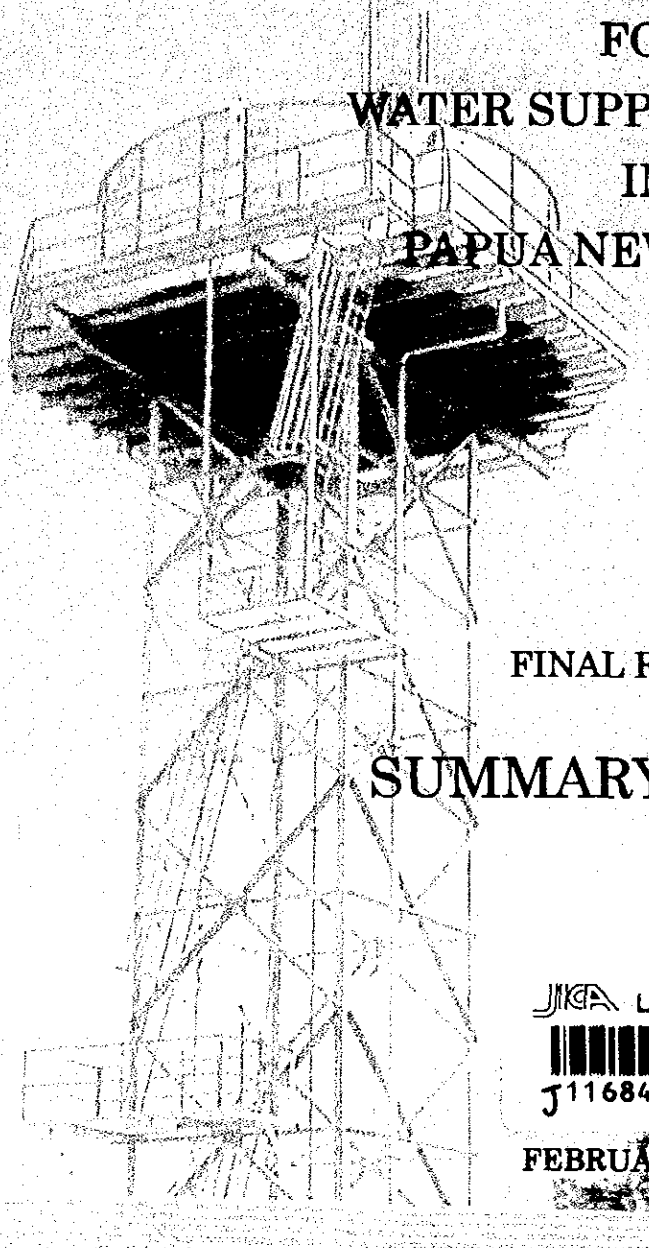
社会開発調査部報告書

No. 22

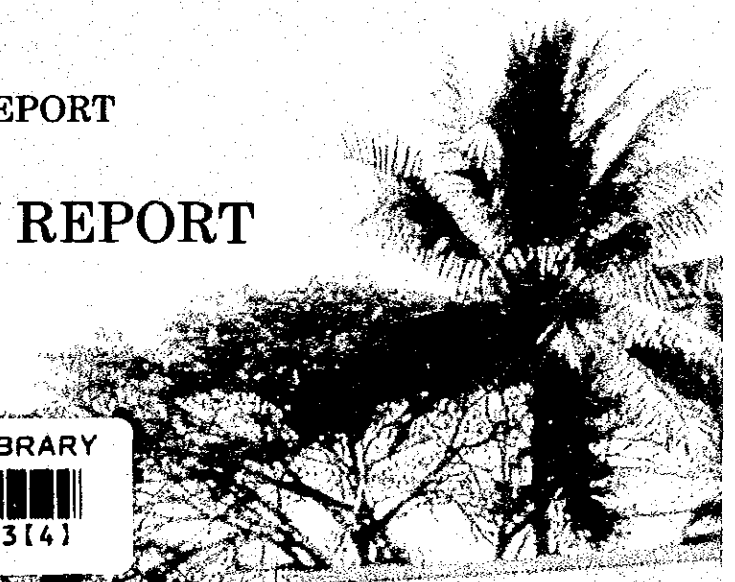
JAPAN INTERNATIONAL COOPERATION AGENCY
THE PAPUA NEW GUINEA WATERBOARD

THE STUDY ON GROUNDWATER DEVELOPMENT FOR WATER SUPPLY SYSTEMS IN PAPUA NEW GUINEA



FINAL REPORT

SUMMARY REPORT



FEBRUARY 2002

JAPAN TECHNO CO., LTD.

THE STUDY ON GROUNDWATER DEVELOPMENT FOR WATER SUPPLY SYSTEMS IN PAPUA NEW GUINEA
FINAL REPORT
SUMMARY REPORT
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FINAL REPORT

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PREFACE

In response to a request from the Government of Papua New Guinea, the Government of Japan decided to conduct the Development Study on Groundwater Development for Water Supply Systems in Papua New Guinea and entrusted the study to the Japan International Cooperation Agency (JICA).

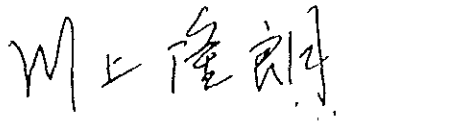
JICA selected and dispatched a study team headed by Mr. Shigeyoshi KAGAWA of JAPAN TECHNO Co., LTD. to Papua New Guinea, three times between March 2000 and February 2002.

The team held discussions with the officials concerned of the Government of Papua New Guinea, and conducted field surveys at the study area. Upon returning to Japan, the team conducted further studies and prepared this final report.

I hope that this report will contribute to the promotion of the project and to the enhancement of friendly relationship between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Governemnt of Papua New Guinea for their close cooperation extended to the Team.

February 2002



Takao Kawakami
President
Japan International Cooperation Agency

February 2002

Mr. Takao Kawakami
President
Japan International Cooperation Agency
Tokyo, Japan

Letter of Transmittal

Dear Mr. Kawakami:

We are pleased to submit to you the study report on Groundwater Development for Water Supply Systems in Papua New Guinea.

The report presents the study results on the present conditions of water supply as well as the groundwater development potential in the 2 Provincial Towns and 6 District Towns in Papua New Guinea. The report includes master plans for improvement in water supply as well as pilot projects for their implementation.

This report consists of the following volumes:

-	*Summary Report*	*A concise report on the whole study results*
-	Main Report	Description of the study results including the groundwater development, water supply master plan, and prioritized pilot project implementation and evaluation
-	Supporting Report	Results of geophysical investigation, test drilling, environmental and social study, training, and pilot project
-	Data Book	Survey data of landsat image, test borehole, resistivity sounding, economy, finance, institution and legal framework, PCM workshop, pre-registration for water supply services, well drilling data, MOU, MOA, concerned persons list, participants and minutes of meetings

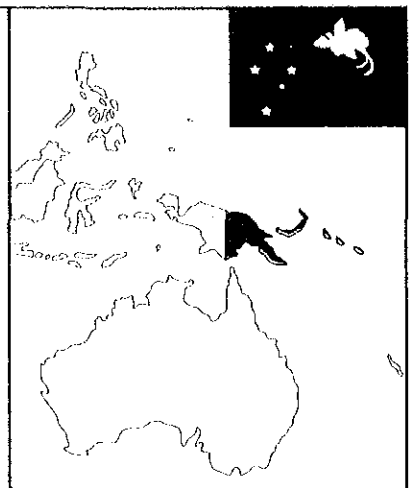
We are confident that the implementation of the pilot project would greatly contribute to the improvement of district centers of water supply and sanitation conditions together with open up new market opportunities for PNGWB in the rural communities where more than 80% of the population is concentrated.

We wish to take this opportunity to express our sincere gratitude to your agency and the Embassy of Japan in Port Moresby. We also wish to express our deep appreciation to the Papua New Guinea Waterboard and Aid Coordination and Management Division, Department of National Planning and Monitoring as well as other authorities concerned of the Government of Papua New Guinea for the close cooperation and assistance extended to us during our study activities in your country.

Very truly yours

Shigeyoshi Kagawa
Team Leader
The Study on Groundwater Development for Water Supply Systems in Papua New Guinea

THE STUDY ON GROUNDWATER DEVELOPMENT FOR WATER SUPPLY SYSTEMS IN PAPUA NEW GUINEA



Location of Study Area

★ Pilot Project Site (4 towns)

◎ Other Study Town (4 towns)

N

0 km 100

Study Area		Province
① Popondetta		Oro
② Daru	★	Western
③ Bereina	★	Central
④ Kupiano		Central
⑤ Kwikila	★	Central
⑥ Finschhafen		Morobe
⑦ Mutzing	★	Morobe
⑧ Oro Bay		Oro

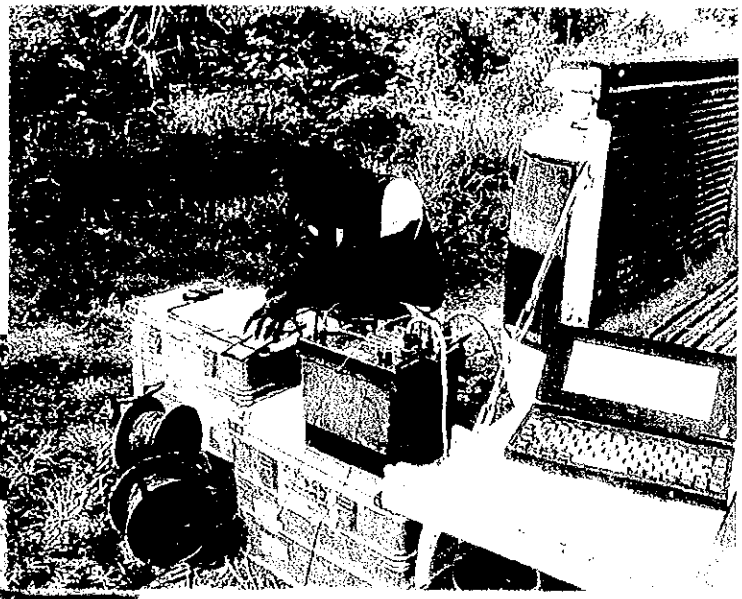
★ : Pilot Project 4 Sites

Vanimo
Wewak
Indonesia
Madang
Wabag
Mt Hagen
Mendi
Kundiawa
Goroka
⑦ Mutzing
Lae
⑥ Finschhafen
WESTERN
MOROBE
Kerema
ORO
① Popondetta
⑧ Oro Bay
② Daru
③ Bereina
PORT MORESBY
⑤ Kwikila
④ Kupiano
CENTRAL

Elevation (m)
3000~
1500
300
0

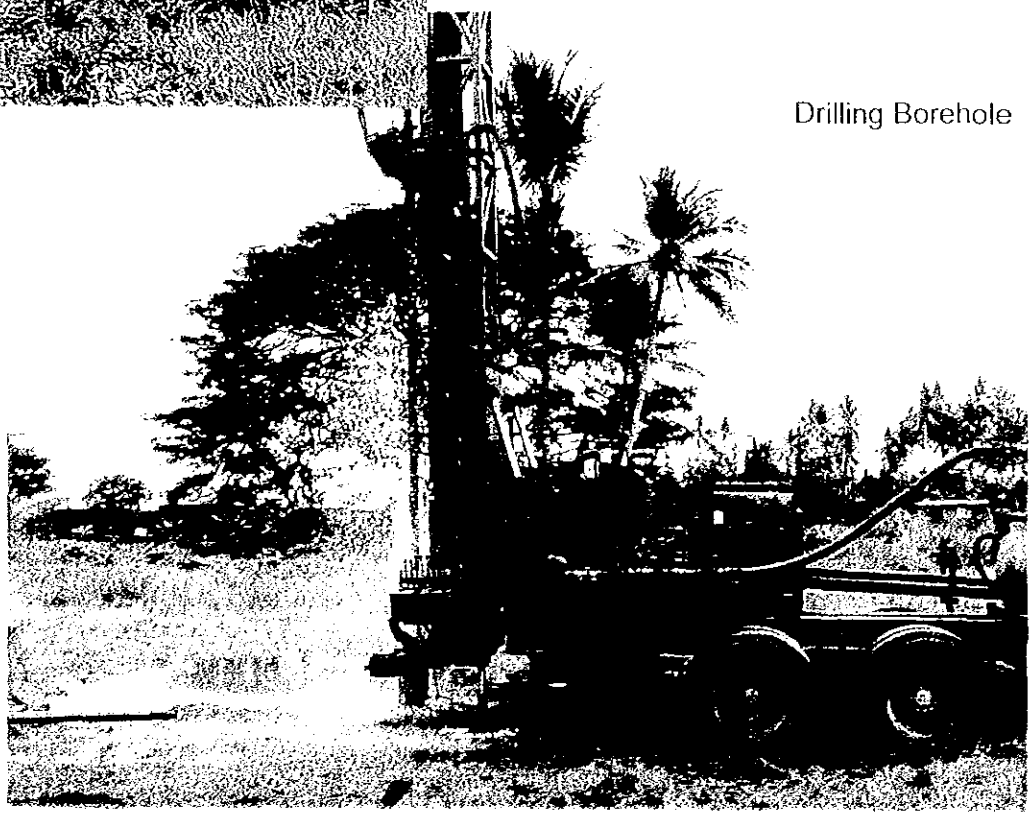
○ Province Capital
□ National Capital
Province Boundary
International Boundary

