CHAPTER 5 PRESENT SITUATION OF STUDY AREA

5.1 Climate and Hydrology

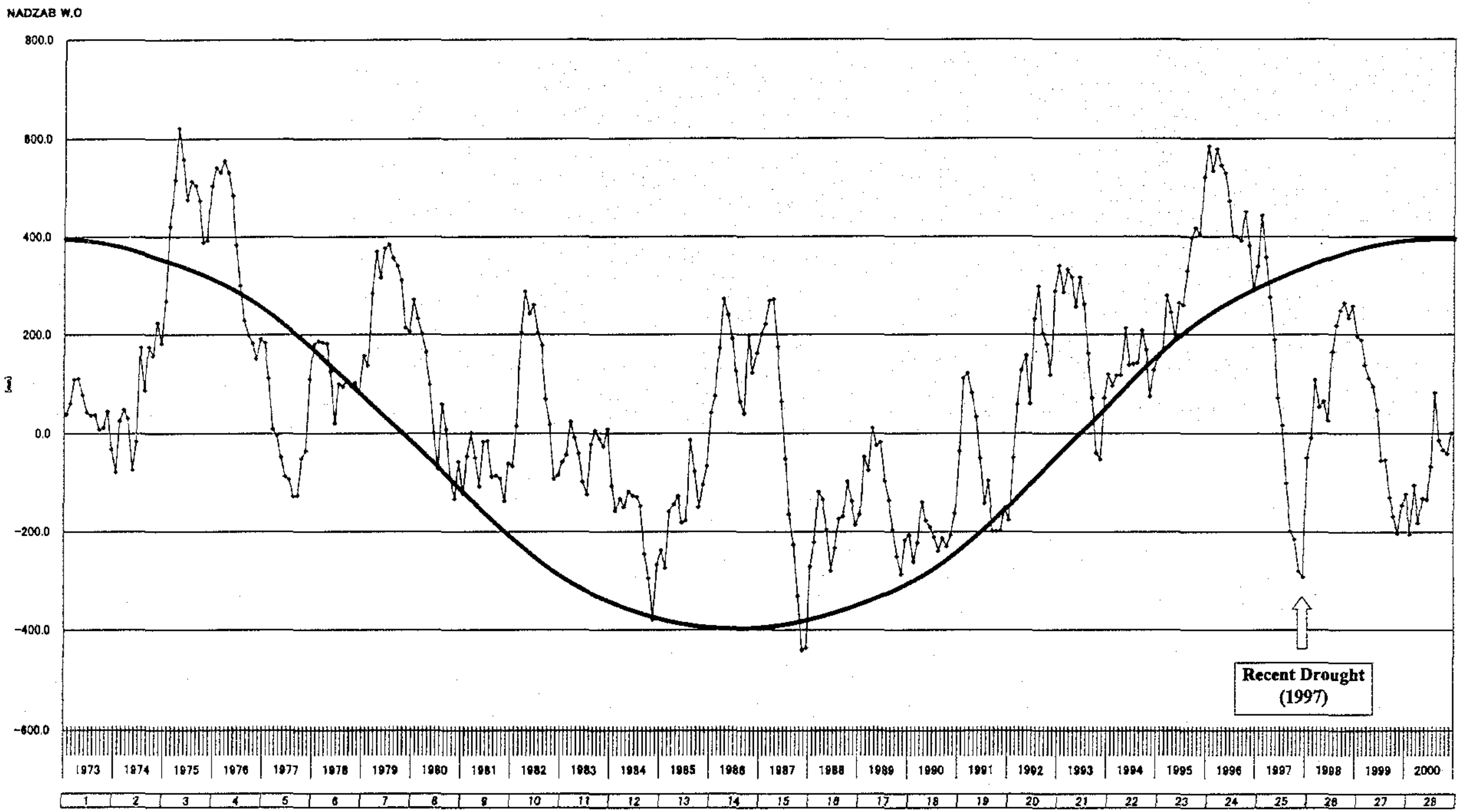
PNG is located in the tropical rainforest climate with a mean annual rainfall of 2,000mm to 3,500mm for the Study Area. There are two seasons of rainy and dry in a year. It was reported that the major drought was faced in 1997- 1978 which was probably more severe than those of 1973-74, 1977, 1980-81, 1984, 1987, 1991, 1993 droughts brought by the El Niño in the last century. Generally, the El Niño occurs in a 5 to 7 years cycle. The monthly rainfall data was collected from Nadzab station in Lae and the rainfall pattern for the recent 28 years from 1973 to 2000 was analysed. It clearly shows the drought in 1997 as seen in Fig.-5.1 and the drought continues to contribute to the shortage of rainfall till 2001.

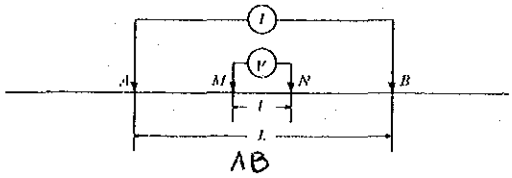
5.2 Geophysical and Hydrogeological Survey

As a part of the Study for groundwater potential, geophysical and hydrogeological survey was carried out in order to assess the distribution and potential of groundwater to be developed. In this survey, both Schulamberger and Wenner methods were applied (Fig.-5.2). In addition, geomagnetic survey method, namely EM method was introduced in Popondetta and Daru depending on the topographical and geological conditions (Fig.-5.3, 5.4). These data were used to select drilling points and target depths. The following describes the results of the geophysical survey and the characteristics of the Study Areas (Fig.-5.5 to 5.11 and refer to Data Book & Supporting Report).

1) Popondetta is located 17 km to the north of from Lamington Volcano (1,679 m in elevation). This area shows generally high earth resistivity (45 to 10,000Ω-m) which is a characteristic of volcanic regions. Geoelectric prospecting was conducted mainly in the town of Popondetta and at the foot of Lamington Volcano, and the underground down to 130m below the ground level was analysed. The analysis shows that the stratum with 85 to 362Ω-m in earth resistivity could be productive. Groundwater is expected at 30m below the ground level in the northeast to the southeast areas from the Town. Based on the above survey, in these areas, two drilling points were selected at 1.0 km from the Town where a drilling rig can access. The target aquifer depth was 100m each.
2) Daru is a small island, north-south 4 km and east-west 6 km, with the highest altitude at 12m. PNG Geological Survey, which investigated the groundwater potential in the past, reported that the area is affected by the intrusion of saline water. Geophysical survey was carried out to identify the areas suffering from the saline water and the depth of the intrusion, so that the potential of potable groundwater can be identified. Judging from earth resistivity, the areas affected by saline water are situated in the north-west to the south of the island. These areas show very low earth resistivity of 2 to 8Ω-m. These depths are 8m to 24m, and especially, the

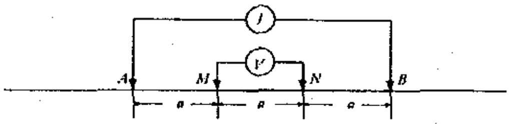
Fig.-5.1 Rainfall Pattern at Lae in Recent 28 Years (1973-2000)





Schlumberger Array, $\rho a = \frac{L^2 - l^2}{4l} \frac{V}{I}$, $L \geq 5l$

A,B : Current electrode, *M,N* : Potential electrode
L : spacing of Current electrode, *l* : spacing of Potential electrode



Wenner Array, $\rho a = 2\pi \frac{V}{I} a$

a : Electrode spacing

Fig.-5.2 Electrode Array in Vertical Electrical Survey

Fig-.5.3 Interpreted Resistivity Sounding in Popondetta

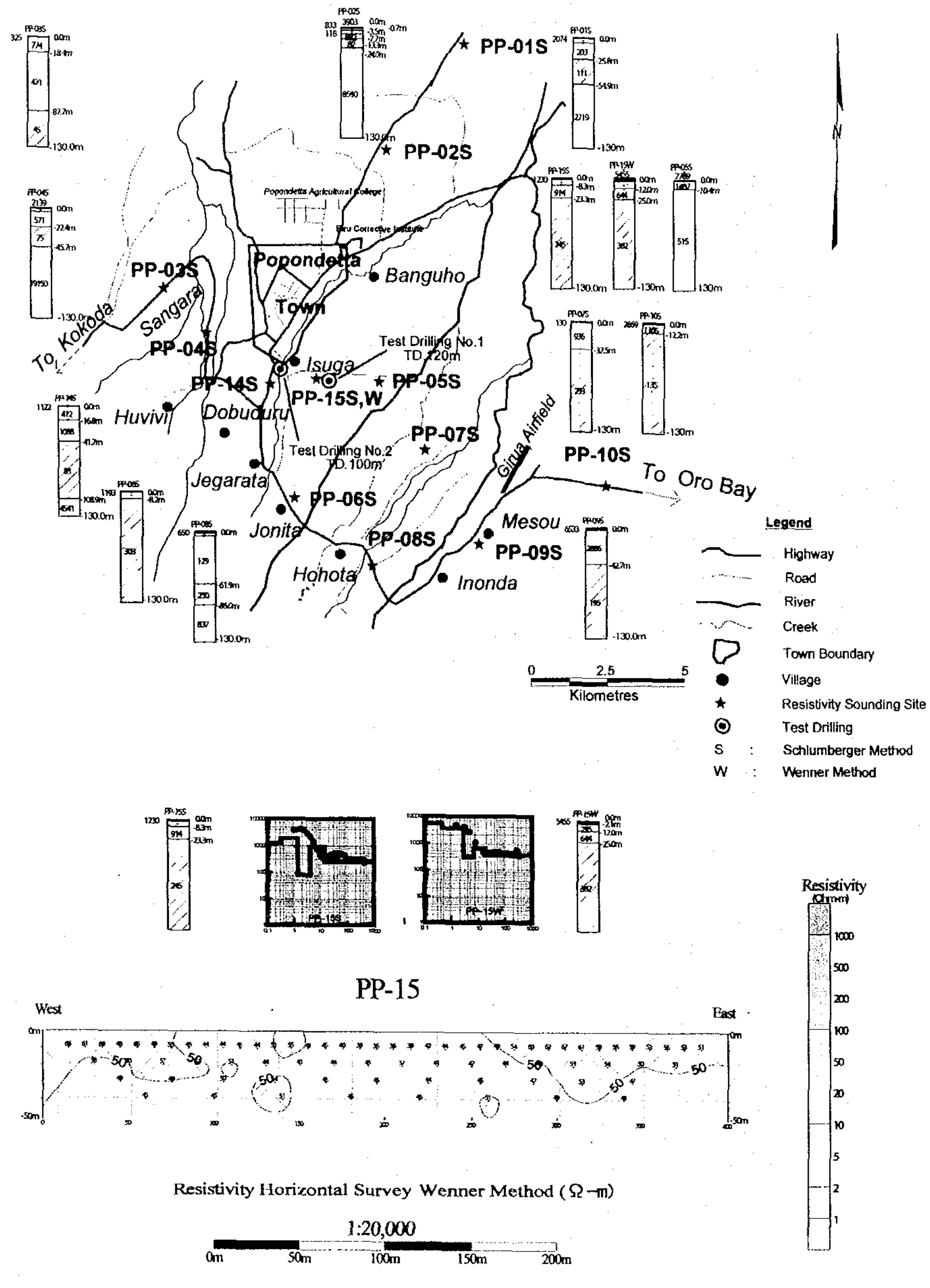


Figure-5.4 VES Curves of Resistivity Sounding in Daru

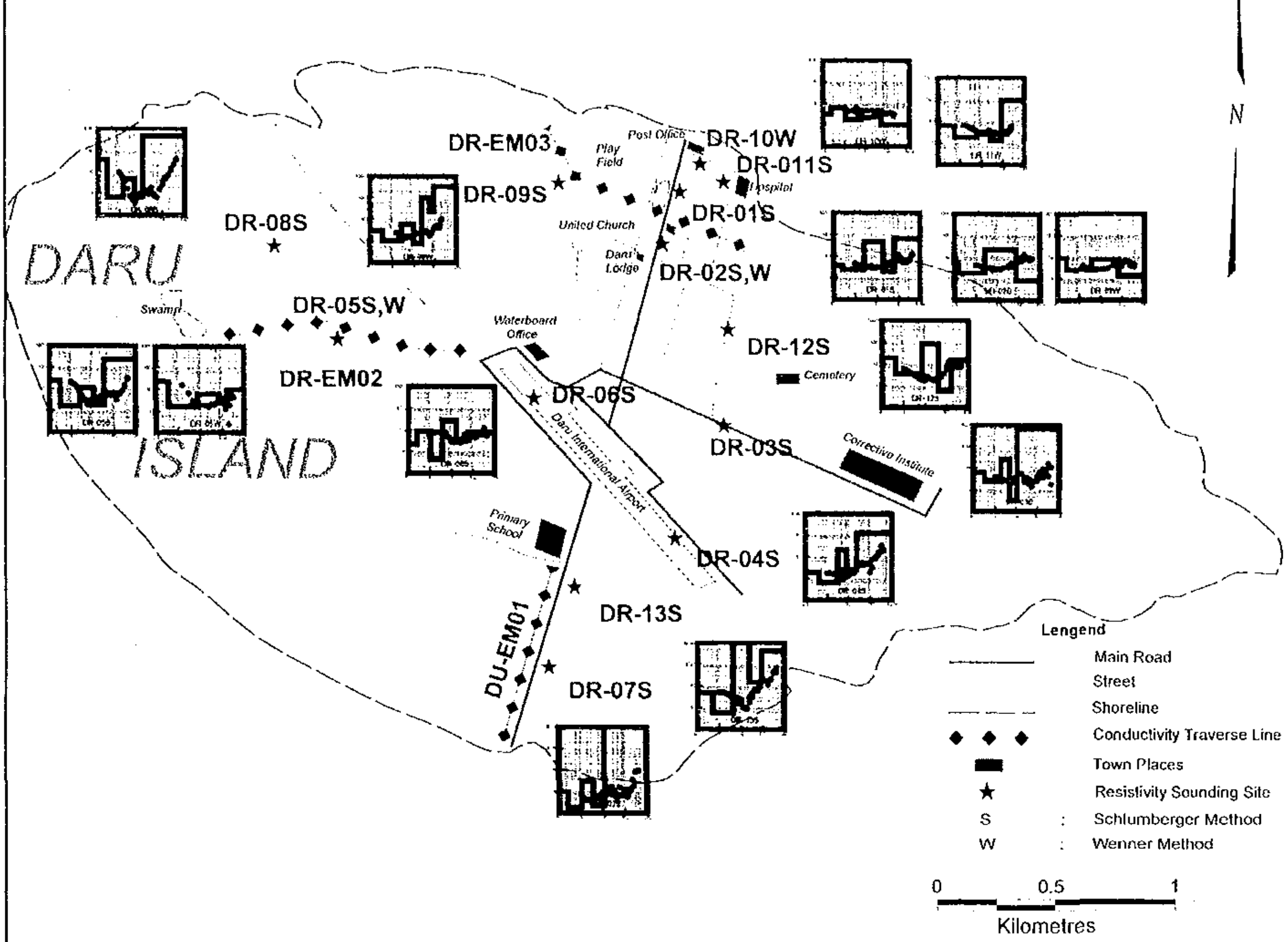
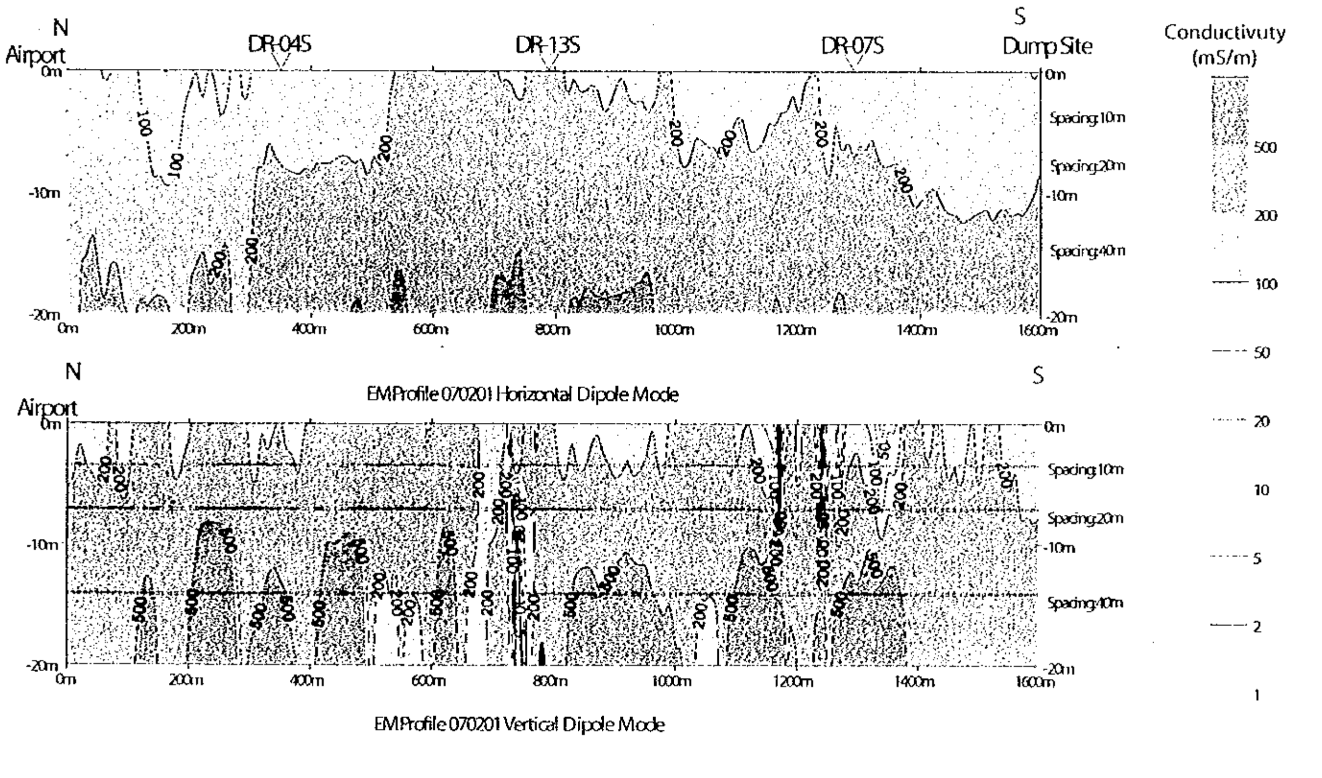


Figure-5.4(2) Condutivity Profile of Electromagnetic Survey between Airport and Dump Site in Daru



