5. WATER RESOURCES & WATER QUALITY DATA

Table 2-1: Stream flow measurement

Binaturi River (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

Bangoho 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).**

Table XX: Water Qualities of Existing Water Sources from the Eight Sites in the Study Area

Study Area	Location	Source	Date of year 2000	Weather	Air Temp. ℃	Physical Parameters						Elements								
						W. temp.*1 ℃	pH	EC mS/m	Turb.*2	Color	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
Detection Limit												0.001	0.001	0.001	0.001	0.001	0.001	0.01	0.1	0.1
1.Popondetta	a. Agr.College	Borehole	24,May	Fine	29.0	28.0	7.2	25.9	0	6	Nil	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.70	<0.1	<0.1
	b. Village	Spring	25,May	Rain	26.5	25.8	6.3	14.8	0	2	Nil	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	0.64	<0.1	<0.1
	c. W. B. Intake	River	25,May	Cloudy	25.8	27.3	7.8	24.2	1	6	Algae	<0.001	<0.001	<0.001	<0.001	0.006	<0.001	0.59	<0.1	<0.1
	d. Town	Tap	25,May	Cloudy	24.7	26.8	7.5	24.1	0	8	Chlorine	<0.001	<0.001	<0.001	<0.001	0.006	<0.001	0.56	<0.1	<0.1
2.Daru	a. U'ume Intake	River	5,June	Rain	28.6	25.0	6.3	5.1	0.5	75	Nil	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	0.14	<0.1	<0.1
	b. Treatment Plant	Tap	6,June	Cloudy	27.3	26.8	5.4	9.1	0.5	5	Nil	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	0.05	<0.1	0.3
	c. Town A	S. Well*3	6,June	Rain	27.3	27.9	7.2	82.9	0	0	Nil	<0.001	<0.001	<0.001	<0.001	0.002	0.002	0.56	<0.1	0.1
	d. Town B	S. Well	7,June	Cloudy	27.1	26.4	7.0	14.0	50	100	Soil	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.21	<0.1	0.2
	e. Town C	S. Well	7,June	Cloudy	27.3	27.2	6.3	21.1	0.5	0	Sulfide	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	0.25	<0.1	<0.1
	f. Town D	S. Well	7,June	Cloudy	28.4	26.9	7.2	*184.3*	*15*	*20*	Scented	*<0.001*	*<0.001*	*<0.001*	*0.002*	*0.005*	*0.005*	*0.49*	*0.1*	*<0.1*
3.Bereina	b. Training C.	Borehole	23,May	Clear	28.3	26.7	7.8	53.2	0	0	Nil	<0.001	<0.001	<0.001	<0.001	0.005	<0.001	0.43	<0.1	<0.1
	c. P.S #1	S. Well	23,May	Clear	27.2	27.7	7.6	175.3	5	6	Nil	<0.001	<0.001	<0.001	<0.001	0.005	<0.001	0.43	<0.1	<0.1
	d. Mainchana Intake	River	23,May	Fine	29.3	24.7	8.0	12.4	150>	100>	Nil	<0.001	<0.001	<0.001	0.003	0.003	0.019	0.23	<0.1	0.1
	e. High School	Borehole	23,May	Fine	29.3	27.4	8.2	117.1	0	2	Nil	<0.001	<0.001	<0.001	<0.001	0.006	<0.001	0.77	<0.1	<0.1
	f. Angabang	River	23,May	Clear	28.0	24.8	7.9	12.6	150>	100>	Nil	<0.001	<0.001	<0.001	0.008	0.004	0.023	0.33	0.1	0.1
4.Kupiano	a. Lako R. intake	River	27,June	Fine	27.7	28.3	7.7	16.4	2	0	Nil	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	0.28	<0.1	<0.1
	c. Iopora	Spring	27,June	Fine	27.0	27.5	8.0	6.5	0	0	Nil	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.19	<0.1	<0.1
5.Kwikila	a. High School	Borehole	18,May	Fine	30.6	27.9	7.3	*73.6*	*0*	*0*	*Nil*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*<0.001*	*0.65*	*<0.1*	*<0.1*
	b. Hospital	Borehole	18,May	Fine	29.5	27.2	7.3	84.3	0	0	Nil	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.70	0.1	0.1
	c. Salvation Army A	Borehole	18,May	Fine	30.0	28.7	6.9	79.7	0	2	Nil	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.49	<0.1	<0.1
	d. Salvation Army B	Borehole	18,May	Fine	30.0	28.8	7.0	86.7	0	0	Nil	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.47	<0.1	0.2
	e. Kemp Welch R.	River	19,May	Fine	29.6	24.5	7.6	13.4	20	50	Nil	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.30	0.1	<0.1
6.Finschhafen	a. Intake	River	30,May	Fine	27.1	25.1	8.0	40.1	0	0	Nil	<0.001	<0.001	0.003	<0.001	<0.001	<0.001	0.71	<0.1	<0.1
	b. Hospital	River	30,May	Cloudy	28.8	25.1	8.2	31.3	0.5	0	Nil	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.80	0.2	<0.1
	c. Village Intake	River	30,May	Cloudy	28.3	25.7	8.2	29.5	3	4	Nil	<0.001	<0.001	0.004	<0.001	<0.001	<0.001	0.56	<0.1	<0.1
	d. Seminary Spring	Spring	30,May	Cloudy	28.0	25.7	7.8	29.9	0	0	Nil	<0.001	<0.001	0.006	<0.001	<0.001	<0.001	0.41	<0.1	<0.1
	e. Town	Tap	30,May	Clear	31.0	26.3	8.1	36.1	0	0	Nil	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	0.43	<0.1	<0.1
7.Mutzing	a. Manging R.	River	28,May	Fine	31.2	32.3	8.5	26.8	150>	100>	Soil	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.41	0.1	0.1
	b. Supply Source-2	Borehole	28,May	Fine	31.2	27.8	7.3	53.4	0	0	Nil	<0.001	<0.001	<0.001	<0.001	0.003	<0.001	0.58	<0.1	<0.1
	c. Village	S. Well	28,May	Clear	31.2	27.9	7.3	32.7	0	1	Soil	<0.001	<0.001	0.002	<0.001	0.002	<0.001	0.82	<0.1	<0.1
	d. High School	Borehole	28,May	Clear	32.3	28.0	7.6	45.2	0	0	Nil	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.60	<0.1	<0.1
8.Oro Bay	a. Kosisi R.	River	25,May	Fine	32.9	26.3	7.4	5.4	8	20	Nil	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	0.24	<0.1	<0.1
	b. Baana R.	River	25,May	Fine	34.0	28.6	7.9	8.0	1	6	Nil	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	0.22	<0.1	0.1
	c. Hospital	River	25,May	Fine	29.0	26.8	7.2	8.0	1	20	Nil	<0.001	<0.001	<0.001	<0.001	0.002	<0.001	0.17	<0.1	<0.1
	d. Fishery	S. Well	25,May	Fine	29.5	26.5	7.5	75.3	5	20	Nil	<0.001	<0.001	<0.001	<0.001	<0.001	*<0.001*	*0.56*	*<0.1*	*<0.1*
Guidelines/Standards for Drinking Water Quality																				
WHO (1993)						–	–	–	5NTU	15TCU	Accepable	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*4	50 units*5	Unobjectionable	0.01	0.001	0.01	0.1	0.05	–	1.5	–	15
Japan (1993)						–	5.8-8.6	–	2	5	Accepable	0.01	0.0005	0.01	0.05	0.01	0.05	0.8	–	1

Table XX: continued

Study Area	Location	Fe	Cu	Na	Mn	Cl	Ni	Sb	B	Mo	Al	CN	NO_2	NO_3	SO_4	TOC	TDS	Bacteria: Total Coli*3	Bacteria: SPC*4	Residual Cl
		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
		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	1	0.05
1.Popondetta	a. Agr.College	0.2	<0.1	7.5	0.36	10	<0.01	<0.001	0.1	0.01	0.1	<0.01	<0.1	0.8	54.9	1	160	13	77	
	b. Village	0.1	<0.1	7.2	0.09	9	<0.01	<0.001	<0.1	0.01	<0.1	<0.01	<0.1	0.5	8.5	1	118	69	200>	
	c. W. B. Intake	0.1	<0.1	13.8	0.02	12	<0.01	<0.001	0.1	0.01	0.1	<0.01	<0.1	0.9	80.7	1	152	200>	200>	
	d. Town	<0.1	<0.1	13.6	0.01	13	<0.01	<0.001	0.1	0.01	0.2	<0.01	<0.1	0.6	82.2	1	154	0	1	1
2.Daru	a. U'ume Intake	0.5	<0.1	2.4	0.01	11	<0.01	<0.001	<0.1	0.01	0.2	<0.01	<0.1	0.5	3.9	3	160	61	73	
	b. Treatment Plant	0.1	<0.1	7.0	0.01	11	<0.01	<0.001	<0.1	<0.01	<0.1	<0.01	<0.1	1.2	51.3	1	34	0	6	0.2
	c. Town A	<0.1	<0.1	20.0	<0.01	100	<0.01	<0.001	<0.1	<0.01	<0.1	<0.01	<0.1	0.6	55.5	3	524	30	200>	
	d. Town B	<0.1	<0.1	5.5	0.49	11	0.01	0.002	<0.1	0.01	0.2	<0.01	<0.1	0.4	2.2	1	72	21	200>	
	e. Town C	0.8	<0.1	20.0	0.04	50	0.01	<0.001	<0.1	0.03	<0.1	<0.01	<0.1	0.5	19.1	1	98	200>	200>	
	f. Town D	0.3	<0.1	157.0	0.16	350	<0.01	<0.001	<0.1	0.02	0.1	<0.01	<0.1	0.6	163.8	1	1030	200>	200>	
3.Bereina	b. Training C.	<0.1	<0.1	95.1	0.03	110	<0.01	<0.001	0.1	0.01	<0.1	<0.01	<0.1	0.6	4.0	1	39	6	62	
	c. P.S #1	0.8	<0.1	172.0	0.28	341	<0.01	<0.001	0.1	0.01	<0.1	<0.01	<0.1	0.7	52.3	1	1020	47	113	
	d. Mainohana Intake	0.2	<0.1	4.0	0.15	9	0.02	<0.001	<0.1	0.02	0.1	<0.01	<0.1	0.6	4.9	1	104	200>	200>	
	e. High School	<0.1	<0.1	206.0	0.05	16	<0.01	<0.001	0.2	0.02	<0.1	<0.01	<0.1	0.5	8.8	1	726	8	7	
	f. Angabang	1.4	<0.1	4.2	0.17	8	0.02	0.002	<0.1	0.01	0.1	<0.01	<0.1	0.4	6.1	1	116	200>	200>	
4.Kupiano	a. Lake R. intake	0.3	<0.1	4.2	0.02	1	<0.01	<0.001	<0.1	<0.01	0.2	<0.01	<0.1	0.6	4.6	1	13	32	81	
	c. Iopora	0.2	<0.1	21.4	0.02	4	<0.01	<0.001	0.1	<0.01	<0.1	<0.01	<0.1	0.6	17.6	1	32	4	5	
5.Kwikila	a. High School	0.1	<0.1	47.6	0.02	54	<0.01	<0.001	<0.1	0.01	<0.1	<0.01	<0.1	1.0	3.1	1	404	200>	99	
	b. Hospital	0.2	<0.1	46.4	<0.01	46	0.01	<0.001	<0.1	<0.01	<0.1	<0.01	<0.1	1.2	9.1	1	444	11	70	
	c. Salvation Army A	0.1	<0.1	51.2	<0.01	50	<0.01	<0.001	<0.1	0.01	<0.1	<0.01	<0.1	0.8	4.0	1	478	0	0	
	d. Salvation Army B	0.4	<0.1	54.1	0.01	50	<0.01	<0.001	<0.1	0.01	<0.1	<0.01	<0.1	1.8	7.9	1	490	72	0	
	e. Kemp Welch R.	0.2	<0.1	4.2	<0.01	35	<0.01	<0.001	<0.1	0.01	0.2	<0.01	<0.1	1.1	3.2	1	28	200>	200>	
6.Finschhafen	a. Intake	<0.1	<0.1	5.7	<0.01	10	<0.01	<0.001	<0.1	<0.01	<0.1	<0.01	<0.1	0.7	9.5	1	250	92	58	
	b. Hospital	<0.1	<0.1	1.8	<0.01	9	<0.01	<0.001	<0.1	0.01	<0.1	<0.01	<0.1	0.6	3.6	1	194	82	103	
	c. Village Intake	0.1	<0.1	1.1	0.02	6	<0.01	<0.001	<0.1	0.01	<0.1	<0.01	<0.1	0.5	2.1	1	182	112	84	
	d. Seminary Spring	<0.1	<0.1	1.0	<0.01	11	<0.01	<0.001	<0.1	<0.01	<0.1	<0.01	<0.1	1.5	2.4	1	166	200>	200>	
	e. Town	<0.1	<0.1	5.8	0.01	7	<0.01	<0.001	<0.1	0.01	<0.1	<0.01	<0.1	0.5	9.3	1	248	200>	200>	
7.Mutzing	a. Manging R.	0.1	0.1	40.8	0.02	10	<0.01	<0.001	0.2	<0.01	<0.1	<0.01	<0.1	0.5	10.2	1	158	200>	200>	
	b. Supply Source-2	<0.1	<0.1	35.9	<0.01	9	<0.01	<0.001	0.2	0.01	<0.1	<0.01	<0.1	0.5	16.2	4	326	109	200>	
	c. Village	0.1	<0.1	35.3	0.03	15	<0.01	<0.001	0.1	<0.01	<0.1	<0.01	<0.1	0.8	18.9	2	310	19	71	
	d. High School	<0.1	<0.1	29.3	<0.01	7	<0.01	<0.001	0.1	<0.01	<0.1	<0.01	<0.1	0.8	14.5	1	344	36	200>	
8.Oro Bay	a. Kosisi R.	0.3	<0.1	3.6	0.01	10	<0.01	<0.001	<0.1	0.01	0.1	<0.01	<0.1	0.7	0.3	4	46	173	74	
	b. Beana R.	0.1	<0.1	5.3	0.01	8	<0.01	<0.001	<0.1	<0.01	0.2	<0.01	<0.1	0.6	0.2	4	60	200>	200>	
	c. Hospital	0.3	<0.1	4.2	0.02	9	<0.01	<0.001	<0.1	<0.01	0.1	<0.01	<0.1	0.8	0.3	1	36	146	200>	
	d. Fishery	0.9	<0.1	35.3	0.11	80	<0.01	<0.001	0.1	<0.01	<0.1	<0.01	<0.1	0.7	3.6	1	426	23	37	
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	*9		5
	PNG (1984)	1	1.5	–	0.5	1000	–	–	–	–	–	0.05	–	45	–	–	–	*10		–
	Japan (1993)	0.3	1	200	0.05	200	0.01	0.002	0.2	0.07	0.2	0.01	10		–	*8	500	*11		1

NB

1. These analyses were carried out to check the water qualities for drinking.

*1: Water temperature
*2: Turbidity
*3: Total Coliform
*4: Standard Plate Count
*5: Shallow well
*6: Jacksons Turbidity Units
*7: on the Platium-Cobalt scale
*8: COD 10mg/L
*9: WHO
All water intended for drinking: E. coli or thermotolerant coliform bacteria must not be detectable in any 100ml sample.
*10: 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.
*11: JPN
SPC: shall be less than 100 in any 1ml sample.
Total Coliform: must not be detectable in any sample.