1.Groundwater Development

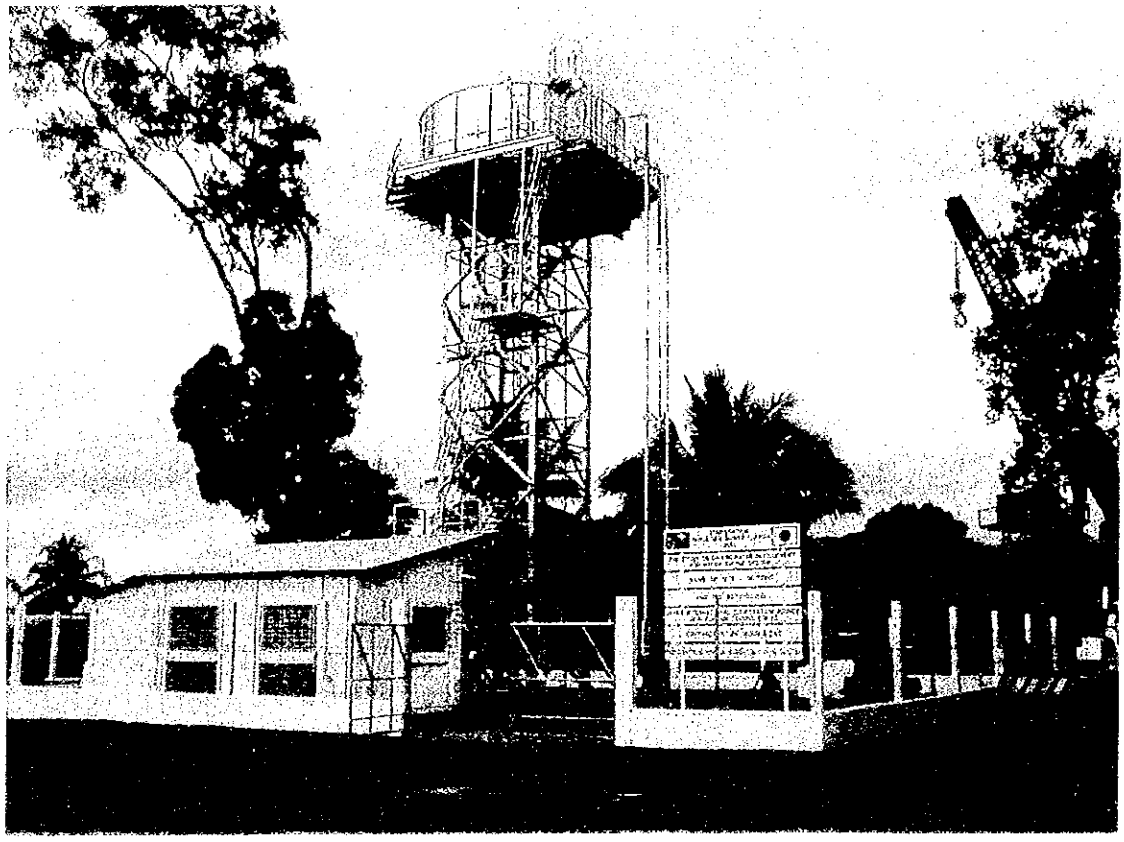


Geophygical Survey

Drilling Borehole



2. Pilot Project for Water Supply Systems

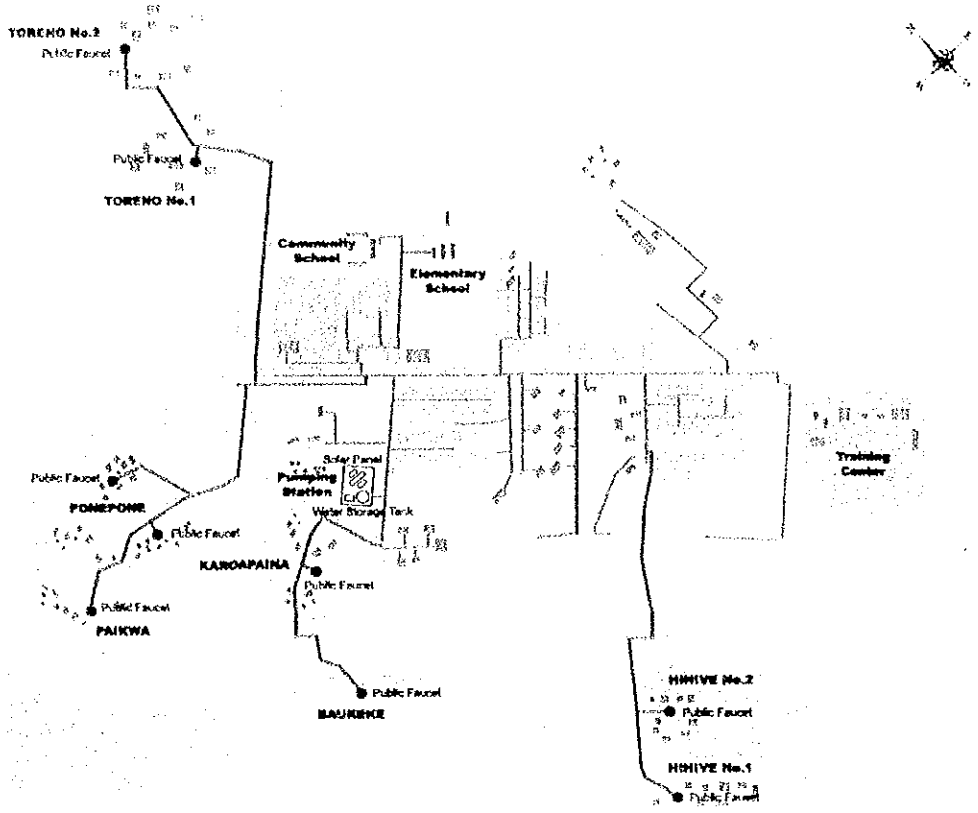


Pumping Station

Public Faucet

Pilot Project for Improvement of Water Supply System

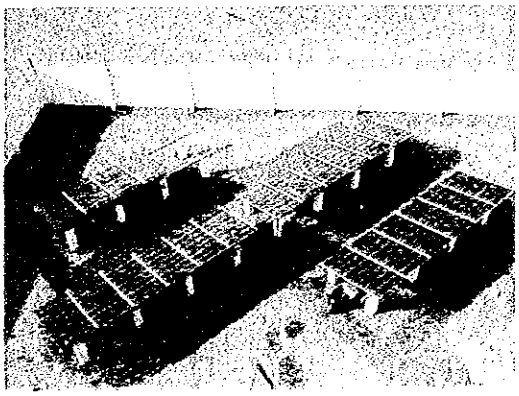
1. Bereina



Reticulation map

Pumping station

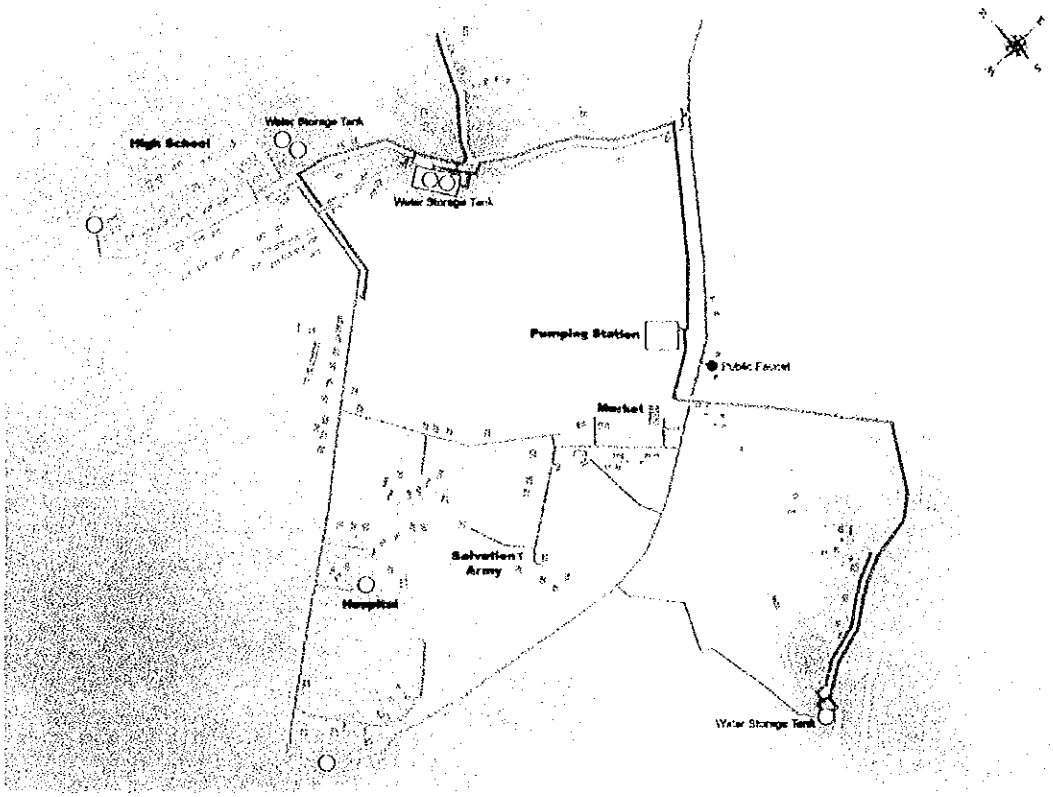
Water storage tank ($80m^3$-15m)