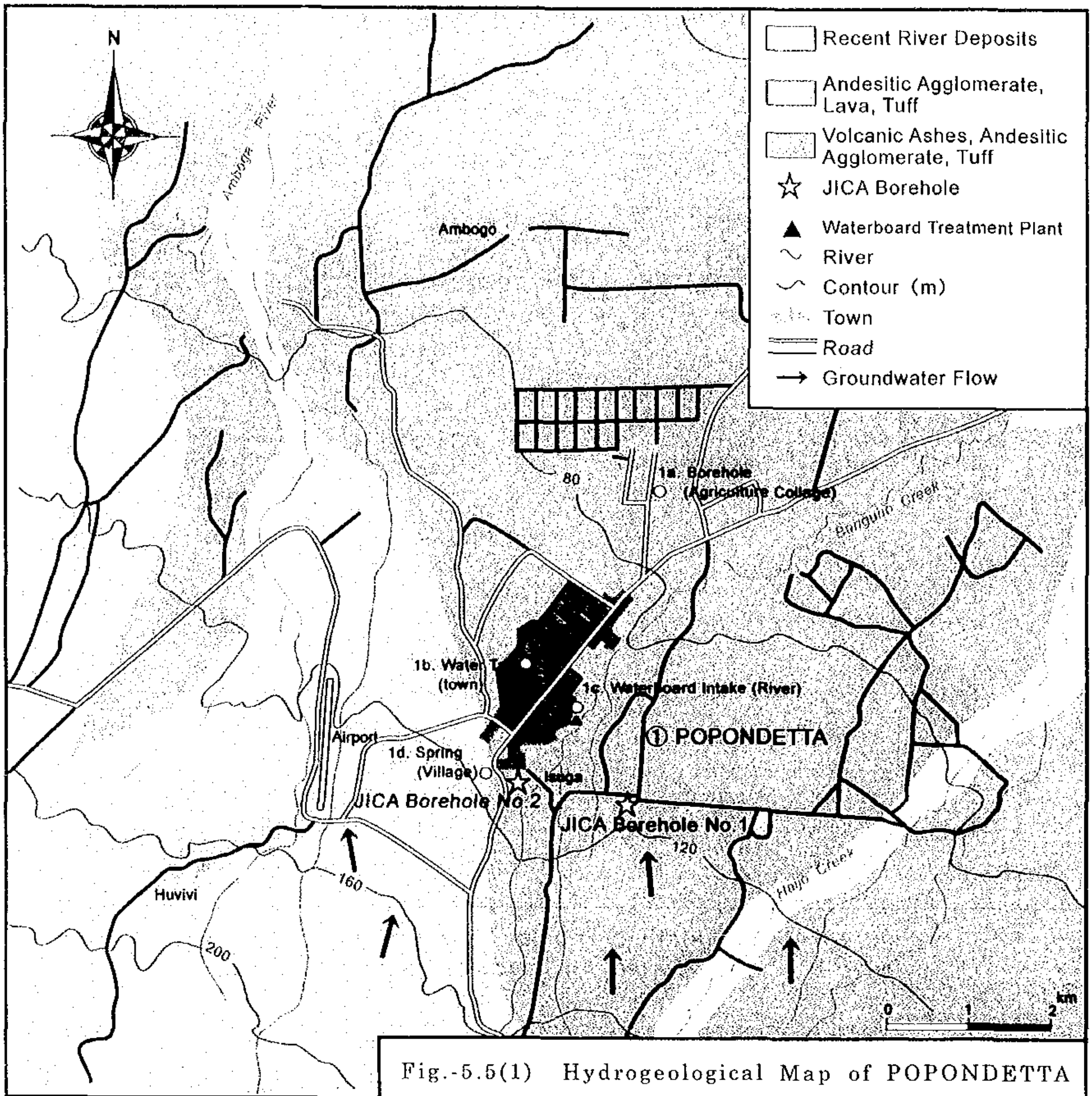


Fig.-5.5(1) Hydrogeological Map of POPONDETTA

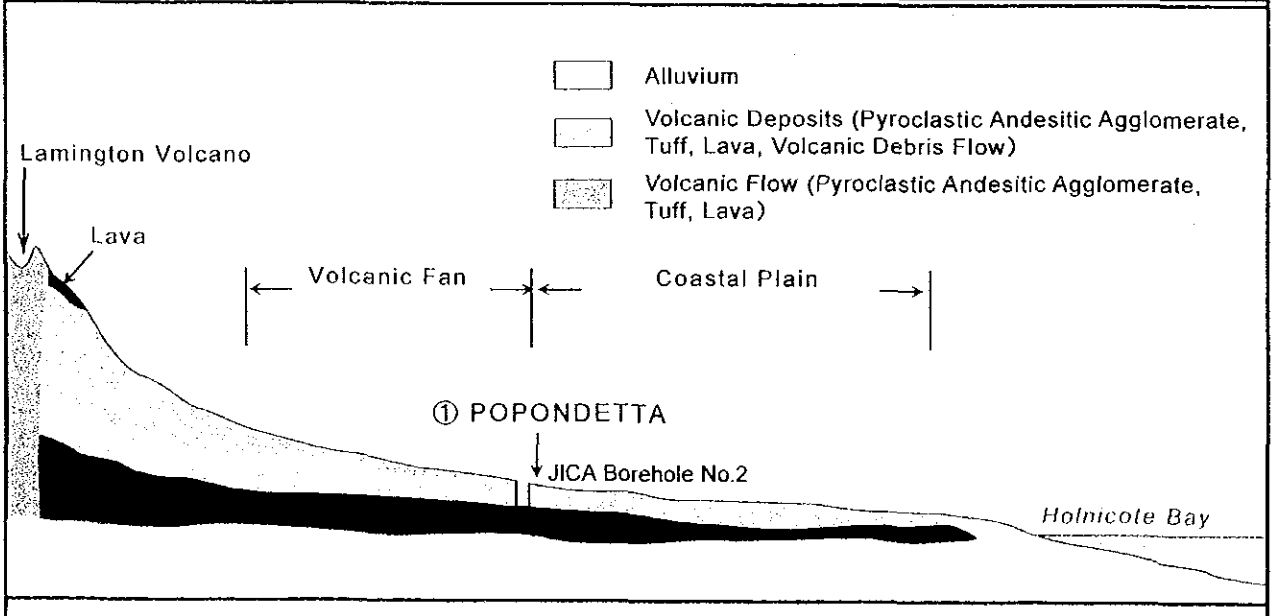


Fig.-5.5(2) Schematic Geological Cross Section Lamington-Holnicote

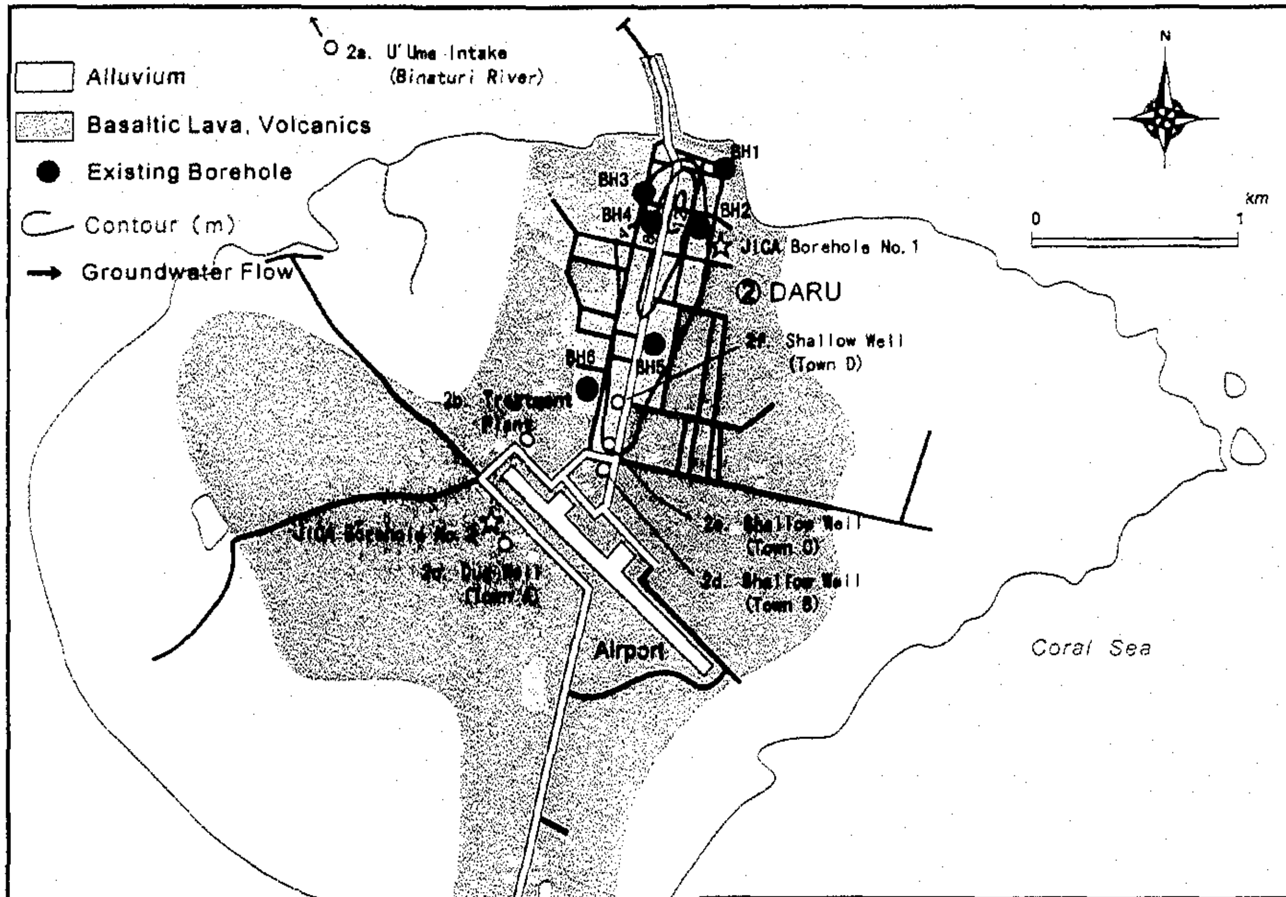


Fig.-5.6(1) Hydrogeological Map of DARU

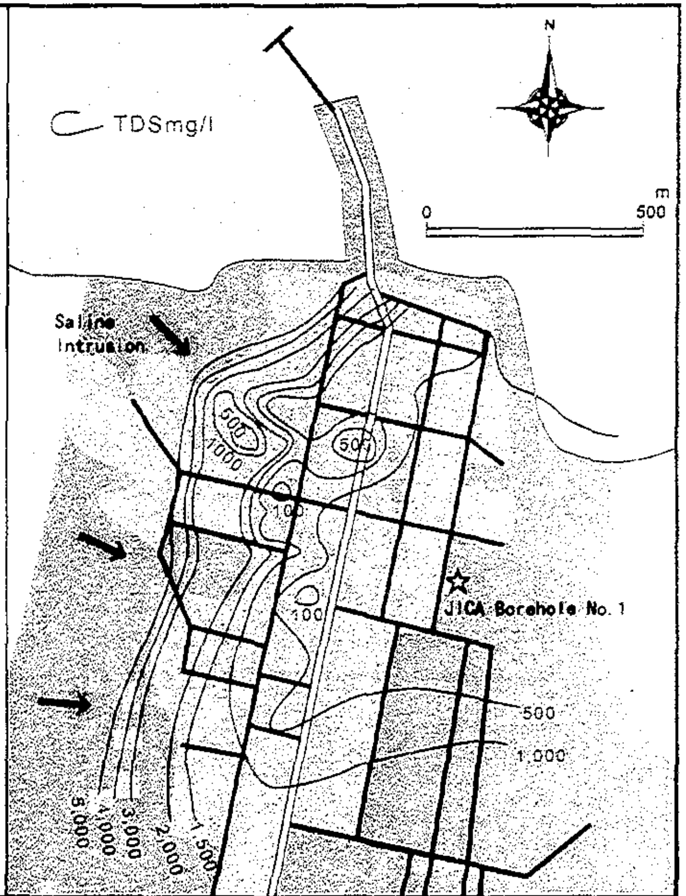
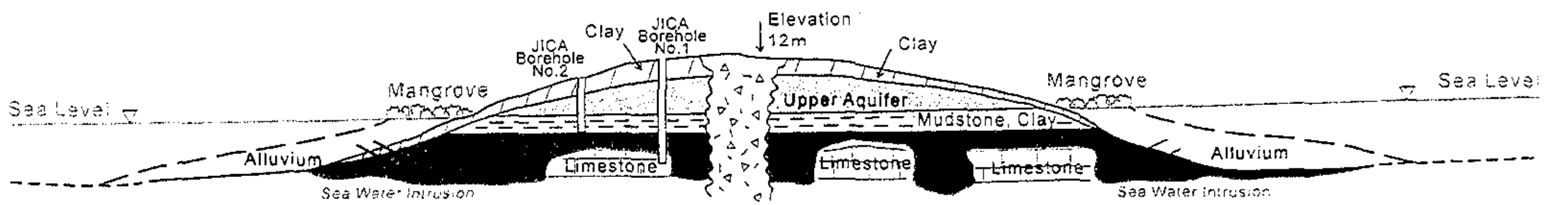


Fig.-5.6(2) Total Dissolved Solids in Upper Aquifer (TDSmg/l)