References

1. WHO (1993), "Guidelines for drinking water quality, second edition, volume 1"
2. "Public Health (Drinking Water) Regulation 1984, No. 8 of 1984"
3. Nihon Kankyo Kanri Gakkai (1996), "Guidebook for new water standards"

Table XX-2: Water Qualities of Existing Water Sources from the Eight Sites in the Study Area (parameters relating to geological characteristics)

Study Area	Location	Source	Date of year 2000	Weather	Air Temp. °C	Physical Parameters				Parameters Representing Geological Characteristics								Hardness & Others					Non-metals	
						W.temp*1 °C	pH	EC mS/m	Turb.*2	Na mg/l	K mg/l	Ca mg/l	Cl mg/l	Mg mg/l	HCO_3 mg/l	CO_3 mg/l	SO_4 mg/l	T-Acid mg/l	T-Alka. mg/l	T-Hard mg/l	TDS mg/l	L I mg/l	NH_4-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	−0.8	<0.1	0.24
	b. Village	Spring	25,May	Rain	26.5	25.9	6.3	14.9	0	7.2	4.59	12.2	9	5.0	69.1	0.5	8.5	34.5	69	55	118	−2.2	0.2	0.22
	c. W. B. Intake	River	25,May	Cloudy	25.8	27.3	7.8	24.2	1	13.8	5.86	20.7	12	7.5	38.5	0.3	80.7	8.3	39	82	152	−0.7	<0.1	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	7.9	33	81	154	−1.1	<0.1	0.09
2.Daru	a. U'ume Intake	River	5,June	Rain	28.6	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	−3.5	<0.1	<0.01
	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	−3.6	<0.1	<0.01
	c. Town A	S. Well*3	6,June	Rain	27.3	27.9	7.2	92.9	0	20.0	0.88	95.4	100	33.6	123.0	1.0	55.5	0.5	124	371	524	−0.1	<0.1	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	−2.1	<0.1	<0.01
	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	88	−3.2	<0.1	0.16
	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	−0.9	<0.1	0.04
3.Bereina	b. Training C.	Borehole	23,May	Clear	28.3	26.7	7.8	53.2	0	95.1	7.18	4.5	110	3.9	208.0	1.6	4.0	6.0	208	28	39	−0.7	<0.1	0.48
	c. P.S #1	S. Well	23,May	Clear	27.2	27.7	7.8	175.3	5	172.0	9.52	111.0	341	38.6	76.1	0.6	52.3	10.5	77	435	1020	0.0	<0.1	0.14
	d. Mainohana Intake	River	23,May	Fine	29.3	24.7	8	12.4	150>	4.0	2.95	19.3	9	3.9	122.0	1.0	4.9	7.0	123	92	104	0.0	<0.1	0.32
	e. High School	Borehole	23,May	Fine	29.3	27.4	8.2	117.1	0	206.0	14.50	8.1	18	7.9	432.0	3.4	6.8	11.3	441	52	726	0.2	<0.1	0.45
	f. Angabang	River	23,May	Clear	28.0	24.8	7.9	12.6	150>	4.2	2.46	20.7	8	4.0	142.0	1.1	6.1	4.0	143	103	116	0.0	<0.1	0.40
4.Kupiano	a. Lako 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	−0.3	<0.1	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	1.2	<0.1	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	0.3	<0.1	<0.01
	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	0.4	0.7	<0.01
	c. Salvation Arny 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	0.0	0.7	<0.01
	d. Salvation Army 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	0.1	<0.1	<0.01
	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	−1.1	<0.1	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	0.6	<0.1	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	0.8	<0.1	<0.01
	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	192	0.8	<0.1	0.03
	d. Seminary Spring	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	166	0.3	<0.1	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	0.9	<0.1	0.04
7.Mutzing	a. Managing 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	2.0	<0.1	1.02
	b. Supply Source-2	Borehole	28,May	Fine	31.2	27.6	7.3	53.4	0	35.9	0.78	73.1	9	9.5	293.0	2.3	18.2	12.3	295	219	326	0.3	<0.1	<0.01
	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	0.4	<0.1	0.02
	d. High School	Borehole	28,May	Clear	32.3	29.0	7.6	45.2	0	29.3	0.64	62.4	7	6.9	244.0	1.9	14.5	10.5	245	181	344	0.5	<0.1	<0.01
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	−2.4	<0.1	0.04
	b. Baana R.	River	25,May	Fine	34.0	28.6	7.9	6	1	5.3	1.39	4.5	8	3.6	29.0	0.2	0.2	5.8	29	27	60	−1.3	<0.1	0.05
	c. Hospital	River	25,May	Fine	29.0	28.8	7.2	6	1	4.2	1.74	3.6	9	2.5	16.0	0.1	0.3	7.8	16	19	36	−2.4	<0.1	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	16.5	249	310	426	0.4	<0.1	0.07

NB *1: Water temperature
*2: Turbidity
*3: Shallow well

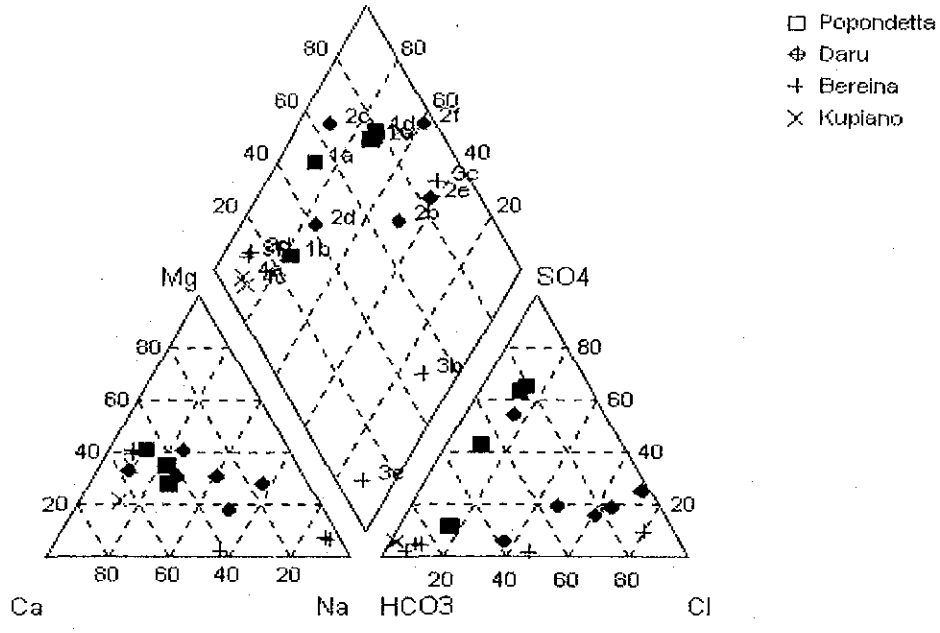


Figure 2-1 (1): Characteristics of water samples in 4 towns

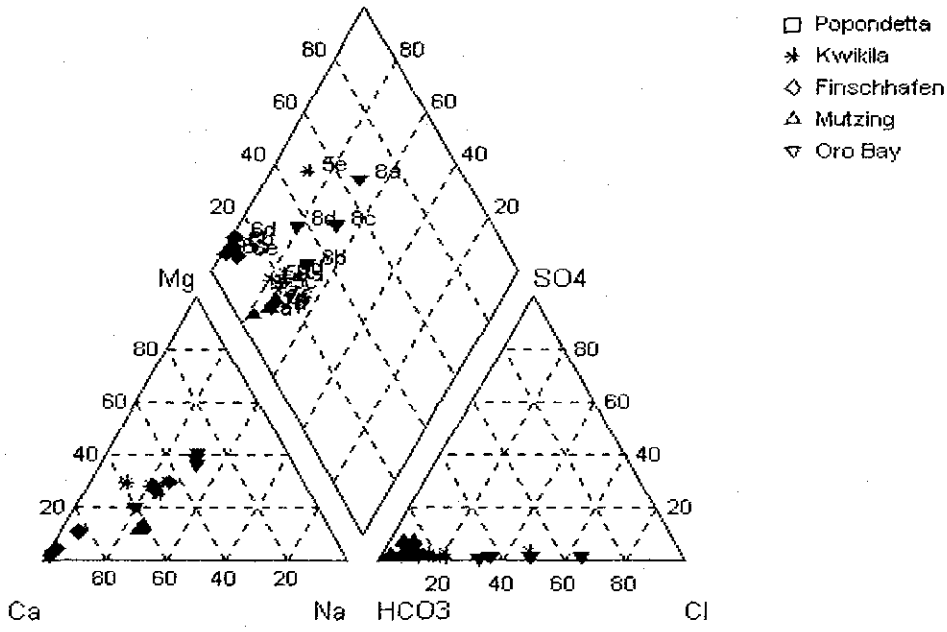


Figure 2-1 (2): Characteristics of water samples in 4 towns

Table XX: 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

Table XX: Qualities of Shallow Wells in Binaturi Area

Site	Source	Date of 2000	Physical Parameters			Elements																			Compounds & Others						Bacteria	
			W. temp*1	pH	EC	Taste & odours	Al	As	B	Ba	Cd	Cl	Cr	Cu	F	Fe	Hg	Mn	Mo	Na	Ni	Sb	Se	Pb	Zn	CN	NO_2	NO_3	SO_4	TOC	TDS	Total Coliform*2	SPC*3
			°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	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l		
Old Mawatta	S. well*4	10-Dec	30.8	6.7	39.9	acceptable	0.07	<0.001	0.1	0.01	<0.001	105	0.005	0.02	0.73	0.16	<0.001	0.19	0.006	45	<0.001	<0.001	<0.001	<0.001	0.03	0.003	0.008	0.01	4.1	2	222	>200	>200
Masingle	S. well	10-Dec	28.3	7.5	70.6	acceptable	0.05	<0.001	<0.01	0.01	<0.001	125	0.018	0.02	1.30	0.22	<0.001	0.14	0.013	77	<0.001	<0.001	<0.001	<0.001	0.03	0.002	0.105	0.18	2.8	3	404	>200	>200
Kunini	S. well	12-Dec	28.7	6.2	677.0	acceptable	0.10	<0.001	<0.01	0.02	<0.001	1895	0.035	0.02	0.80	0.12	<0.001	0.08	0.004	1107	<0.001	<0.001	<0.001	<0.001	0.16	0.002	0.007	1.03	76.5	2	4220	>200	>200
Boze	S. well	8-Dec	28.6	4.1	30.5	acceptable	0.54	<0.001	<0.01	0.04	<0.001	45	0.006	0.03	0.37	0.04	<0.001	0.10	0.006	22	0.012	<0.001	<0.001	<0.001	0.06	0.001	0.003	1.30	10.8	3	484	>200	>200
Daru Tap	Tap	8-Dec	28.3	7.4	49.9	acceptable	0.11	<0.001	<0.01	0.02	<0.001	70	0.010	0.07	0.41	0.01	<0.001	0.01	0.009	17	<0.001	<0.001	<0.001	0.009	0.20	0.003	0.003	0.70	6.1	2	498	0	0
Guidelines/Standards for Drinking Water Quality																																	
WHO (1993)			-	-	-	acceptable	0.2	0.01	0.5	0.7	0.003	250	0.05	2	1.5	0.3	0.001	0.5	0.07	200	0.02	0.005	0.01	0.01	3	0.07	3	50	250	-	1000	*6	
PNG (1984)			-	6.5-9.2	-	unobjectionable	-	0.05	-	-	0.01	1000	-	1.5	1.5	1	0.001	0.5	-	-	-	-	0.01	0.1	15	0.05	-	45	-	-	-	*7	
JPN (1993)			-	5.8-8.6	-	accecptable	0.2	0.01	0.2	-	0.01	200	0.05	1	0.8	0.3	0.0005	0.05	0.07	200	0.01	0.002	0.01	0.05	1	0.01	10		-	*5	500	*8	

NB

*1: Water temperature

*2: Total coliform

*3: Standard plate count

*4: Shallow well

*5: *In Japanese standard, COD should be less than 10mg/L instead of TOC.*

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

*7: 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.

*8: JPN – SPC: shall be less than 100 in any 1ml sample. Total Coliform: must not be detectable in any sample.

Water Qualities of Drilled Boreholes in the Eight Sites

Site	No.	Water source	Date of Year 2000	Weather	Air Temp °C	Physical Parameters						Elements								
						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
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

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.	Elements										Compounds & Others						Bacteria	
		Fe	Cu	Na	Mn	Cl	Ni	Sb	B	Mo	Al	CN	NO_2	NO_3	SO_4	TOC	TDS	Total Coli[*3]	SPC[*4]
		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	

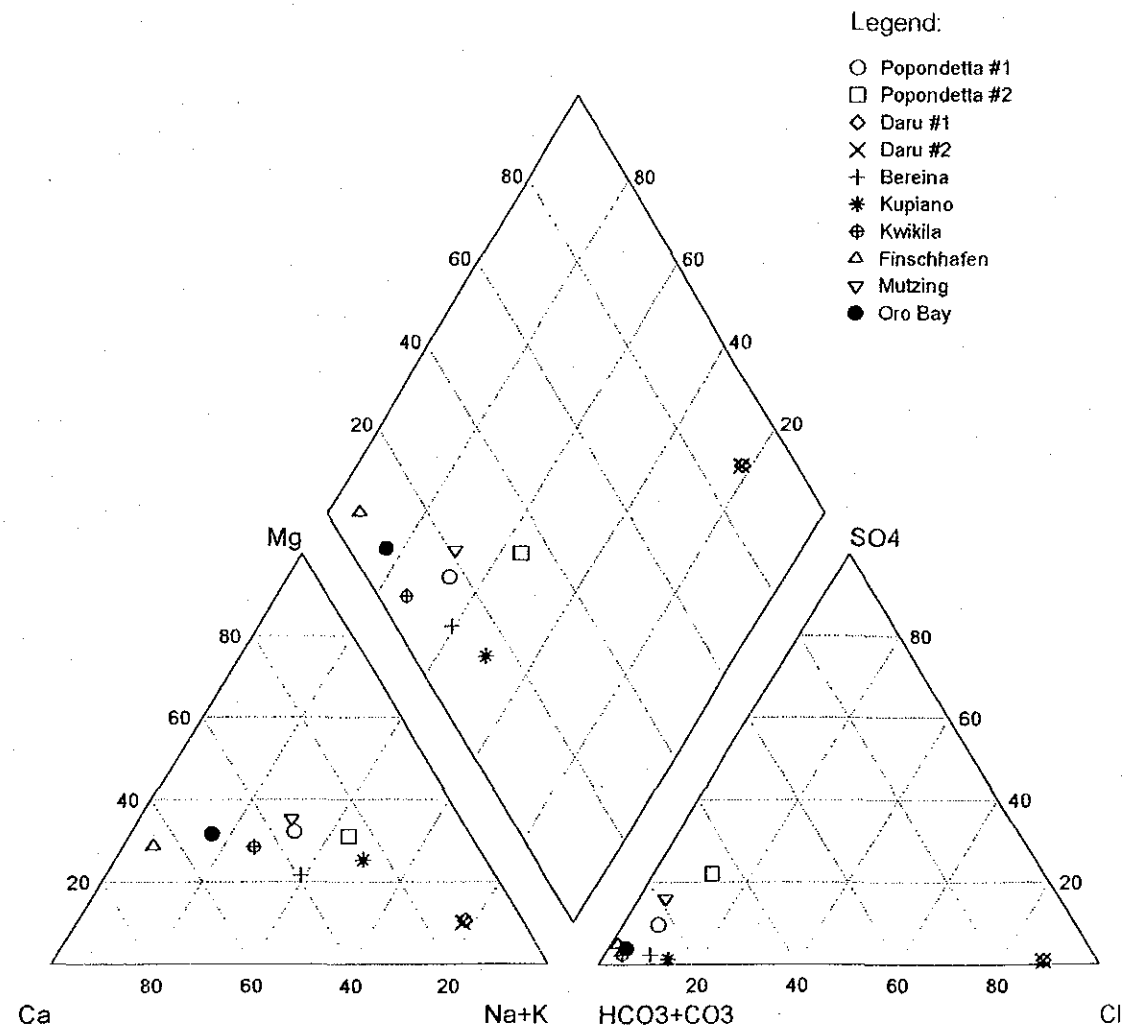
References

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"

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	36	<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



Water characteristics of boreholes in PNG

6. GROUNDWATER DEVELOPMENT BOREHOLE DATA

ELECTRICAL WELL LOGGING OF TEST BOREHOLES FOR THE STUDY ON GROUNDWATER DEVELOPMENT FOR WATER SUPPLY SYSTEMS IN PAPUA NEW GUINEA

INTRODUCTION

The project for test Boreholes for The Study on groundwater Development for Water Supply Systems in Papua New Guinea had been granted by Japan International Co-operation (JICA). It is proposed to construct 10 wells at the eastern part of Papua New Guina Island.