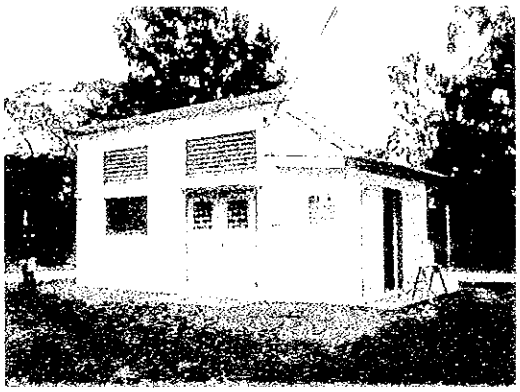
Solar panel

Public faucet

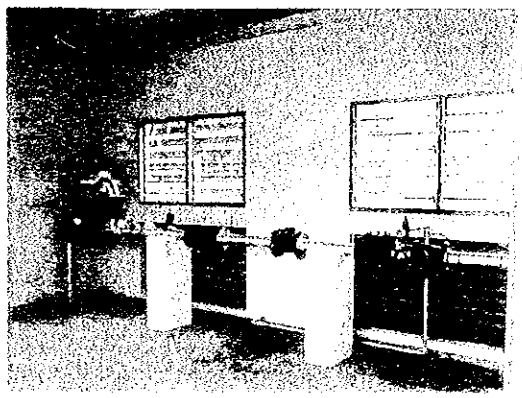
2. Kwikila



Reticulation map

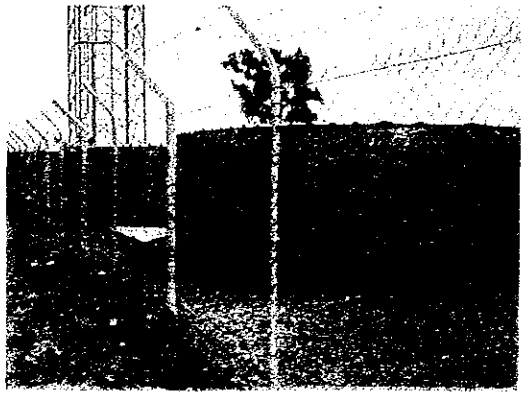


Pumping house



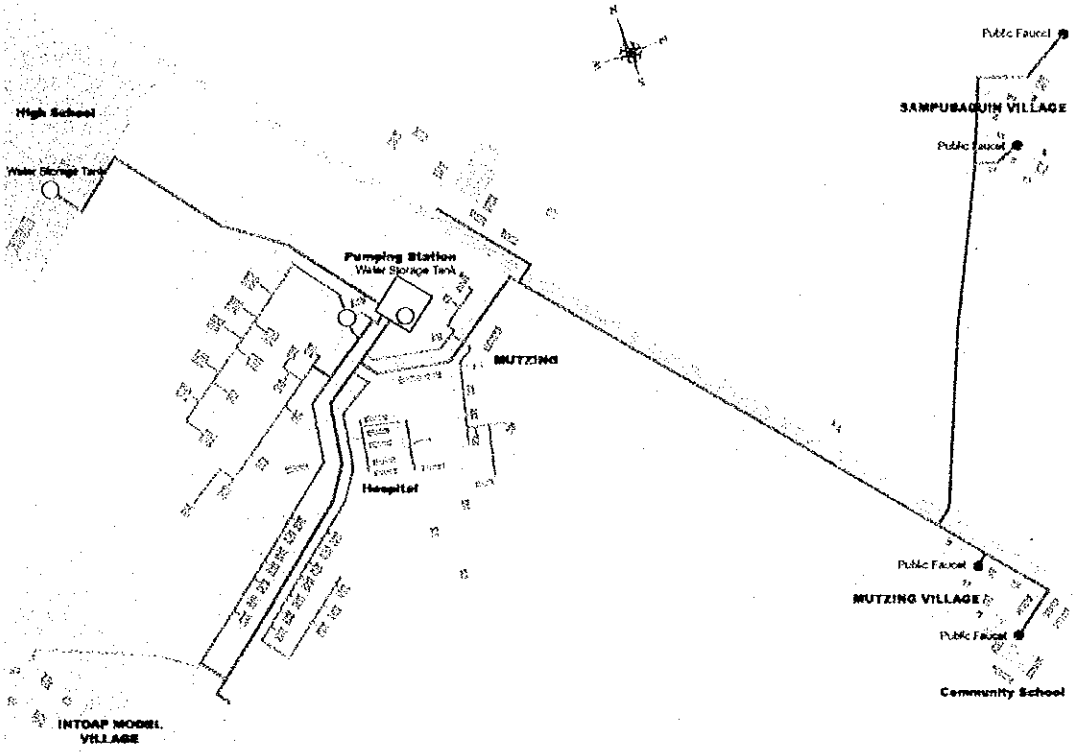
Interior of pumping house

Public faucet

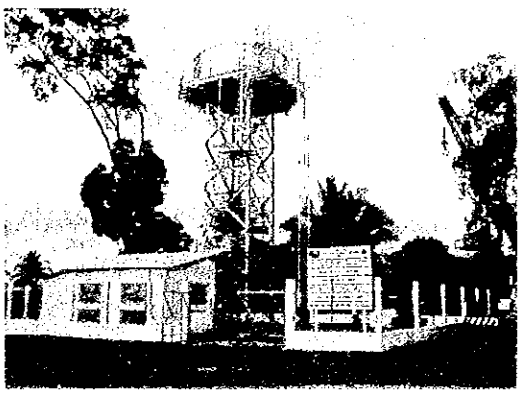


Water storage tanks ($60m^3$ x2)

3. Mutzing

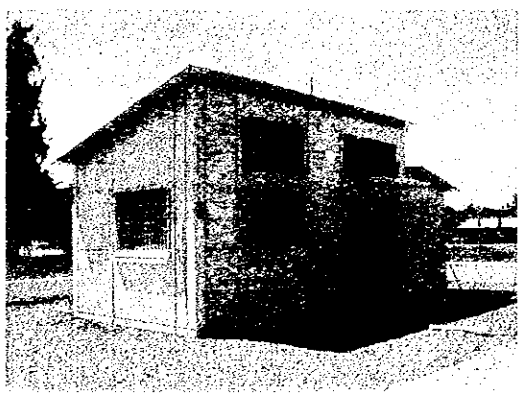


Reticulation map

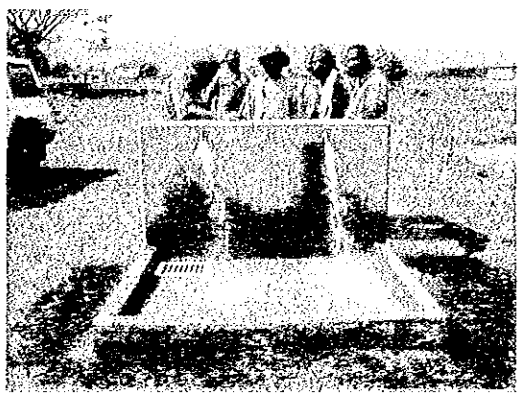


Pumping station

Borehole pit



Pumping house



Public faucet

THE STUDY ON GROUNDWATER DEVELOPMENT FOR WATER SUPPLY SYSTEMS
IN PAPUA NEW GUINEA

FINAL REPORT
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ABBREVIATIONS

ADB	Asian Development Bank
ADF	Average Daily Flow
AHF	Average Hourly Flow
APEC	Asia-Pacific Economic Cooperation
Aus AID	Australian Agency for International Development
BOT	Build, Operate and Transfer
CSA	Commercial Statutory Authority
DEC	Department of Environment and Conservation
DF	Daily Flow
DNPM	Department of National Planning and Monitoring
DOH	Department of Health
DOW	Department of Works
DWC	Daily Water Consumption
ELCOM	Papua New Guinea Electricity Commission
GDP	Gross Domestic Product
GNP	Gross National Product
HDPE	High Density Polyethylene Pipe
IMF	International Monetary Fund
JICA	Japan International Cooperation Agency
K	Kina
LLG	Local Level Government
MOA	Minutes of Agreement
MOU	Minutes of Understanding
NARI	National Agricultural Research Institute
NAL	National Analysis Laboratory
NCD	National Capital District
NGO	Non-Governmental Organization
NPV	Net Present Value
NSC	National Standard Council
NWSS Act	National Water Supply and Sewerage Act 1986
ORD	Office of Rural Development
PCM	Project Cycle Management
PDF	Peak Daily Flow
PG	Provincial Governments
PHF	Peak Hourly Flow
PNGS	Papua New Guinea Standards
PNGWB	Papua New Guinea Waterboard

PVC	Polyvinyl Chloride Pipe
RRA	Rapid Rural Appraisal
SAA	Standards Association of Australia
TC	Tank Capacity
TP	Target Population
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund
VAT	Value Added Tax
WET	Water Executive Team
WHO	World Health Organization
WRMD	Water Resources Management Division
WVU	Water Vending Unit

CHAPTER 1 INTRODUCTION

1.1 General

This is the Summary Report for the Study on Groundwater Development for Water Supply Systems in Papua New Guinea. The Study commenced in the middle of March 2000 in Japan and was completed by the end of February 2002 with submission of the Final Report. The Study is divided into two phases as follows.

Phase I: Investigation of Groundwater and Formulation of Water Supply Plan
- 1) Work in PNG (1) Investigation of Groundwater Potential and Water Supply System

Phase II: Pilot Project for Improvement of Water Supply System
- 2) Work in PNG (2) Pilot Project
- 3) Work in Japan (1) Preparation for Draft Final Report
- 4) Work in PNG (3) Explanation and Discussion on Draft Final Report, Implementation of the Seminar for Technology Transfer, and Evaluation for Pilot Project.
- 5) Work in Japan (2) Completion of Final Report

The JICA Study Team carries out the work in close co-operation with the counterpart personnel from the Papua New Guina Waterboard (PNGWB), with emphasis on technology transfer.

1.2 Background of the Study

The Government of PNG requested a technical assistance from the Japanese Government in 1998 to conduct the study for groundwater development for water supply systems due to the serious drought in 1997-1998 affected by El Niño.

The Pilot Project involves a new concept, with three particular aspects. The first aspect, which is the first of its kind, involves experimental and trial studies of District Water Supply at Bereina, Kwikila and Mutzing in PNG consisting of construction and rehabilitation of existing water supply facilities and operation, management and maintenance by the PNGWB. The second aspect involves the trial studies of a Water Vending Unit system supplying clean drinking water for lower income groups on Daru Island as part of the Provincial Town Water Supply. The third and final aspect of this concept looks at the involvement and participation of villagers in a water supply project as part of the Rural Water Supply Project. In Phase II, a Pilot Project for the construction and rehabilitation of water supply systems was executed successfully from December 2000 to July 2001 and handed over to PNGWB to operate, manage and maintain.

The 26 years old Independent State of PNG in the South Pacific lies just below the equator in the Eastern South Pacific. The country comprises of more than 600 islands and covers a total area of over 462 thousand km^2. The main island of New Guinea is shared with West Irian, Indonesia. The population of the country is estimated to be about 5 million in 2001 distributing about 26% in the coastal plains of the main island and 36% in the high mountains, 20% in the southern part of the main island, and 16% in the island archipelagos. PNG has a moderate tropical climate with high levels of seasonal rainfall totalling more than 2,000mm to 6,000 mm in a year. However, the low rainfall in 1997-98 led to drought over large areas of PNG. Some parts of the mountains were also affected by serious frosts due to El Niño. There was widespread destruction of the food gardens on which much of the PNG population depends. At the same time, water sources for water supply systems were dry and serious shortage of drinking water affected by the drought was encountered.

Water resources in PNG are not well developed though in some areas the potential is high. The study of water resources for both surface and groundwater will enable proper planning of this natural resource for social welfare. In the Five Years Development Plan, 2002-2006 for each District, the plans for supplying safe and potable water and construction of water supply facilities are given high priority. The PNGWB, which was established under the National Water Supply and Sewerage Act, 1986, was required to be both a commercially oriented agency, delivering eleven (11) Provincial Towns water supply and sewerage and the main sector of advisory and planning division for local town water supply in PNG. Japan has assisted the Government of PNG in the sectors of transportation, public health facilities and drinking water supply and sewerage as well as other kinds of official development assistance programs.

Many communities throughout the country are seriously affected by the lack of safe drinking water and adequate sanitation facilities. Only 30 % of the population has access to safe drinking water and about 22 % of the population has adequate sanitation facilities. Therefore, it is planned to improve the coverage of water supply to 50 % in 2010 by the Government of PNG.

1.3 The Objectives of the Study

The objectives of the Study are:

1) To formulate a water supply plan through the investigation of groundwater potential,
2) To conduct the pilot project for improvement of water supply system in the selected areas, and
3) To transfer technology to counterpart personnel in the course of the Study.

1.4 Study Area and Pilot Project Sites

The proposed population of the Study area was totally 23,800 in 1999, however after the Study of PNG (1) in 2000, the surveyed population was 46,160, which was almost two times.

Table-1.1 Study Area and Pilot Project Sites

No.	Province	Study Area	Pilot Project Area	Provincial/ District	Population (1999) Proposed by PNGWB	Surveyed Population 2000
1	Oro	Popondetta		Provincial Town	8,500	14,656
2	Western	Daru *	◎	Provincial Town	9,000	10,286
3	Central	Bereina	◎	District Town	1,000	1,343
4	Central	Kupiano		District Town	1,000	7,131
5	Central	Kwikila	◎	District Town	1,000	2,926
6	Morobe	Finschhafen		District Town	800	3,802
7	Morobe	Mutzing	◎	District Town	500	2,100
8	Oro	Oro Bay		District Town	2,000	3,916
		8 Areas	4 Areas		23,800	46,160

1.5 Basic Study Policy

As agreed in the Minutes of Discussions on Inception Report dated May 4, 2000 in Port Moresby, the JICA Study Team executed the Study in accordance with the following basic policies:

1) Existing data and information were organized systematically and used effectively to fully comprehend local conditions related to the living environment, water supply, sanitation, hydrogeology and other relevant subjects, and accurate field survey results were acquired to formulate an optimum development plan for groundwater development for water supply systems. In addition, similar studies were carried out through other donor organizations as well as previous projects implemented through JICA studies, and plans related to the Study were reviewed and reflected in the present Study.