Data : PNG Geological Survey

Fig.-5.6(3) Geological Cross Section of Daru Island

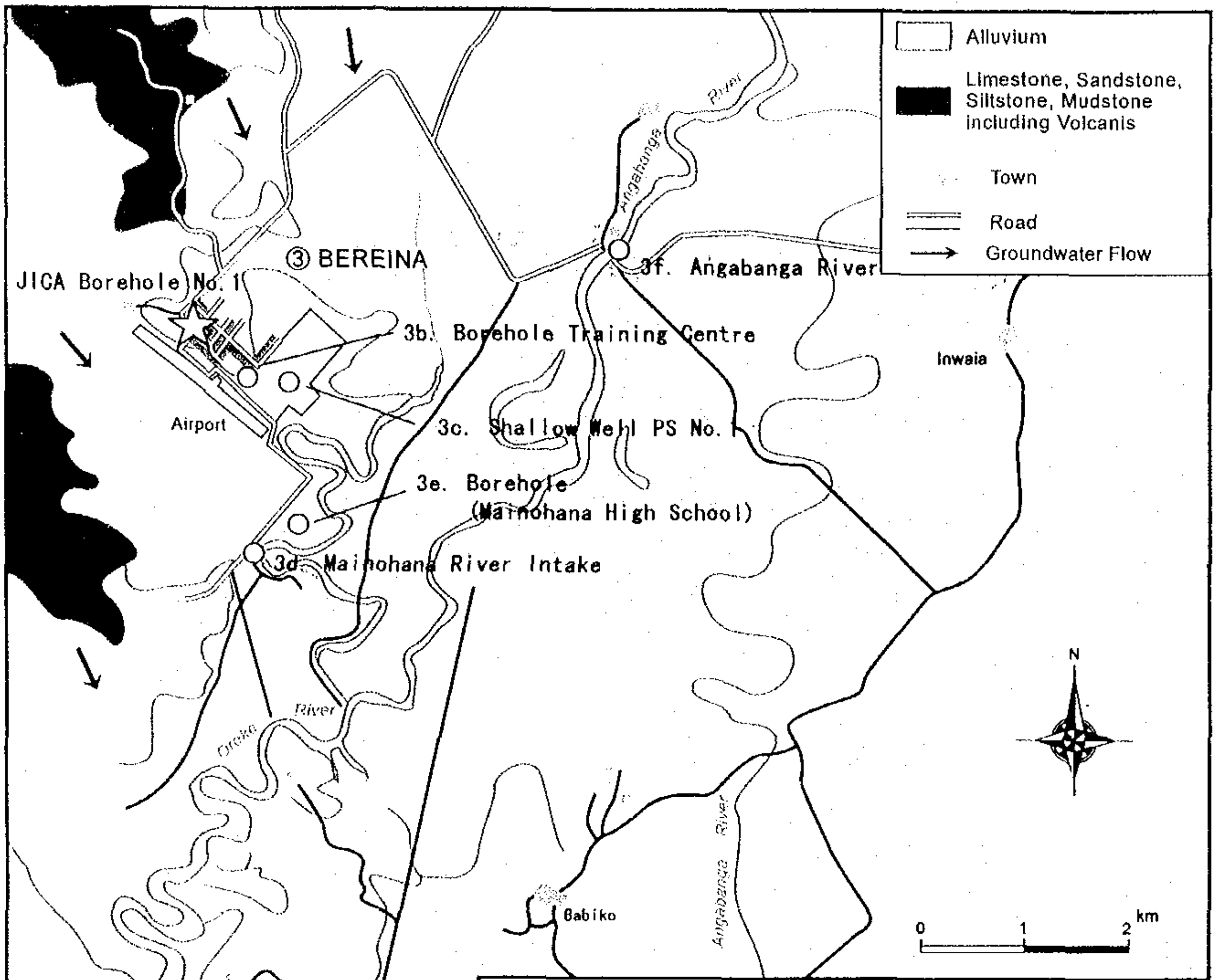


Fig.-5.7 Hydrogeological Map of BEREINA

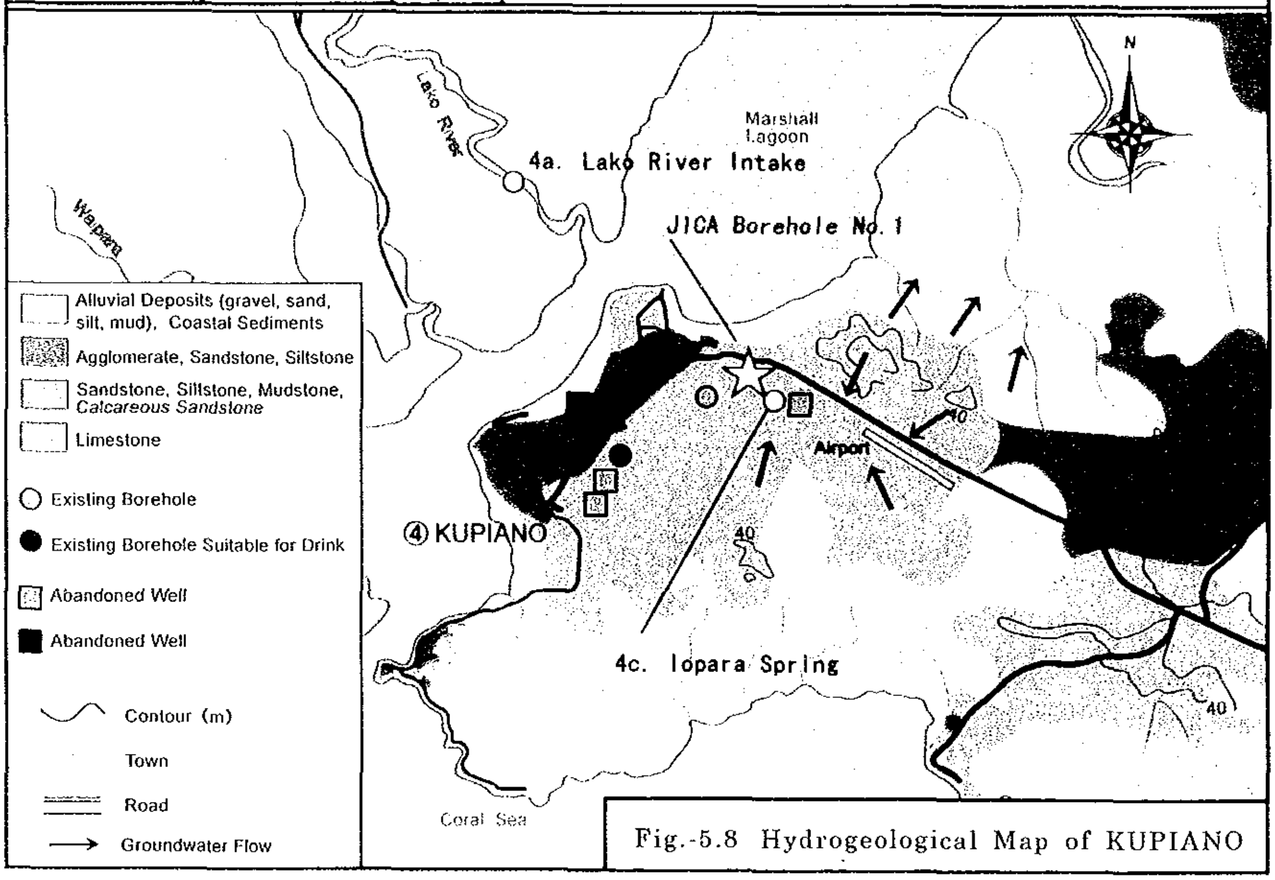


Fig.-5.8 Hydrogeological Map of KUPIANO

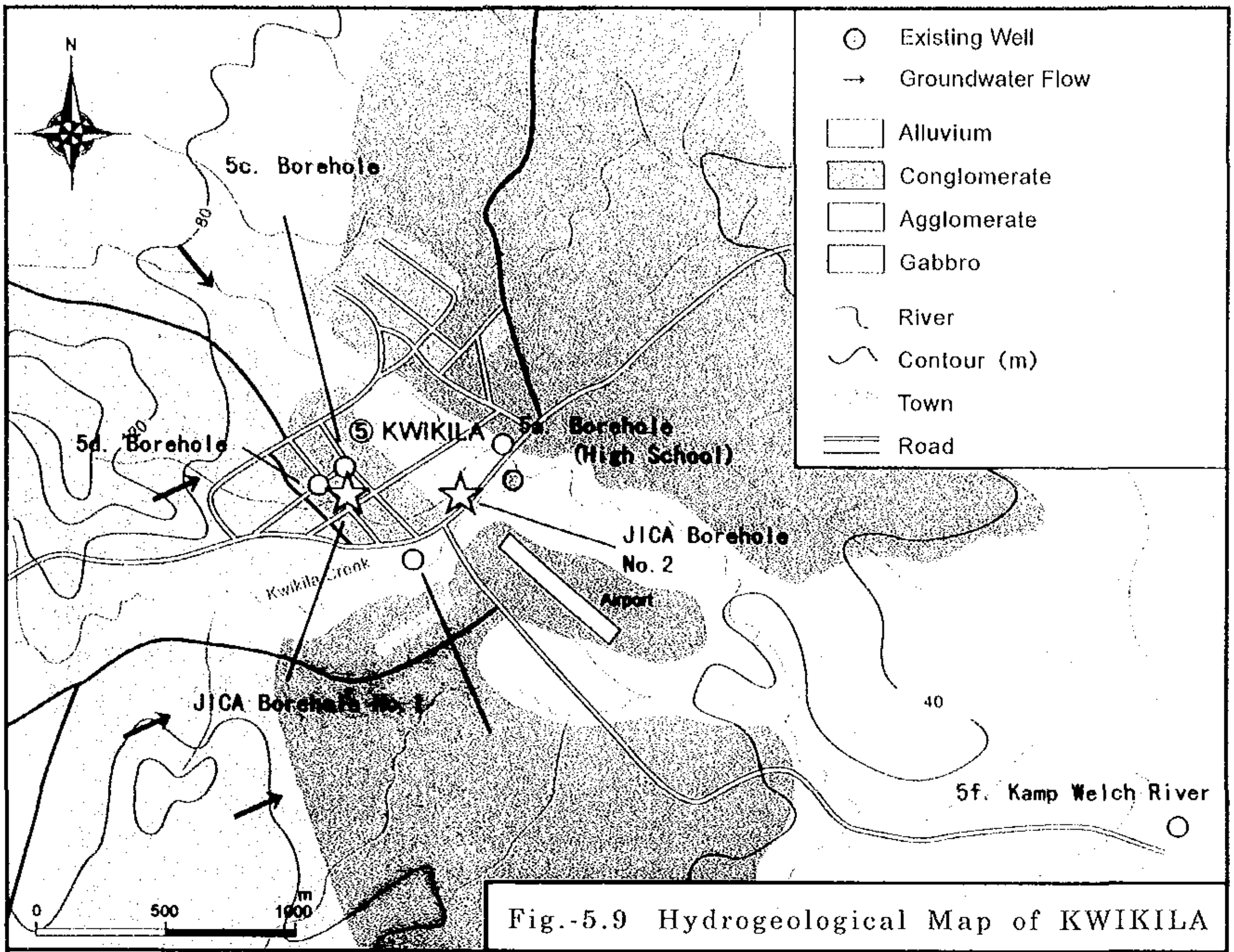


Fig.-5.9 Hydrogeological Map of KWIKILA

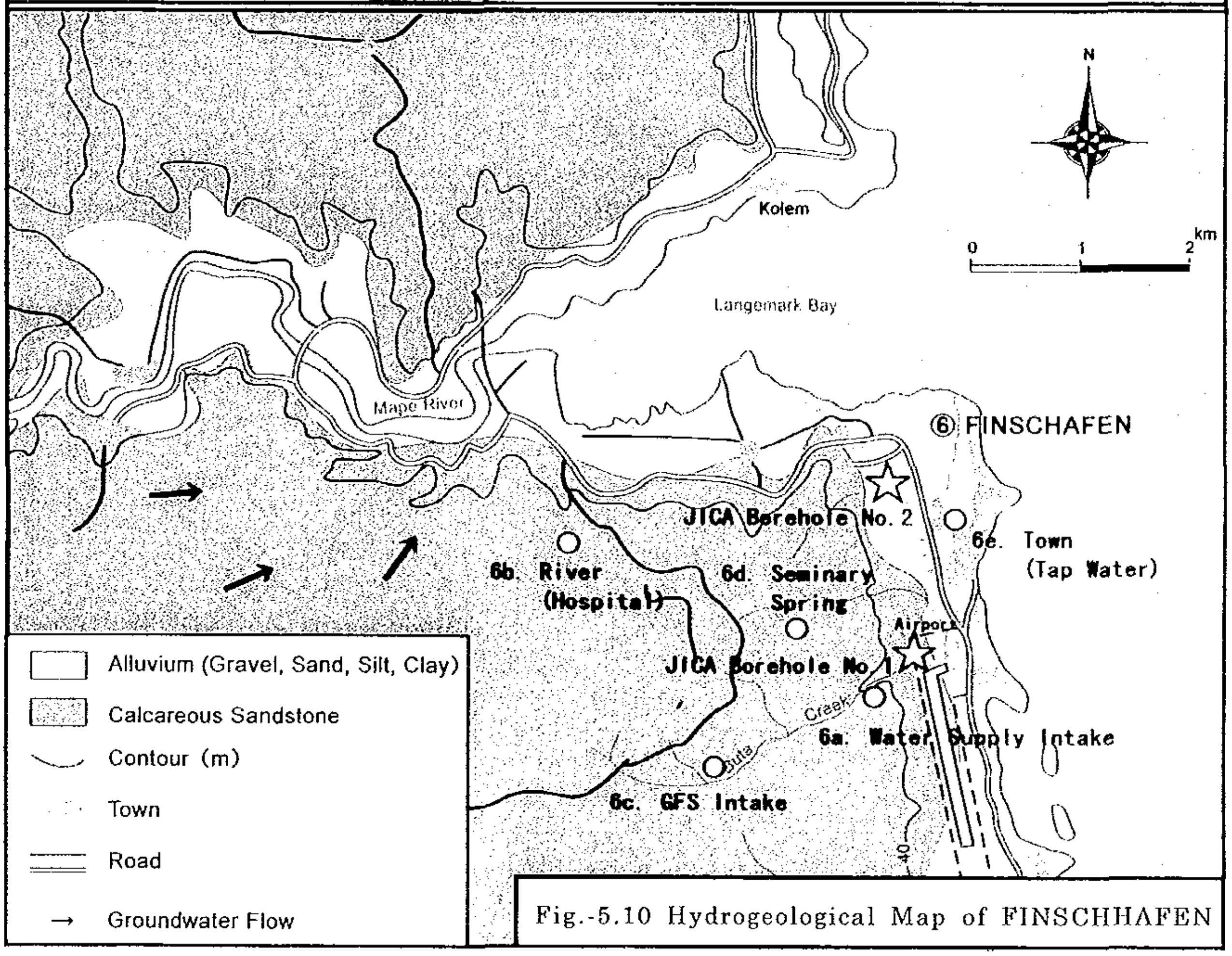


Fig.-5.10 Hydrogeological Map of FINSCHHAFEN

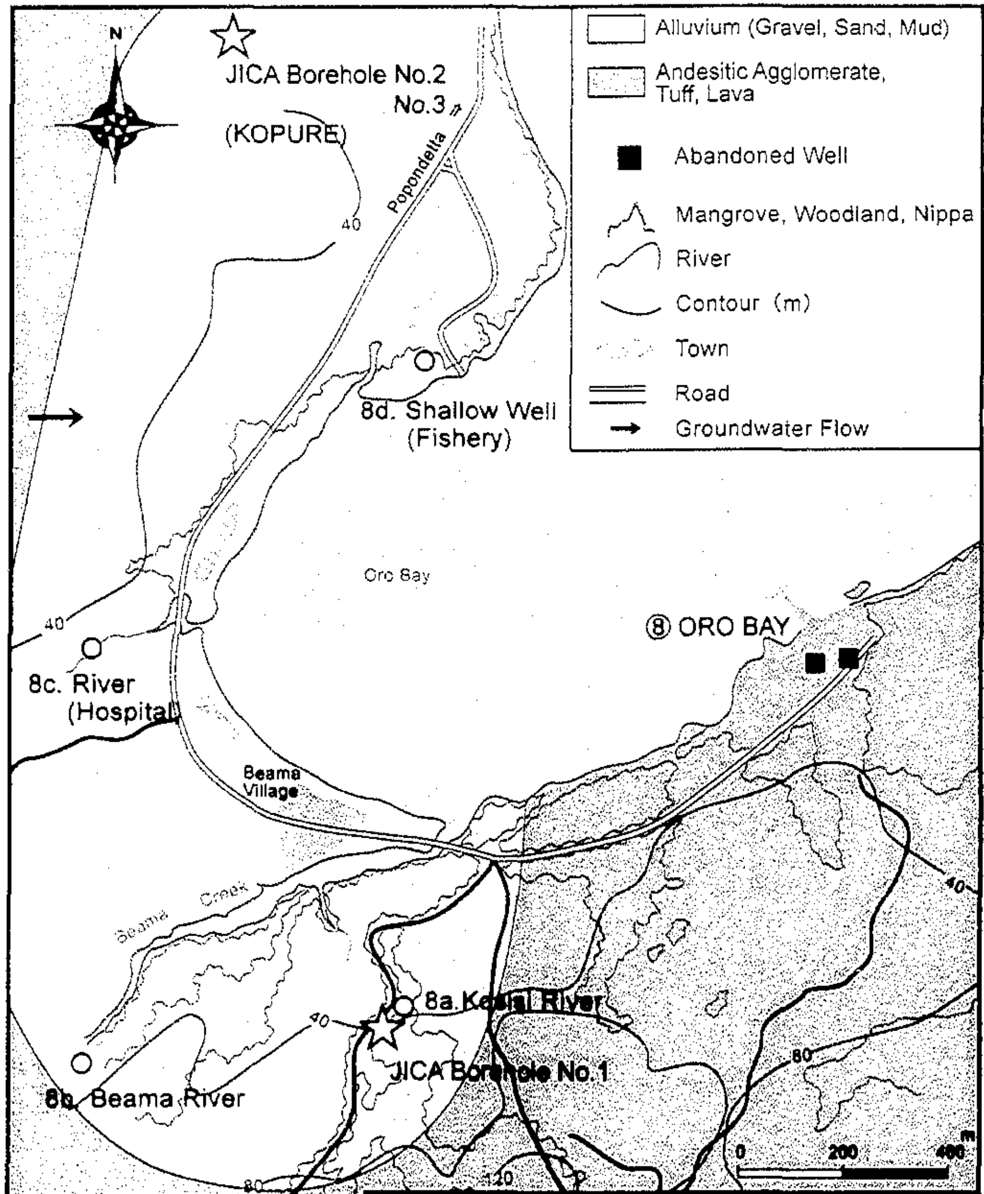


Fig.-5.12 Hydrogeological Map of ORO BAY

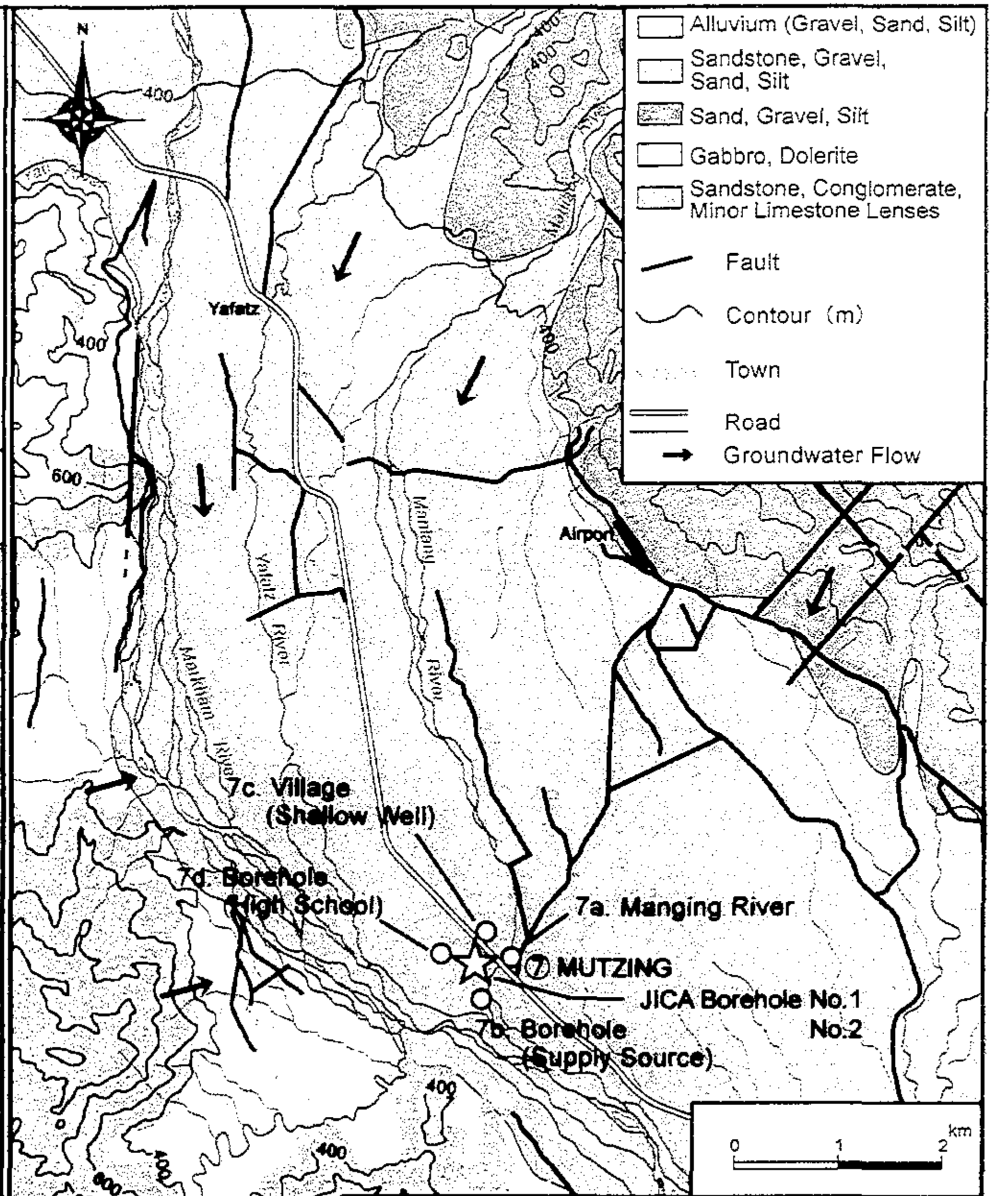


Fig.-5.11 Hydrogeological Map of MUTZING north-west of the island is 40m in depth. On the other hand, the relatively high areas in altitude, which are in the north-east of the island and 5m to 10m above the sea level, show relatively high earth resistivity of 18 to 80Ω-m and the depths are 3m to 50m. Since groundwater can be expected in these areas, drilling point No.1 was selected there. Whereas the drilling point No.2 was selected in the south-west of the island where the first 6.9m from the ground level shows a low earth resistivity of 4Ω-m but the stratum below this shows the value of 33 to 282Ω-m where groundwater is expected.

3) Bereina is located in the plain along the coast. North-west of the town is a hilly area where coral limestone is covered by the Quaternary conglomerate. Artesian basin is expected in the town located in the lowland of the coastal plain and the inland. To find a water source that is close to the town and has a confined aquifer, the site for geophysical survey had been selected in the north-east from the town. As hydrogeologically expected, the analysis showed that there might be an aquifer with earth resistivity of 15 to 95Ω-m in the north-east of the town. The aquifer could become thicker (25m to 95m) and deeper toward the direction from the town. The drilling point was selected near the health centre for the ease of the distribution of water and the accessibility. An aquifer is expected to be 30m to 40m deep and 19 to 33Ω-m in earth resistivity. Finshhafen, Oro Bay, Kupiano and Kwikila are similar conditions of Bereina.

4) Mutzing is characterized as the centre of agricultural development and located in Markham Valley. The area has thick Quaternary deposit along the tectonic line and is known to have high groundwater potential. Geoelectric survey was carried out to identify the area and the depth of the aquifer in the study area. As a result of the survey, the area showing the earth resistivity of 24 to 282Ω-m is expected to be an aquifer of sand and gravel, and it could be located at 10m to 130m depth. The area is generally sand and gravel stratum showing the smooth geoelectric survey curve of around 100Ω-m. Thus, the drilling point is selected in the town centre where the earth resistivities are 48 to 63Ω-m and the aquifer is expected to be in the strata of 6m to18m and 43m to 122m in depth.

5) The processes from the geophysical, geological and hydrogeological survey to select the drilling point, test drillings were carried out considering the following.
   a. The results of the geophysical survey are analysed considering the geographical, geological and hydrogeological characteristics of each site.
   b. Based on the analyses, the drilling points and the depths are determined.
   c. Priorities for drilling are given to the sites that have accessibilities to mobilise a drilling rig.
   d. Among prospective sites with same groundwater potentials, the site closest to the town is selected to minimise the distance of the distribution pipes installed.
   e. In terms of securing lands, priorities are given to the State Lands. In case a drilling site is selected in a customary land, the owner's permission should be obtained in advance.
   f. Hydrogeological maps show the drilling points for the Study Area.

5.3 Hydrogeological Study

1) Hydrogeological study is done based on the existing borehole data, the results of geological survey, water quality analysis, geoelectric prospecting and test drilling. The hydrogeological data of limited existing boreholes in the Study Areas are collected and summarized in Table-5.1. Figure-5.13 shows hydrogeological evaluation of test boreholes, the discharge and drawdown graph, coming from the step drawdown pumping tests at the Study Area.
2) When we consider the groundwater potential, the concept of Specific Capacity (SC) is the most important factor as well as the other factors, namely discharge, drawdown, pumping water level, static water level as follows.
   a. Specific Capacity (m^3/day/m) =
      Discharge of Pumping Test (m^3/day) / Drawdown (m)
   b. Drawdown (m) = Pumping Water Level – Static Water Level
   c. Groundwater Potential (m^3/day) =
      Specific Capacity (m^3/day/m) x Allowable Drawdown (m)
3) The groundwater potentials are calculated as the volume of water taken from a borehole assuming the groundwater is continuously pumped for allowable drawdown.
   The 10 m of allowable drawdown was determined in this study based on the results of the continuous discharge test of the test boreholes, the structure of boreholes, total depth and the static water level. Nevertheless, in Daru, Finshhafen, Oro Bay and other specific areas where the saline water intrusion is reported, the allowable drawdown is reduced to 1 m instead of 10 m so that the saline water intrusion could be minimized.
4) The groundwater potential per borehole in the Study Area including depth of main aquifer was evaluated as shown in Table-5.2, and the master plan for groundwater development program should be prepared considering the water demand for the target year of 2015.