PURPOSE OF WORK

The purpose of the electrical well logging of the test boreholes is to survey and obtain the hydrogeological conditions of the drilling site in order to be the criterior of well screen position to get the sufficient yield of groundwater.

LOCATION OF WORK

The test boreholes for the electrical well logging were designated by the Client in eight (8) study areas, i.e. ; Mutzing and Finschhafen in Morobe Province, Popondetta and Oro Bay in Oro Province, Bereina, Kwikila and Kupiano in Central Province, and Daru in Western Province (To be referred to the attached map). The Total ten (10) numbers of test boreholes were constructed as summerised in figure 1.

BOREHOLE GEOPHYSICAL LOGGING

Geophysical logs was taken by the geologger 3030 Mark 2 in all holes drilled.

The logging device is capable of producing a continuous simultaneous strip record of spontaneous potential, resistivity and separately a continuous strip of gamma radiation.

AUTOMATIC ELECTRIC LOGGING METHOD

1. *Set E-Logging machine (Geologger-3030, OYO) at specified location (see fig. 2)*
2. *Connect cable with combination probe to electric logging machine.*
3. *Set zero depth, then, set the suitable detecting range in electric logging programme.*
4. *In case of carry out by upward method, the combination probe shall be lower down to the bottom of the hole.*
5. *After that the combination probe shall be slowly pull up by winch or handle device in suitable rate, and at the same time the measuring shall be started.*
6. *The computerized electric logging machine shall automatically read the value every spacing depth and record in disket.*
7. *After completion, the recorded data shall be printed out in the selected scale.*

RESISTIVITY LOGGING (MANUAL) METHOD

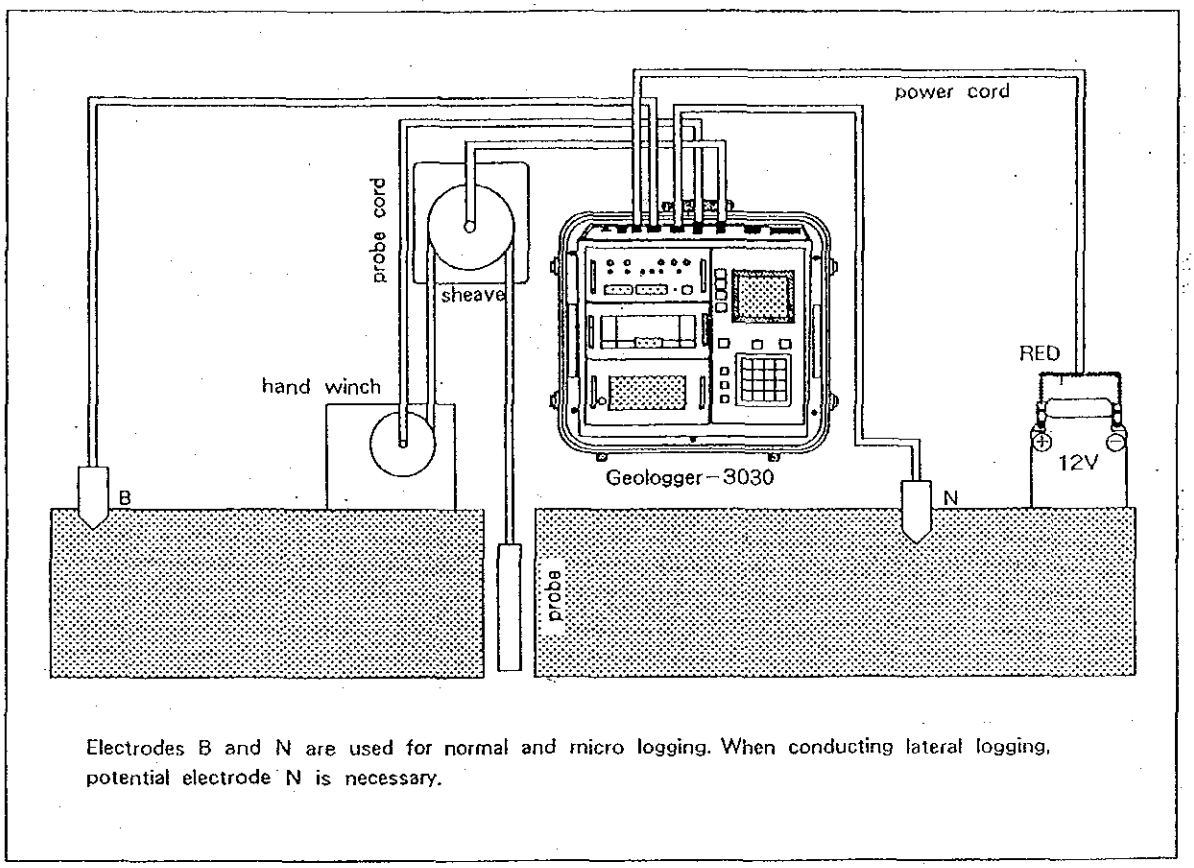
1. *Set resistivity machine, ABEM meter (see fig. 3).*
2. *Marking on cable at every 1 meter interval.*
3. *Install the lead probes until the bottom of hole. The reading point shall be at the center between P1 and P2.*
4. *Pull up the probes slowly and take recording of the resistance value(R) that show on the monitor at every 1 m.*
5. *The resistivity value shall be calculated by the formula as follows :*

$$\rho = 4\pi aR$$

ρ = *Resistivity (Ohm)*
a = *Distance (spacing) from pole to pole (0.5 m.)*
R = *Resistance value (Ohm-m)*

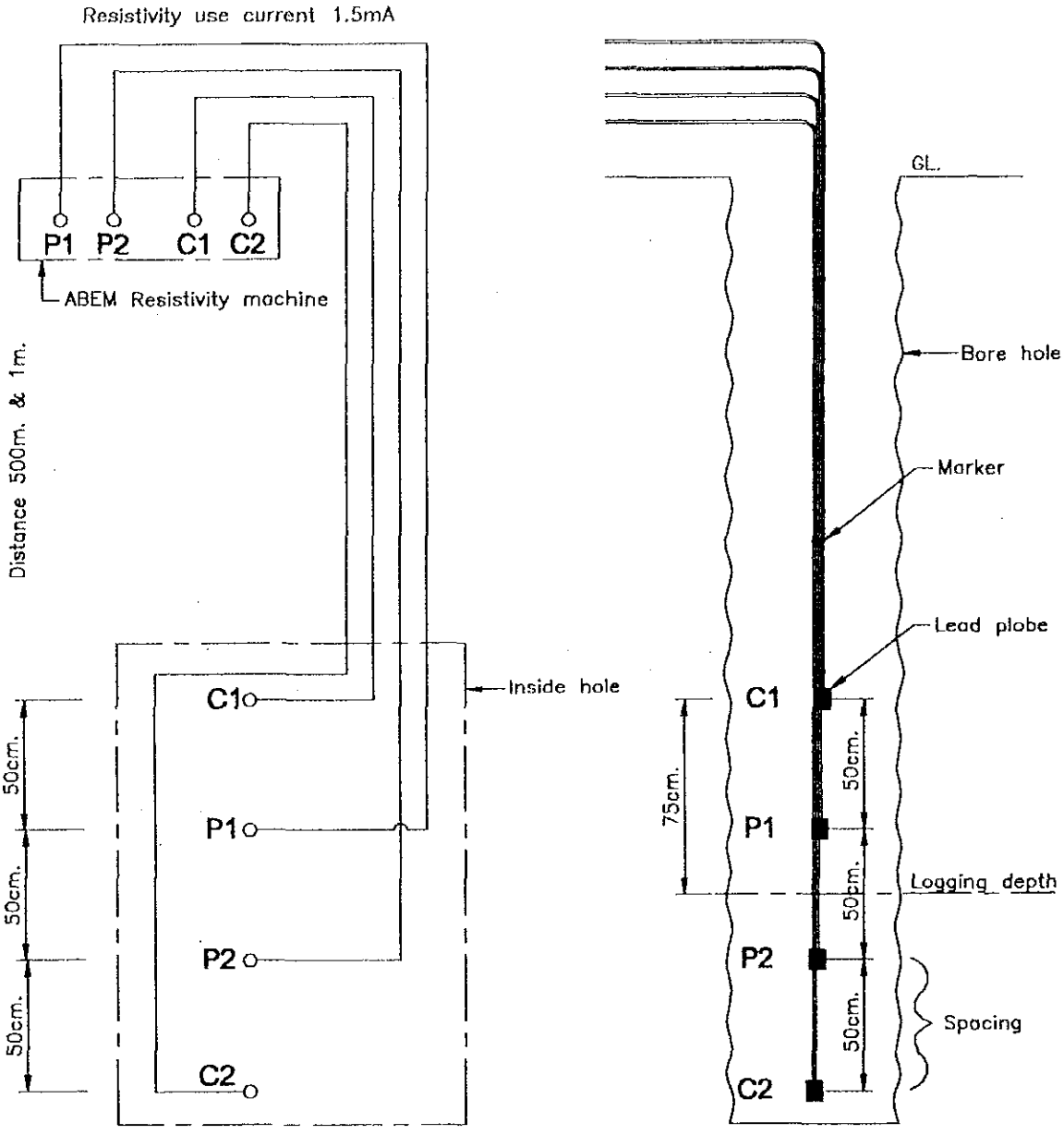
Then, $\rho = 6.28\,R$

6. *Plot on normal graph y = depth (m.), X = Resistivity value (ohm)*



Electrodes B and N are used for normal and micro logging. When conducting lateral logging, potential electrode N is necessary.

Fig 2. Electric Logging Machine



Resistivity Value are $\rho = 4\pi aR$

$\rho = 6.28R$ (0.5m. spacing)

