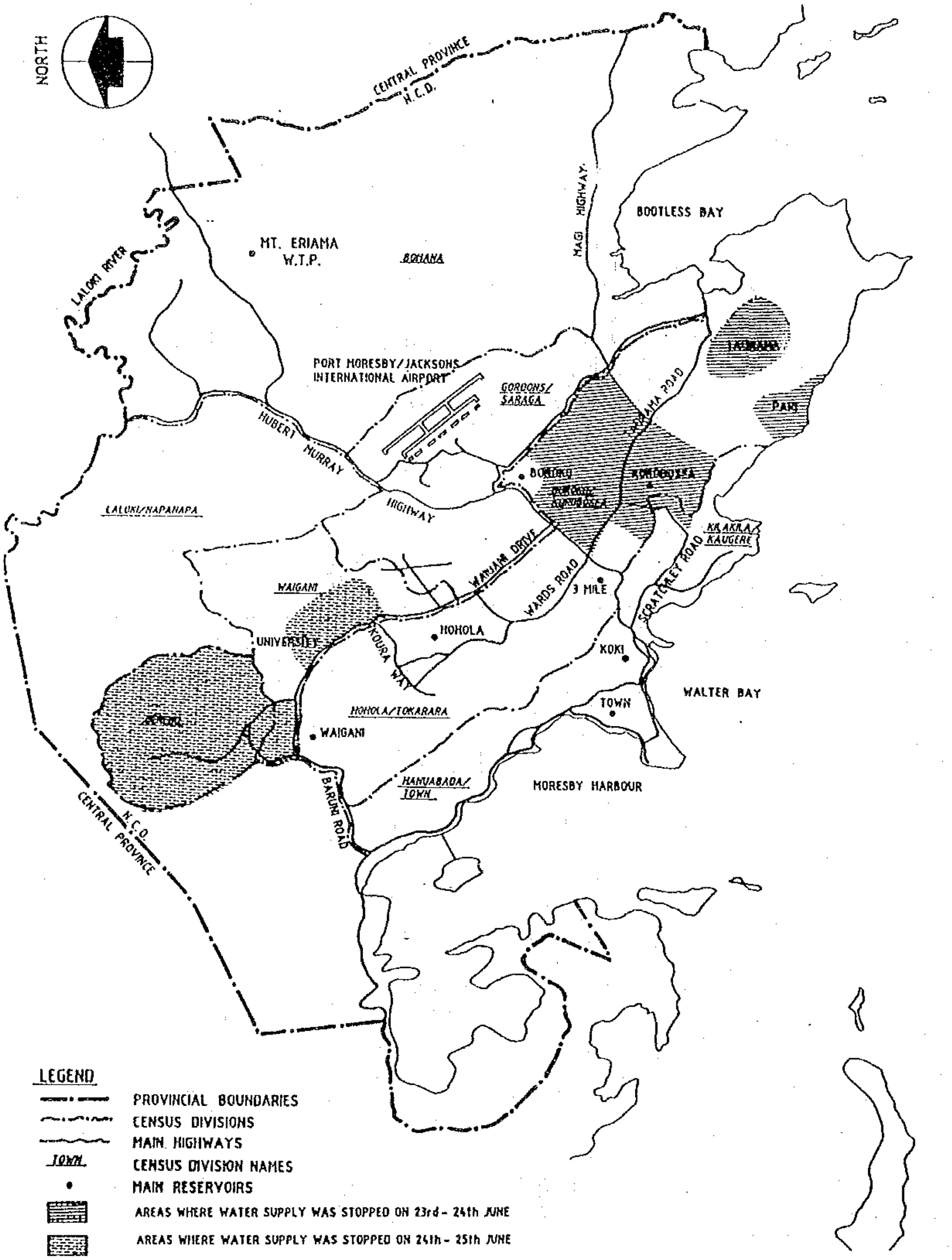
TITLE

ORGANIZATIONAL SET-UP OF PERSONNEL INVOLVED IN IMPLEMENTATION OF TRIAL WATER RATIONING EXPERIMENT

Fig. No. **L.1**

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANS in association with PACIFIC CONSULTANTS INTERNATIONAL



TITLE

WATER SUPPLY CUT-OFF AREAS DURING TRIAL WATER RATIONING

Fig. No. **L.2**

PORT MORESBY WATER SUPPLY DEVELOPMENT PLAN

TOKYO ENGINEERING CONSULTANS in association with PACIFIC CONSULTANTS INTERNATIONAL