Table-5.2 Groundwater Potential Capacity

Study Area	Borehole Depth (m)	Static Water Level (m)	Pumping Water Level (m)	Depth of Aquifer (m)	Potential Capacity per Well (m^3/day/well)
1. Popondetta	110	7.0	17.0	70-100	850
2. Daru	50	2.5	3.5	20-40	325
3. Bereina	50	6.0	16.0	20-40	751
4. Kupiano	70	2.0	12.0	30-60	350
5. Kwikila	50	4.0	14.0	20-40	470
6. Finschhafen	50	6.0	7.0	20-40	540
7. Mutzing	50	2.0	12.0	30-40	8,640
8. Oro Bay	50	4.0	14.0	20-40	150
9. Oro Bay (Kopure)	50	4.0	14.0	20-40	700

Table-5.1 Hydrogeological Evaluation

No.	Area		Year of completion	TD (m)	SWL (m)	Q (l/s)	Q (m3/d)	PWL (m)	ΔS (m)	SC (m3/d/m)	Groundwater Potential (m3/d)
	1. Popondetta										
1		BH-A	1985	24.0	4.10	1.90	164.16	16.00	11.90	13.8	138
2		BH-B	1985	61.0	5.30	2.30	198.72	7.39	2.09	95.0	950
3		BH-C	1985	29.0	0.50	2.30	198.72	3.02	2.52	79.0	790
4		BH-D	1985	46.0	1.30	dry	-	-	-	-	-
5	(Town supply)	BH-E	1986	24.0	10.00	2.50	216.00	15.00	5.00	43.2	432
6		BH-F	1986	60.0	-	dry	-	-	-	-	-
7		BH-G	1986	12.5	-	dry	-	-	-	-	-
8		BH-I	1979	20.5	8.00	dry	-	-	-	-	-
9		Explo	1994	100.0	4.00	dry	-	-	-	-	-
10		PB-1	1995	50.0	3.99	4.50	388.80	7.25	3.26	119.2	1192
	2. Daru										
1	Hospital	BH-1	1964	7.8	5.60	5.00	432.00	-	-	-	-
2	Hotel	BH-2	1964	183.0	14.90	0.90	77.76	15.02	0.12	648.0	brackish
3	PWD	BH-3	1964	32.0	2.70	4.50	388.80	4.80	2.10	185.1	brackish
4		BH-4	1964	30.5	-	-	-	-	-	-	brackish
5	Missionary	BH-5	1964	42.4	4.60	6.30	544.32	7.30	2.70	201.6	brackish
6	High school	BH-6	1964	35.1	2.40	7.80	673.92	4.00	1.60	421.2	brackish
	3. Bereina										
1		No. 1	1989	25.0	1.90	0.90	77.76	8.33	6.43	12.1	121
	4. Kupiano										
1	Town	No. 1	1965	30.5	-	-	-	dry	-	-	-
2		No. 2	1965	19.5	6.00	0.75	64.80	-	-	-	-
3		No. 3	1966	12.2	7.30	0.75	64.80	-	-	-	-
4		No. 4	1966	21.3	6.10	-	-	dry	-	-	-
5	Town	No. 1	1973	17.7	6.50	0.75	64.80	14.03	7.53	8.6	86
6		No. 2	1973	30.5	6.10	-	-	-	-	-	-
7		No. 3	1973	21.2	1.52	-	-	-	-	-	-
		No. 3A	1973	30.5	-	-	-	dry	-	-	-
	Lako R.	No. 1	1974	12.2	1.90	-	-	-	-	-	-
		No. 2	1974	7.6	2.20	-	-	-	-	-	-
		No. 3	1975	16.8	2.30	1.30	112.32	2.60	0.30	371.5	3715
		No. 4	1975	16.8	2.20	1.60	138.24	4.30	2.10	65.7	657
		No. 5	1975	12.2	2.40	-	-	dry	-	-	-
	5. Kwikila										
	Town	No. 1	1964	9.8	2.70	-	-	dry	-	-	-
		No. 2	1964	9.8	3.10	0.30	25.92	7.42	4.32	6.0	60
		No. 3	1964	14.6	4.90	0.90	77.76	5.90	1.00	77.8	778
		No. 4	1964	9.2	3.40	0.40	34.56	5.00	1.60	21.6	216
	AID post	No. 1	1966	8.2	-	-	-	-	-	-	-
		No. 2	1966	16.8	-	-	-	-	-	-	-
		No. 3	1966	7.6	-	-	-	-	-	-	-
	High school		1966	9.1	4.60	0.90	77.76	6.10	1.50	51.8	518
	Hotel		1969	15.2	-	-	-	-	-	-	-
		No. 1	1969	9.1	5.10	0.63	54.43	5.76	0.66	82.900	829
		No. 2	1969	32.0	4.90	1.00	86.40	-	-	-	-
		No. 3	1969	9.1	5.00	0.63	54.43	-	-	-	-
	High school	No. 1	1972	31.0	4.90	-	-	dry	-	-	-
		No. 2	1972	12.2	6.50	0.70	60.48	7.82	1.32	45.8	458
	Vocational centre	No. 1	1973	12.5	4.30	1.10	95.04	4.60	0.30	319.7	3197
		No. 2	1973	11.9	4.30	0.90	77.76	4.90	0.60	129.6	1296
	6. Finschhafen										
	Buta creek		1987	45.0	-	1.00	-	fine sand/lime stone	-	saline	-
	7. Mutzing										
	Station	No. 1		15.0	-	10.00	864.00	-	-	-	high potential
		No. 2		12.0	-	7.00	604.80	-	-	-	high potential
	8. Oro Bay										
	Harbour	BH-21	1976	22.0	-	-	-	-	-	-	brackish
		BH-26		6.0	-	-	-	-	-	-	brackish
		BH-22		6.0	-	-	-	-	-	-	brackish
		RDW-1		17.0	-	-	-	-	-	-	brackish

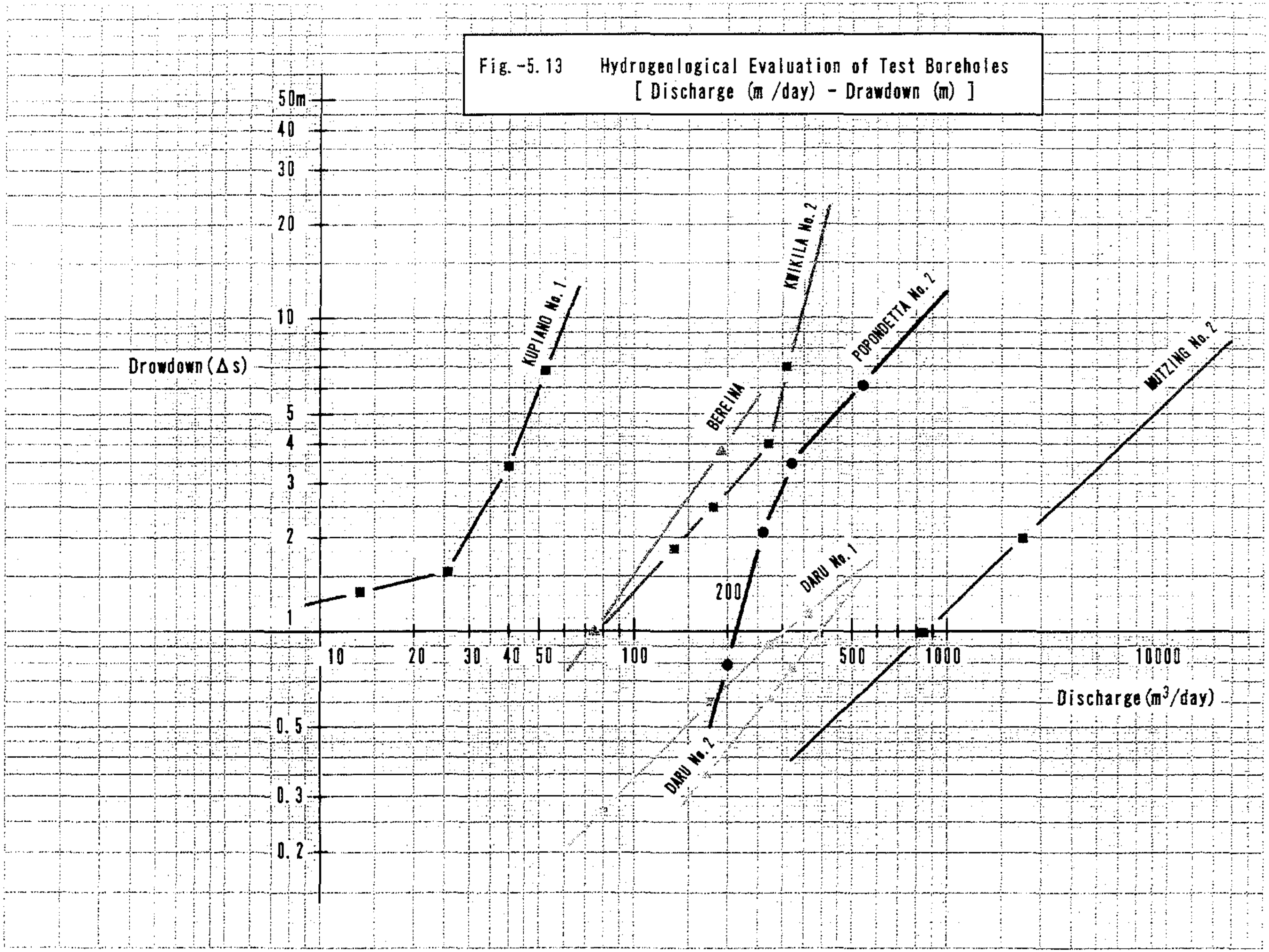


Fig.-5.13 Hydrogeological Evaluation of Test Boreholes
[Discharge (m /day) - Drawdown (m)]

5.4 Basic Information

1) Population

The population projection in accordance with the results from the population census as held in 1980, 1990 and 2000 was carried out by the government of PNG. However, the government did not announce the census of 2000, yet. Therefore, study population was utilized for the baseline field survey data in 2000 at each study area. The average population growth was 2.3% coming from the census of 1990, and population growth at each Study Area was selected from 1.40% to 2.46%. Recent national populations are as follows, and the national population in 2000 is more than 5 million.

Table-5.3 The National Population in PNG (1990-1998)

Year	1990	1996	1997	1998
Population (x 1 thousand)	3,920	4,400	4,500	4,600

2) Nationality, Society and Culture

A prominent feature of PNG's 4.6 million population in 1998 is that it comprises about 800 languages and cultural groups. Therefore, not only is the traditional social-cultural structure of the country extremely fragmentary among social groups, it is also thought to contribute to weak relationships of mutual trust and cooperation within the society.

Although it is not easy to articulate a common characteristic within such a complex and rich cultural society, the existence of traditional status, called *Big Man*, could be classified as a common feature of PNG society. *Big Man* is the traditional leading status acquired mainly based on the personal ability to redistribute wealth. It is also known as a common characteristic of Melanesian society of which most of the people of PNG belong. In contrast to Polynesian society in which one patrimonial chief is common, it is common that there are plural *Big Man* within one society. The presence of *Big Man* is thought to be prominent in the Highlands of PNG.

With regard to introducing a project to villages, it appears inadequate to establish a consensus among villagers through leaders such as a village head or "*Committee*" due to the above-mentioned social environment. As compared to societies that exhibit patrimonial chiefdom and a hierarchical structure, it should be stressed that the required timeframe to establish certain consensus in PNG is longer than that of hierarchical societies and the process is invisible. Bearing this in mind, when a meeting is organized to promote the process, it is best to hold it in the presence of all villagers instead of inviting just major representatives.

Furthermore, *Wan Tok,* derived from the English words 'One Talk', is a commonplace custom that rules human relationships in PNG. Originally, this indicates those who speak the same language, and further implies an attitude of assisting those who belong to the same tribe or clan as a matter of course. Occasionally, the concept also implies there is a close relationship between persons. It is important to know that this custom is firmly embedded in PNG society, and therefore there is a tendency for nepotism to be apparent in the public and private sectors. As mentioned above, it appears that this shows the other side of the society's phenomenon of possessing weak relationships of mutual trust and cooperation.

3) NGOs and CBOs

Although no NGOs can be identified as covering the entire country, World Vision, the body subcontracted for the JICA Pilot Project, is thought of as one of the largest and best equipped organizations in PNG.

According to a division of the NGO/Church, the Department of Social Welfare & Development is the public organization responsible for the affairs of NGOs in PNG. Their role is to collect information relating to domestic NGOs, however, they appear to have limited data.

4) Income Level

The following table is a summary of a survey in relation to the monthly cash income of eight (8) Study Areas. From this data it can be concluded that firstly, income levels are highest in Daru and Popondetta (provincial capitals), and secondly, Kwikila and Mutzing, where transport is comparatively convenient, possess higher levels of incomes than other towns.

Table-5.4 Monthly Cash Income

	Mutzing	Finschhafen	Oro Bay	Bereina	Kwikila	Kupiano	Daru	Popondetta
Formal Residents								
Median (K)	742.50	589.50	N/A	654.66	906.25	695.78	924.75	956.58
Average (K)	790.63	1,654.11	N/A	700.86	994.65	1,427.69	1,734.11	1,212.92
Informal Residents/ Villagers								
Median (K)	283.50	90.00	189.59	237.50	408.33	159.75	696.50	394.65
Average (K)	797.04	176.43	337.91	349.43	486.10	236.93	928.45	432.01

2.66Kina=1US$ (Aug. 2000)

As for the provincial capitals, due to a high opportunity for employment from service and commerce industries excluding the public sector, the monthly cash income for formal and informal residents is thought to be high.

As for formal residents in district towns, because most depend on income from the public sector, the salary level from the organizations of which they belong is thought to be not much different. However, many women also engage in small businesses such as selling garden products or cooked food in the informal sector, thus the location of each district town is thought to influence their cash income. It would be highly advantageous to be located in district towns where transportation is convenient, such as along a national road where there are many passers-by and there is opportunity for small businesses to thrive.

Informal residents/villagers also depend on small businesses in the informal sector such as selling supplemental products from subsistence farming. Therefore, the location of their district towns is influential and the trend of their cash income is almost the same as formal residents in district towns.

Table-5.5 Number of self-employment per household

	Mutzing	Finschhafen	Oro Bay	Bereina	Kwikila	Kupiano	Daru	Popondetta
Formal residents								
Males	0.14	0.11	N/A	0.03	0.03	0.13	0.25	0.10
Females	0.89	0.40	N/A	0.55	0.68	0.41	0.68	0.19
Informal Residents / Villagers								
Males	0.43	0.24	0.30	0.14	0.33	0.58	0.32	0.14
Females	0.93	1.04	1.00	0.97	1.13	1.28	0.78	0.75

From the questionnaires and field observations, the majority of participants in the informal sector are females and the amount that they generate can not be neglected.

5) Land Use

Land in PNG is classified into two (2) categories based on form of ownership: Customary Land and Alienated Land. Alienated Land is the land that is alienated from Customary Land or removed from custom and is largely owned by the PNG government. However, 99% of national land is Customary Land and the rules and principals of customary land tenure are in accordance with native customs rather than those set out in any formal documentation. Therefore, state intervention in customary land tenure is very limited. It is thought, on the one hand, such an ambiguous situation seems to have conserved traditional culture and personal identity. However, on the other hand, it has also prevented the utilization of Customary Land and presented obstacles for perhaps more desirable objectives such as development projects. Although the government has tried to promote the registration of Customary Land to solve such issues, no significant progress appears to have been made.

Facilities for the JICA Pilot Project have been constructed on State Land in consideration of the above-mentioned situation. For example, although facilities for a Water Vending Project in Daru had planned to be constructed in an informal residential area, the location was changed to State Land because all informal residential areas are thought to be on Customary Land. An exceptional case was the installation of communal taps in villages. In this case, the landowners coincide with the beneficiaries from the communal taps and thus willingly allowed the installation to progress.

Land is a very sensitive issue in PNG and any issue relating to it should be paid with careful attention. Even State Land is not always free from disputes and there are some cases where trials relating to land ownership or compensation are still evident. In fact, even some of the surveyed sites are still engaged in trials. In general though, it would be impossible to utilize Customary Land for the benefit of those who have nothing to do with its ownership. And in practice, such a project as is indispensable to utilize Customary Land is very difficult, unless certain direct benefits for its owners are sure and obvious.

6) Education

According to the "*Human Development Report 2000*" compiled by the UNDP, the Adult Literacy Rate, which is thought of as an indicator of the general educational level for a country, is 63.9% for PNG (male 71.4% / female 56.0%). This rate is considered to be around the middle level for developing countries.

Table-5.6 Adult Literacy Rate

Developing Countries	72.9%
Least Developing Countries	51.6%
East Asia & the Pacific	69.2%
Middle Income Countries	69.5%
Papua New Guinea	63.9%

(Source-; Human Development Report 2000)

According to the "*Demographic and Health Survey 1996*" by the National Statistics Office, 24.4% have not received formal education and 35.1% have received formal education for more than seven (7) years in urban areas. In the case of rural areas, percentages are 50.5% and 8.6%, respectively. In addition, the combined primary, secondary, and tertiary gross enrolment ratio as stated by the "*Human Development Report 2000*" is 39%. Although endeavours to improve school enrolments are being made, education in PNG still lags global standards.

Table-5.7 Combined Primary, Secondary, and Tertiary Gross Enrolment Ratio

Developing Countries	61%
Least Developing Countries	38%
East Asia & the Pacific	71%
Middle Income Countries	74%
Papua New Guinea	39%

(Source; Human Development Report 2000)

As results of the survey involving questionnaires has indicated that over 50% of formal residents have attended more than seven (7) grades. Whereas in the case of informal residents/villagers, the majority of formal schooling undertaken is from four (4) to six (6) grades, and those with more than seven (7) grades is uncommon. Judging from this, it can be said that the educational background of formal residents is higher than that of informal residents/villagers. Meanwhile, the average rate of those who have received no schooling is not more than 24.4% except for Kwikila, even if this rate is higher for informal residents/villagers. Although it is rather ambiguous whether the surveyed sites are considered to be urban or rural areas except for Daru and Popondetta, it is thought that schooling at surveyed sites is comparatively better than that of the national average.

Table-5.8 Schooling Experience

	Mutzing	Finschhafen	Oro Bay	Bereina	Kwikila	Kupiano	Daru	Popondetta
Formal residents								
No schooling	20%	12%	N/A	8%	5%	3%	2%	2%
Less than 3G	11%	7%	N/A	3%	3%	5%	7%	3%
4G – 6G	23%	26%	N/A	21%	27%	23%	28%	25%
More than 7G	46%	56%	N/A	68%	65%	70%	64%	70%
Informal Residents/Villagers								
No schooling	18%	11%	2%	19%	43%	11%	1%	21%
Less than 3G	7%	23%	4%	14%	14%	7%	8%	12%
4G – 6G	32%	51%	80%	42%	32%	48%	45%	40%
More than 7G	43%	15%	14%	25%	11%	34%	45%	26%

7) Social Status and Working Conditions for Women (Gender Consideration)

There are very rich and complex cultural traditions in PNG and it may not be accurate to say that the social status of women has been traditionally lower than that for men. However, at present, it may be fair to say that the social status of women may be at a disadvantage to that of men. As shown in following Table-5.9, various social indicators in relation to gender support this assertion. Furthermore, although there is no objective data available, it is thought that domestic violence and rape are widespread.