R = Reading from ABEM meter

FIG.3 WELL LOGGING BY ABEM MACHINE

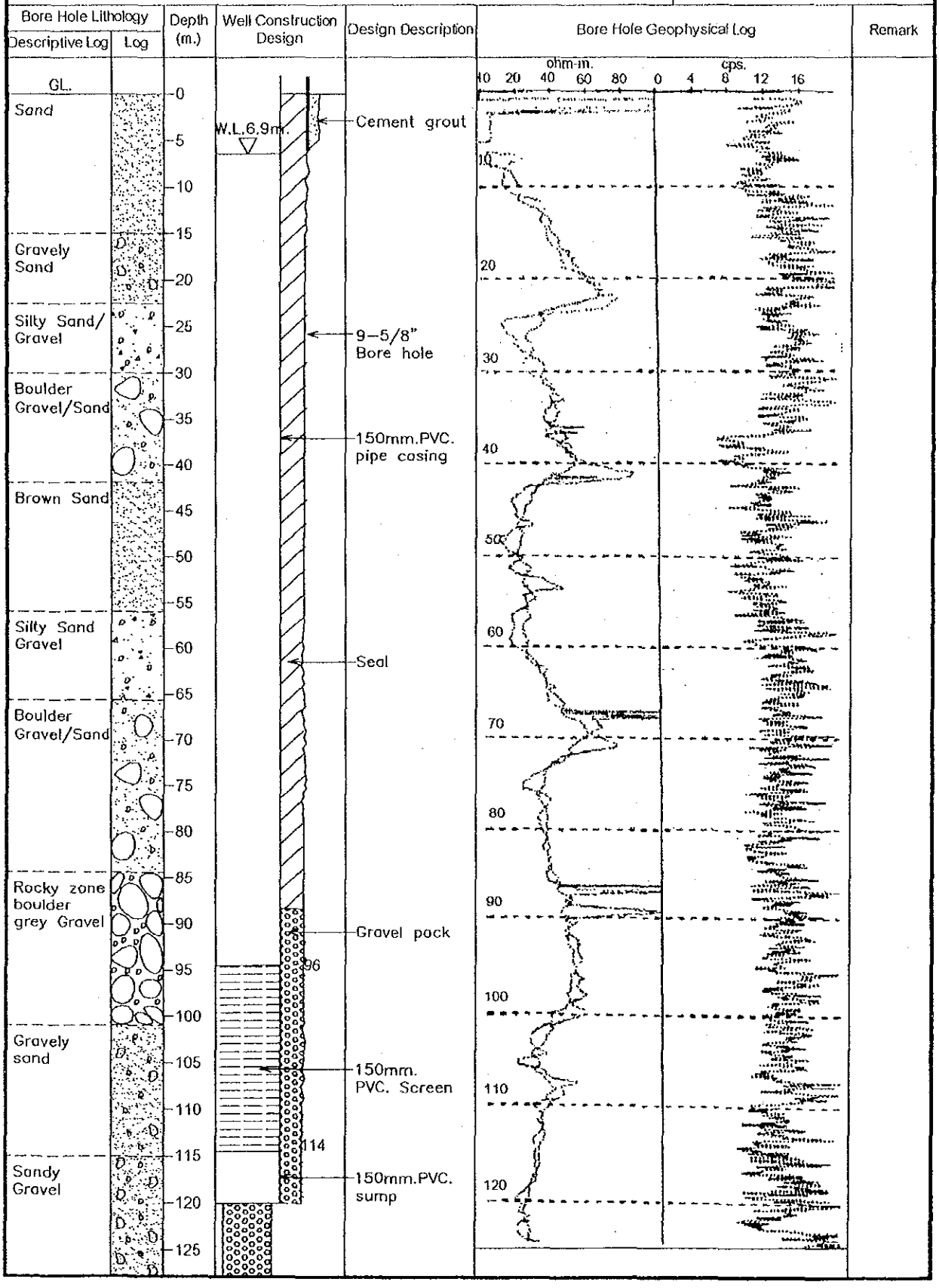
TABLE 1 : SUMMARY OF LOGGING BOREHOLE

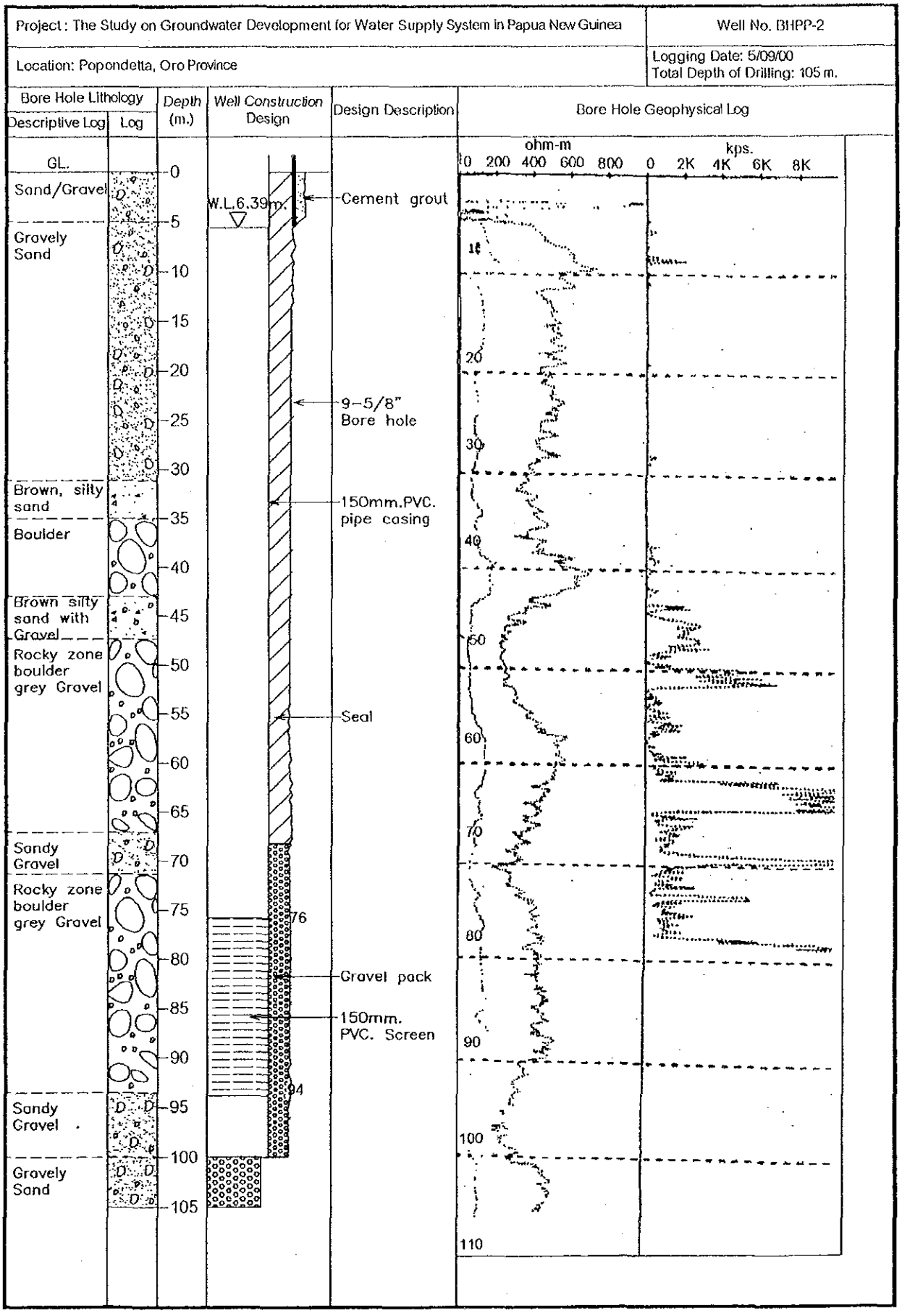
Item	Hole No.	Location	Depth of Drilling (m.)	Depth of Logging (m.)	Date of Logging	Remark
1	BHPP-1	Popondetta / Oro	126	126	31/08/00	
2	BHPP-2	"	105	105	05/09/00	
3	DABH-1	Daru / Western	80	45	20/09/00	Probe struck at depth 45 m.
4	DABH-2	"	42	25	25/09/00	Logging when drilled at depth 25 m. (instruction by Client)
5	* KUBH-1	Kupiano / Central	63	60	02/11/00	Probe struck at 60 m.
6	BRBH-1	Bereina / Central	36	32	21/07/00	Probe struck at depth 32 m.
7	KKBH-1	Kwikila / Central	100	72	10/08/00	Probe struck at depth 72 m.
8	KKBH-2	"	44	32	16/08/00	Probe struck at depth 32 m.
9	FIBH-1	Finschfen / Morobe	13	13	29/09/00	(Logging inside casing) = no data
10	MUBH-1	Mutzing / Morobe	73	58	28/09/00	No record (Logging inside casing) = no data
11	ORBH-1	Orabag/Oro				Callaped hole no logging = no data

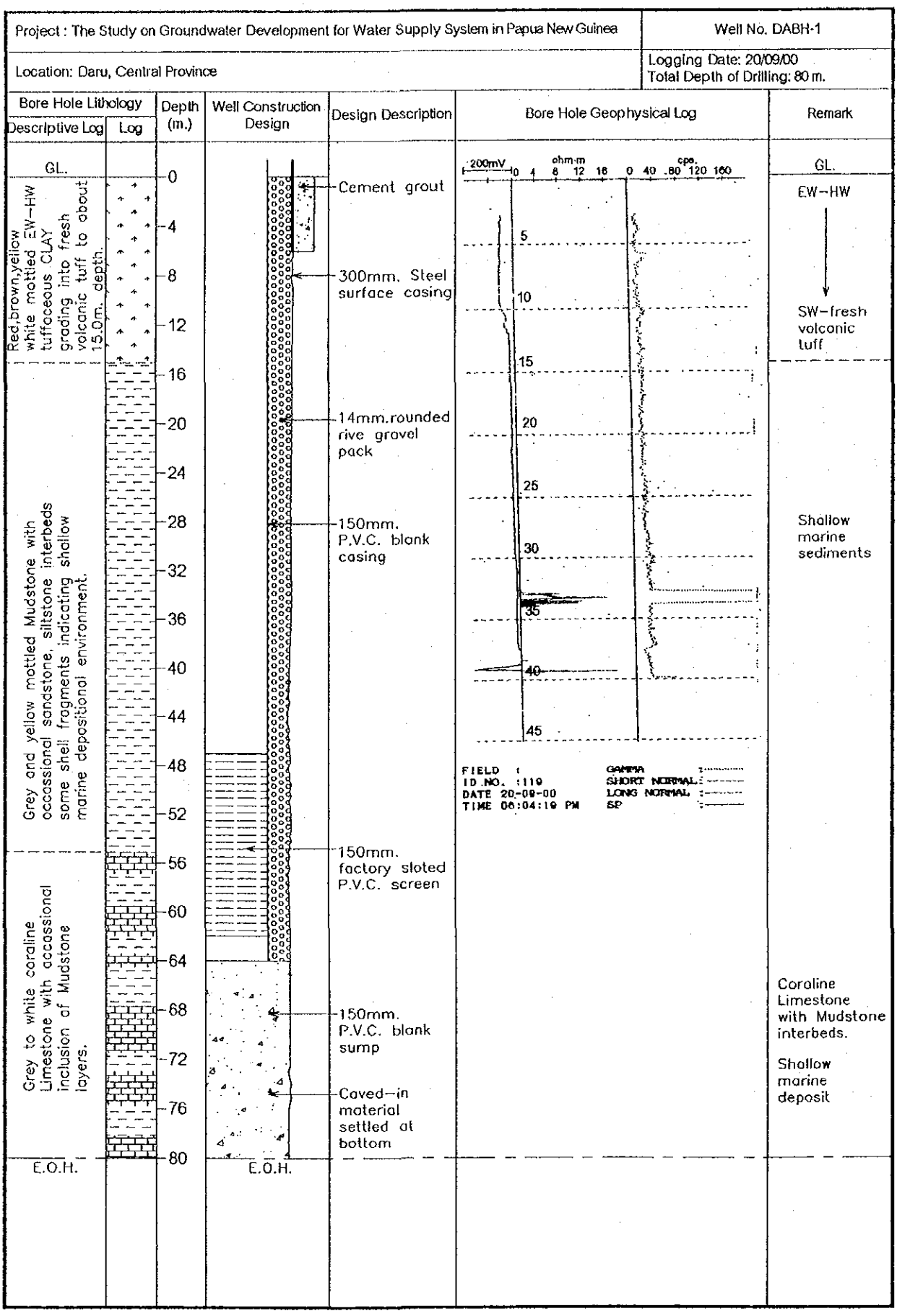
Remark : - In case probe struck, logging was stoped by instruction of client.

- (*) Borehole was logged by ABEM machine.

Project : The Study on Groundwater Development for Water Supply System in Papua New Guinea	Well No. BHPP-1
Location: Popondetta, Oro Province	Logging Date: 31/08/00 Total Depth of Drilling: 126 m.




Project : The Study on Groundwater Development for Water Supply System in Papua New Guinea
Well No. BHPP-2
Location: Popondetta, Oro Province
Logging Date: 5/09/00
Total Depth of Drilling: 105 m.
Bore Hole Lithology
Descriptive Log
Log
Depth (m.)
Well Construction Design
Design Description
Bore Hole Geophysical Log
ohm-m
0 200 400 600 800
kps.
0 2K 4K 6K 8K
GL.
Sand/Gravel
Gravely Sand
Brown, silty sand
Boulder
Brown silty sand with Gravel
Rocky zone boulder grey Gravel
Sandy Gravel
Rocky zone boulder grey Gravel
Sandy Gravel
Gravely Sand
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
100
105
W.L.6.39m.
Cement grout
9-5/8" Bore hole
150mm.PVC. pipe casing
Seal
76
Gravel pack
150mm. PVC. Screen
94
10
20
30
40
50
60
70
80
90
100
110


Project : The Study on Groundwater Development for Water Supply System in Papua New Guinea
Well No. DABH-1
Location: Daru, Central Province
Logging Date: 20/09/00
Total Depth of Drilling: 80 m.
Bore Hole Lithology
Descriptive Log
Log
Depth (m.)
Well Construction Design
Design Description
Bore Hole Geophysical Log
Remark
GL.
Red,brown,yellow white mottled EW-HW tuffaceous CLAY grading into fresh volcanic tuff to about 15.0m. depth.
Grey and yellow mottled Mudstone with occassional sandstone, siltstone interbeds some shell fragments indicating shallow marine depositional environment.
Grey to white coraline Limestone with accassional inclusion of Mudstone layers.
E.O.H.
0
4
8
12
16
20
24
28
32
36
40
44
48
52
56
60
64
68
72
76
80
Cement grout
300mm. Steel surface casing
14mm.rounded rive gravel pack
150mm. P.V.C. blank casing
150mm. factory sloted P.V.C. screen
150mm. P.V.C. blank sump
Caved-in material settled at bottom
E.O.H.
200mV
ohm-m
cps.
0 4 8 12 16
0 40 80 120 160
5
10
15
20
25
30
35
40
45
FIELD :
ID.NO. :110
DATE 20-09-00
TIME 06:04:10 PM
GAMMA
SHORT NORMAL
LONG NORMAL
SP
GL.
EW-HW
SW-fresh volconic tuff
Shallow marine sediments
Coraline Limestone with Mudstone interbeds.
Shallow marine deposit

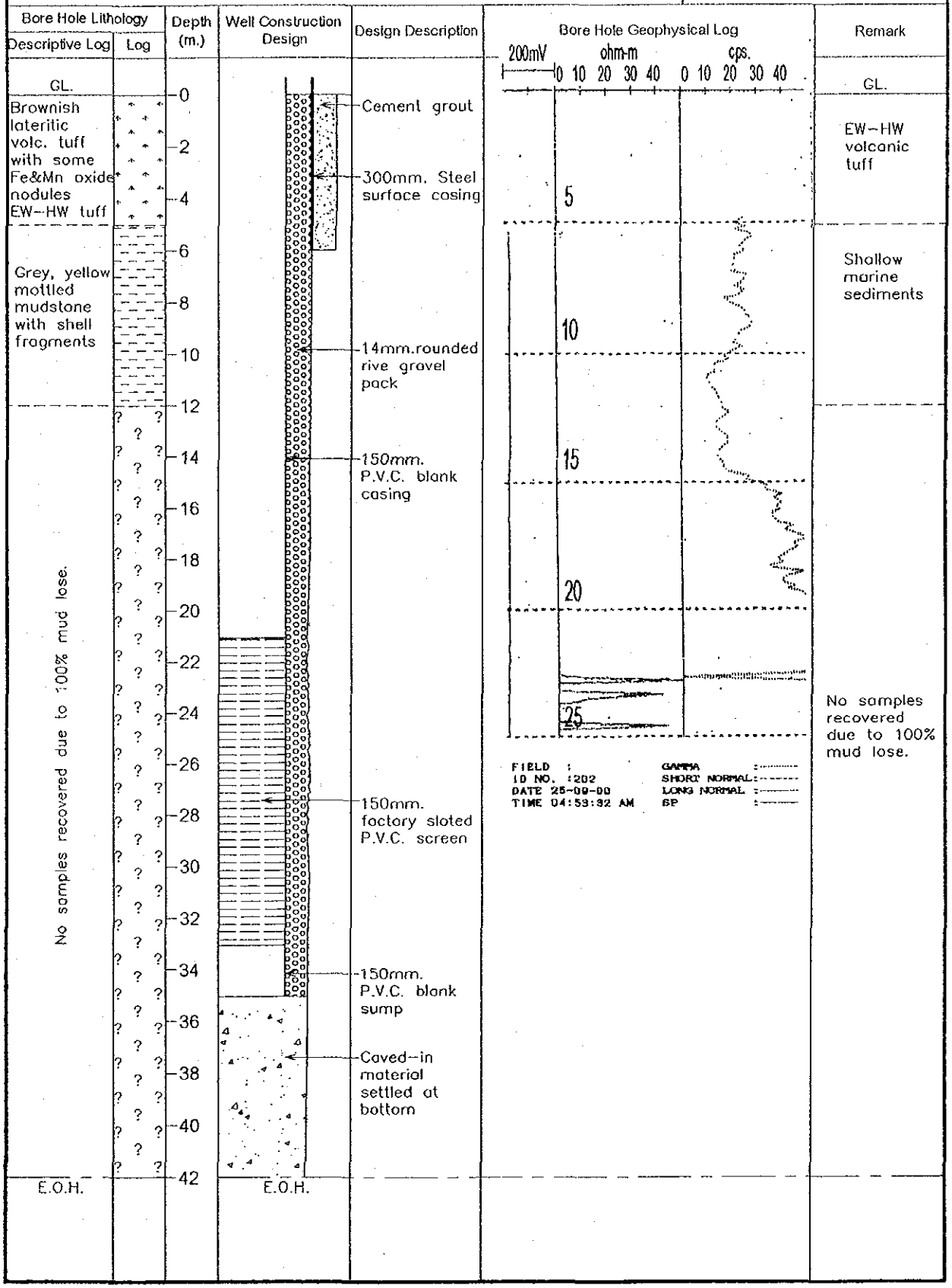
Project : The Study on Groundwater Development for Water Supply System in Papua New Guinea