2) The Study was effectively carried out for mutual understanding of current water supply conditions, local requirements, and technology transfer in order to:
   (a) Establish optimum solutions to the prevailing problems;
   (b) Formulate a water supply improvement plan which is most suitable in terms of groundwater development; and
   (c) Prepare an optimum operation and maintenance plan for a sustainable water supply system.

3) The Study was executed in cooperation with counterpart personnel from the PNGWB, local government in order to complete the Study according to the schedule with emphasis on technology transfer in pursuit of capacity building for water resources survey, design and construction and/or rehabilitation of water supply system, and its proper management, operation and maintenance.

4) Through this development study, the Pilot Project was implemented at the selected district towns based on the results of test drillings, reviews and plans for improvement of existing water supply facilities, operation and maintenance, and willingness of people to pay for the water. Through workshops and seminars, the results of the Study were opened and views were exchanged with the participants such as government personnel, water supply/sanitation sector related personnel, concerned donor and international agencies representatives, NGOs and other relevant persons.

1.6 Social Survey Method

1) The RRA (Rapid Rural Appraisal) enables to rapidly and intensively assess the features of the living conditions of the district town and rural population for diagnosis of issues and problems. The basic concept underlying RRA is that the people know their own life best and have wisdom empirically.
2) On the other hand, the PCM (Project Cycle Management) method was used for logical composed planning of development project with a participatory approach. The main purpose of the PCM workshops were to exchange information between the JICA Study Team and the PNG side consisting of national government, district officers, local level government and PNGWB. Also by analysing existing problems in relation to water supply, realistic solutions for existing problems were sought. Each workshop was scheduled for 2 days. Because of time constraints, Participation Analysis (Stakeholders Analysis), Problems Analysis, Objective Analysis and part of Alternatives Analysis were done during the workshops.

1.7 Study Team and JICA Advisory Team

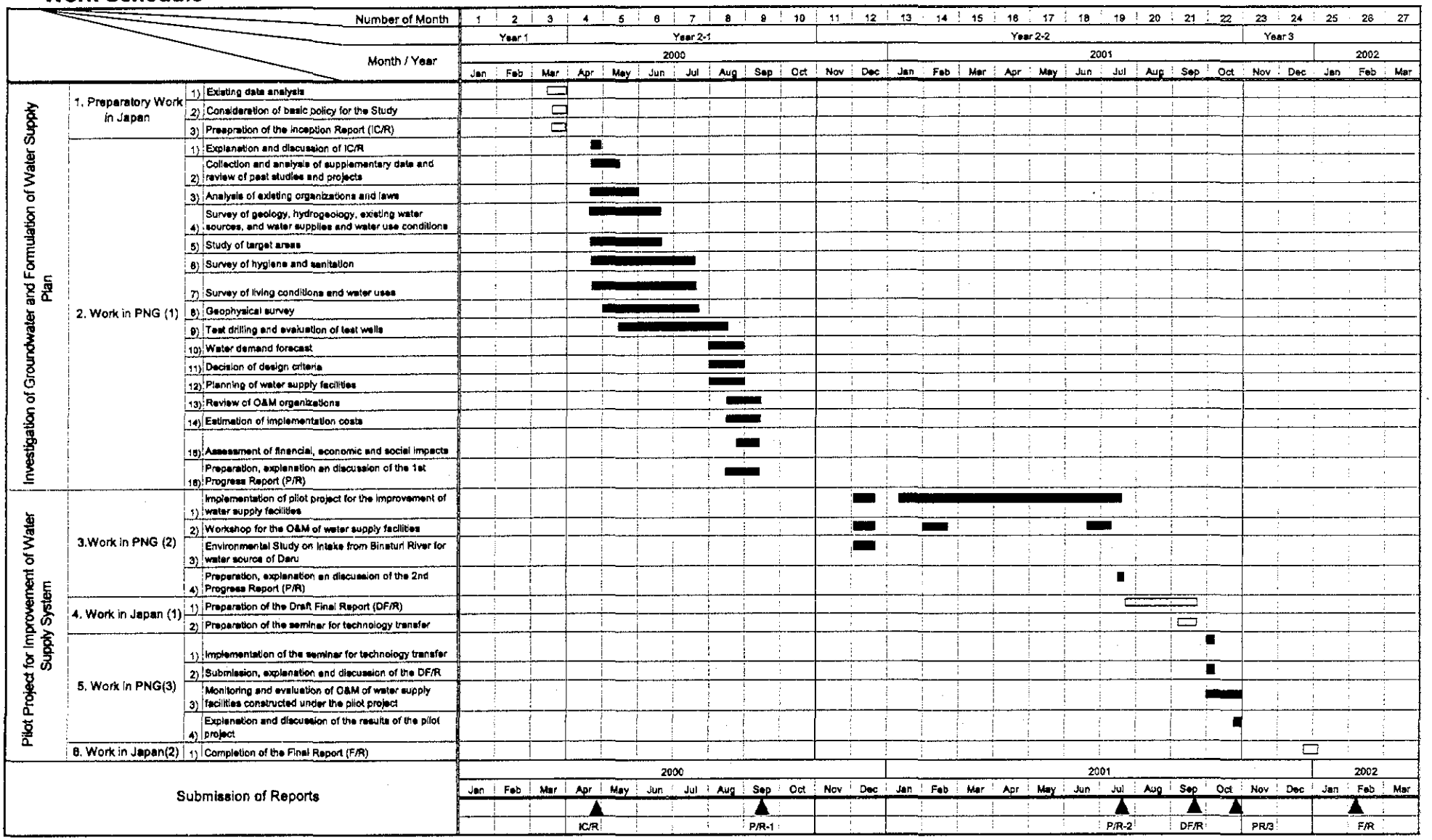
The JICA Study Team is composed of eleven (11) experts and one (1) coordinator. The work assignment of the team members is as shown in the attached assignment schedule.

Table-1.2 JICA Study Team and JICA Advisory Committee

JICA Study Team		
Name	Function	Affiliation
1. Mr. Shigeyoshi KAGAWA	Team Leader/Water Supply Planning	Japan Techno Co., Ltd.
2. Mr. Ichiro TAKAMATSU	Economic, Finance, Institution and Legal Framework	Japan Techno Co., Ltd.
3. Mr. Christopher JAYAKARAN	Hydrology & Hydraulics	Japan Techno Co., Ltd.
4. Mr. Masaru FUJITA	Geophysics Survey & Geology	Japan Techno Co., Ltd.
5. Mr. Chifumi YAMASHITA	Drilling Supervisor 1	Japan Techno Co., Ltd.
6. Mr. Yoshihiro YAMAUCHI	Drilling Supervisor 2	Japan Techno Co., Ltd.
7. Mr. Toyosaku KATO	Water Quality Analysis	Japan Techno Co., Ltd.
8. Mr. Nobuyuki ISHII	Facilities Design & Water Supply 1	Japan Techno Co., Ltd.
9. Mr. Minoru KIMISHIMA	Facilities Design & Water Supply 2	Japan Techno Co., Ltd.
10.Mr. Masahiko SUGINAGA	Social Survey	Japan Techno Co., Ltd.
11.Mr. Jun YOSHIKAWA	Facilities Design & Water Supply 3	Japan Techno Co., Ltd.
12.Mr. Hideaki MATSUOKA	Coordinator	Japan Techno Co., Ltd.
JICA Advisory Committee		
Dr. Yuji MARUO	JICA Headquarter, Development Specialist,	

Table-1.3 The Study on Groundwater Development for Water Supply Systems in Papua New Guinea

Work Schedule



CHAPTER 2 BASIC CONSIDERATIONS ON GROUNDWATER DEVELOPMENT FOR WATER SUPPLY SYSTEMS

1. Considering groundwater development, the geophysical investigations were carried out to determine the drilling points and target depths. The selection for drilling points were decided based upon the considerations for the priority of groundwater potentials and water supply area.

2. The targeting areas were decided based on the cooperative works of geophysicists and hydrogeologists thorough discussions on their survey results and interpretation. The good groundwater potential areas are not always the best drilling points due to consideration of the distance to the water supply area and the ownership of land.

3. The groundwater development study was carried out to evaluate the groundwater potential based on the results of test boreholes drilled in Phase I in 2000. Considering the results of groundwater discharge and existing water supply conditions, Pilot Project, Phase II was implemented in 2001 to save time and costs for the Project. However, the maximum discharge of successful boreholes was 350 m^3/day due to the limited diameter of test borehole of 6 inch and the available capacity of submersible motor pump. Therefore, this type of pilot study was useful for District Town water supply rather than Provincial Town water supply due to the suitable supply population of several to five thousand persons to be covered by one test borehole. Production boreholes for Provincial Town water supply shall be recommended with diameter of 10 inch.

4. Considering groundwater development, we need experts consisting of geophysicists, hydrogeologists and drilling supervisors together with experienced drilling contractors. Through our groundwater study we found difficulties to complete production boreholes of 10-inch diameter with 100m well depths due to low technology and their old drilling rigs.

5. All future groundwater projects in PNG should involve groundwater specialists and capable drilling rigs such as combination types of mud circulation and Down-the-Hole air hammer (DTH). Also, it is necessary for close cooperation between PNGWB and Geological Survey of PNG, and exchanging of viewpoints on water supply to increase their low level of national water supply coverage of about 30% in PNG.

6. This drilling programme was regarded as an investigation/test drilling programme and those six (6) Study Areas out of eight (8) Study Areas were successful. Then, three (3) Study Areas of the

successful boreholes in Bereina, Kwikila and Mutzing were utilized as production boreholes for the Pilot Project.

7. The transfer of technology for groundwater development to the counterparts from PNGWB was carried out considering the operation and management for geophysical prospecting and water well drilling at the sites with emphasis on sustainable groundwater supply as the water source for water supply system.

8. In this study, rehabilitation, construction and extension of the water supply systems at six (6) District Towns were considered. The revenue from this kind of small-scale water supply system serving populations from two (2) to ten (10) thousands is not enough to cover the operation cost, and the financial evaluation tends to be severe. All six (6) District Towns gave negative financial balances in 15 years to the target year of 2015. However, if the Provincial Government's subsidy is provided to PNGWB in the amount which is equivalent to the amount of their budget being spent for current water supply systems, the deficit from the operation will be compensated to PNGWB, and PNGWB will be able to sustain operation of water supply services in these District Towns. The most serious problem is the fact that water supply service in more District Towns means heavier financial burden for PNGWB. Therefore, the extension of water supply services in District Towns has to be at a slow pace. If a system to flexibly allocate the development fund for capital investment from the budget of the Central Government is established, the situation would change. However, currently the Central Government faces a severe financial condition and it seems difficult to expect such change immediately.

9. Economic evaluation confirms that the economic benefit will exceed the cost if the water supply system is run properly. Moreover, it is assumed that improvement of water supply services will bring larger positive effects socially than the economic one. It is expected to contribute to development activities in the area and favourable economic effect caused by this development would spread further.

10. The actual construction works for Pilot Project was planned from February 2001 to July 2001. Although the works were done in accordance with the planned schedule the following problems seriously affected the construction works for water supply systems. Therefore, when we prepare the construction schedule we should carefully consider the factors and implementing periods.
    1) The delay of customs clearance and legal processes for tax exemption
    2) Deteriorated conditions of the access roads due to heavy rains

3) The delay of transportation of the materials and the equipment by sea due to bad weathers

4) The air flights not on schedule

5) The delay of electricity works by ELCOM

6) The land issues, especially changed opinions and attitudes by the villagers, and so forth.

11. Another factor affecting the schedule was the land issues, which are common in PNG. Although the routes for pipelines and the locations of public faucets and other water facilities were explained to the local residents and the agreements were made in advance, different opinions and attitudes came out from the residents after commencement of the construction works in many areas. As a result of which, the construction works were inevitably interrupted in order to have agreements again. Many of the land issues in this country have complicated historical backgrounds with conflicts between the Government and the landowners. Therefore, there are cases that the problems emerge after the commencement of the construction works. The following should be done to avoid the problems above.

1) To avoid nation wide scattering of project sites, and to consider the access to the sites for execution and management of the project and the transportation of material and equipments to the selected sites,

2) To avoid rainy seasons for the construction works and allow enough time in the inplementation schedule,

3) To pay high attentions to the access roads, and ask appropriate agencies immediately in case there are some negative factors,

4) To keep several options to prepare for unpredictable incidents and be flexible for the change of the schedule.