Table-5.9 Selected Social Indicators in Relation to Gender

	Male	Female
Life Expectancy at Birth	55.4	57.3
Adult Literacy Rate	71.4%	56.0%
Combined primary, Secondary and Tertiary Gross Enrolment Rate	42%	35%
Seat in Parliament by Gender	90.7%	9.3%

(Source; Human Development Report 2000)

In addition, it is also possible to point out that the unfair land tenure system may be a factor that prevents women from starting their own businesses. It is believed that women were the traditional owners of land tenure in places where matrilineal heirship was common. However, all rights in relation to land are held by men at present, and women appear to have been relegated to witnesses, even where traditionally matrilineal heirship is predominant. Today, land is considered to be important collateral for making loans, thus women seem to be treated discriminately from an economical point of view.

Table-5.10 Responsibility for Fetching Water

	Mutzing	Finschhafen	Oro Bay	Bereina	Kwikila	Kupiano	Daru	Popondetta
Formal Residents								
Adult Male	0%	13%	N/A	9%	24%	25%	20%	7%
Adult Female	92%	98%	N/A	88%	84%	97%	95%	86%
Boy	0%	2%	N/A	0%	11%	6%	3%	0%
Girl	12%	16%	N/A	3%	11%	9%	5%	11%
Informal Residents/ Villagers								
Adult Male	29%	17%	32%	10%	20%	63%	22%	7%
Adult Female	93%	96%	98%	90%	67%	100%	100%	93%
Boy	0%	4%	0%	7%	7%	5%	0%	0%
Girl	14%	13%	18%	14%	20%	8%	15%	25%

In the survey, it has been observed that the voice of women was limited in meetings, and committee members for the Pilot Project tended to consist of only men.

As results of the survey and questionnaires show, the responsibility of fetching water is predominantly borne by adult women. In addition, the majority of participants in the informal sector from informal residents/villagers are women and it is inferred that a considerable amount of income is generated by them. The income from informal sector activities is also able to be disposed of by women. From field observations, daily domestic duties like preparation of meals are carried out by women, thus the water supply service should be closely related with their daily life and it is thought that the needs for water by women is keener than that of men. Therefore, it is considered that women are a more appropriate stakeholders and should play the main role of maintaining communal water taps. Although it would be difficult to expect women to lead activities as a chairperson of the Water Management Committee considering the social context of PNG, the benefit should be high to promote the positive participation of women. In practice, the Water Management Committee organized for the period of the Pilot Project has given certain attention not to exclude women from its membership

8) Poverty Issue

Although GDP per capita of US$896 (1999) in PNG classifies it as a lower to middle income country, distribution of income is very uneven, with the wealthiest 25% of the population possessing a real per capita consumption level of over eight (8) times that of the poorest quartile. Compared to other countries classified in the same group in terms of economical conditions or the same region of East Asia and the Pacific, PNG scores poorly with respect to several basic social indicators. In the past, traditional safety nets were adequate to mitigate the most serious consequences of absolute poverty like the aged, the handicapped, or those who had no direct access to land. However, these traditional safety nets are no longer considered to be adequate.

Table-5.11 Selected Social Indicators

	Papua New Guinea	Middle Income Countries	East Asia and Pacific
Infant Mortality Rate per 1000 Births	79	32	34
Life Expectancy at Birth	56.2	69.5	69.2
Combined Primary, Secondary and Tertiary Gross Enrolment Rate	39%	74%	71%
GDP per Capital (PPP US$)(1999)	2,367	3,850	3,950

(Source; Human Development Report 2000)

Although there does not exist an official poverty line in PNG, the poverty line determined based on a minimum acceptable level of consumption is K461 per adult/ year according to a household survey conducted in 1996. Referring to this poverty line, 41% of villagers are considered to be under the poverty line. It would be difficult to apply the above-mentioned poverty line to compare the living conditions of surveyed sites with the national level. However, the cash income of surveyed sites like Finschhafen, Bereina and Kupiano is comparatively low, and over 30% of households would have a cash balance deficit after deducting monthly expenditure from monthly cash income. Considering such data, it is thought that those sites are poverty-intensive sites.

Table-5.12 Households with a Deficit in Cash Balance

Mutzing	Finschhafen	Oro Bay	Bereina	Kwikila	Kupiano	Daru	Popondetta
Formal Residents							
3%	9%	N/A	9%	0%	9%	7%	4%
Informal Residents / Villagers							
14%	33%	8%	45%	0%	35%	2%	4%

From a socio-economic point of view, three (3) different groups of living conditions are identified inside of each surveyed site. The first is the group of formal residents who have an official right to stay in town. Most of their families are employed by the public sector and they have staple income soürces. The second is informal residents who stay in town, but their status in town is not officially admitted. Some are employed by the public sector, but the majority are considered to participate in informal sector activities. The third is villagers who stay out of but adjacent to towns and whose income sources mainly derive from sales of surplus products from subsistence farming. The distinction between the second and third groups is not always clear and has still left some ambiguity at some sites. However the difference between the first group and the second and third groups is obvious from a socio-economic point of view and it is recognized that the latter are apparently at a disadvantage. The gap is not only in cash income, but also accommodation, water and hygiene conditions, and educational background. The water supply service conducted by PNGWB has targeted the first group, while the second and third groups have been left out of their target except in rare cases. In the Pilot Project, the mitigating activities have been applied taking into account this socio-economic gap.

9) Current Water Usage and Satisfaction

Formal residents depend on water taps for drinking and cooking in Mutzing, Finschhafen, Daru and Popondetta, where there are water supply facilities that seem to work constantly. The formal residents use water tanks mainly in Bereina, Kwikila and Kupiano, where there are either no water supply facilities or they do not work well. As for informal residents/villagers, wells and rivers are the main sources of water except in Daru and Finschhafen.

As for the availability of water through the year for formal residents, it seems that water availability is stable in Daru and Popondetta, where PNGWB operate services, and next to them are Mutzing and Finschhafen, where there are working water supply facilities. Towns like Bereina, Kwikila and Kupiano, where water tanks are the main source of water, seem to be the least stable. In the case of informal residents/villagers, their main water sources are rivers and wells and their feelings about the availability of water sources throughout the year is generally better than that of formal residents. Although it is understandable that it is possible to fetch water more constantly from rivers and wells compared to rainwater, rainwater in tanks would be of preference over rivers and wells considering the quality and workload involved in fetching water. Many informal residents/villagers feel that their water source is dirty. Therefore they are not satisfied with existing water sources.

Table-5.13 Water Availability throughout The Year

Mutzing	Finschhafen	Oro Bay	Bereina	Kwikila	Kupiano	Daru	Popondetta
Formal Residents							
49%	42%	N/A	12%	5%	6%	81%	99%
Informal Residents / Villagers							
79%	80%	82%	28%	27%	80%	93%	93%

Table-5.14 Water Source Problem (Dirty)

Mutzing	Finschhafen	Oro Bay	Bereina	Kwikila	Kupiano	Daru	Popondetta
Formal Residents							
85%	49%	N/A	27%	30%	31%	79%	60%
Informal residents / Villagers							
64%	80%	56%	66%	47%	70%	78%	68%

Yet, many formal residents in Mutzing, Finschhafen, Daru and Popondetta also feel that their water source is dirty, even though water supply facilities are equipped and functioning. Therefore there is some gap between the present situation and what is desired. As the extent of this gap differs depending on site, it will be necessary to inquire as to why they consider their water source dirty in more details as a public water supply service.

Table-5.15 Main Water Sources for Drinking and Cooking

	Mutzing	Finschhafen	Oro Bay	Bereina	Kwikila	Kupiano	Daru	Popondetta
Formal Residents								
House Connection	60%	60%	N/A	0%	0%	3%	92%	89%
Public Faucet	17%	11%	N/A	0%	0%	0%	2%	1%
Rain Water Collection Tank	6%	18%	N/A	100%	89%	94%	7%	4%
Neighbours Rain Water Tank	0%	11%	N/A	0%	3%	0%	0%	0%
Public Rain Water Tank	0%	0%	N/A	0%	0%	3%	0%	1%
Dug Well	6%	0%	N/A	0%	0%	0%	0%	0%
Neighbours Dug Well	6%	0%	N/A	0%	0%	0%	0%	0%
Public Well	0%	0%	N/A	0%	8%	0%	0%	1%
River Stream, Spring	6%	6%	N/A	0%	0%	0%	0%	1%
Informal residents/villagers								
House Connection	7%	16%	0%	0%	0%	0%	71%	21%
Public Faucet	0%	40%	0%	0%	0%	0%	27%	11%
Rain Water Collection Tank	0%	8%	4%	35%	53%	13%	0%	7%
Neighbours Rain Water Tank	0%	4%	0%	0%	13%	0%	0%	0%
Public Rain Water Tank	0%	0%	0%	0%	0%	0%	0%	0%
Dug Well	36%	0%	0%	14%	0%	0%	0%	4%
Neighbours Dug Well	0%	0%	0%	21%	0%	0%	2%	4%
Public Well	43%	0%	0%	45%	13%	0%	0%	21%
River Stream, Spring	14%	44%	96%	3%	20%	88%	0%	32%

10) Awareness for Water Supply Service

A. Expectation for Water Supply Service

As shown in Table-5.16 below, almost 100% of households hope to join a water supply service and there should not be any obstacles to paying water charges.

In the case of starting a new water supply service at the surveyed sites, it is thought that each household of formal residents can make a contract with PNGWB (as is the case in other provincial towns where PNGWB operates) because most formal residents are public servants and have a staple income source. However, as water charges have been provided free of charge in the past and are considered to be to poor and inadequate, it is uncertain how a change will affect the willingness of people to pay for the services in the future.

It is considered that water supply services for informal residents/villagers will require different conditions. Most do not have stable income sources and their monthly cash income is lower than that of formal residents.

Table-5.16 Willingness to Join Water Supply Service

Mutzing	Finschhafen	Oro Bay	Bereina	Kwikila	Kupiano
Formal Residents					
100%	96%	N/A	97%	97%	100%
Informal Residents/ Villagers					
100%	100%	100%	100%	100%	100%

When communal taps were introduced to informal residents/villagers as a part of the Pilot Project, it was observed that those informal residents/villagers tended to limit their water usage to save on water charges. Thus, if such a limitation is applied too strictly, the benefit of the water supply service may not be fully realized. On the other hand, if water is used carelessly, large water charges may bring about serious problems for sustainable use. In any case, continual monitoring of communal tap usage will be required.

B. Willingness and Ability to Pay

As results from a survey conducted in Daru and Popondetta show, where PNGWB is operating water supply services, the most frequent range of actual payments for water by formal residents is from K5 to K10. In the case of informal residents/villagers in Daru, although the most frequent level is no payment, distribution is spread evenly from K5 to K30. In the case of informal residents/villagers in Popondetta, about 70% do not pay water charges and are considered to be excluded from the water supply services.

As the result of a survey regarding the willingness to pay for water supply services in six (6) District Towns show, K10 is an acceptable level for over 50% of residents, and around K5 to K10 is acceptable for informal residents/villagers.

Considering that the average monthly cash income of formal residents ranges from K700 to K1,660 (mean: K590 to K910), K10 is thought to be an amount both possible and willing to be paid.

Table-5.17 Willingness to Pay for Water Supply Services

	Mutzing		Finschhafen		Oro Bay		Bereina		Kwikila		Kupiano	
Formal Residents												
Less than K2	6%	100%	0%	100%	N/A	N/A	0%	100%	0%	100%	0%	100%
-K4	9%	94%	2%	100%	N/A	N/A	16%	100%	3%	100%	6%	100%
-K6	26%	85%	26%	98%	N/A	N/A	34%	84%	43%	97%	31%	94%
-K8	3%	59%	5%	72%	N/A	N/A	6%	50%	3%	54%	3%	63%
-K10	44%	56%	44%	67%	N/A	N/A	28%	44%	27%	51%	47%	59%
Over K10	12%	12%	23%	23%	N/A	N/A	16%	16%	24%	24%	13%	13%
Informal Residents / Villagers												
Less than K2	0%	100%	32%	100%	34%	100%	4%	100%	0%	100%	20%	100%
-K4	7%	100%	8%	68%	14%	66%	4%	96%	7%	100%	20%	80%
-K6	14%	93%	36%	60%	24%	52%	39%	93%	33%	93%	53%	60%
-K8	7%	79%	4%	24%	6%	28%	0%	54%	0%	60%	0%	8%
-K10	36%	71%	12%	20%	16%	22%	46%	54%	40%	60%	8%	8%
Over K10	36%	36%	8%	8%	6%	6%	7%	7%	20%	20%	0%	0%

As for informal residents/villagers, average monthly cash income ranges from K180 to K800 (mean: K90 to K410), thus K10 is thought to be rather expensive for supplying water services at some lower cash income sites. The water charge for communal taps installed by the Pilot Project has fixed a monthly flat rate of K5 per household (informal residents/villagers). Through discussions with beneficiaries, payments of K5 appear both possible and willing to be paid. However, for sites like Oro Bay, Finschhafen and Kupiano, where average cash income is lower than Pilot Project sites, it is doubtful that K5 can be paid. Although actual consumption of water for each communal water tap has not yet been measured, according to beneficiaries, a minimum monthly water charge by PNGWB of K3.5 for 12,000L is thought to be adequate per household. If it is certain that the required amount per household is less than K5, water supply services by PNGWB through communal water taps is thought to be realistic and sustainable.

11) Willingness to Participate in The Affairs of Maintenance

In the first field survey, over 80% of people at most sites have expressed willingness to participate in maintenance work and bear the required costs for water supply and sewage facilities. However, after water supply facilities were renovated and enhanced through the Pilot Project, the willingness to repair water related facilities like water pipes and taps inside each house at a user's own expense show a different tendency. The percentage willing to bear the cost was 67.7% in Bereina, but 4.0% in Mutzing and 25.4% in Kwikila. It is thought that this level of willingness is not very high.

As for formal residents in district towns, most are public servants and live in official residences, therefore it would be difficult to expect them to realistically participate in maintenance. However, it is agreed that the responsibility for maintaining the water supply facilities from main facilities to meter boxes at each house is borne by PNGWB and maintenance of interior facilities in official residences is borne by authorities concerned. Thus the above-mentioned factor is not so crucial for water supply services operated by PNGWB.

As for informal residents/villagers, over 90% expressed willingness to participate in maintenance and bear the required costs in the first field survey. In addition, those concerned reached the consensus that daily maintenance including required costs will be borne by them through the process of implementing the pilot project. Although it will be required to monitor the operation and maintenance of communal taps hereafter, it is thought that their willingness is high and the promotion of communal taps through participation is a realistic option.

Table-5.18 Willingness to Participate in Maintenance

Mutzing	Finschhafen	Oro Bay	Bereina	Kwikila	Kupiano
Formal Residents					
94%	91%	N/A	97%	100%	88%
Informal Residents/ Villagers					
100%	92%	98%	93%	93%	100%

Table-5.19 Willingness to Bear The Cost of Maintenance

Mutzing	Finschhafen	Oro Bay	Bereina	Kwikila	Kupiano
Formal Residents					
80%	82%	N/A	88%	92%	56%
Informal Residents/ Villagers					
100%	88%	98%	93%	100%	98%

5.5 Health Situation

1) Allocation of Health Facilities

There are facilities providing medical services at the eight (8) Study Areas, but the level of service and status of practices vary.

In Daru and Popondetta, Provincial Towns, hospitals exist and function as the centre of medical services in the provinces. In other District Towns, there are clinics. In Finschhafen, a clinic in the centre of town and a hospital operated by a missionary organization in the neighbourhood collects patients in and out of Morobe Province. The hospital is considered to be the largest among the institutions at Study Areas.

In the case of clinics, patients seem to only come from villages nearby due to difficult access because of poor road conditions. Especially, it is reported that pregnant women coming to the clinics for delivery are limited.

Details of the facilities are as below.

Table-5.20 Summary of Health Facilities

	Mutzing	Finschhafen	Oro Bay	Bereina	Kwikila	Kupiano	Daru	Popondetta
Status	Clinic	Clinic	Clinic	Clinic	Clinic	Clinic	Hospital	Hospital
Doctor	×	×	×	×	×	×	○	○
Nurse	○	○	○	○	○	○	○	○
In-patient ward	○	×	○	△	○	△	○	○
Delivery Ward	○	×	○	△	○	△	○	○
Electricity	○	○	△	△	○	△	○	○
Water Supply	○	○	×	△	○	△	○	○

Full-Time or Exist ○ / Temporary or Closed △ / Nil ×

2) Condition of Medical Services

In Bereina and Kupiano, supply of water and electricity is not stable so in-patients are not allowed, although wards are attached to all medical institutions except Finschhafen. In Kwikila, although water facilities of the town do not work, the health centre has an independent water well. In the case of Finschhafen, full-time doctors work at a hospital operated by a missionary organization in the neighbourhood, and serious sick persons or patients necessary to be hospitalised are thought to be treated there.

According to hospital/clinic records, patients with malaria are most common, while those with skin diseases, diarrhoea, or pneumonia are the next more prevalent.

Expenses for treatment are not standardized, and fees are not collected at some institutions. Even if fees are collected, circumstances differ among places. Some staff have admitted that a reason that fees are not properly collected is that there is a fear of creating trouble with some patients.

Although it cannot be said that people are satisfied with the poor conditions of the institutions, they do not seem to think it is that important to collect fees. This may be because medicine is distributed by the central government.

5.6 Situation Regarding Sanitation

1) Sanitary Customs

As to sanitary customs, results of a survey concerning boiling water for drinking and washing hands after visiting toilets are described below.

In general, the percentage of people that boil drinking water is not very high; formal residents are more careful with drinking water than informal residents. There are some sites where informal residents hardly display a custom of boiling drinking water. Considering most residents use rivers and/or wells as source of water, it should be of concern that people do not boil water for drinking.

Table-5.21 Custom of Boiling Water

	Mutzing	Finschhafen	Oro Bay	Bereina	Kwikila	Kupiano	Daru	Popondetta
Formal Residents								
Always	0%	11%	N/A	27%	18%	13%	14%	8%
Sometimes	24%	60%	N/A	48%	47%	59%	63%	81%
Not usual	76%	29%	N/A	24%	34%	28%	24%	11%
Informal Residents/ Villagers								
Always	0%	0%	0%	14%	7%	0%	10%	0%
Sometimes	21%	24%	14%	48%	53%	50%	56%	36%
Not usual	79%	76%	86%	38%	40%	50%	34%	64%

Table-5.22 Washing Hands after Visiting Toilets

	Mutzing	Finschhafen	Oro Bay	Bereina	Kwikila	Kupiano	Daru	Popondetta
Formal Residents								
Always	25%	24%	N/A	61%	79%	34%	31%	26%
Sometimes	67%	76%	N/A	36%	21%	66%	69%	72%
Not usual	7%	0%	N/A	3%	0%	0%	0%	1%
Informal residents/villagers								
Always	7%	28%	4%	17%	40%	3%	24%	0%
Sometimes	86%	72%	88%	59%	53%	93%	73%	93%
Not usual	7%	0%	8%	24%	7%	5%	2%	7%

Washing hands after visiting toilets is more customary than boiling drinking water. However, according to information gained from a workshop at Mutzing, people understand the importance of washing hands but they do not necessarily practice it. It is explained that there are no facilities available to wash hands near toilets and as villagers need to carry water from wells and/or rivers, washing hands is difficult to practice. Since lifestyle customs of informal residents/villagers at other sites is similar to Mutzing, it is considered that the results of the questionnaires considerably reflect hope rather than reality.