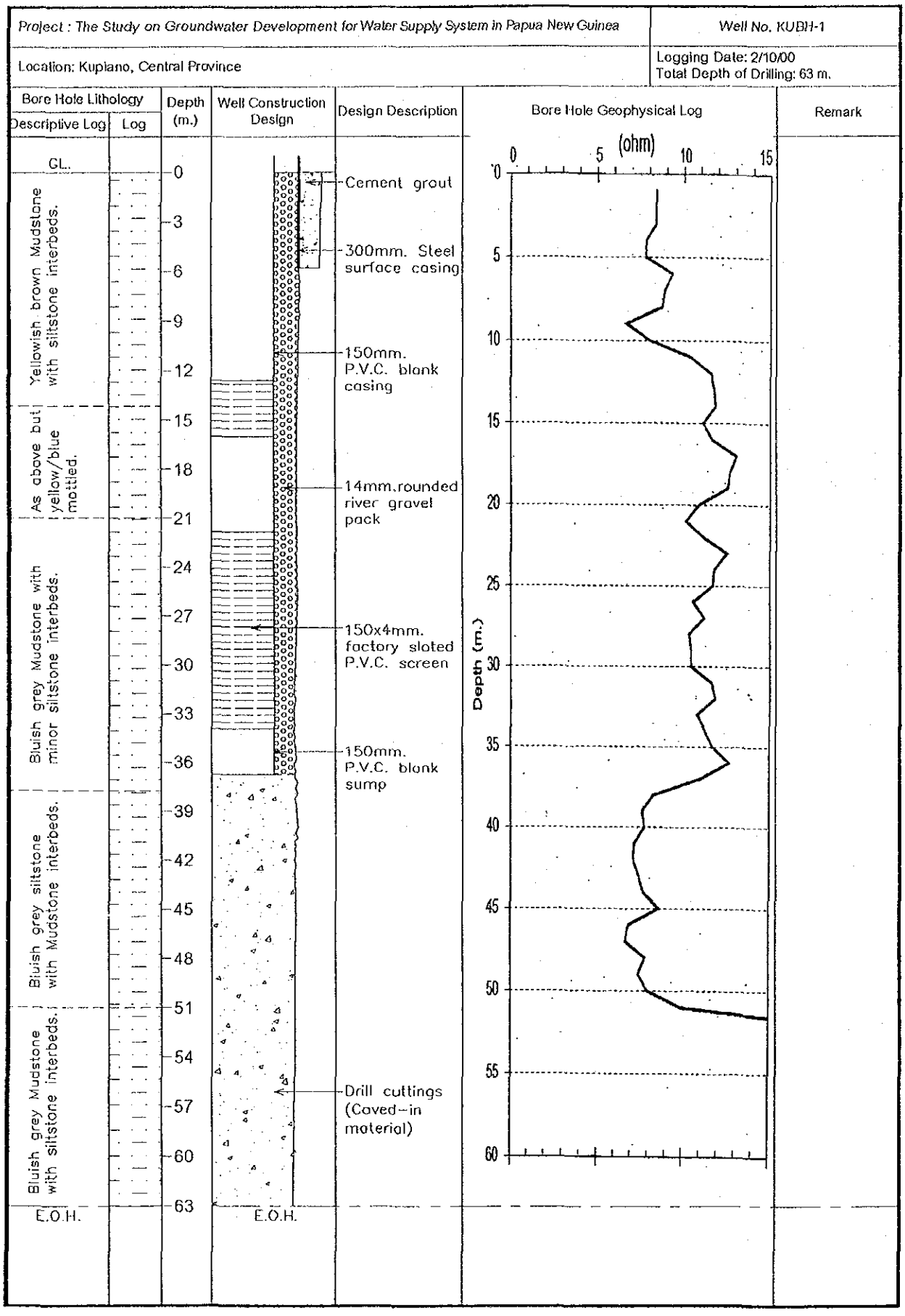
Well No. DABH-2

Location: Daru, Central Province

Logging Date: 25/09/00

Total Depth of Drilling: 42 m.



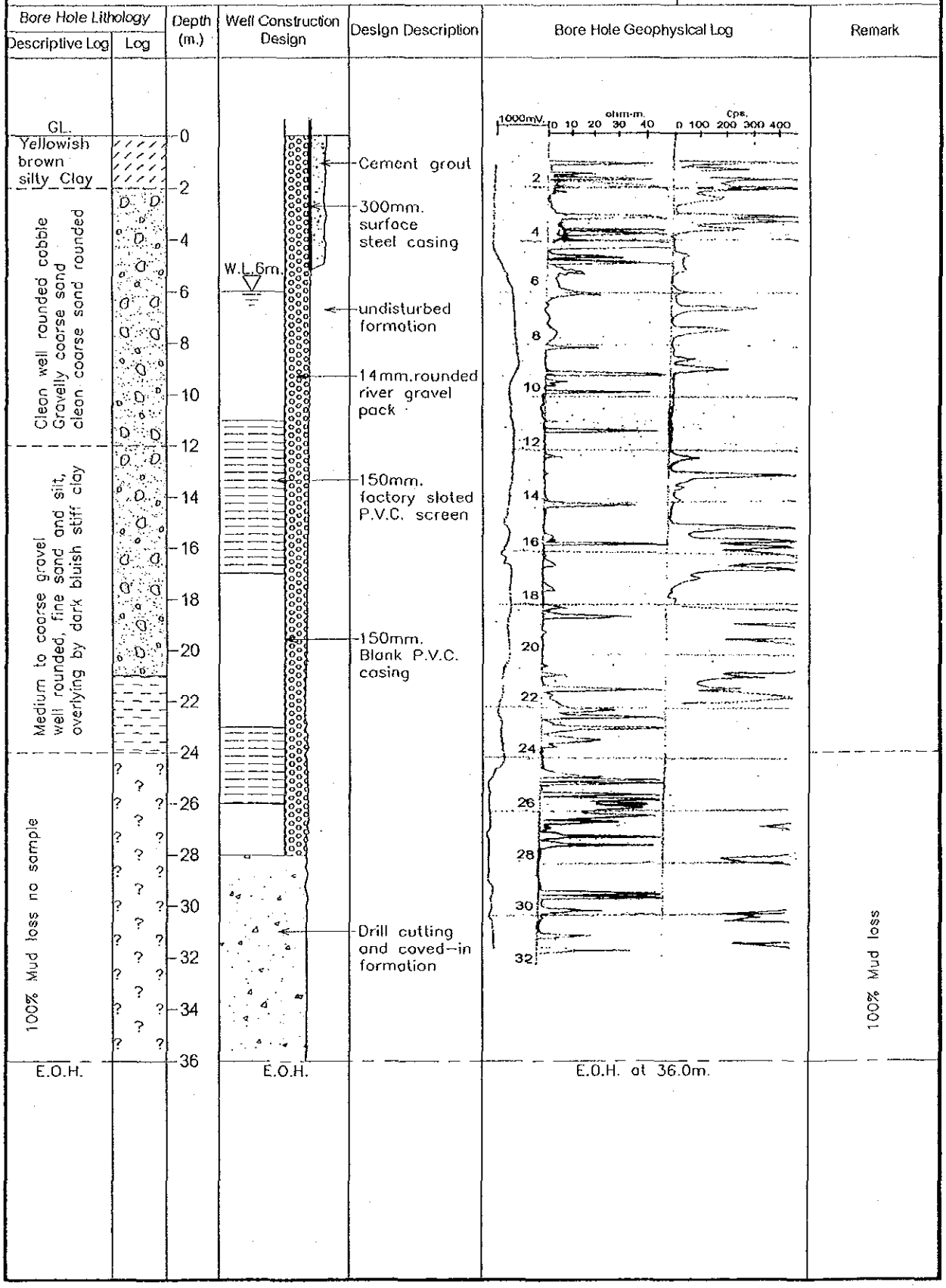

Project : The Study on Groundwater Development for Water Supply System in Papua New Guinea
Well No. KUBH-1
Location: Kupiano, Central Province
Logging Date: 2/10/00
Total Depth of Drilling: 63 m.
Bore Hole Lithology
Descriptive Log
Log
Depth (m.)
Well Construction Design
Design Description
Bore Hole Geophysical Log
Remark
(ohm)
Depth (m.)
GL.
Yellowish brown Mudstone with siltstone interbeds.
As above but yellow/blue mottled.
Bluish grey Mudstone with minor siltstone interbeds.
Bluish grey siltstone with Mudstone interbeds.
Bluish grey Mudstone with siltstone interbeds.
E.O.H.
Cement grout
300mm. Steel surface casing
150mm. P.V.C. blank casing
14mm.rounded river gravel pack
150x4mm. factory sloted P.V.C. screen
150mm. P.V.C. blank sump
Drill cuttings (Caved-in material)
E.O.H.

Project : The Study on Groundwater Development for Water Supply System in Papua New Guinea

Well No. BRBH-1

Location: Beraina, Central Province

Logging Date: 2/08/00
Total Depth of Drilling: 36 m.

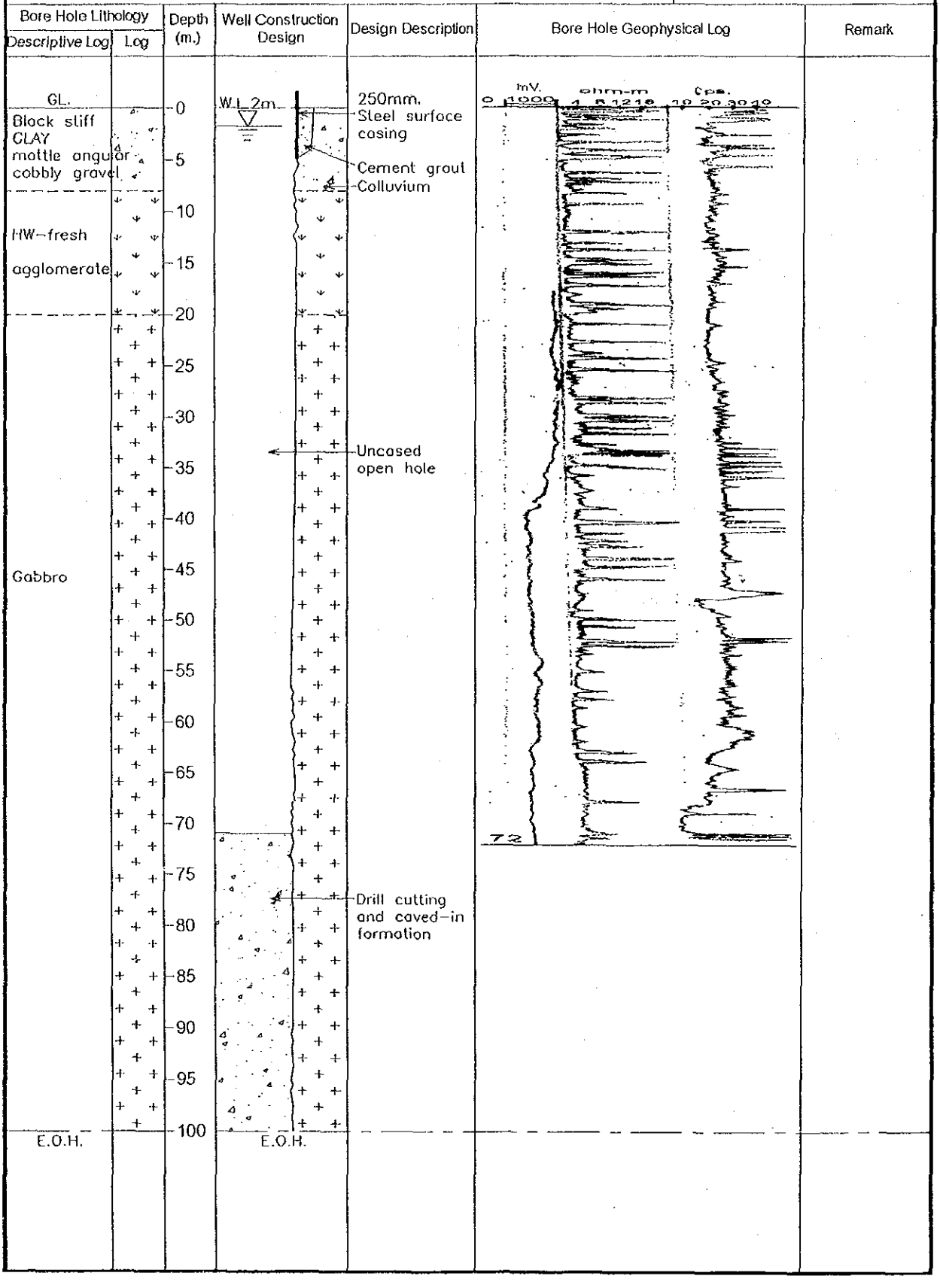


Project : The Study on Groundwater Development for Water Supply System in Papua New Guinea

Well No. KKBH-1

Location: Kwikila, Central Province

Logging Date: 10/08/00
Total Depth of Drilling: 100 m.

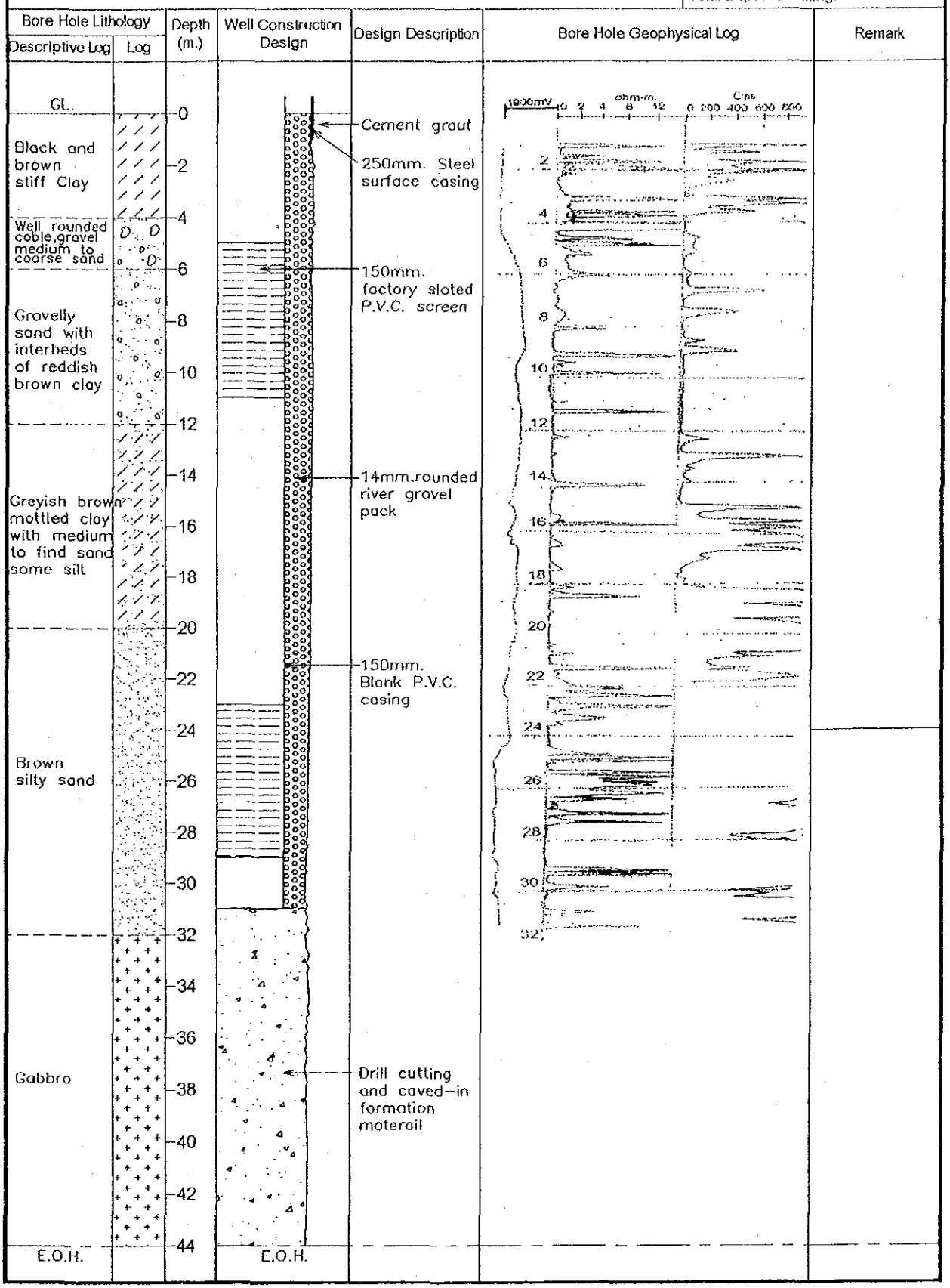


Project : The Study on Groundwater Development for Water Supply System in Papua New Guinea