CHAPTER 3 NATURAL ENVIRONMENT

3.1 Climates and Hydrology

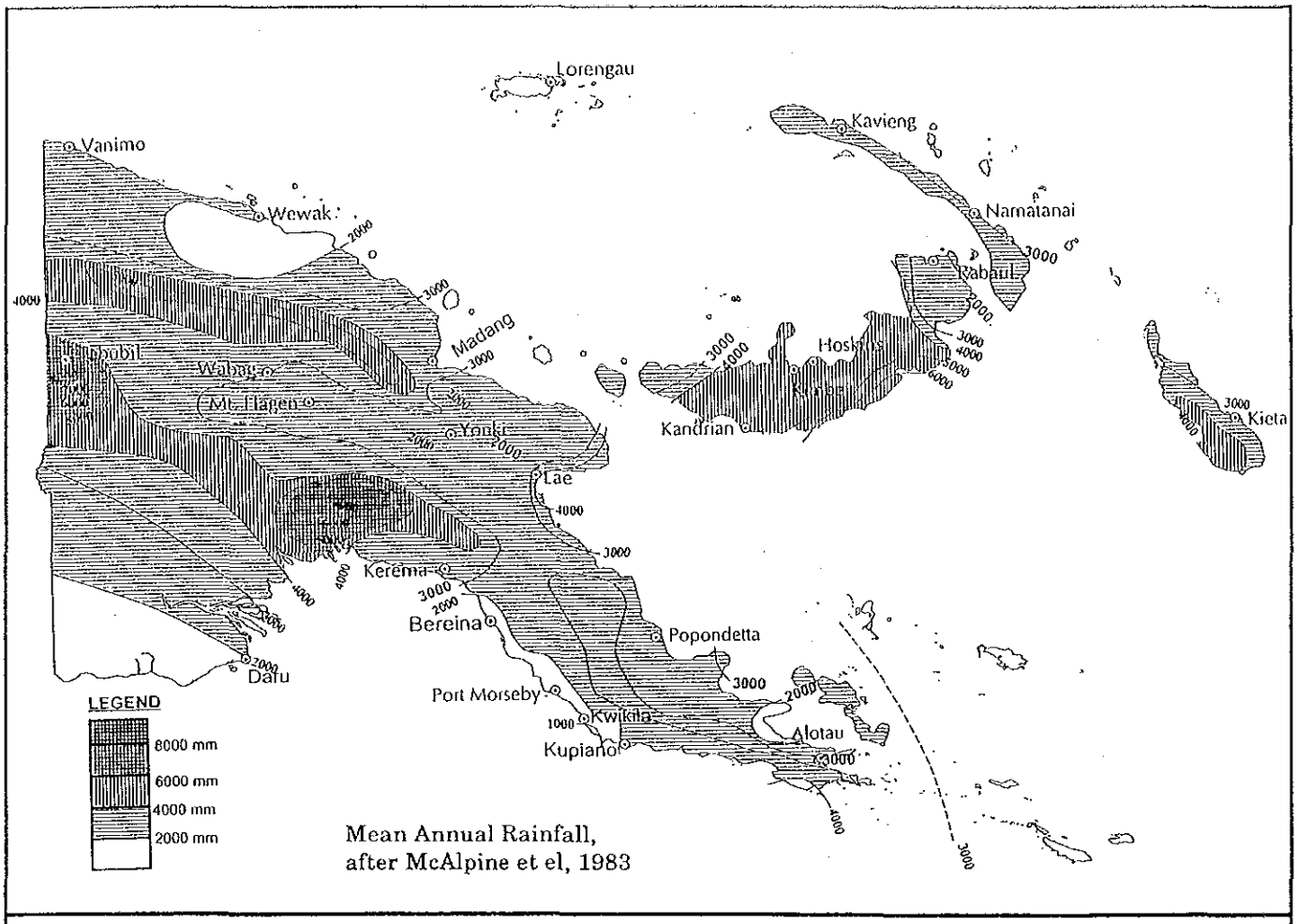
PNG is one of the wettest countries in world with a mean annual rainfall of 2,000 to 6,000 mm and significant areas have mean annual rainfall above 6,000 mm as shown in the study map of Fig.-3.1 (1) by McAlpine et al, 1982. The eight Study areas of the country experiences relatively high annual rainfall of 2,500 to 3,500 mm, with the maximum rainfall occurring during January to April (rainy season) and with a minimum during May to August (dry season). Mean monthly rainfall lies between 250 to 300mm in January, falling to around 100 to 150 mm in July.

A major drought and associated frost in the high altitudes affected much of PNG in 1997 and 1998. It was prolonged and widespread like the major droughts in 1914 and 1941, and probably more severe than those of 1956, 1964/1965, 1972 and 1987 droughts in the last century. In some locations the drought commenced in March 1997, with much of PNG affected by drought in May 1997.

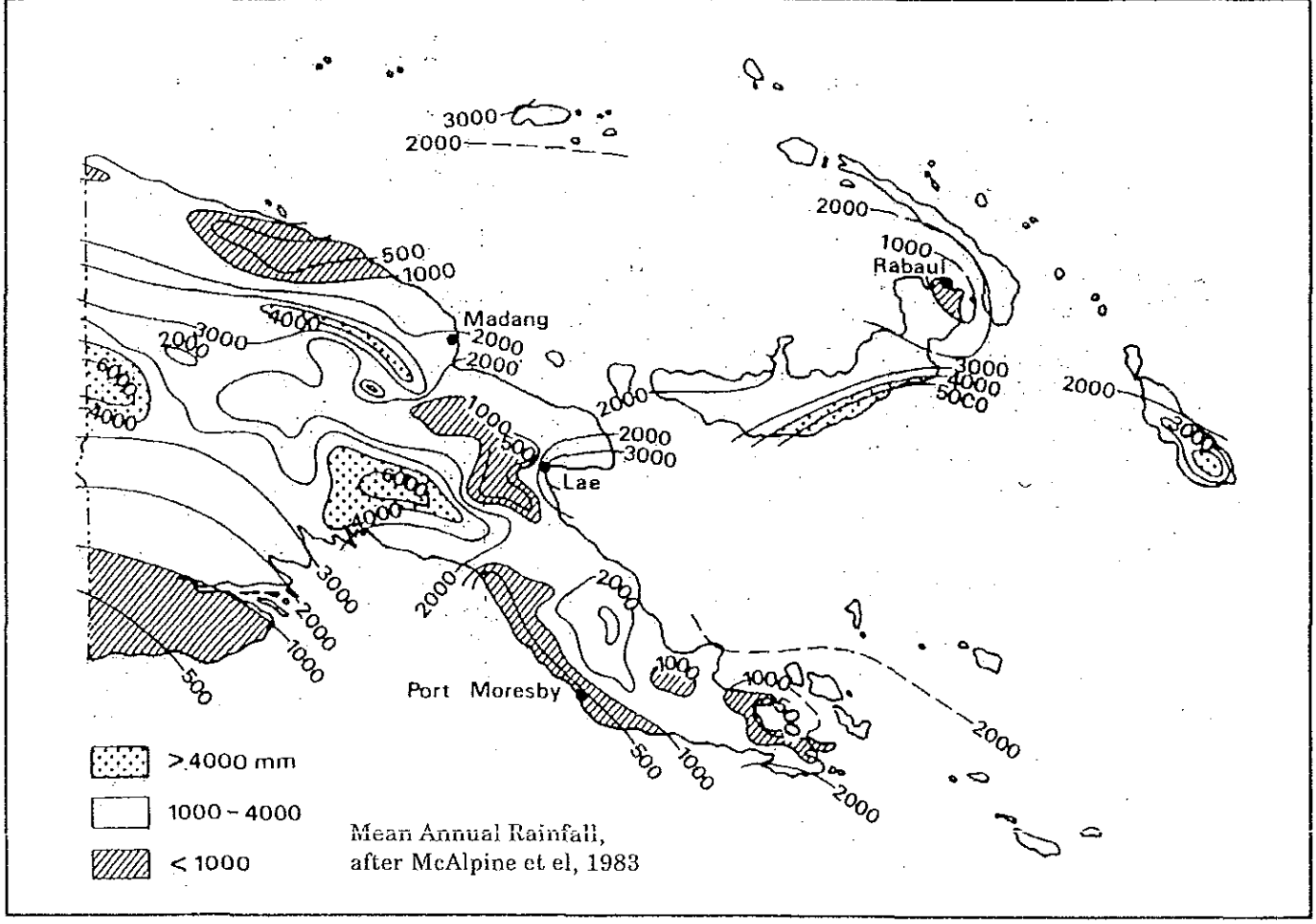
The drought had a major impact on many institutions because of water supply problems. A number of High Schools and Health Centres were similarly threatened. Many primary and community schools were closed because children along with their parents were scattered looking for food and drinking water.

3.2 Geomorphology, Geology and Hydrogeology

The geomorphologic history of PNG is linked with geological history that is dominated by young tectonic process, which has been responsible for their present day framework of landforms. The shape of the present landmass became apparent only by Pliocene. During much of Miocene the highlands were still covered by shallow seas and fluvial depositional plains. In the New Guinea mobile belt, active island arc volcanism accompanied the tectonic and igneous activity since the middle Miocene. During Plio-Pleistocene this land surface was uplifted. A number of drainage systems were interrupted by the volcanic activity leading to intramontanne basins. In the mountain forelands the rivers draining the mountains accumulated extensive alluvial deposits. Extensive fans were formed due to greater tectonic activity. Rivers with considerable steeper gradients such as Markham experienced increase of gradients. Groundwater contains these young sediments.



Mean Annual Rainfall,
after McAlpine et el, 1983



Mean Annual Rainfall,
after McAlpine et el, 1983

Fig.-3.1 Mean Annual Rainfall and Runoff of PNG

3.3 Existing Water Sources in the Study Area

The situation of the water usage in the eight Study areas was investigated. It was found that tap water is currently supplied at 4 study areas: Popondetta, Daru, Finschhafen and Mutzing. Among these areas, the systems are managed by PNGWB in Popondetta and Daru, while these systems are managed by the Local Government in the other two. In Bereina, Kupiano, Kwikila, the existing systems are not working. There is no existing water supply system in Oro Bay. The investigation revealed that there are six types of water sources for drinking and other domestic uses namely rainwater, river water, shallow wells, boreholes, spring and piped water. Since the country has relatively high annual precipitation of more than 2,000 mm, households and public facilities generally use rain water collected by water tanks. However, rain water can be used only seven months in a year, and therefore, they need safe drinking water in the dry season.

3.3.1 Hydrologic Measurement

1) General

Four Study areas from where water is being pumped and one spring source that could possibly augment the present supply were visited. Hydrologic measurements were carried out at the following five areas in the Study area during the period May-June, 2000:

i) Daru water supply, Binaturi River Intake
ii) Kupiano water supply, Lako River Intake
iii) Popondetta, Bangoho River Intake
iv) Finschhafen, Buta Creek and Buta Weing Creek,
v) Iapora Spring/Stream Flow outside Kupiano Town.

2) Methodology:

Binaturi River intake for Daru water supply and Lako river intake for Kupinao were approached travelling upstream of Binaturi and Lako Rivers by boats fitted with out-board motors. Stream flow measurements were made using San-Ei Current Meter manufactured by San-Ei Sokuryoki Co.Ltd, Japan. This is a Price's Current Meter – vertical axis type. The rating equation of this particular instrument is $v = 0.161\ N + 0.004$. Measurements were made across rivers and streams at suitable locations, moving by boat or by wading. The mean velocity flow was determined by making velocity measurements across the stream at suitable intervals ranging between 0.5 m to 5 m horizontally depending on the width of the river or stream. Vertical measurements were made

every 50 cms starting from the bottom of the river or stream. Computations were carried out using 'Two Points Method' applying the following formula: Vm = (v 0.2 + v 0.8).