In a survey involving questionnaires, questions regarding whether villagers at the Study Areas think diarrhoea is a preventable disease were conducted. While most residents consider it preventable, informal residents at some sites do not. As to education regarding health and sanitation, the survey shows that informal residents have less experience than formal residents. This conveys that the educational opportunities for these issues are necessary, especially for informal residents/villagers.

Table-5.23 Experiences Health and Sanitation Education

Mutzing	Finschhafen	Oro Bay	Bereina	Kwikila	Kupiano	Daru	Popondetta
Formal Residents							
74%	71%	N/A	58%	55%	56%	56%	78%
Informal Residents / Villagers							
71%	44%	48%	32%	20%	43%	46%	21%

2) Sanitation Facilities

At the surveyed sites, formal residents have flush toilets and/or private pit latrines, and households with no toilets represent 8% at most sites. Daru is an exceptionally flat coral island, where the groundwater level is high, so pit latrines cannot be constructed. Thus the main form of toilet is a bucket toilet.

As to informal residents, there are some sites where more than 90% of households do not use toilets such as Oro Bay, Bereina, Kupiano. On the other hand, there are other sites where almost all households have toilets such as Mutzing, Popondetta. Although reasons for the extreme difference among the sites is not clear, there is a datum that households without a toilet comprise 14.1% countrywide. Thus, it is a serious situation that more than 90% of households do not use toilets. In PNG, where there are continual outbreaks of water-borne diseases like typhus, it is important to spread sanitary facilities in order to minimize the chances of such outbreaks occurring.

Table-5.24 Sanitation Facilities

Private Flush Toilet	9.1%
Shared Flush Toilet	2.5%
Traditional Pit Latrine	69.1%
Improved Pit Latrine	1.8%
Bucket Toilet	0.5%
Closet Over Sea	2.8%
No Toilet	14.1%

(Source: Papua New Guinea Demographic and Health Survey 1996)

CHAPTER 6 GROUNDWATER DEVELOPMENT AND EVALUATION

6.1 Test Drilling

Test drillings were carried out to evaluate the groundwater potential, which were predicted by the geophysical surveys. The Study Areas were located in 8 areas of 4 Provinces. Most were accessible by road except Daru Island and Finschhafen.

1) The specifications for test borehole construction and necessary groundwater development study

The specifications for test borehole construction in the Study Areas were considered as follows. At the same time, necessary groundwater development study including the well development, pumping test, water level measurements, geological sampling, sieve analysis, well logging, water quality analysis, reporting, and technology transfer on supervision of drilling work was carried out at the job sites.

Table-6.1 The Specifications for Test Borehole Construction in the Study Areas

1.Borehole Specifications	Type of Boreholes	Type (PVC Casing & Screen)
	Gravel Packing	To be done with proper materials
	Drilling Diameter and Depth	1) ϕ 12-1/4" for Surface Casing (ϕ 10") x 6 m 2) ϕ 9-5/8" for Casing (ϕ 6") x 80 m 3) ϕ 9-5/8" for Screen (ϕ 6") x 20 m Averaged length of drilling per borehole: 100m.
	Total Depth (m)	Averaged length 100 m/borehole
	Casing Diameter/ Length/Material	ϕ 6" x 80m (80% of Total Depth)
	Screen Diameter/ Length/Material	ϕ 6" x 20m (20% of Total Depth)
2.Well Development		More than 6 hours until water becomes clear
3.Pumping Test	Step Drawdown Test	5 Steps Minimum 4 to 6 hours at each step
	Constant Drawdown Test	24 hours
	Recovery Test	12 hours
3.Measurements to be made during Water Level Measurements		pH, temperature, conductivity
4.Geological Sampling		To be sampled at every 2 m
5.Sieve Analysis		To be done for main aquifer(s)
6.Well Logging		To be done for each borehole: 1) Gamma 2) Resistively for Short and Long Normal and 3) Self Potential

7.Water Quality Analysis	General	To be done for each borehole and the analysis shall be done at the officially licensed laboratory
	Standard	According to WHO's Drinking Water Standard
	Items to be analysed	*35 items as per the attached list*
8.Reporting		Daily Reporting: To be done to the Client's supervisor at the drilling site. Completion Report (including drilling report and pumping test report): To be submitted to the Client within two (2) weeks after the completion of the drilling & construction.
9.Technology Transfer on Supervision of Drilling Work		- Boring - Well logging (geological sampling) - Screen and casing installation - Gravel packing - Well cleaning (Well development) - Pumping test - Water quality analysis - Water level measurements

Table-6.2 Water Quality Analysis Items for Test Borehole

Water Quality Analysis Items		
1. Fe	16. Cl	31. Alkalinity
2. Mn	17. Ca	32.Hardness
3. As	18. Na	33.CN
4. B	19. K	34. TOC
5. F	20. Mg	35. TDS
6. Cd	21.NO_2-N	
7. Cr	22. NO_3-N	
8. Zn	23. NH_4-N	
9. Al	24.T-N	
10. Ba	25.T-P	
11. Cu	26.HCO3	
12. Pb	27. CO3	
13. Hg	28. SO_4	
14. Sb	29. Acidity	
15. Se	30. Total Acidity	

2) Selection of Drilling Contractors

After comparing the quotations for the test drilling submitted by drilling contractors stationed in PNG, three (3) drilling companies were selected as follows.

a) The four areas of Bereina, Kwikila, Kupiano and Daru drilled by Central Drillers Ltd having office in Port Moresby, National Capital District

b) The three areas of Popondeatta, Oro Bay and Finshhafen drilled by New Britain Drillers having office in Kokopo, Eastern New Britain Island

c) The one area of Mutzing drilled by Paradise Drillers having office in Lae, Morobe Province

These companies had to have the advantage of mobility to each site. Since there was no geoelectric logging company in PNG, an Australian firm and another third world country firm were considered and in the end a Thailand company, Siam Tone was selected based on cost performance.

The field surveys for the selection of the drilling sites were affected by the unusually prolonged rainy period. The survey in Kupiano was delayed for more than a month because a bridge to the site was washed away by a flood. The drilling started for Bereina in the late June 2000 by Central Drillers, Port Moresby.

The three drilling contractors completed their drilling works. However there were large differences in their outfit, such as capacity of drilling machine, supporting machine and equipment for drilling, drilling method and technique between each company.

(1) Potential aquifers were not developed properly due to lack of skills and techniques in drilling fluids control. Generally materials like bentonite and/or polymer were used to protect drilling bore from collapsing during mud circulation drilling. However in PNG the drillers are familiar with polymer but not with bentonite. Polymer was not effective enough to stop the collapse of loose sands and cobbles from the inside of the water well. Although bentonite was used under the supervisor's suggestion, it did not work well.

(2) Moreover, the collapse of the water well cannot be prevented by the injection of bentonite after the collapse started. Therefore, bentonite must be used from the beginning in the areas which consist of sand, gravel and cobbles. The drilling was successful in Popondetta because New Britain Drillers had the ability to manage such a situation. Meanwhile, the other two drilling Contractors are yet to reach such capabilities.

(3) Where the boreholes were successfully drilled, geophysical well loggings of potential aquifers could not be completed as expected due to caving in and boreholes, which were not vertically straight after drilling. On the other hand, the result of some of geophysical well loggings were not satisfactory enough to identify aquifer depth due to technical problems encountered with the logging probe during well logging. Such a problem may have occurred

during transit of the logging equipment to the various sites.

6.2 Results of Test Drilling

In accordance to the request of the PNG Government, a Groundwater Development Study was conducted for Water Supply Systems with the intention to avoid the failure of water supply systems as experienced during the last drought (1997-98) brought about by the last El Niño. The Groundwater development included geophysical survey, hydrogeological study and test drilling which were carried out from April 2000 to September 2000, and the results of test drillings at the Study Areas are shown in Table-6.3 .

Table-6.3 Results of Test Drilling

Study Area	Drilled Depth (m)	Completion Depth (m)	Static Water Level (m)	Discharge m^3/d	Specific Capacity $m^3/d/m$	Groundwater Potential $m^3/d/w$ (Allowable Drawdown 10m)
Popondetta No.1	126	120	7.3	536	85.9	Successful
Popondetta No.2	106	100	6.9	544	87.6	850 $m^3/d/w$
Daru No.1	80	64	2.6	353	250	Saline Water Problem
Daru No.2	42	35	2.1	320	400	3,250 $m^3/d/w$
Bereina	36	28	5.4	290	75.1	Successful 751 $m^3/d/w$
Kupiano	62	36	1.4	53	7.7	Small Discharge 77 $m^3/d/w$
Kwikila No.1	100	74	2.3	88	15.7	Successful
Kwikila No.2	44	31	3.7	216	47.0	470 $m^3/d/w$
Finschhafen No.1	40	13	4.0	43	Small	Successful
Finschhafen No2	37	36	5.9	540	540	5,400 $m^3/d/w$
Mutzing No.1	82	62	2.0	864	Clashed	Successful
Mutzing No.2	83	60	2.0	432	864	8,640 $m^3/d/w$
Oro Bay No.1	54	50	7.0	43	Small	Unsuccessful due to loose
Oro Bay No.2	12	Boulders	1.5	864	Abundant	boulders however
Oro Bay No.3	6	Boulders	1.5	864	Abundant	abundant groundwater was confirmed.
Total	910	709				

1) Test boreholes were drilled at each Study Area to confirm the groundwater potential for water supply and in total there were eight (8) sites test drilled. The results of test drilling at seven (7) sites were successful in terms of their use as sources for water supply systems while the test drilling at Oro Bay was unsuccessful. The measured discharge could only cater for a hand pump. Two additional boreholes were tested at Oro Bay but drilling was unsuccessful due to technical problems, as the mud circulation-type drilling machine could not be drill through the loose boulders. There is, however abundant groundwater around Kopure village, as this was encountered between the depths of 10 to 20m.

2) Two boreholes were drilled on Daru Island and a high potential of groundwater was confirmed but salinity of the water is a problem. During the Phase II of the Study from January 2000 to July 2001 the Study Team monitored BH Daru #2 (total depth of 42m, static water level 2m) and observed freshwater with a thickness of 20 m and it's suitable quality for drinking under stable conditions. The borehole therefore can be utilized as a supplementary water source for Daru at pumping rate of approximately 325 m^3/day subject to the test pumping for water quality changes within allowable drawdown of 1m to 2m.

3) The above successful test boreholes at the seven (7) sites can be utilized as a new water source for water supply systems in the future. Bereina, Kwikila and Mutzing were selected for the Pilot Project and test boreholes at these three sites were used as water sources of the new water supply systems. The discharge of test boreholes at Kupiano is not good enough for production well comparing with groundwater potential in the area. Therefore, Kupiano water supply system should be a production well drilled in the future.

4) In Popondetta, where the potential of groundwater had not been identified in the past studies, two successful test drillings revealed there were several aquifers with a high potential of groundwater at depths between 70 and 120 m. Based on these results, it was concluded that these boreholes could be used as production wells with yields at about 850 m^3/day/well. Though these were designed as test boreholes with a diameter of 6 inches that produce about 350 m^3/day/well due to the limitation in submersible pump capacity. Therefore, we recommend drilling new production wells with a diameter of more than 8 inches due to large water demands for Provincial Town of Popondetta.

Table-6.4 Evaluation of Groundwater Potential of the Study Area

(Test Drilling : ◎ Successful, × Unsuccessful)

(Groundwater Potential : ◎ Production ○ Groundwater Potential Confirmed but Need to Saline Water Problem)

Study Area	Test Drilling	Groundwater Potential	Study Results
Popondetta	◎	◎	Abundant groundwater potential (850m^3/day/well) was confirmed, and test boreholes shall be utilized as production boreholes. However, the inner diameter of test boreholes is ϕ 143mm, therefore groundwater discharge is 350 m^3/day due to pump capacity. When we need discharge of 850 m^3/day we should drill the production borehole with ϕ 200mm of inner diameter.
Daru	◎	○	Abundant groundwater potential (3,250 m^3/day/well) was confirmed, however chloride content of 700mg/l was reported by the water quality analysis. Through the follow up study in 2001 groundwater quality was measured by depths. Freshwater was found in the depths of more than 30m due to flowting water based on the concept that the Ghyben-Herzberg (H=42h). We should consider the saline water intrusion in future, however we may get water at about 325 m^3/day/well with 1m drawdown due to very high potential. We recommend to pumping test with careful water quality changes at the site.
Bereina	◎	◎	Abundant groundwater potential (751 m^3/day/well) was confirmed, and the test borehole was used for production of Pilot Project. There is no problem of water quality.
Kupiano	◎	○	The test hole was drilled out of town about 3 km away due to the saline water and contamination. Groundwater was found with small discharge of 77 m^3/day/well, and therefore we could not use it as production well.
Kwikila	◎	◎	Abundant groundwater potential (470 m^3/day/well) was confirmed, and the test borehole was used for production of Pilot Project.
Finschhafen	◎	◎	Abundant groundwater potential (5,400 m^3/day/well) was confirmed and it is possible to use it as a production well. However, water quality especially for saline intrusion should be considered due to being near the sea coast.
Mutzing	◎	◎	Abundant groundwater potential (8,640 m^3/day/well) was confirmed, and the test borehole was used for production of Pilot Project.
Oro Bay	×	◎	The first test hole was drilled at about 2 km away from the coast to avoid saline water but water discharge was small. The second and third borehole was tested near the village, however it could not be drilled deeper due to loose boulders.

6.3 Groundwater Quality Analysis

Each of the test boreholes had groundwater samples collected from the boreholes after the pumping test. National Agricultural Research Institute (NARI) in Port Moresby and National Analysis Laboratory (NAL) in Lae did the water quality test under the responsibility of well drilling contractors. Table-6.5 (1) and 6.5 (2) show the results of groundwater quality at the eight test drilling sites namely as Popondetta, Daru, Bereina, Kupiano, Kwikila, Finschhafen, Mutzing and Oro Bay. The Guidelines for drinking water quality, second edition, WHO 1993 and Public Health (Drinking Water) Regulation, 1984 as the PNG drinking water standard were considered and will be released in July 2001.

1) With regard to the water qualities of the test boreholes from which the water qualities were analysed for drinking water purposes and for the characteristics of groundwater. As far as the 19 elements, which are described in the PNG Water Standard, are concerned, all of the parameters except for iron, chloride and TDS are satisfied for all of the Study Areas.

   The concentrations of iron do not meet the standard value (0.3 mg/l) in two sites: Popondetta #2, (0.54 mg/l) and Oro Bay, (0.71 mg/l). For the other components, the values of chloride and total dissolved solids (TDS) did not meet the standard value of 250 mg/l and 1000 mg/l, respectively at Daru #1, (700 mg/l and 1940 mg/l) and Daru #2, (700 mg/l and 2402 mg/l). In Popondetta, the tested water had a high concentration of Aluminium, which could have originated from the drilling mud.

2) To evaluate the characteristics of groundwater in the Study Areas the results are also shown in tri-linear diagrams in Fig.-6.1.

3) Analyses of The Physical Parameter of Groundwater.
   The 6 physical parameters of water temperature, pH, Electric Conductivity (EC), turbidity and colour and odours & tastes were analysed as general characteristics of groundwater at the drilling sites by the drilling supervisor of the Study Team and PNGWB

Table-6.5 Water Qualities of Drilled Boreholes in the Eight Sites

Site	No.	Water source	Date of Year 2000	Weather	Air Temp °C	W. temp*1 °C	pH	EC mS/m	Turb*2	Colour	Odour & taste	Cd mg/l	Hg mg/l	Se mg/l	Pb mg/l	As mg/l	Cr mg/l	F mg/l	Ba mg/l	Zn mg/l
												Elements								
Detection limit												0.001	0.001	0.001	0.001	0.001	0.001	0.1	0.001	0.01
1.Popondetta	#1	Borehole	30-Aug	Fine	32.0	27.8	7.6	25.7	0	0	Acceptable	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.1	0.018	<0.01
	#2	Borehole	25-Aug	Fine	31.6	28.7	7.1	27.1	0	0	Acceptable	<0.001	<0.001	<0.001	0.001	0.001	<0.001	0.1	0.022	<0.01
2.Daru	#1	Borehole	29-Sep	Fine	32.5	28.8	8.1	330.0	0	0	Salty	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.3	0.048	0.01
	#2	Borehole	5-Oct	Cloudy	35.5	29.5	8.3	340.0	0	0	Salty	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	1.0	0.044	0.01
3.Bereina	#1	Borehole	27-Jul	Fine	33.3	29.0	8.5	58.2	0	0	Acceptable	<0.001	0.001	<0.001	<0.001	0.004	<0.001	0.6	0.010	<0.01
4.Kupiano	#1	Borehole	27-Jul	Cloudy	32.4	29.4	7.7	110.0	0	0	Acceptable	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.9	0.024	0.01
5.Kwikila	#1	Borehole	6-Nov	Fine	31.5	28.8	7.4	101.5	0	0	Acceptable	<0.001	<0.001	<0.001	<0.001	0.001	<0.001	0.2	0.020	0.01
6.Finschhafen	#2	Borehole	10-Oct	Rain	32.2	28.5	7.9	31.2	0	0	Acceptable	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.6	0.004	0.01
7.Mutzing	#1	Borehole	8-Oct	Fine	33.5	28.2	7.4	25.5	0	1	Acceptable	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.1	0.003	<0.01
8.Oro Bay	#1	Borehole	3-Sep	Fine	31.8	28.7	6.9	24.6	1	0	Acceptable	<0.001	<0.001	<0.001	0.001	<0.001	0.002	0.1	0.016	<0.01
Guidelines/Standards for Drinking Water Quality																				
WHO (1993)						-	-	-	5NTU	15TCU	Acceptable	0.003	0.001	0.01	0.01	0.01	0.05	1.5	0.7	3
PNG (1984)						-	6.5-9.2	-	25 units*5	50 units*6	Unobjectionable	0.01	0.001	0.01	0.1	0.05	-	1.5	-	15
Japan (1993)						-	5.8-8.6	-	2	5	Acceptable	0.01	0.0005	0.01	0.05	0.01	0.05	0.8	-	1

Physical Parameters: W. temp, pH, EC, Turb, Colour, Odour & taste. Elements: Cd, Hg, Se, Pb, As, Cr, F, Ba, Zn.

NB

*1: Water temperature, *2: Turbidity, *3: Total coliform, *4: Standard plate count, *5: Jacksons turbidity units, *6: on the Platium-cobalt scale, *7: COD 10mg/L

*8: WHO

All water intended for drinking: E. coli or thermotolerant coliform bacteria must not be detectable in any 100ml

*9: PNG

(i) There shall be no E. coli in any sample of 100 ml.(ii) If E. coli is absent, no sample shall contain more than 3 coliform organisms per 100 ml.

*10: JPN

SPC: shall be less than 100 in any 1ml sample.