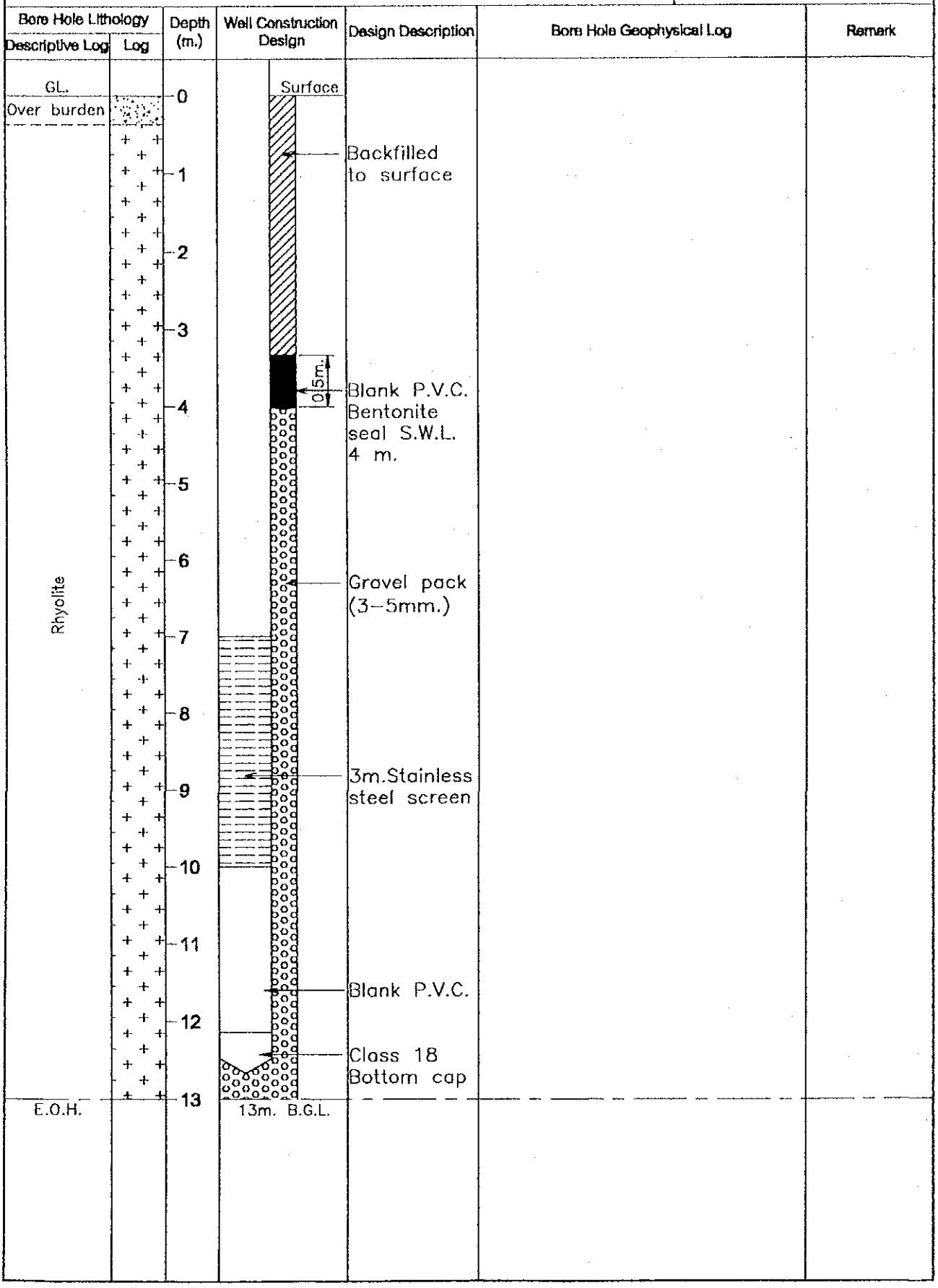
Well No. KKBH-2

Location: , Central Province

Logging Date: 16/08/00
Total Depth of Drilling: 44 m.



Project : The Study on Groundwater Development for Water Supply System in Papua New Guinea	Well No. FBH-1
Location: Finschafen, Morobe Province	Logging Date: 29/06/00 Total Depth of Drilling: 13 m.



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Project 33121
October 2000

REPORT ON GROUNDWATER DEVELOPMENT FOR WATER SUPPLY SYSTEMS IN PAPUA NEW GUINEA - POPONDETTA #1 BORE COMPLETION REPORT

1.0 INTRODUCTION

This report describes the test bore completion details and analysis of pumping test data for Popondetta #1 that was recently installed in the Popondetta district. It is understood the bore was drilled and installed as part of the study on Groundwater Development for Water Supply Systems in Papua New Guinea, which is funded by JICA and being carried out by Japan Techno Co Ltd. Douglas Partners Pty Ltd (DP) were commissioned by New Britain Drillers Ltd (NBD) to prepare this bore completion report.

The pumping test carried out on the bore by NBD included:

- a step drawdown test;
- a 24 hour constant rate test; and
- a water level recovery test.

The pumping test data, supplied by NBD, was analysed with the objective of assessing the long term 'safe' yield for the bore (i.e. Popondetta #1).

DP did not supervise the drilling, construction, or pump testing of this test bore on-site. All information (i.e. bore construction, logging and pump test data) contained in this report was obtained by third parties including NBD and sent to DP. Therefore DP cannot be held responsible for the accuracy of the pump test data or the subsequent analysis contained in this report.

2.0 DRILLING AND BORE CONSTRUCTION

The exploratory drilling and bore construction was undertaken by NBD during the period August 2000 using a Bournedrill THD25 truck-mounted drilling rig.

Test bore Popondetta #1 was drilled initially with a 310 mm diameter hole to 6 m depth and installing 254 mm diameter steel casing (collar pipe). A 244 mm diameter hole was then drilled to 126 m depth using conventional rotary mud drilling techniques. A biodegradable liquid polymer mud was used as drilling fluid to remove the cuttings from the borehole.

The rock cuttings were logged on-site by Jim Devlin of NBD. At completion of drilling a suite of geophysical logs consisting of natural Gamma and Resistivity were run. A composite bore log showing both the lithological and geophysical logs is provided in Appendix A. The geological sequence encountered during the drilling of Popondetta #1 consisted primarily of alluvium and some pumiceous ash deposits to 126 m depth. The deposits comprised a layered sequence of sand, silty sand and sandy gravel material. It was reported a hard layer was intersected at 84 m depth and possibly comprised broken, fractured basalt interlayered with sand.

It is understood Popondetta #1 was completed by installing an in-line string of sump, screen and casing into the bore. Class 12 PVC pipe 150 mm diameter, supplied by Islex (Australia) Pty Ltd, was used as a casing and a sump (6 m long). A 150 mm diameter factory slotted screen, with 0.8 mm aperture and an open surface area of 8%, was installed from 96 m to 114 m depth. A filter pack consisting of 5-10 mm diameter gravel was placed in the annulus between the hole wall and casing/screen. The bore was developed by jetting, chemical treatment, and airlift surging until it produced clean, essentially sand free water. The top section of the annulus between the surface casing and the bore casing was cemented and bentonite sealed to prevent surface contamination from entering the bore.

The construction details provided by NBD for Popondetta #1 are summarised in Table 1 and are shown on the composite bore log in Appendix A.

Table 1: Bore Construction Details – Popondetta #1

Bore No.	Total Depth (mbgL)	Casing Diameter (mm)	Slotted Interval (mbgL)	Gravel Pack (mbgL)	Static Water Level (29/8/00) (mbgL)
Popondetta #1	120	150	96-114	20-126	7.34

Notes: mbgL - metres below ground level

NBD reported the yield whilst airlifting the bore, at the end of the development process, was about 15 L/s.

3.0 PUMPING TESTS AND ANALYSIS

Following completion of Popondetta #1, pumping tests were undertaken to assess the hydraulic parameters of the aquifer and long term yield of the bore. The pumping tests and analysis were carried out in accordance with Australian Standard AS2368-1990[1].

3.1 Pumping Test Set-Up

A Calpeda (4SD15\23, 5.5 kW) multistage, electric submersible pump powered by a 60 kVA generator was used for the step drawdown and constant rate pumping tests. The pump intake was set at 32.5 m below ground level, about 27 m below the standing water level. Flow was controlled by an inline gate valve and was monitored using a 50 mm PMS inline flow meter.

Water level drawdown was manually measured in Popondetta #1 using electric dipmeters.

3.2 Step Drawdown Test

The step test was conducted in order to provide information on bore yield and efficiency in relation to the bore's construction and development. The data was analysed using the Eden and Hazel[2] method which gives an equation for the bore, enabling drawdown for the chosen flow rate over a given time period to be calculated, viz:

$$S_{wt} = (a + b \log t)\, Q + cQ^2$$

where:

S_{wt}	=	drawdown of the water table at a given time (t)
Q	=	pumping rate (m^3/day)
t	=	time in minutes
a,b,c	=	bore constants assessed from the step drawdown data

An assessment of the efficiency of the bore was made using the equation, viz:

$$\text{bore efficiency} = \frac{(a + b \log t)\, Q}{(a + b \log t)\, Q + cQ^2 \times 100}$$

where:

$(a + b \log t)\, Q$ = drawdown due to formation loss

cQ^2 = drawdown due to bore loss

---

[1] *Standards Australia, 1990. Test Pumping of Water Wells AS2368-1990, Published by Standards Assoc. of Australia.*
[2] *Eden, R.N. and Hazel, C.P. (1973) "Computer and Graphical Analyses of Variable Discharge Pumping Test of Wells", Inst. Engrs. Australia, Civil Engng. Trans. pp 5-10*

3.2.1 Popondetta #1 Analysis

A step drawdown test on Popondetta #1 comprising four, two hour steps, was undertaken on 29 August 2000. Prior to commencement of the test, the static water level was measured at 7.34 m below ground level. The step test analysis sheets are given in Appendix B. The pumping rates were progressively increased as follows:

Step 1 - 126.7 m^3/day (1.5 L/s)
Step 2 - 259.2 m^3/day (3.0 L/s)
Step 3 - 345.6 m^3/day (4.0 L/s)
Step 4 - 540 m^3/day (6.25 L/s)

The step drawdown test data is summarised in Table 2.

Table 2: Step Test Analysis

Step	Q (m^3/day)	Δs (m)	Δs/Q (m/m^3/day)	S_w(1min) (m)	S_w(1min)/Q (m/m^3/day)
1	126.7	0.12	9.47×10^{-4}	0.55	4.34×10^{-3}
2	259.2	0.34	1.31×10^{-3}	1.56	6.02×10^{-3}
3	345.6	0.34	9.84×10^{-4}	2.65	7.67×10^{-3}
4	540.0	0.54	1.00×10^{-3}	5.05	9.35×10^{-3}

By undertaking graphical analysis as shown in Appendix B, values for the bore constants were obtained as follows:

$a = 3.2 \times 10^{-3}$
$b = 1.06 \times 10^{-3}$
$c = 1.125 \times 10^{-5}$

Based on these, the 'bore equation' for test bore Popondetta #1 is assessed to be:

$$S_{wt} = (3.2 \times 10^{-3} + 1.06 \times 10^{-3} \log t)\, Q + 1.125 \times 10^{-5}$$

This equation predicts a drawdown of 6.82 m after 24 hours pumping at a rate of 540 m^3/day (6.25 L/s) which compares favourably with a measured drawdown of 6.69 m during the 24 hour constant rate pumping test, undertaken at the same time.

Using this scenario, the 'bore equation' indicates that Popondetta #1 is about 50% efficient.

The bore equation indicates that pumping the bore at a constant rate of 2160 m^3/day (25 L/s) for ten years will give a drawdown of approximately 75 m, about 82.3 m below ground level (maximum available drawdown is 84.6 m about 92 m below ground level, i.e. recommended pump intake level).

This is considered to be the maximum long term safe yield for this bore based on the step test analysis of the data supplied to DP.

3.3 Constant Rate and Recovery Tests

A constant rate test is undertaken to assess the hydraulic parameters of the aquifer and the presence of boundary conditions which may increase or decrease the rate of drawdown. Boundaries may be in the form of a barrier (impermeable) boundary which will increase the rate of drawdown, or recharge boundaries which would reduce the rate of drawdown. The information, together with the hydraulic parameters, allows a more accurate assessment of the long term 'safe' yield of a bore or borefield.

A 24 hour constant rate pumping test was commenced at 0800 hours on 30 August 2000 and was completed at 0800 hours on 31 August 2000. The bore was pumped continuously at a rate of 540 m^3/day (6.25 L/s), and at completion of pumping a water level recovery test was undertaken.

The constant rate drawdown and recovery data by Popondetta #1 were analysed using the "Aquifer Test Version 2.0" software package[3].

The constant rate drawdown data was analysed using the Cooper-Jacob straight line analysis and curve matching techniques of the Neuman method for an unconfined aquifer. The recovery data was analysed using the Theis recovery method. Details of these analysis methods are outlined in Kruseman and de Ridder (1991)[4].

Analysis of the drawdown and recovery data provides an estimate of the hydraulic parameter of aquifer transmissivity. Transmissivity is the coefficient of hydraulic conductivity (permeability) multiplied by the aquifer thickness. The drawdown and recovery analysis sheets for Popondetta #1 are given in Appendix C and a summary of the analysis is provided in Table 3.

Table 3: Summary of Analysis of Pumping Test Data

Bore	Pumping Rate 'Q' (m^3/day)	SWL (mbgL)	Depth of Screen (mbgL)	Maximum Drawdown (m) During Test	Transmissivity 'T' (m^2/day)	Method of Analysis
Popondetta #1	540 (6.25 L/s)	7.34	96-114	6.69	133 94 143	Cooper/Jacob Neuman Theis Recovery

Note: mbgL – metres below ground level

[3] *Waterloo Hydrogeologic 1996, "Aquifer Test Version 2.0".*
[4] *Kruseman, G.P., and N.A. de Ridder, 1991. Analysis and Evaluation of Pumping Test Data. Second Edition, ILRI publication 47, Wageningen, The Netherlands.*

The constant rate test data and analysis indicate that the aquifer is unconfined and receives delayed yield as a result of the groundwater extraction. The delayed yield is indicated by a slight flattening of the drawdown curve, refer to Theis – Jacobs analysis plot in Appendix C, towards the end of the test.