3) Hydrological Observations

i) Daru Water Supply, Binaturi River Intake

Binaturi River flows in the Western Province, along the southern coast of the South Fly District, West-Northwest of Daru Island. The Binaturi catchment area spreads for 842 sq. km. There is a pumping station at U'Ume on Binaturi River, approximately 15km West North West of Daru, which supplies Daru with water. It was reported that approximately 1,250 m^3 of river water is pumped for the use of Daru town every day. Stream flow measurements were carried out near the intake point. Here the river is 35 m wide and 5 m deep at the deepest point. The flow was worked out as 37.8 m^3/sec (136,080 m^3/h = 3,266,920 m^3/d). Therefore, about 0.04% of the river discharge was pumped to Daru in June 2000. This was during the rainy season and so it is felt that there is more detailed study to be taken during dry season. Earlier study by Unisearch, team of University of Papua New Guinea, conducted in 24th January 1994 measured 30 m downstream and 500m upstream of the river intake using flotation method. Cross sectional volume 500 upstream was worked out as 17.5 m^3/sec (63,000 m^3/h), while cross sectional volume 30m down-stream was worked out as 12.5 m^3/sec (45,000 m^3/h). Therefore, about 0.08% of river discharge was pumped to Daru in January 1994.

ii) Lako River Intake, Kupiano Water Supply

Kupiano is supplied by an intake at Lako River about 2.5 km north of the Town, located about 1.5 km upstream from the confluence of the river. Lako River drains into Marshall Lagoon, which is tidal. The river is 50 m wide and at the deepest point was 75 cm deep. This depth varies when the tide rises and the current tide moves in. The cross sectional area of the flow during the time of measurement was 28.03 m^2 and the river was flowing with a velocity of 2.08 m/sec. The stream flow was noted to be 58.3 m^3/s (209,880 m^3/h). This figure is felt to be slightly higher due to the seasonal increase after a rainy spell. As such this may not be quite representative of the average flow of the river. However stream flow measurements were carried out. But the need to measure during the dry season is being emphasised.

iii) Popondetta, Banguho Creek Intake:

Banguho Creek takes rise in Mt. Lamington and is a 20 km long creek, draining about 60 km^2 of the slopes of the mountain and forms a tributary of Girua River. Representative stream measurements were done closer to PNGWB Intake point near Popondetta Town. The discharge was noted to be 1.6 m^3/sec (5,760 m^3/h). It was reported that approximately 1,700

m^3 of river water is pumped for the use of Popondetta Town every day. Therefore, about 1.2 % of the river discharge was pumped to Popondetta Water Supply in May 2000.

iv) Finschhafen, Buta Creek:

Buta Creek is the water source of the existing Finschafen Town water supply. The flow of the stream during the time (23rd May 2000) of inspection was noticed to be 16.5 l/sec (59.4 m^3/h). Approximately 150 m^3 of river water is pumped for the use of Finschhafen Town every day. Therefore, about 10.5 % of the river discharge was pumped to Finschhafen Water Supply in May 2000. However when the stream was visited in late June 2000 the flow was noticed to be over double the flow.

v) Iopora Spring/Stream Flow Outside Kupiano Town.

Iopora is a stream originating from a spring in Olupara hillock located about 2 km northeast of the existing treatment plant that is not working now. The stream is reported to be perennial. The stream flow was measured to be 1.25 l/sec (4.5 m^3/h). The possibility of utilising this stream, by probably capping the spring source to augment the water supply, needs to be studied in the future due to the reduction of discharge in dry season

3.4 Existing Water Sources and Water Quality Analyses

In this Study, the existing water sources and the groundwater potentials were investigated, and the possibility of the development was considered. Regarding the water quality analysis of the water sources and the pollution caused by human activities, 2 to 6 sampling points were selected in each site covering the above mentioned water sources except for rainwater. The water samples were analysed by National Agricultural Research Institute (NARI) in Port Moresby from the viewpoints of the PNG water standard and characteristics.

Table-3.1 Stream Flow Measurement

Binaturi River Intake (measured on 6 June 2000)

Distance from one end of water surface (m)	1.0	6.0	11.0	16.0	21.0	26.0	31.0	35.0
Depth (m)	2.30	3.00	4.00	4.80	5.85	4.70	1.60	1.50
Average velocity (m/s)	0.032	0.165	0.290	0.395	0.344	0.362	0.159	0.032
Discharge in the strip (m3/s)	0.074	2.468	5.800	9.468	10.062	8.507	1.272	0.192
Total Flow (m3/s)	**37.8**							

KUPIANO

Lako R. Intake (measured on 27 June 2000)

Distance from one end of water surface (m)	1.0	5.0	10.0	20.0	30.0	40.0	49.0
Depth (m)	0.26	0.30	0.76	0.53	0.51	0.76	0.53
Average velocity (m/s)	0.232	1.555	1.677	2.3335	2.2125	2.494	1.542
Discharge in the strip (m3/s)	0.060	1.866	6.373	12.368	11.284	18.954	7.355
Total Flow (m3/s)	**58.3**						

POPONDETTA

Banguho R. Intake (measured on 20 May 2000)

Distance from one end of water surface (m)	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Depth (m)	0.21	0.27	0.35	0.42	0.56	0.61	0.71	0.60
Average velocity (m/s)	0.519	0.799	0.815	0.785	1.002	0.9275	0.674	0.356
Discharge in the strip (m3/s)	0.163	0.108	0.143	0.165	0.281	0.283	0.239	0.107

Distance from one end of water surface (m)	5.5	6.0	6.5	7.0
Depth (m)	0.36	0.24	0.30	0.20
Average velocity (m/s)	0.318	0.2555	0.169	0.41
Discharge in the strip (m3/s)	0.057	0.031	0.025	0.041
Total Flow (m3/s)	**1.6**			

FINSCHHAFEN

Buta Creek (measured on 23 May 2000)

The stream flow was measured to be **16.5 L/s (0.0165 m3/s).**

1) Water Quality Analysis in NARI

The analyses of the parameters relating to the PNG water standard is shown in Table-3.2 (1), and Table3.2 (2) shows that for parameters relating to the water characteristics. The PNG water standards are the same as those recommended by the WHO guidelines. The items for water standards include general items, elements, compounds, bacteria groups and residual chlorine as shown in Table-3.2 (1). In 23 sites out of a total 35 sites (66%), water from the sources is used for drinking. Turbidity, odour and taste satisfy the standard in all of the sites. For colour, the sample from Oro Bay (8c) does not meet the standard. Concerning pH, the value at the water treatment plant in Daru (2b) is relatively low (pH:5.4) due to the influence of aluminium sulphate used as coagulant. This might cause corrosion in the distribution pipes, and thus, the pH value needs to be strictly controlled.

As far as the 19 elements which are described in the PNG water standards are concerned, in all of the samples, the water standards are satisfied except for iron. The concentrations of iron do not meet the standard value (0.3 mg/L) in two sites: Daru (2c), 0.8 mg/L; and Kwikila (5d), 0.4 mg/L. For other compounds, the value of total acidity, total alkalinity, total hardness, total dissolved solids (TDS), and Langelier's index (LI) meet the standards. In Popondetta and Daru, the tap water is chlorinated, and the waters in these two towns satisfy the standards in terms of total coliform groups. No total coliform group was detected from the sample from the borehole in Kwikila (5c). On the other hand, it was found that the samples from the other 20 sites (87%) were contaminated by total coliforms, although the people are using this source for drinking water. These contaminated water sources include 3 high schools and 2 hospitals. According to the standard, the maximum value of residual chlorine is 5 mg/L, and the desirable minimum value is 0.1 mg/L. Treated tap waters in Popondetta and Daru have 1.0 mg/L and 0.2 mg/L of residual chlorine respectively.

The results of characteristics of water in the study areas are also shown in tri-linear diagrams and hexa-diagrams as shown in Figure-3.2 and Figura-3.3.

Table-3.2(1) Analysis of Existing Water Sources from Eight Sites in the Study Area (parameters relating to the PNG water standard)