Total Coliform: must not be detectable in any sample.

continued

Site	No.	Fe	Cu	Na	Mn	Cl	Ni	Sb	B	Mo	Al	CN	NO_2	NO_3	SO_4	TOC	TDS	Total Coli[*3]	SPC[*4]
		Elements										Compounds & Others						Bacteria	
		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		
		0.01	0.001	1	0.001	1	0.001	0.001	0.1	0.01	0.01	0.01	0.01	1	1	0.1	1	1	1
1.Popondetta	#1	<0.01	0.005	16	0.010	6	<0.001	<0.001	0.1	<0.01	0.57	<0.01	<0.01	<1	11	1.7	200	0	0
	#2	0.54	0.006	5	0.002	4	<0.001	<0.001	0.1	<0.01	1.60	<0.01	<0.01	<1	10	2.8	230	0	0
2.Daru	#1	<0.01	<0.001	408	0.002	700	<0.001	<0.001	<0.1	<0.01	0.06	<0.01	<0.01	1	11	5	1940	0	0
	#2	<0.01	<0.001	399	0.011	700	<0.001	<0.001	<0.1	<0.01	0.03	<0.01	<0.01	1	10	5	2402	0	0
3.Bereina	#1	0.20	<0.001	66	0.045	20	<0.001	<0.001	0.1	<0.01	0.01	<0.01	0.37	1	7	1.9	437	0	0
4.Kupiano	#1	0.01	0.001	88	0.004	30	<0.001	<0.001	0.1	<0.01	0.04	<0.01	0.03	<1	4	3	745	0	0
5.Kwikila	#1	<0.01	<0.001	66	0.184	11	<0.001	<0.001	<0.1	<0.01	<0.01	0.01	0.01	<1	10	1.4	440	0	0
6.Finschhafen	#2	0.08	0.005	6	0.001	2	<0.001	<0.001	<0.1	<0.01	0.65	<0.01	<0.01	<1	10	3.2	260	0	0
7.Mutzing	#1	<0.01	0.007	16	0.030	4	<0.001	<0.001	<0.1	<0.01	0.57	<0.01	0.04	2	16	3.9	190	0	0
8.Oro Bay	#1	0.71	0.008	6	0.020	2	<0.001	<0.001	<0.1	<0.01	0.69	<0.01	0.02	<1	3	4.8	110	0	0
Guidelines/Standards for Drinking Water Quality																			
WHO (1993)		0.3	2	200	0.5	250	0.02	0.005	0.5	0.07	0.2	0.07	3	50	250	–	1000	*8	
PNG (1984)		1	1.5	–	0.5	1000	–	–	–	–	–	0.05	–	45	–	–	–	*9	
Japan (1993)		0.3	1	200	0.05	200	0.01	0.002	0.2	0.07	0.2	0.01	10		–	*7	500	*10	

References

1: WHO (1993), "Guidelines for drinking water quality, second edition, volume 1"

2: http://www.who.int/ (April 2001)

3: "Public Health (Drinking Water) Regulation 1984, No. 8 of 1984"

4: Nihon Kankyo Kanri Gakkai (1996), "Guidebook for new water standards"

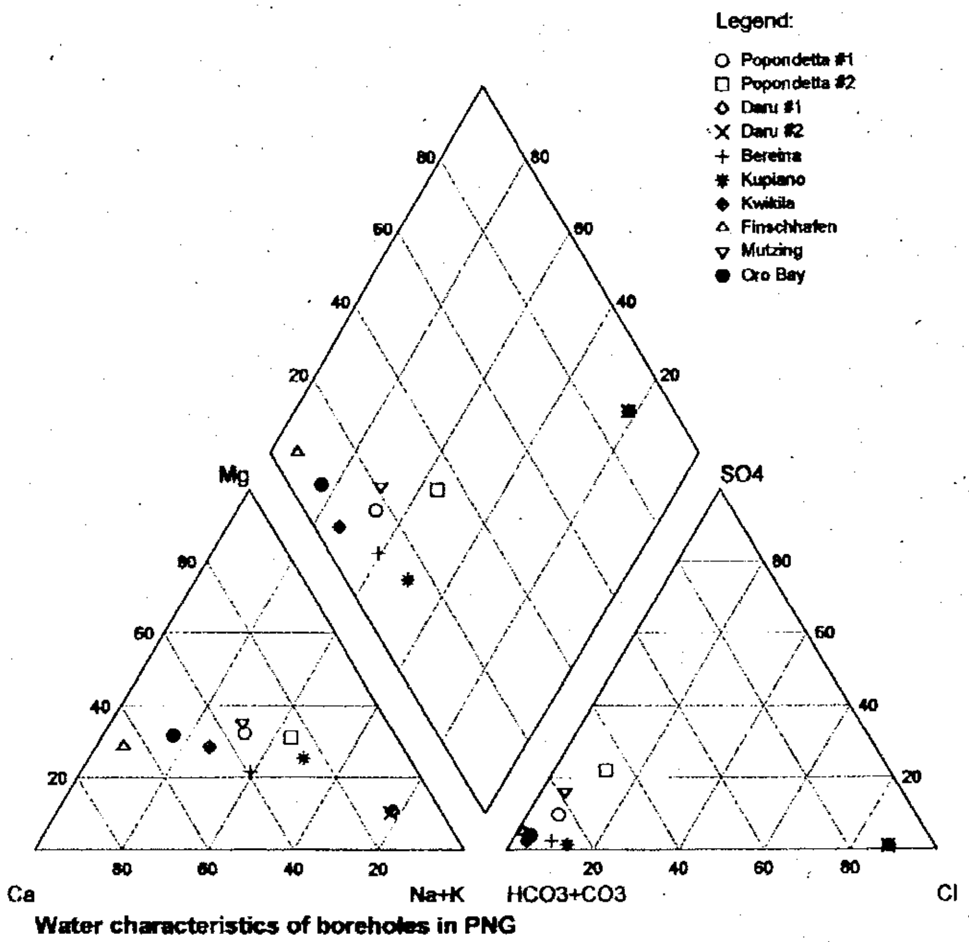


Fig.-6.1 Groundwater Characteristics of Test Boreholes in Study Area

Table-6.6 Water Qualities of Drilled Boreholes in the Eight Sites (parameters relating to geological characteristics)

Site	No.	Water Source	Date of Year	Physical Parameters						Parameters representing Geological Characteristics								Hardness & Others					Non-metals	
				W. temp[*1]	pH	EC	Turb[*2]	Colour	Odour & taste	Na	K	Ca	Cl	Mg	HCO_3	CO_3	SO_4	Acid	T-Alka.	T-Hard	TDS	L I[*3]	NH_4	T-P
			2000	°C		mS/m				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
1.Popondetta	#1	Borehole	30-Aug	27.8	7.6	25.7	0	0	acceptable	16	5.3	18	6	10	120	<1	11	5.6	120	87	200	-0.3	<0.01	0.21
	#2	Borehole	25-Aug	28.7	7.1	27.1	0	0	acceptable	5	5.2	4	4	3	38	<1	10	7.6	38	20	230	-2.0	0.01	0.63
2.Daru	#1	Borehole	29-Sep	28.8	8.1	330.0	0	0	salty	408	12.9	53	700	30	141	1.7	11	<5.0	143	257	1940	0.6	0.47	<0.05
	#2	Borehole	5-Oct	29.5	8.3	340.0	0	0	salty	399	10.2	55	700	28	142	2.6	10	<5.0	145	252	2402	0.8	0.52	<0.05
3.Bereina	#1	Borehole	27-Jul	29.0	8.5	58.2	0	0	acceptable	66	4.8	60	20	20	331	1.4	7	48.0	333	231	437	1.4	0.09	0.31
4.Kupiano	#1	Borehole	27-Jul	29.4	7.7	110.0	0	0	acceptable	88	1.4	39	30	24	329	2.1	4	<5.0	331	197	1	0.5	<0.01	<0.05
5.Kwikila	#1	Borehole	6-Nov	28.8	7.4	101.5	0	0	acceptable	66	0.4	100	11	38	510	1.3	10	48.0	511	406	440	0.7	0.08	0.17
6.Finschhafen	#2	Borehole	10-Oct	28.5	7.9	31.2	0	0	acceptable	6	1.6	64	2	17	240	<1	10	17.0	240	228	260	0.8	0.01	<0.05
	#1	Dry																						
7.Mutzing	#1	Borehole	8-Oct	28.2	7.4	25.5	0	1	acceptable	16	0.6	16	4	10	100	<1	16	7.2	100	81	190	-0.7	0.01	0.08
8.Oro Bay	#1	Borehole	3-Sep	28.7	6.9	24.6	1	0	acceptable	6	1.3	19	2	7	90	<1	3	5.6	90	76	110	-1.1	<0.01	0.12

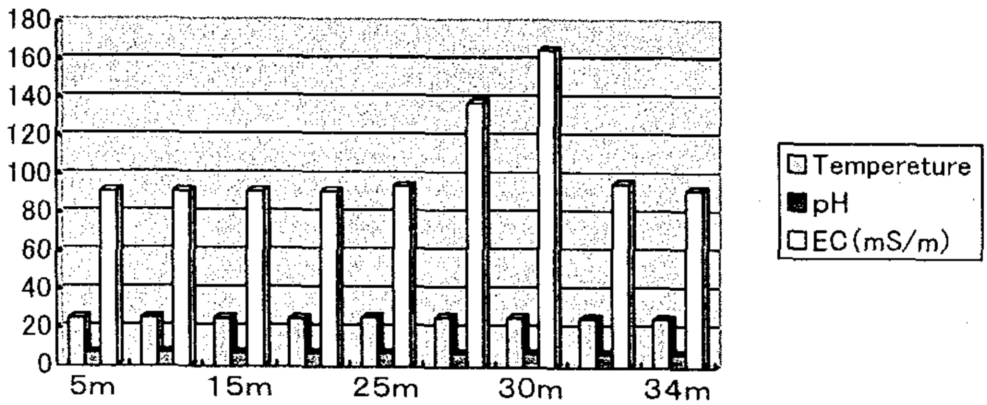
NB
1: Water temperature
2: Turbidity
3: Langelier index

At the same time, the weather and the air temperature were also recorded on the sampling day. All of the 7 sites recorded showed that the groundwater is of suitable quality for water supply except Daru, due to saline conditions affected by seawater. Daru showed a high level of electric conductivity (>330 mS/m, pH 8.1 to 8.3) in 2000. However, the Study Team monitored the Daru borehole (BH DR #02) from January to June 2001, and found the electric conductivity to range from 91.7 to 165.7 mS/m and pH value of 7.2, indicating suitability for drinking water supply.

The completed borehole depth was 35 m, and therefore the upper parts of groundwater are suitable for supplementary water source to Daru Island. The results of water quality monitoring are shown in Table-6.7, as follows.

Table-6.7 Test Borehole Daru No.2 Water Quality Monitoring (18th June 2001)
Borehole Depth: 42.8m, Statistic Water Level: 1.8m

1.Depth (m)	5m	10m	15m	20m	25m	27m	30m	32m	34m
2.Water Temperature (C)	25.3	25.5	25.4	25.3	25.7	25.9	25.9	25.7	25.5
3. pH	7.24	7.23	7.25	7.24	7.23	7.17	7.20	7.25	7.25
4.EC (S/m)	91.7	91.7	91.6	91.7	94.4	138.1	165.7	95.9	92.6



4) Sampling, Storage and Analysis of Water Samples

Five (5) 600ml bottles of water (3 in total) were sampled in each site. Among them, nitric acid was added to one bottle so that it contained about 1% of HNO_3 in order to stabilise metallic ions. The other bottles were kept cool with the temperature of about 0°C in a cooler box until they were handed in to NARI or NAL for analyses. The addition of nitric acid to water sample is not common practise in PNG. The difference between samples with or without nitric acid was tested for the iron concentration as tabulated below, Table-6.8.

Table-6.8 Water Quality Analysis of Iron (Fe) Concentration with or Without Acid, 2000

Site Name	Type of Water	Fe (With HNO_3) 1) 1st Analysis 2) 2nd Analysis after 1day to 3 weeks	Fe (Without HNO_3) 3) 1st Analysis 4) 2nd Analysis after 1day to 3 weeks
1. Daru (Binaturi)	River Water	1) 0.54 mg/l 2) 0.55 mg/l	3) 0.54 mg/l 4) 0.28 mg/l
2. Daru (Island)	Groundwater	1) 0.77 mg/l 2) 0.78 mg/l	3) 0.77 mg/l 4) 0.29 mg/l
3. Bereina	River Water	1) 1.44 mg/l 2) 1.44 mg/l	3) 1.44 mg/l 4) 0.25 mg/l
4. Oro Bay	River Water	1) 0.34 mg/l 2) 0.35 mg/l	3) 0.34 mg/l 4) 0.29 mg/l
5. Oro Bay	Groundwater	1) 0.90 mg/l 2) 0.90 mg/l	3) 0.90 mg/l 4) 0.26 mg/l

With regard to the iron concentration there is the marked difference between the 1st analysis and 2nd analysis of samples with and without acid HNO_3 . On the other hand, Figure-6.2 in the next page show the cases of various concentration, namely Fe, As, Mn, B, Ca, K and Mg. We only considered the difference in the metals of Fe, Mn and As for samples with and without nitric acid.

6.4 Water Source of Water Supply System

The test boreholes namely Bereina, Kwikila and Mutzing were evaluated hydrogeologically for water source of water supply system as summarised in Table-6.9.

Table-6.9 Hydrogeological Evaluation of Water Source at 3 Sites

1. Site Name	1. Bereina	2. Kwikila	3. Mutzing
2. Total Depth	36 m	44 m	83m
3. Well Depth	28 m	31 m	60m
4. Static Water Level	5.4 m	3.7 m	2.0 m
5. Pumping Water Level	9.2 m	8.3 m	2.5 m
6. Drawdown	3.8 m	4.6 m	0.5 m
7. Discharge	290 m^3/d	216 m^3/d	432 m^3/d
8. Specific Capacity	76.3m^3/d/m	47.0 m^3/d/m	864 m^3/d/m
9. Groundwater Potential (Allowable Drawdown of 10m)	763 m^3/d	470 m^3/d	8,640 m^3/d

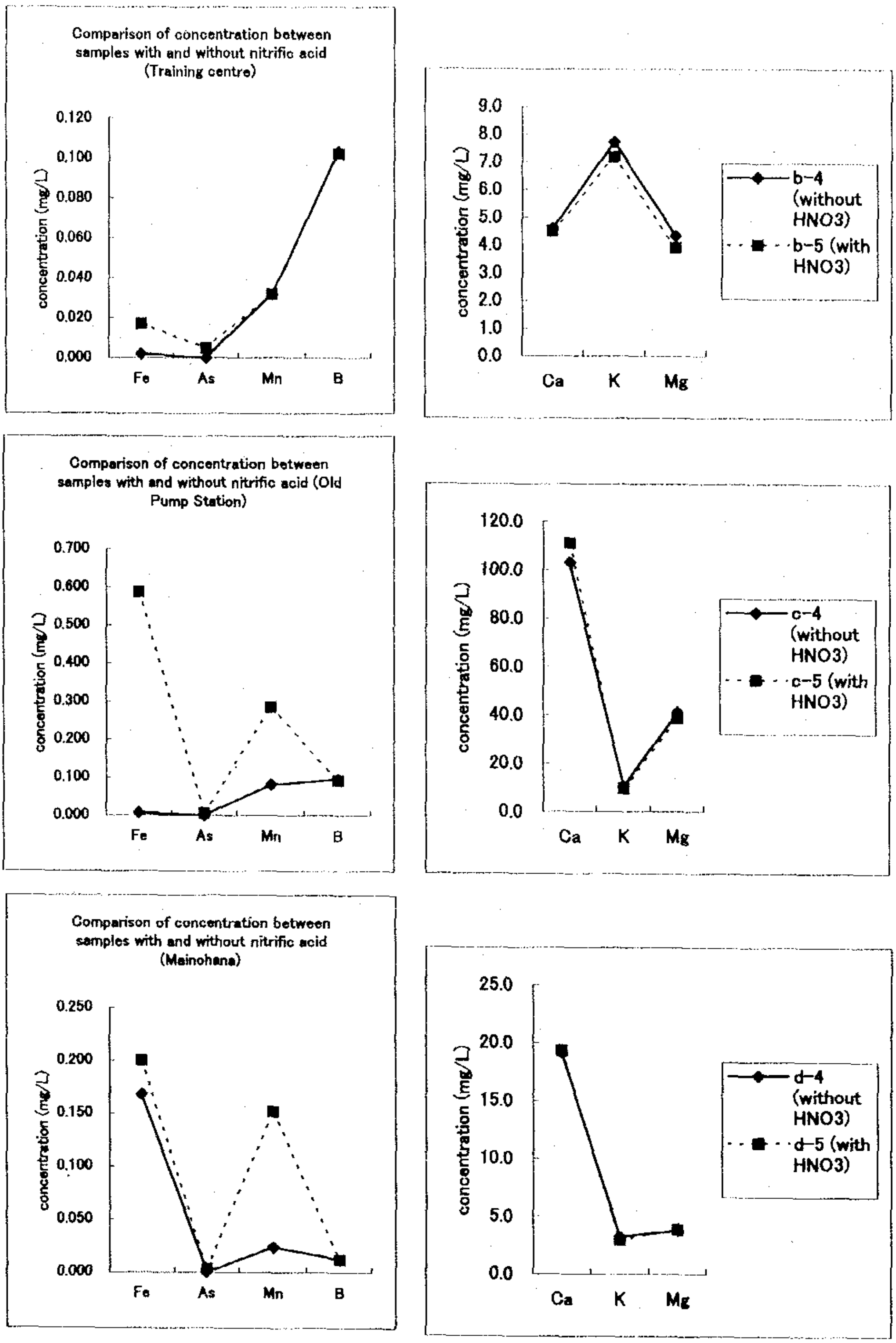


Fig.-6.2 Comparison of Concentration between Samples With and Without Nitrific Acid

1) The test boreholes of the three sites were confirmed to have good groundwater potential both in quality and quantity. These groundwater potentials were calculated as the quantity of water taken from a test borehole assuming that the boreholes are continuously pumped until the drawdown (pumping water level – static water level) became 10m. This drawdown of 10m was determined based on the results of the continuous discharge test of the boreholes pumping test, the structure of boreholes, and the static water level.

2) Table-6.10 and 6.11 show the borehole data together with the design of submersible motor pump and installation depth at the three sites. The pump capacity of the sites for water supply was decided based on the water demands and groundwater potential. For example at Kwikila, the pump capacity of 200 l/min was decided based on the water demands of 253m^3/d and groundwater potential of more than 470 m^3/d/w. And pump installation depth is 20m avoiding the depth of screen.

Table-6.10 Borehole Data at 3 Sites, Bereina, Kwikila and Mutzing

Site Name	Borehole Design (Dia.) x (Depth)	Screen Depth	Water Level	Results of Pump Test
1. Bereina	150(143) mm x 28m	11.0m-17.0m 23.0m-26.0m	SWL: 5.4m PWL: 9.2m	Q: 290 m^3/day, s: 3.8m SC: 76.3 m^3/d/m
2. Kwikila (No.2)	150(143) mm x 31m	5.1m-11.1m 23.1m-29.1m	SWL: 3.7m PWL: 8.3m	Q: 261 m^3/day, s: 4.6m SC: 47.0 m^3/d/m
3. Mutzing	150(143) mm x 82m	24.0m-36.0m 47.0m-59.0m	SWL: 2.0m PWL: 2.5m	Q: 432 m^3/day, s: 0.5m SC: 864.0 m^3/d/m

Table-6.11 Design of Submersible Motor Pump and Installation Depth at the above 3 Sites

Site Name	Pump Capacity	Designed Drawdown	Water Demand	Operational Water Level	Pump Installation Depth
1. Bereina	300 l/min x 45m	Q: 432 m^3/day ΔS: 5.75m	124 m^3/d (2005)	SWL: 5.4m PWL: 7.0m	20m
2. Kwikila	200 l/min x 65m	Q: 288 m^3/day ΔS: 6.13m	253 m^3/d (2005)	SWL: 3.7m PWL: 9.1m	20m
3.Mutzing	250 l/min x 40m	Q: 360 m^3/day ΔS: 0.30m	256 m^3/d (2015)	SWL: 2.0m PWL: 2.3m	18m

SWL: Static Water Level, PWL: Pumping Water Level

6.5 Improvement of Water Supply Conditions in Daru and Binaturi

1) Daru Water Supply Improvement

There will be installation of Water Vending Units (WVU) in Daru where the PNGWB already has an office. This WVU concept aims at improving water supply conditions for low-income groups in the Town where water venders sell the drinking water by bucket to people who do not have house connections or have a disconnected water supply. Among the low-income group residents there is a certain number of households who have been disconnected from water supply because of no payment of water bills owed to the PNGWB. This is the first trial experiment in Provincial Town water supply by PNGWB to relieve the above-mentioned people who are faced with drinking water problems by installing the Water Vending Units. The details of these components and locations in Daru are shown in Table-6.12 and Fig.-6.3.