The pumping test data indicates that the aquifer has a transmissivity of about 125 m^2/day at the drilling site.

No barrier or impermeable boundaries were reflected in the data recorded during the 24 hour constant rate test for Popondetta #1.

4.0 GROUNDWATER QUALITY

A groundwater sample collected during the pumping test was analysed on-site for water electrical conductivity (EC), salinity, pH and temperature with a standard hand held instrument. The results of the field measurements are summarised in Table 4.

Table 4: Results of Field Water Quality Analysis

Date	Analysis			
	pH	EC (µS/cm)	Salinity (ppk)	Temp (^{0}C)
29/8/2000	7.7	30	0.03	25.7

Note: µS/cm - micro siemens per centimetre
ppk - parts per thousand

The water is of a high quality with respect to EC and hence salinity or total dissolved solids. For comparison, the World Health Organisation (WHO) guidelines for total dissolved solids of 1000 mg/L in drinking water is approximately equal to an EC of 1500 µS/cm. The pH is slightly alkaline but is well within the WHO guidelines range of 6.5 to 8.5.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The groundwater exploratory drilling program was successful in locating a viable groundwater resource at the location of test bore Popondetta #1. The analysis of the pumping tests indicates the bore has intersected an unconfined aquifer with a transmissivity of about 125 m^2/day. Field water quality measurements indicated the water to be fresh with a slightly alkaline pH of 7.7.

The pumping test analysis indicates the long term 'safe' yield of Popondetta #1 is up to 2160 m^3/day or 25 L/s. A relatively steady state drawdown of about 75 m, about 82-83 m below ground level, is expected to result from long term pumping at this rate.

It is recommended the pump intake be set at 92 m below ground level to allow for seasonal water level fluctuations, deterioration of bore efficiency and drought conditions. Under no circumstances should the intake of the pump be installed within or close (<2 m) to the slotted screen section (refer composite log in Appendix A) of the bore as this will induce turbulent flow within the bore, thereby decreasing the bore efficiency.

Future pump testing of production bores in this area should be carried out with a pump that is capable of producing 16-20 L/s at least in order to confirm the long term safe (maximum) yields of the bores. Assessing the drawdown with the 'bore equation' (from the step test analysis) for pumping rates 3 times or greater than the test pumping rate (i.e. 6.25 L/s) is difficult and prone to error, especially when the bore efficiency is low.

In order to confirm the potential bore yields from this aquifer, future production bores should be constructed with 200 mm diameter (minimum) casing and 10 m of stainless steel screens in order to take full advantage of the potential bore yields. This should increase the bore's efficiency and allow the housing of a pump capable of pumping up to 25 L/s.

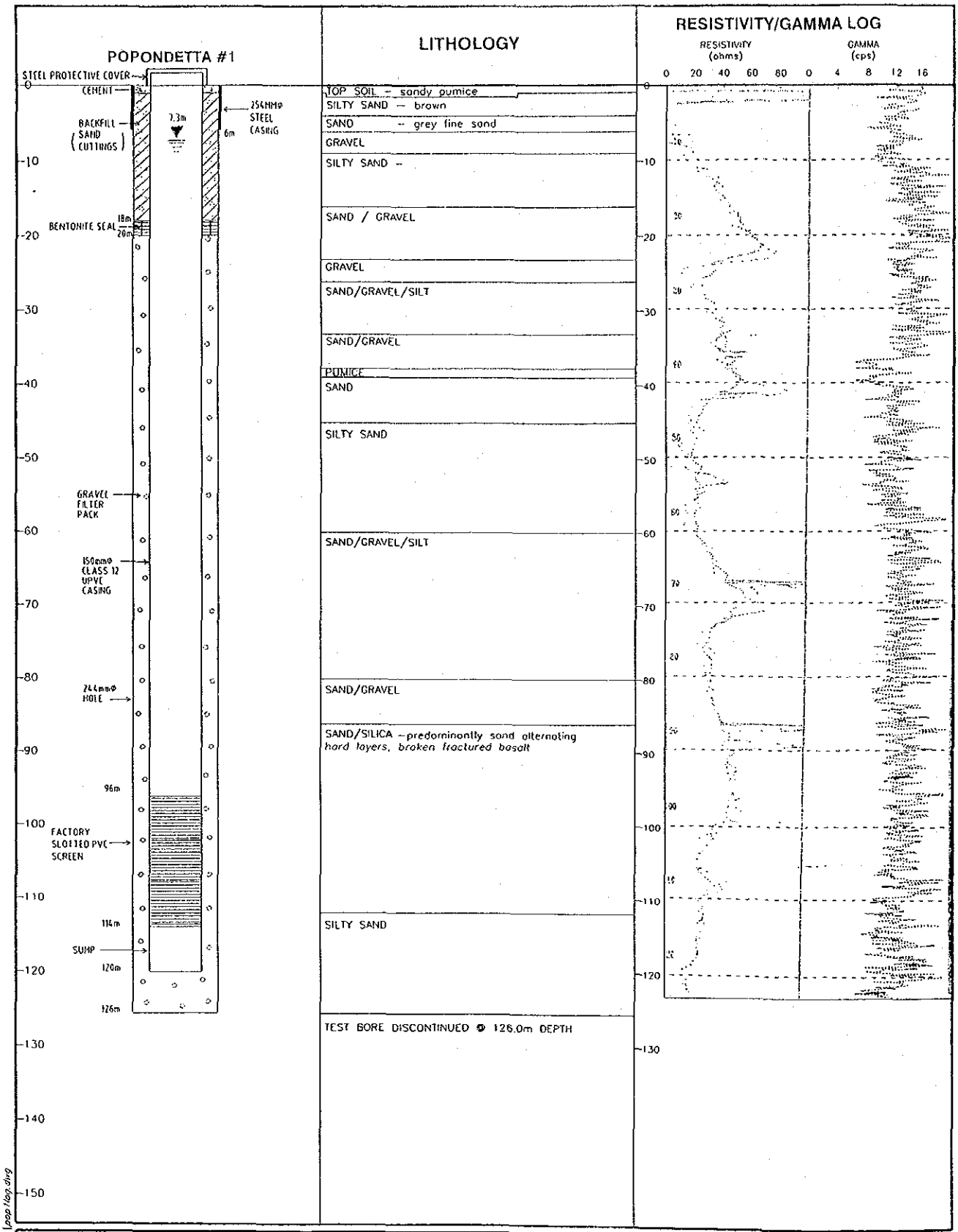
DOUGLAS PARTNERS PTY LTD

Reviewed by:

Carl Deegan
Associate/Hydrogeologist

Adrian Bulcock
Principal/Hydrogeologist

COMPOSITE BORE LOG OF:
TEST BORE POPONDETTA #1



Douglas Partners
Geotechnics · Environment · Groundwater

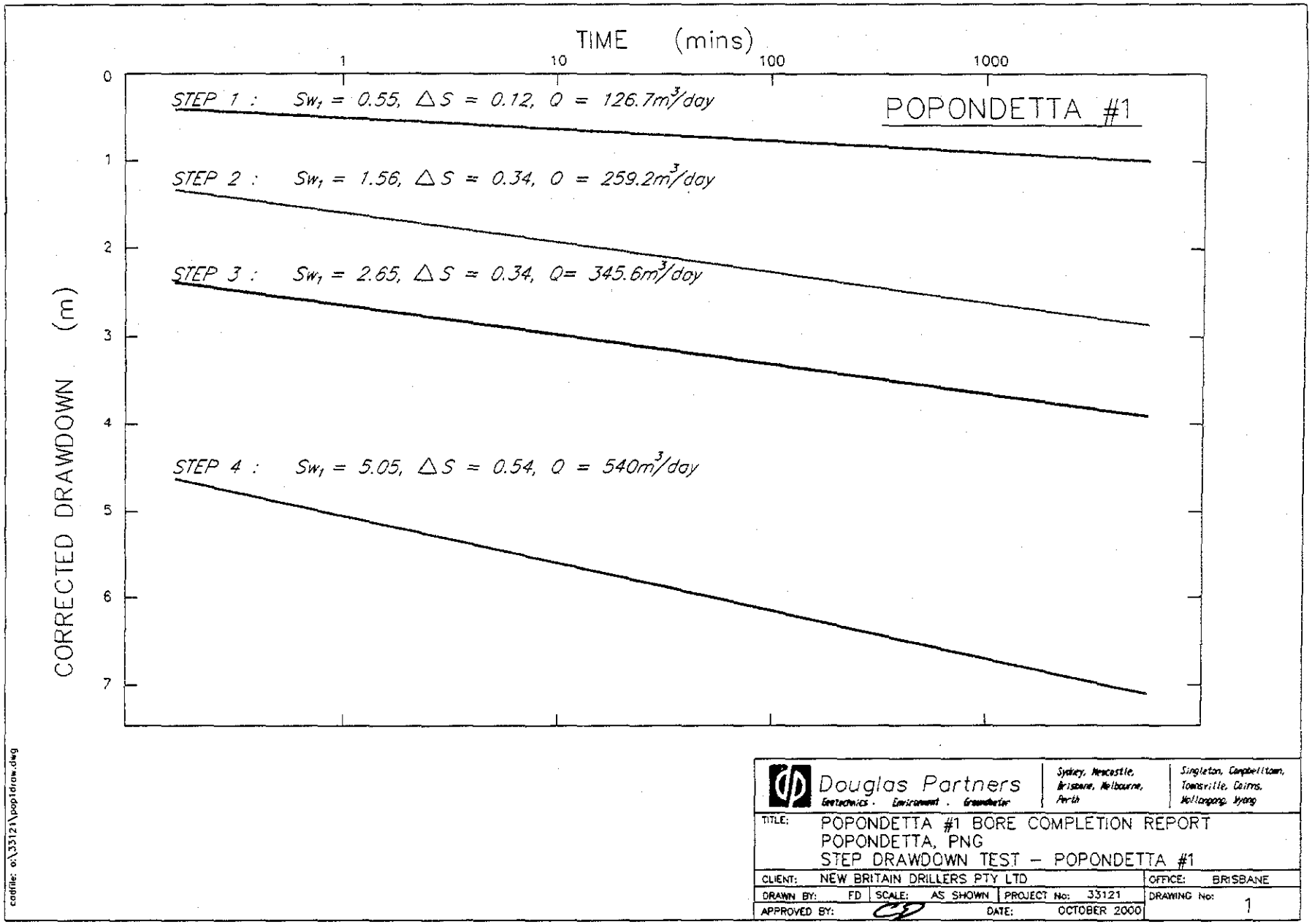
Sydney, Newcastle, Brisbane, Melbourne, Perth, Darwin

Campbelltown, Townsville, Cairns Wollongong, Wyong

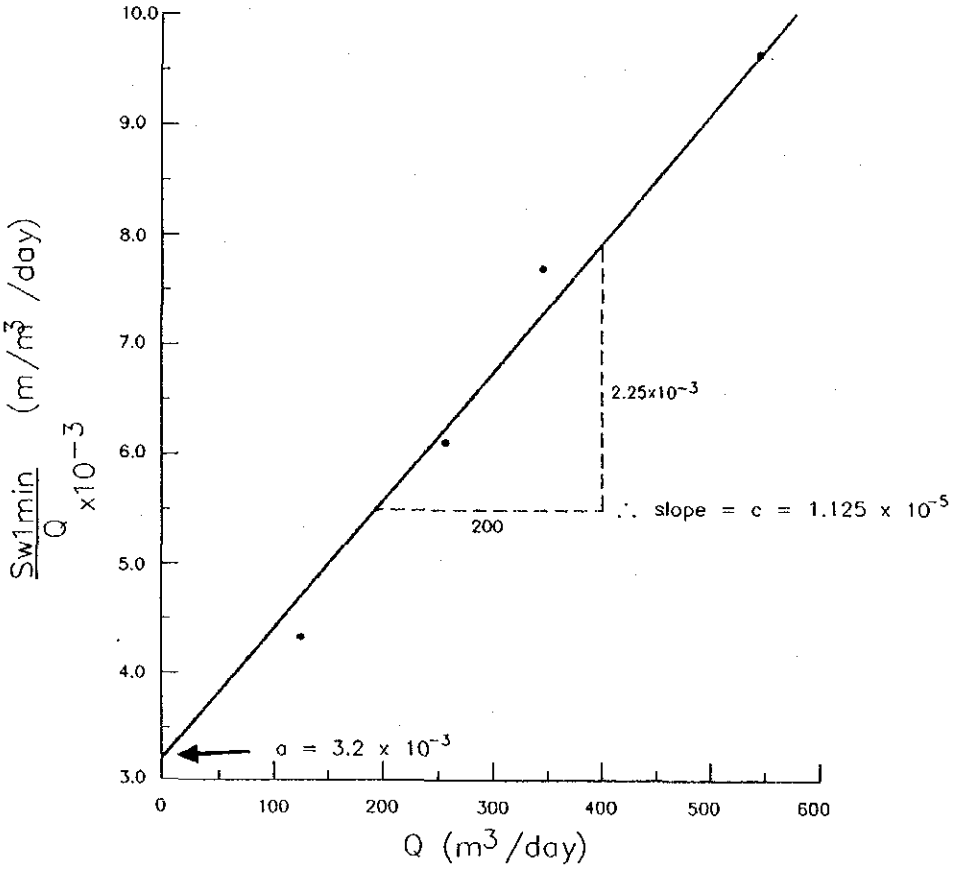
TITLE: **POPONDETTA #1 BORE COMPLETION REPORT**
POPONDETTA , PNG

CLIENT:	NEW BRITAIN DRILLING PTY LTD			OFFICE: BRISBANE	BORE: POPONDETTA #1
DRAWN BY:	FD	DATE: OCTOBER 2000	PROJECT No: 33121	APPROVED:	APPENDIX A

cadfile: c:\dwgs2000\33121\Logs\log.dwg


TIME (mins)
1
10
100
1000
0
1
2
3
4
5
6
7
CORRECTED DRAWDOWN (m)
POPONDETTA #1
STEP 1 : Sw1 = 0.55, ΔS = 0.12, Q = 126.7m³/day
STEP 2 : Sw1 = 1.56, ΔS = 0.34, Q = 259.2m³/day
STEP 3 : Sw1 = 2.65, ΔS = 0.34, Q= 345.6m³/day
STEP 4 : Sw1 = 5.05, ΔS = 0.54, Q = 540m³/day
Douglas Partners
Geotechnics · Environment · Groundwater
Sydney, Newcastle, Brisbane, Melbourne, Perth
Singleton, Campbelltown, Townsville, Cairns, Wollongong, Nyrang
TITLE: POPONDETTA #1 BORE COMPLETION REPORT
POPONDETTA, PNG
STEP DRAWDOWN TEST – POPONDETTA #1
CLIENT: NEW BRITAIN DRILLERS PTY LTD
OFFICE: BRISBANE
DRAWN BY: FD
SCALE: AS SHOWN
PROJECT No: 33121
DRAWING No: 1
APPROVED BY:
DATE: OCTOBER 2000
cadfile: o:\33121\popdraw.dwg