Study Area	Location	Source	Date of year 2000	Weather	Atm. Temp.	General Quality						Elements																						Compounds & Others						Bacteria		Residual Cl
						Temp.	pH	EC	Turb.	Color	Odour	Cd	Hg	Se	Pb	As	Cr	F	Ba	Zn	Fe	Cu	Na	Mn	Cl	Ni	Sb	B	Mo	Al	CN	NO2-N	NO3-N	SO4	TOC	TDS	Total	SPC	Cl
					℃	℃		mS/m			Taste	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	Colony		mg/l
1.Popondetta	a. Agri.College	Borehole	24.May	Fine	29.0	28.0	7.2	25.9	0	5	Nil	ND	ND	ND	ND	ND	ND	0.70	ND	ND	0.2	ND	7.5	0.38	10	ND	ND	0.1	0.01	0.1	ND	ND	0.6	54.9	1	160	13	77	
	b. Vikaze	Spring	25.May	Rain	26.5	25.8	6.3	14.8	0	2	Nil	ND	ND	ND	ND	0.002	ND	0.64	ND	ND	0.1	ND	7.2	0.09	9	ND	ND	ND	0.01	ND	ND	ND	0.5	8.5	1	118	59	200>	
	c. W. B. Intake	River	25.May	Cloudy	25.8	27.3	7.8	24.2	1	6	Algae	ND	ND	ND	ND	0.005	ND	0.59	ND	ND	0.1	ND	13.6	0.02	12	ND	ND	0.1	0.01	0.1	ND	ND	0.9	80.7	1	152	200>	200>	
	d. Town	Tap	25.May	Cloudy	24.7	26.8	7.5	24.1	0	5	Chlorine	ND	ND	ND	ND	0.006	ND	0.56	ND	ND	ND	ND	13.6	0.01	13	ND	ND	0.1	0.01	0.2	ND	ND	0.6	82.2	1	154	0	1	1
2.Daru	a. Ufune Intake	River	5.June	Rain	26.6	25.0	6.3	5.1	0.5	75	Nil	ND	ND	ND	ND	0.003	ND	0.14	ND	ND	0.5	ND	2.4	0.01	11	ND	ND	ND	0.01	0.2	ND	ND	0.5	3.9	3	160	51	73	
	b. Treatment Plant	Tap	5.June	Cloudy	27.3	26.6	5.4	9.1	0.5	5	Nil	ND	ND	ND	ND	0.002	ND	0.05	ND	0.3	0.1	ND	7.0	0.01	11	ND	ND	ND	ND	ND	ND	ND	1.2	51.3	1	34	0	6	0.2
	c. Town A	S. Well	5.June	Rain	27.3	27.9	7.2	92.9	0	0	Nil	ND	ND	ND	ND	0.002	0.002	0.56	ND	0.1	ND	ND	20.0	ND	100	ND	ND	ND	ND	ND	ND	ND	0.6	555	3	524	30	200>	
	d. Town B	S. Well	7.June	Cloudy	27.1	26.4	7.0	14.0	30	100	Soil	ND	ND	ND	ND	ND	ND	0.21	ND	0.2	ND	ND	5.5	0.49	11	0.01	0.002	ND	0.01	0.2	ND	ND	0.4	2.2	1	72	21	200>	
	e. Town C	S. Well	7.June	Cloudy	27.3	27.2	6.3	21.1	0.5	0	Sulfide	ND	ND	ND	ND	0.003	ND	0.25	ND	ND	0.8	ND	20.0	0.04	50	0.01	ND	ND	0.03	ND	ND	ND	0.5	19.1	1	98	200>	200>	
	f. Town D	S. Well	7.June	Cloudy	28.4	26.9	7.2	184.3	15	20	Scented	ND	ND	ND	0.002	0.005	0.005	0.49	0.1	ND	0.3	ND	157.0	0.15	350	ND	ND	ND	0.02	0.1	ND	ND	0.6	163.6	1	1030	200>	200>	
3.Bereina	b. Training C.	Borehole	23.June	Clear	28.3	26.7	7.8	53.2	0	0	Nil	ND	ND	ND	ND	0.006	ND	0.43	ND	ND	ND	ND	95.1	0.03	110	ND	ND	0.1	0.01	ND	ND	ND	0.6	4.0	1	39	6	62	
	c. P.S #1	S. Well	23.June	Clear	27.2	27.7	7.6	175.0	5	6	Nil	ND	ND	ND	ND	ND	ND	0.43	ND	ND	ND	ND	172.0	0.08	341	ND	ND	0.1	0.01	ND	ND	ND	0.7	52.3	1	1022	47	113	
	d. Manikihana Intake	River	23.June	Fine	29.0	24.7	8.0	12.4	150>	100>	Nil	ND	ND	ND	0.003	ND	0.019	0.23	ND	0.1	0.2	ND	4.0	0.08	9	0.02	ND	0.1	0.02	0.1	ND	ND	0.6	4.9	1	104	200>	200>	
	e. High School	Borehole	23.June	Fine	29.3	27.4	8.2	117.1	0	2	Nil	ND	ND	ND	ND	0.003	ND	0.77	ND	ND	0.1	ND	206.0	0.05	18	ND	ND	0.2	0.02	ND	ND	ND	0.5	8.8	1	725	8	7	
	f. Angabang	River	23.June	Clear	29.0	24.8	7.9	12.6	150>	100>	Nil	ND	ND	ND	0.008	0.004	0.023	0.33	0.1	0.1	1.4	ND	4.2	0.03	8	0.02	0.002	0.1	0.01	0.1	ND	ND	0.4	5.1	1	116	200>	200>	
4.Kupiano	a. Lake R. intake	River	27.June	Fine	27.7	28.3	7.7	16.4	2	0	Nil	ND	ND	ND	ND	0.003	ND	0.28	ND	ND	0.3	ND	4.2	0.02	11	ND	ND	ND	ND	0.2	ND	ND	0.6	4.6	1	13	32	81	
	c. Iocoa	Spring	27.June	Fine	27.0	27.5	8.0	6.5	0	0	Nil	ND	ND	ND	ND	ND	ND	0.19	ND	ND	0.2	ND	21.4	0.02	4	ND	ND	0.1	ND	ND	ND	ND	0.6	17.6	1	32	4	5	
5.Kwikila	a. High School	Borehole	18.May	Fine	30.5	27.9	7.3	73.6	0	0	Nil	ND	ND	ND	ND	ND	ND	0.66	ND	ND	0.1	ND	47.6	0.02	54	ND	ND	ND	0.01	ND	ND	ND	1.0	3.1	1	404	200>	99	
	b. Hospital	Borehole	18.May	Fine	29.5	27.2	7.3	84.3	0	0	Nil	ND	ND	ND	ND	ND	ND	0.70	0.1	0.1	0.2	ND	46.4	ND	46	0.01	ND	ND	ND	ND	ND	ND	1.2	9.1	1	444	11	70	
	c.SalvationAmy A.	Borehole	18.May	Fine	30.0	28.7	6.9	79.7	0	2	Nil	ND	ND	ND	ND	ND	ND	0.49	ND	ND	0.1	ND	51.2	ND	50	ND	ND	ND	0.01	ND	ND	ND	0.8	4.0	1	478	0	0	
	d.SalvationArmy B	Borehole	18.May	Fine	30.0	28.6	7.0	86.7	0	0	Nil	ND	ND	ND	ND	ND	ND	0.47	ND	0.2	0.4	ND	54.1	0.01	50	ND	ND	ND	0.01	ND	ND	ND	1.8	7.9	1	490	72	0	
	e. Kemp Welch R.	River	19.May	Fine	29.6	24.5	7.6	13.4	20	50	Nil	ND	ND	ND	ND	ND	ND	0.30	0.1	ND	0.2	ND	4.2	ND	35	ND	ND	ND	0.01	0.2	ND	ND	1.1	3.2	1	28	200>	200>	
6.Finschhafen	a. Intake	River	30.May	Fine	27.1	25.1	8.0	40.1	0	0	Nil	ND	ND	0.003	ND	ND	ND	0.71	ND	ND	ND	ND	5.7	ND	10	ND	ND	ND	ND	ND	ND	ND	0.7	9.5	1	250	92	58	
	b. Hospital	River	30.May	Cloudy	28.8	25.1	8.2	31.3	0.5	0	Nil	ND	ND	ND	ND	ND	ND	0.80	0.2	ND	ND	ND	1.8	ND	9	ND	ND	ND	0.01	ND	ND	ND	0.6	3.6	1	194	82	103	
	c. Vilaye Intake	River	30.May	Cloudy	28.3	25.7	8.2	29.5	3	4	Nil	ND	ND	0.004	ND	ND	ND	0.55	ND	ND	0.1	ND	1.1	0.02	6	ND	ND	ND	0.01	ND	ND	ND	0.5	2.1	1	192	112	84	
	d. Seminary	Spring	30.May	Cloudy	28.0	25.7	7.8	29.9	0	0	Nil	ND	ND	0.006	ND	ND	ND	0.41	ND	ND	ND	ND	1.0	ND	11	ND	ND	ND	ND	ND	ND	ND	1.5	2.4	1	186	200>	200>	
	e. Town	Tap	30.May	Clear	31.0	26.3	8.1	38.1	0	0	Nil	ND	ND	ND	ND	0.003	ND	0.43	ND	ND	ND	ND	5.6	0.01	7	ND	ND	ND	0.01	ND	ND	ND	0.5	9.3	1	248	200>	200>	
7.Mutzing	a. Marujing R.	River	28.May	Fine	31.2	32.3	8.5	28.8	150>	100>	Soil	ND	ND	ND	ND	ND	ND	0.41	0.1	0.1	0.1	0.1	40.8	0.02	10	ND	ND	0.2	ND	ND	ND	ND	0.5	10.2	1	158	200>	200>	
	b. Supply Source-2	Borehole	28.May	Fine	31.2	27.6	7.3	53.4	0	0	Nil	ND	ND	ND	ND	0.003	ND	0.55	ND	ND	ND	ND	35.9	ND	9	ND	ND	0.2	0.01	ND	ND	ND	0.5	18.2	4	326	109	200>	
	c. Village	S. Well	28.May	Clear	31.2	27.9	7.3	52.7	0	1	Soil	ND	ND	0.002	ND	0.002	ND	0.82	ND	ND	0.1	ND	35.3	0.03	15	ND	ND	0.1	ND	ND	ND	ND	0.6	18.9	2	310	19	71	
	d. High School	Borehole	28.May	Clear	32.3	28.0	7.6	45.2	0	0	Nil	ND	ND	ND	ND	ND	ND	0.60	ND	ND	ND	ND	29.3	ND	7	ND	ND	0.1	ND	ND	ND	ND	0.6	14.5	1	344	36	200>	
8.Oro Bay	a. Kaiei R.	River	25.May	Fine	32.9	26.3	7.4	5.4	5	20	Nil	ND	ND	ND	ND	0.002	ND	0.24	ND	ND	0.3	ND	3.6	0.01	10	ND	ND	ND	0.01	0.1	ND	ND	0.7	0.3	4	46	173	74	
	b. Beana R.	River	25.May	Fine	34.0	28.6	7.9	8.0	1	6	Nil	ND	ND	ND	ND	0.002	ND	0.22	ND	0.1	0.1	ND	5.3	0.01	8	ND	ND	ND	ND	0.2	ND	ND	0.6	0.2	4	60	200>	200>	
	c. Hospital	River	25.May	Fine	29.0	26.8	7.2	6.0	1	20	Nil	ND	ND	ND	ND	0.002	ND	0.17	ND	ND	0.3	ND	4.2	0.02	9	ND	ND	ND	ND	0.1	ND	ND	0.8	0.3	1	36	146	200>	
	d. Fishery	S. Well	25.May	Fine	29.5	26.5	7.5	75.3	5	20	Nil	ND	ND	ND	ND	ND	ND	0.56	ND	ND	0.9	ND	35.3	0.11	80	ND	ND	0.1	ND	ND	ND	ND	0.7	3.6	1	425	23	37	
Analysis Limit												0.001	0.001	0.001	0.001	0.001	0.001	0.01	0.1	0.1	0.1	0.1	0.1	0.01	1	0.01	0.001	0.1	0.01	0.1	0.01	0.1	0.1	0.1	1	1	1	0.05
Drinking Water Standard																																								
PNG(WHO-1993)						-	-	-	5	15	Acceptable	0.003	0.001	0.01	0.01	0.01	0.05	1.5	0.7	3	0.3	2	200	0.5	250	0.02	0.005	0.3	0.07	0.2	0.07	3	50	250	-	1000	0	-	5
Japan						-	5.8~8.6	-	2	5	Acceptable	0.01	0.0005	0.01	0.05	0.01	0.05	0.8	-	1	0.3	1	200	0.05	200	0.01	0.002	0.2	0.07	0.2	0.01	10		-	*	500	0	100	1

NOTE : The above analyses is relevant to drinking water standard

Atm. Temp.: Atmospheric Temperature
W. Temp.: Water Temperature
SPC : Standard Plate Count
Turb.: Turbidity
ND : Not Detected
S. Well: Shallow Well
- : Not Mentioned
* : COD 10mg/L

Table-3.2(2) Analysis of Existing Water Sources from Eight Sites in the Study Area (parameters relating to water characteristics)

Study Area	Location	Source	Date of year 2000	Weather	Atm. Temp. ℃	General Quality				Parameters Represented Graphically								Hardness & Others					Non-metals	
						W.Temp ℃	pH	EC mS/m	Turb.	Na mg/l	K mg/l	Ca mg/l	Cl mg/l	Mg mg/l	HCO3 mg/l	CO3 mg/l	SO4 mg/l	T-Acid mg/l	T-Alka. mg/l	T-Hard mg/l	TDS mg/l	L I mg/l	NH4-N mg/l	T-P mg/l
1.Popondetta	a. Agr.College	Borehole	24,May	Fine	29.0	28.0	7.2	25.9	0	7.5	5.22	24.4	10	13.1	75.6	0.6	54.9	12.0	76	114	160	-0.81	ND	0.24
	b. Village	Spring	25,May	Rain	26.5	25.6	6.3	14.8	0	7.2	4.59	12.2	9	6.0	69.1	0.5	8.5	34.5	69	55	118	-2.09	0.2	0.22
	c. W. B. Intake	River	25,May	Cloudy	25.8	27.3	7.8	24.2	1	13.6	5.86	20.7	12	7.6	38.5	0.3	80.7	8.3	39	82	152	-0.58	ND	0.15
	d. Town	Tap	25,May	Cloudy	24.7	26.8	7.5	24.1	0	13.6	5.74	20.4	13	7.6	32.9	0.3	82.2	7.8	33	81	154	-0.97	ND	0.09
2.Daru	a. U'ume Intake	River	5,June	Rain	26.6	25.0	6.3	5.1	0.5	2.4	0.55	3.1	11	1.4	7.1	0.1	3.9	0.0	7	14	160	-3.69	ND	ND
	b. Treatment Plant	Tap	6,June	Cloudy	27.3	26.6	5.4	9.1	0.5	7.0	0.54	3.7	11	1.3	36.1	0.3	51.3	0.0	36	14	34	-3.77	ND	ND
	c. Town A	S. Well	6,June	Rain	27.3	27.9	7.2	82.9	0	20.0	0.88	95.4	100	33.6	123.0	1.0	55.5	0.5	124	371	524	-0.01	ND	0.03
	d. Town B	S. Well	7,June	Cloudy	27.1	26.4	7	14	50	5.5	0.20	6.7	11	4.8	29.9	0.2	2.2	0.1	30	36	72	-2.00	ND	ND
	e. Town C	S. Well	7,June	Cloudy	27.3	27.2	6.3	21.1	0.5	20.0	1.43	4.6	50	5.2	21.0	0.2	19.1	0.1	21	33	98	-3.01	ND	0.15
	f. Town D	S. Well	7,June	Cloudy	28.4	26.9	7.2	184.3	15	157.0	4.62	94.5	350	62.0	27.0	0.2	163.8	1.0	27	486	1030	-0.69	ND	0.04
3.Bereina	b. Training C.	Borehole	23,June	Clear	28.3	26.7	7.8	53.2	0	95.1	4.47	4.4	110	4.0	208.0	1.6	4.0	6.0	208	28	39	-0.54	ND	0.48
	c. P.S #1	S. Well	23,June	Clear	27.2	27.7	7.6	175.3	5	172.0	5.51	111.0	341	40.2	76.1	0.6	52.3	10.5	77	435	1020	0.25	ND	0.14
	d. Maniohana In.	River	23,June	Fine	29.3	24.7	8	12.4	150>	4.0	4.30	21.2	9	9.7	122.0	1.0	4.9	7.0	123	92	104	0.09	ND	0.32
	e. High School	Borehole	23,June	Fine	29.3	27.4	8.2	117.1	0	206.0	8.24	8.0	18	7.9	432.0	3.4	8.8	11.3	441	52	726	0.46	ND	0.45
	f. Angabang	River	23,June	Clear	28.0	24.8	7.9	12.6	150>	4.2	2.57	23.1	8	11.2	142.0	1.1	6.1	4.0	143	103	116	0.09	ND	0.40
4.Kupiano	a. Lake R. intake	River	27,June	Fine	27.7	28.3	7.7	16.4	2	4.2	0.33	18.5	1	7.0	89.7	0.8	4.6	4.9	90	75	13	-0.35	ND	0.02
	c. Iopora	Spring	27,June	Fine	27.0	27.5	8	6.5	0	21.4	0.59	92.3	4	18.4	369.9	0.1	17.6	11.5	371	306	32	1.25	ND	0.03
5.Kwikila	a. High School	Borehole	18,May	Fine	30.6	27.9	7.3	73.6	0	47.6	1.44	70.8	54	28.5	342.0	2.7	3.1	22.0	342	294	404	0.40	ND	ND
	b. Hospital	Borehole	18,May	Fine	29.5	27.2	7.3	84.3	0	46.4	0.94	98.5	46	33.1	427.0	3.3	9.1	22.0	428	382	444	0.63	0.7	ND
	c.SalvationArmy A	Borehole	18,May	Fine	30.0	28.7	6.9	79.7	0	51.2	0.78	87.2	50	26.9	398.0	3.1	4.0	43.0	399	329	478	0.17	0.7	ND
	d.SalvationArmy B	Borehole	18,May	Fine	30.0	28.6	7	86.7	0	54.1	0.84	97.2	50	29.8	323.0	2.5	7.9	37.5	323	252	490	0.23	ND	ND
	e. Kemp Welch R.	River	19,May	Fine	29.6	24.5	7.6	13.4	20	4.2	1.43	17.1	35	5.2	63.0	0.5	3.2	4.5	33	50	28	-0.56	ND	0.05
6.Finschhafen	a. Intake	River	30,May	Fine	27.1	25.1	8	40.1	0	5.7	6.13	71.9	10	5.9	189.0	1.5	9.5	6.8	190	201	250	0.81	ND	0.04
	b. Hospital	River	30,May	Cloudy	28.8	25.1	8.2	31.3	0.5	1.8	0.93	69.1	9	2.0	151.0	1.2	3.6	5.5	153	178	194	0.90	ND	ND
	c. Village Intake	River	30,May	Cloudy	28.3	25.7	8.2	29.5	3	1.1	0.30	67.1	6	1.4	149.0	1.2	2.1	5.0	151	170	182	0.89	ND	0.03
	d. Seminary	Spring	30,May	Cloudy	28.0	25.7	7.8	29.9	0	1.0	0.15	67.2	11	0.9	134.0	1.0	2.4	9.5	135	169	156	0.44	ND	0.03
	e. Town	Tap	30,May	Clear	31.0	26.3	8.1	38.1	0	5.6	6.06	71.0	7	5.5	187.0	1.5	9.3	7.0	190	197	248	0.93	ND	0.04
7.Mutzing	a. Manging R.	River	28,May	Fine	31.2	32.3	8.5	28.8	150>	40.8	2.12	81.2	10	27.5	560.0	4.4	10.2	5.3	571	315	158	1.95	ND	1.02
	b. Supply Source-2	Borehole	28,May	Fine	31.2	27.6	7.3	53.4	0	35.9	0.76	73.1	9	9.5	293.0	2.3	16.2	12.3	295	219	326	0.35	ND	ND
	c. Village	S. Well	28,May	Clear	31.2	27.9	7.3	52.7	0	35.3	0.51	72.7	15	8.4	281.0	2.2	18.9	19.5	282	214	310	0.33	ND	0.02
	d. High School	Borehole	28,May	Clear	32.3	28.0	7.6	45.2	0	29.3	0.64	62.4	7	6.9	244.0	1.9	14.5	10.5	246	181	344	0.51	ND	ND
8.Oro Bay	a. Kosisi R.	River	25,May	Fine	32.9	26.3	7.4	5.4	6	3.6	1.28	3.1	10	2.4	9.0	0.1	0.3	8.3	9	18	46	-2.46	ND	0.04
	b. Beana R.	River	25,May	Fine	34.0	28.6	7.9	8	1	5.3	1.39	4.5	8	3.8	29.0	0.2	0.2	5.8	29	27	60	-1.25	ND	0.05
	c. Hospital	River	25,May	Fine	29.0	26.8	7.2	6	1	4.2	1.73	3.6	9	2.5	16.0	0.1	0.3	7.8	16	19	38	-2.34	ND	0.04
	d. Fishery	S. Well	25,May	Fine	29.5	26.5	7.5	75.3	5	35.3	7.91	94.8	80	19.5	248.0	1.9	3.6	18.5	249	310	426	0.57	ND	0.07