Table-6.12 Water Vending Unit in Daru

Daru Water Supply Improvement	Water Vender unit (Public Faucet): 2 units

2) Binaturi River Basin Water Supply and Environmental Survey

a. Binaturi River Basin Water Supply

The Binaturi River Basin Water Supply is aimed at improving their water supply conditions with villagers' participation. The villagers are encouraged to construct their own water supply facilities namely, rain water collection tanks, hand dug wells with hand pumps and hand augered boreholes with hand pumps in their respective village working together with community organizers arranged by the Study Team for community development. The Study Team supplies the necessary equipment and materials for the construction. Supervisors participate also under the management of the Study Team. On the other hand, villagers provide their own labour and locally available basic materials such as sand and wood. The development plan and work schedule are prepared through discussions with the villagers, and preparation of their own implementation schedule is done through facilitation by community organizers and supervisors. The plan for operation, management and maintenance of water supply facilities and plan for public awareness building and community participation are included in this component of the Study. The location map is shown in Fig.-6.4.

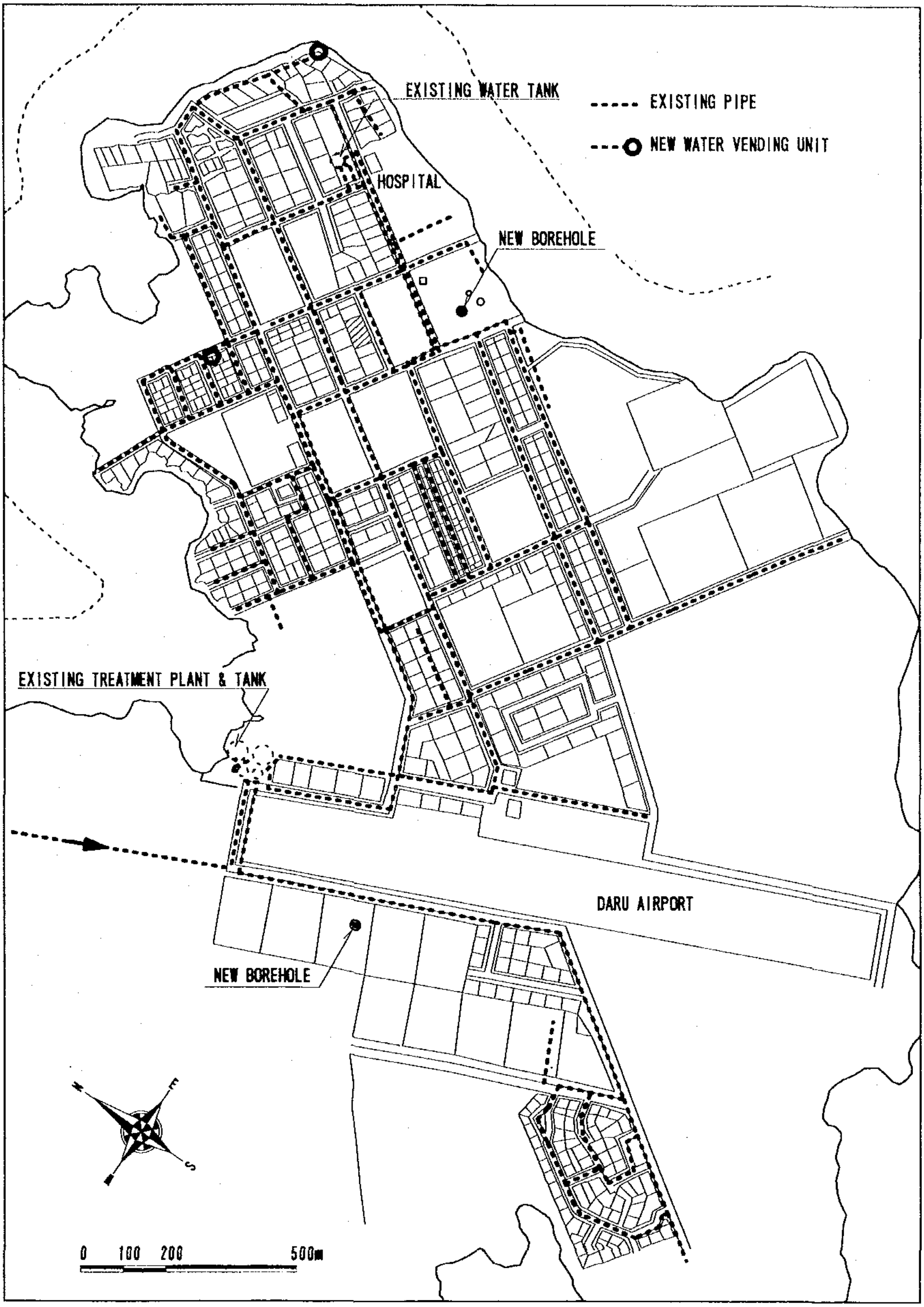


FIG.-6.3 SITE PLAN FOR VENDING FACILITIES (DARU)

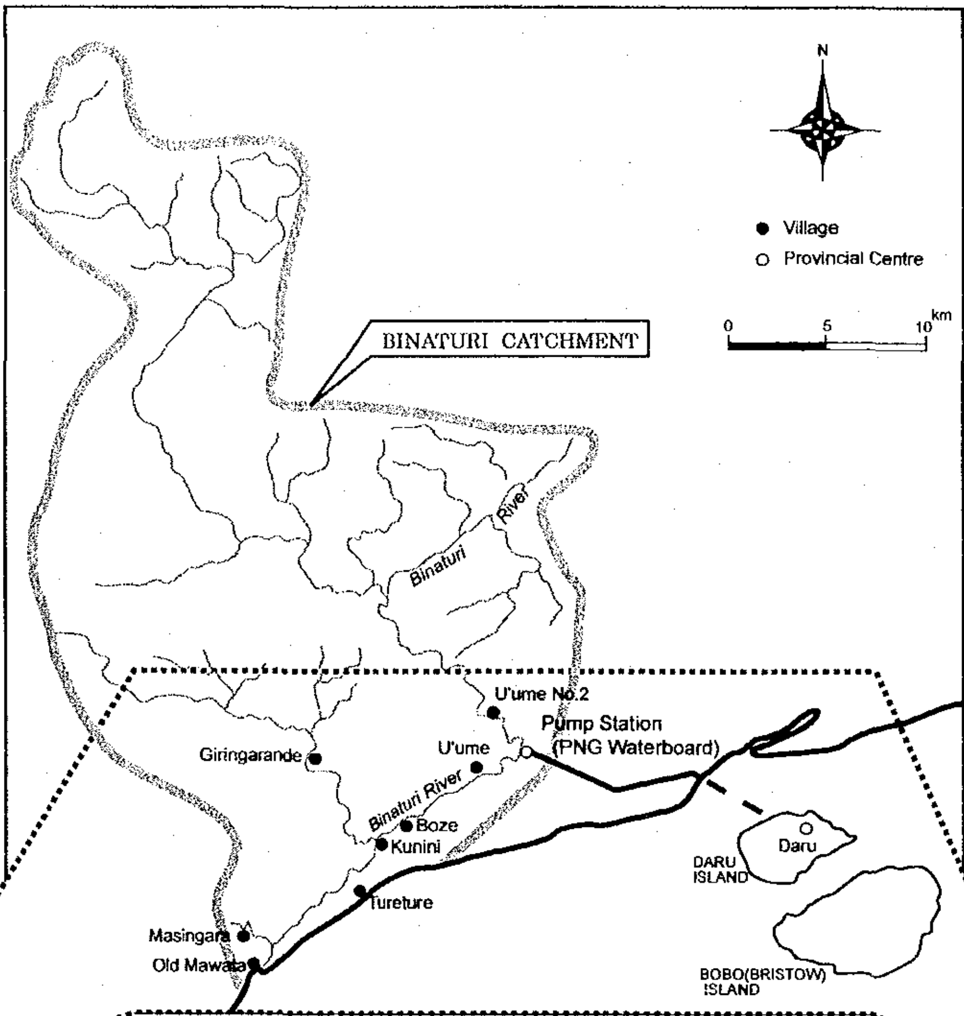


Fig.-6.4(1) Binaturi River Hydrogeological Area

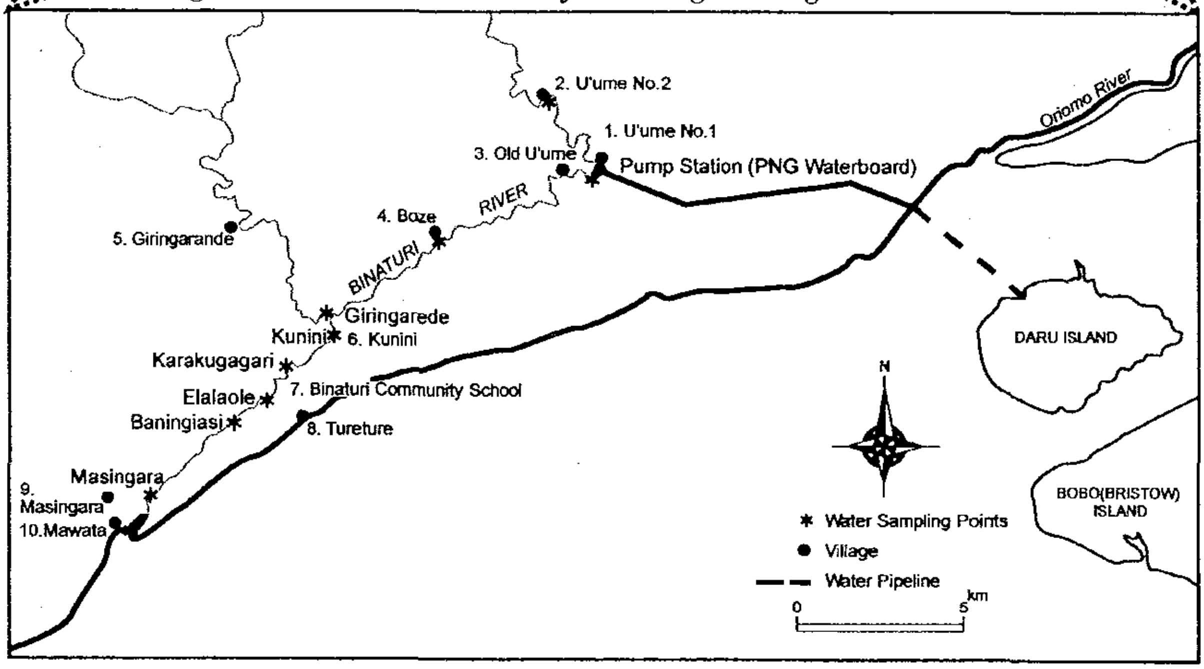


Fig.-6.4(2) Location of Project Villages along the Binaturi River

b. Environmental Survey in Binaturi River

The environmental survey in Binaturi River is to survey and analyse the impact of saline water intrusion on environment conditions of river basin of Binaturi where the intake of pump station for water supply to Daru Town is located. The Environmental Survey in Binaturi River consists of the following two main items and the scope of works are shown as follows;

(1) Hydrological Survey

(2) Environmental Study including Water Quality Analysis

This work was done by the Unisearch, which is a local consultant with academic backgrounds. Unisearch composes of the researchers from the University of Papua New Guinea. The field survey was conducted in December 2000 and the results of the study were presented in a seminar held in June 2001 at Boze village, Binaturi river basin. The followings are the summary of their study results.

(1) Fig.-6.4 shows the Binaturi River Catchment Area together with villages in the area for rural water supply improvement namely U'ume, U'ume No.1, U'ume No.2, Boze, Giringarade, Kunini, Binaturi Community School, Tureture, Mashingle and Mawatta.

(2) From chemical and Electric Conductivity (EC) data, it was established clearly that the salt front was positioned below Kunini village, 10 km upstream of Binaturi river mouth as shown in Fig.-6.5. Dissolved salt levels, as indicated by the EC values, were quite high 4,140 mS/m near the mouth of the river and dropped to the level of almost pure freshwater at 60.2 mS/m in Kunini village.

(3) The river water at Kunini had a tinge of saltiness (EC= more than 100 mS/m) during high tide and so water collection for drinking purposes was postponed until low tide. Fig.-6.5 shows the difference of EC between high tide and low tide. The EC values at Boze village remained close to 30 mS/m for both high and low tides.

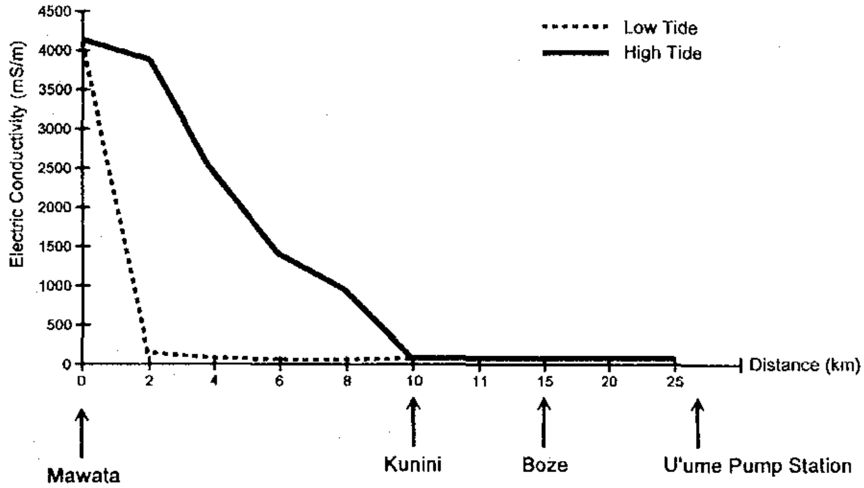
(4) The correlation between the difference of vegetation types and salinity of the water would give an indication of the nature of saline water intrusion into fresh water condition along the river system. Kunini is the present boundary of salinity influence to the fresh water condition, and the mangrove distribution which is observed there might be the evidence.

(5) Water extraction of 800 to 1,600 m^3/day pumped from Binaturi River does not contribute to salinity migrations. The percentage extraction at the pump station of U'ume in peak period is estimated at 0.2 to 2.0 % of the river discharge.

Table-6.13 Qualities of Bianturi River Water

Point	Depth from the surface	Elements						Others			
		Ca	Cl	F	K	Na	Mg	T-Acidity	T-Alkalinity	Hardness	TDS
		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
1A	to 25cm	405	13500	1.33	494	9540	1310	14.8	115.0	6.41	15074
	to 50cm	499	13900	1.23	565	9460	1650	17.2	116.3	8.04	14210
	to 100cm	529	13900	1.23	599	9340	1770	14.1	113.8	8.61	12095
	to 200cm	552	14000	1.23	626	9260	1960	19.1	113.1	9.45	15618
	to 300cm	510	14500	1.26	638	9220	1950	15.5	114.4	9.30	16087
1B	to 25cm	485	12500	1.40	580	9040	1600	17.5	120.0	7.80	32174
	to 50cm	509	13000	1.40	610	9060	1620	17.0	113.8	7.86	31076
	to 100cm	543	12000	1.45	626	9100	1830	17.5	116.5	12.59	31754
	to 200cm	755	12000	1.45	766	9020	2600	19.0	115.0	17.95	37030
	to 300cm	1070	12500	1.40	934	9000	3710	19.3	114.8	0.07	11364
2A	to 25cm	13	58	0.22	3	12	9	9.0	58.8	0.08	462
	to 50cm	15	40	0.24	3	14	10	7.0	58.8	0.08	460
	to 100cm	16	37	0.27	2	11	10	8.3	57.5	0.08	252
	to 200cm	16	38	0.23	3	21	11	9.5	59.3	0.09	146
	to 300cm	17	35	0.23	3	9	11	9.3	57.5	0.07	266
2B	to 25cm	15	19	0.22	1	11	8	14.8	52.5	0.07	268
	to 50cm	15	17	0.21	1	11	8	10.0	56.3	0.08	262
	to 100cm	16	15	0.21	1	11	9	11.3	56.3	0.07	230
	to 200cm	15	13	0.19	1	10	8	9.5	55.0	0.07	110
	to 300cm	15	11	0.18	1	10	8	9.1	56.3	0.04	122
3	to 25cm	9	10	0.15	1	7	5	13.5	40.3	0.04	188
	to 50cm	10	8	0.13	1	7	5	13.3	39.8	0.04	94
	to 100cm	10	7	0.13	1	7	5	12.5	38.0	0.04	136
	to 200cm	10	6	0.12	1	7	5	12.8	40.0	0.04	274
	to 300cm	10	6	0.13	1	8	5	11.5	38.8	0.04	132
4	to 25cm	13	8	0.14	1	9	6	12.3	48.0	0.06	800
	to 50cm	13	7	0.13	1	9	6	12.0	47.5	0.06	380
	to 100cm	13	7	0.14	1	9	6	12.2	48.8	0.06	236
	to 200cm	14	6	0.13	1	9	6	10.5	47.8	0.06	240
	to 300cm	13	6	0.15	1	9	6	11.6	47.8	0.06	246
5	to 25cm	11	10	0.16	1	9	5	10.0	39.3	0.05	204
	to 50cm	11	9	0.12	1	8	5	10.0	38.3	0.05	166
	to 100cm	11	8	0.14	1	9	5	9.6	38.2	0.05	214
	to 200cm	11	8	0.09	1	8	5	11.3	39.4	0.05	122
	to 300cm	11	7	0.09	1	8	5	10.5	38.0	0.05	200

(A)



(B)

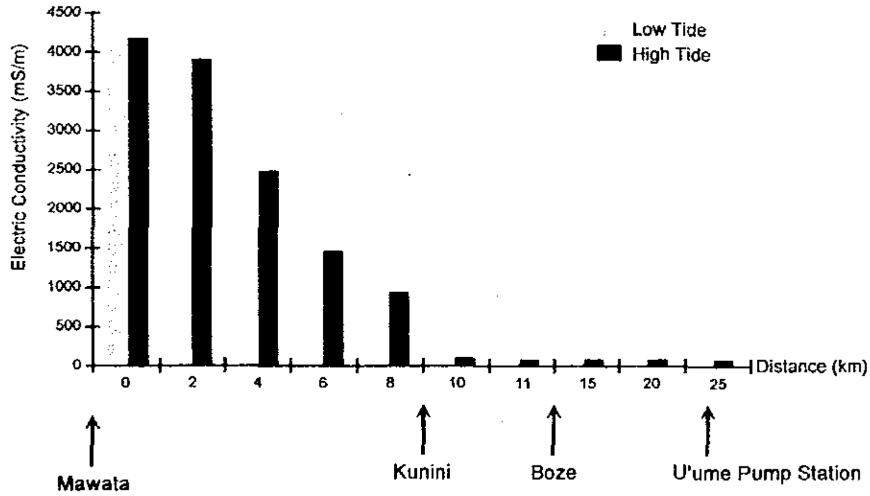


Fig.-6.5 Binaturi River Water Quality Change Influenced by the Tide (December 2001)