Atm. Temp.: Atmospheric Temperature W. Temp.: Water Temperature Turb.: Turbidity S. Well: Shallow Well

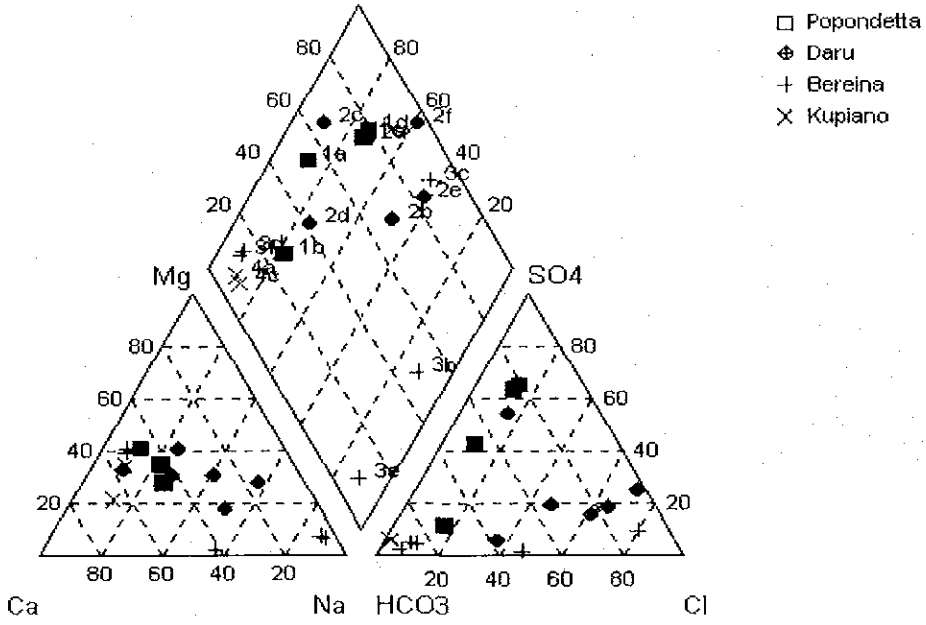


Fig.-3.2(1) Characteristics of water samples in 4 towns, Popondetta, Daru, Bereina and Kupiano

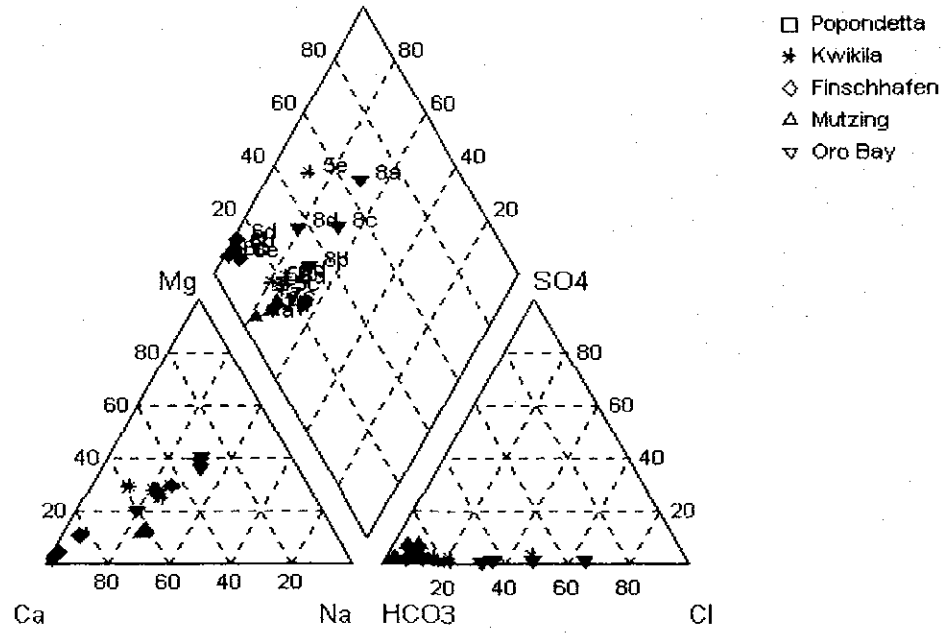


Fig.-3.2(2) Characteristics of water samples in 4 towns, Kwilila, Finschhafen, Mutzing and Oro Bay

Fig.-3.3(1) Hexadiagrams of Chemical Components of Water Samples Collected in Study Areas (Popondetta, Daru, Bereina and Kupiano)

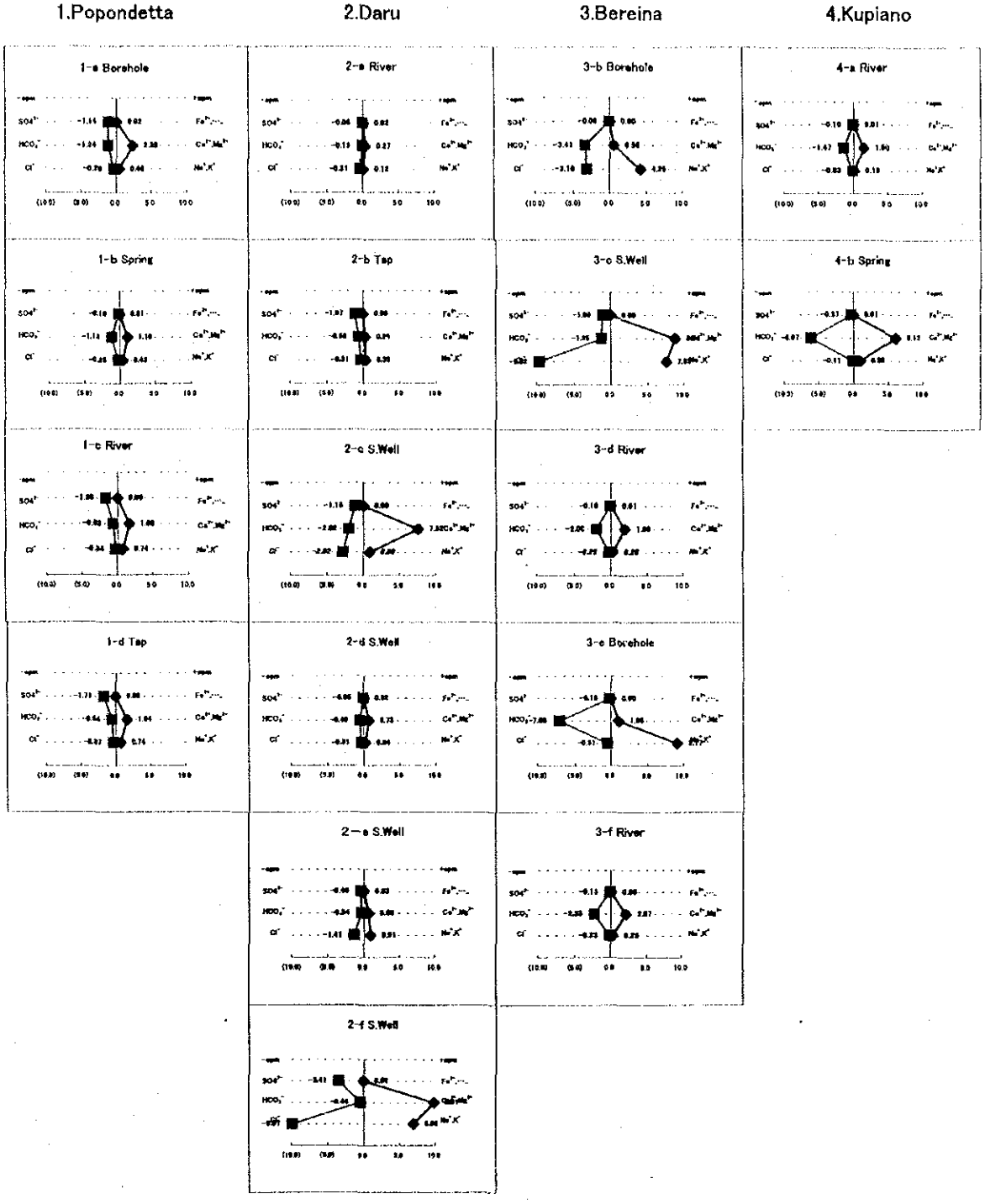


Fig.-3.3(2) Hexadiagrams of Chemical Components of Water Samples Collected in Study Areas
(Kwikila, Finschhafen, Mutzing and Oro Bay)