POPONDETTA #1



Since b = average $\frac{\Delta s}{Q}$ = 1.06×10^{-3}

The Bore Equation is :

$Swt = (3.2 \times 10^{-3} + 1.06 \times 10^{-3} \log t)\, Q + 1.125 \times 10^{-5} Q^2$

codfile: a:\33121\pop1step.dwg

Douglas Partners
Geotechnics · Environment · Groundwater

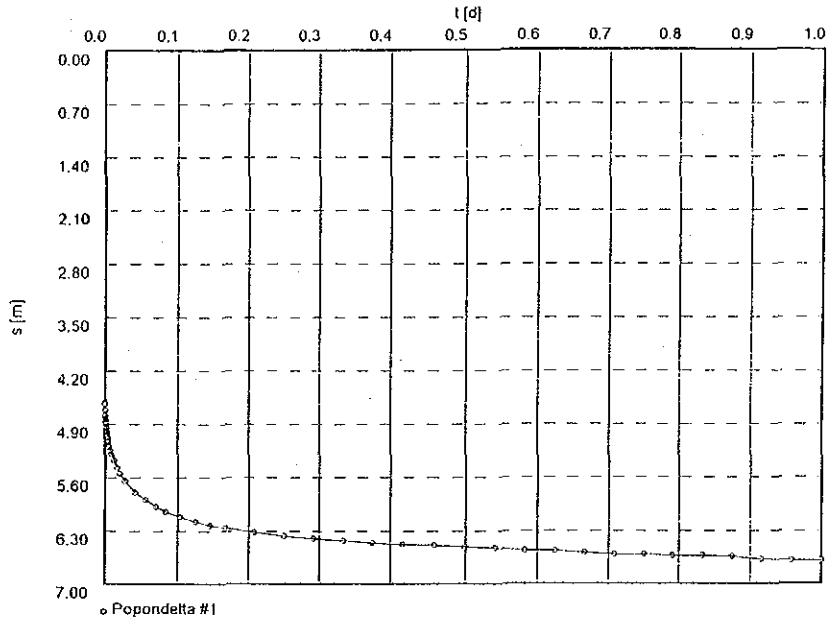
Sydney, Newcastle, Brisbane, Melbourne, Perth, Wyong, Singleton, Campbelltown, Townsville, Cairns Darwin

TITLE: POPONDETTA #1 BORE COMPLETION REPORT
POPONDETTA, PNG
STEP DRAWDOWN TEST – POPONDETTA #1

CLIENT: NEW BRITAIN DRILLERS PTY LTD			OFFICE: BRISBANE
DRAWN BY: FD	SCALE: AS SHOWN	PROJECT No: 33121	APPENDIX B:
APPROVED BY: CD		DATE: OCTOBER 2000	2

Douglas Partners Geotechnics · Environment · Groundwater	Pumping test analysis Time-Drawdown plot	Page 1 Project: Popondetta #1 Bore Completion Evaluated by: CMD | Date: 29/9/00

Pumping Test No. 1, 24 hour Constant Rate	Test conducted on: 30 August 2000
Popondetta #1	
Discharge 6.25 l/s	



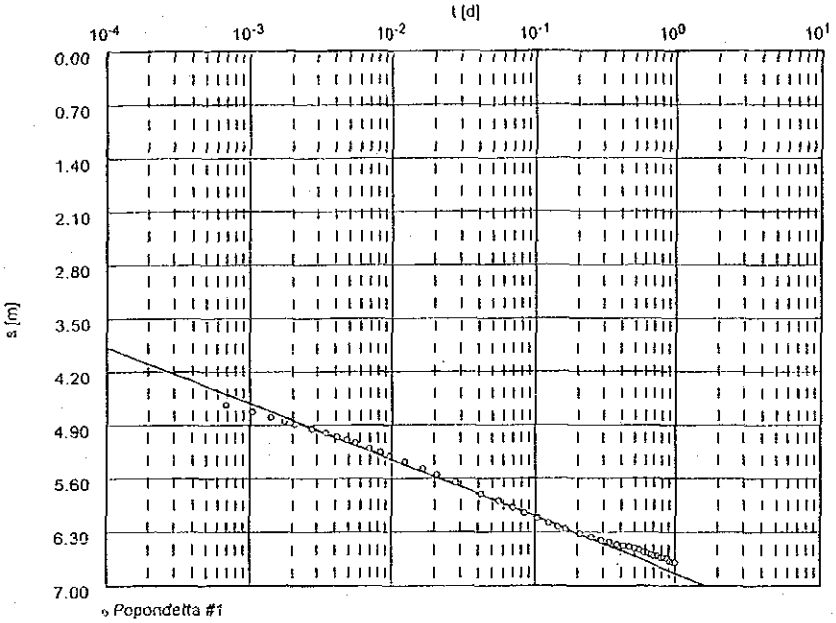
Douglas Partners Geotechnics · Environment · Groundwater	Pumping test analysis Time-Drawdown plot	Page 2 Project: Popondetta #1 Bore Completion Evaluated by: CMO | Date: 29/9/00

Pumping Test No. 1, 24 hour Constant Rate	Test conducted on: 30 August 2000
Popondetta #1	Popondetta #1
Discharge 6.25 l/s	Distance from the pumping well 0.010 m

Static water level: 7.340 m below datum

	Pumping test duration (d)	Water level (m)	Drawdown (m)	
1	0.00069	11.970	4.630	
2	0.00104	12.060	4.720	
3	0.00139	12.130	4.790	
4	0.00174	12.190	4.850	
5	0.00208	12.220	4.880	
6	0.00278	12.290	4.950	
7	0.00347	12.340	5.000	
8	0.00417	12.390	5.050	
9	0.00486	12.430	5.090	
10	0.00556	12.470	5.130	
11	0.00694	12.540	5.200	
12	0.00833	12.590	5.250	
13	0.00972	12.640	5.300	
14	0.01250	12.720	5.380	
15	0.01667	12.810	5.470	
16	0.02083	12.890	5.550	
17	0.02778	12.990	5.650	
18	0.04167	13.140	5.800	
19	0.05556	13.230	5.890	
20	0.06944	13.320	5.980	
21	0.08333	13.390	6.050	
22	0.10417	13.460	6.120	
23	0.12500	13.520	6.180	
24	0.14583	13.570	6.230	
25	0.16667	13.600	6.260	
26	0.20833	13.660	6.320	
27	0.25000	13.710	6.370	
28	0.29167	13.740	6.400	
29	0.33333	13.770	6.430	
30	0.37500	13.800	6.460	
31	0.41667	13.820	6.480	
32	0.45833	13.830	6.490	
33	0.50000	13.850	6.510	
34	0.54167	13.870	6.530	
35	0.58333	13.900	6.560	
36	0.62500	13.910	6.570	
37	0.66667	13.930	6.590	
38	0.70833	13.950	6.610	
39	0.75000	13.950	6.610	
40	0.79167	13.970	6.630	
41	0.83333	13.970	6.630	
42	0.87500	13.980	6.640	
43	0.91667	14.020	6.680	
44	0.95833	14.030	6.690	
45	1.00000	14.030	6.690	

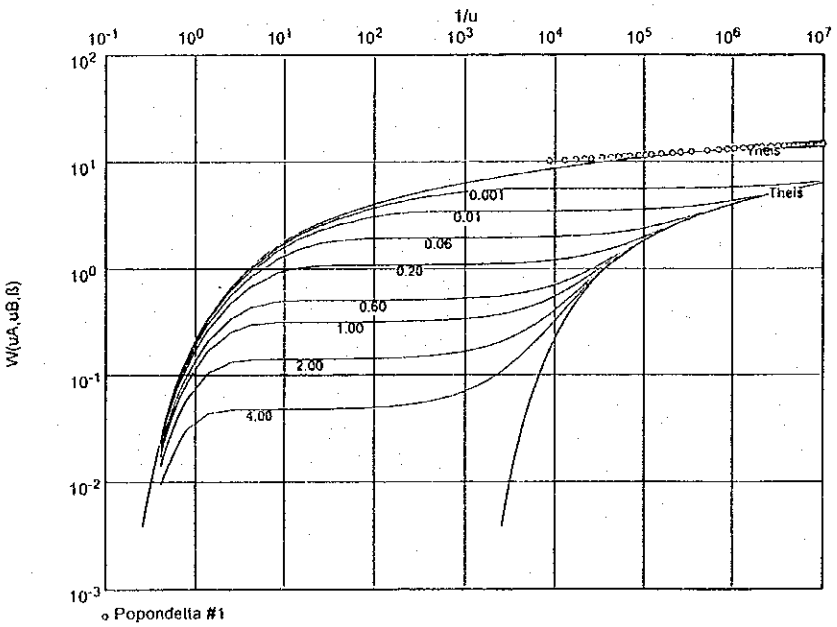
Douglas Partners Geotechnics · Environment · Groundwater	Pumping test analysis Time-Drawdown-method after COOPER & JACOB Confined aquifer	Page 1 Project: Popondetta #1 Bore Report Evaluated by: CMD Date: 29/9/00
Pumping Test No. 1, 24 hour Constant Rate		Test conducted on: 30 August 2000
Popondetta #1		
Discharge 6.25 l/s		



Transmissivity [m²/d]: 1.33 x 10^2

Douglas Partners Geotechnics · Environment · Groundwater	Pumping test analysis NEUMAN's method Unconfined aquifer with delayed watertable response	Page 1 Project: Popondetta #1 Bore Report Evaluated by: CMD Date: 29/9/00

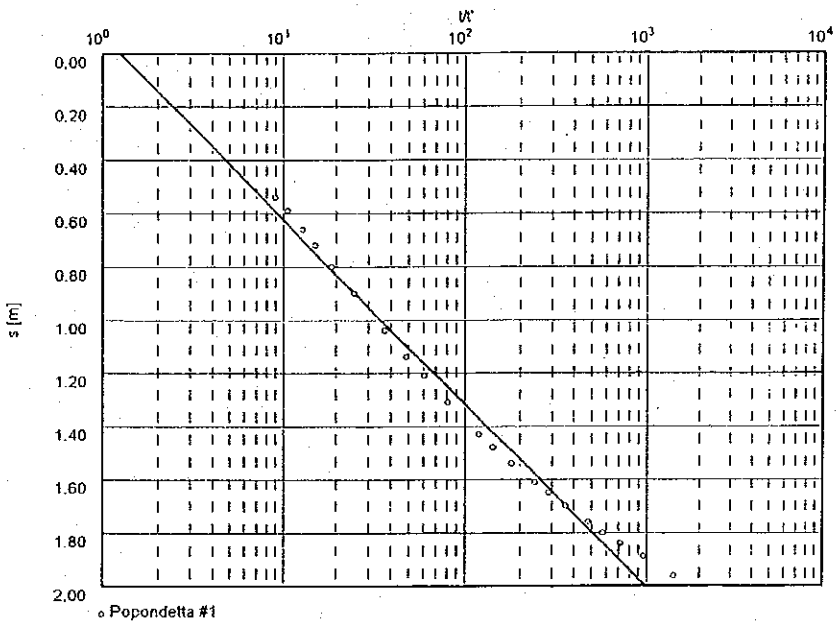
Pumping Test No. 1, 24 hour Constant Rate	Test conducted on: 30 August 2000
Popondetta #1	
Discharge 6.25 l/s	



Transmissivity [m²/d]: 9.43×10^{1}

Douglas Partners Geotechnics · Environment · Groundwater	Pumping test analysis Recovery method after THEIS & JACOB Confined aquifer	Page 1 Project: Popondetta #1 Bore Report Evaluated by: CMD | Date: 29.09.00

Pumping Test No. Water Level Recovery Test	Test conducted on: 31 August 2000
Popondetta #1	
Discharge 6.25 l/s	
	Pumping test duration: 1.00000 d



Transmissivity [m²/d]: 1.43×10^2

Douglas Partners Geotechnics · Environment · Groundwater	Pumping test analysis Recovery method after THEIS & JACOB Confined aquifer	Page 2 Project: Popondetta # t.Bore Report Evaluated by: CMD | Date: 29.09.00

Pumping Test No. Water Level Recovery Test	Test conducted on: 31 August 2000
Popondetta #1	Popondetta #1
Discharge 6.25 l/s	
Static water level: 7.340 m below datum	Pumping test duration: 1.00000 d

	Time from end of pumping [d]	Water level [m]	Residual drawdown [m]	
1	0.00069	9.300	1.960	
2	0.00104	9.230	1.890	
3	0.00139	9.180	1.840	
4	0.00174	9.140	1.800	
5	0.00208	9.100	1.760	
6	0.00278	9.040	1.700	
7	0.00347	8.990	1.650	
8	0.00417	8.950	1.610	
9	0.00556	8.880	1.540	
10	0.00694	8.820	1.480	
11	0.00833	8.770	1.430	
12	0.01250	8.650	1.310	
13	0.01667	8.550	1.210	
14	0.02083	8.480	1.140	
15	0.02778	8.380	1.040	
16	0.04167	8.240	0.900	
17	0.05556	8.140	0.800	
18	0.06944	8.060	0.720	
19	0.08333	8.000	0.660	
20	0.10417	7.930	0.590	
21	0.12500	7.880	0.540	

CD:gk(RD22)
Project 33121
October 2000

REPORT ON
GROUNDWATER DEVELOPMENT FOR WATER SUPPLY SYSTEMS IN PAPUA NEW GUINEA
- POPONDETTA #2 BORE COMPLETION REPORT

1.0 INTRODUCTION

This report describes the test bore completion details and analysis of pumping test data for Popondetta #2 that was recently installed in the Popondetta district. It is understood the bore was drilled and installed as part of the study on Groundwater Development for Water Supply Systems in Papua New Guinea, which is funded by JICA and being carried out by Japan Techno Co Ltd. Douglas Partners Pty Ltd (DP) were commissioned by New Britain Drillers Ltd (NBD) to prepare this bore completion report.

The pumping test carried out on the bore by NBD included:

- a step drawdown test;
- a 24 hour constant rate test; and
- a water level recovery test.

The pumping test data, supplied by NBD, was analysed with the objective of assessing the long term 'safe' yield for the bore (i.e. Popondetta #2).

DP did not supervise the drilling, construction, or pump testing of this test bore on-site. All information (i.e. bore construction, logging and pump test data) contained in this report was obtained by third parties including NBD and sent to DP. Therefore DP cannot be held responsible for the accuracy of the pump test data or the subsequent analysis contained in this report.

2.0 DRILLING AND BORE CONSTRUCTION

The exploratory drilling and bore construction was undertaken by NBD during the period August 2000 using a Bournedrill THD25 truck-mounted drilling rig.

Test bore Popondetta #2 was drilled initially with a 310 mm diameter hole to 6 m depth and installing 254 mm diameter steel casing (collar pipe). A 244 mm diameter hole was then drilled to 108 m depth using conventional rotary mud drilling techniques. A biodegradable liquid polymer mud was used as drilling fluid to remove the cuttings from the borehole.

The rock cuttings were logged on-site by Jim Devlin of NBD. At completion of drilling a suite of geophysical logs consisting of natural Gamma and Resistivity were run. A composite bore log showing both the lithological and geophysical logs is provided in Appendix A. The geological sequence encountered during the drilling of Popondetta #2 consisted primarily of alluvial deposits to 108 m depth. The alluvial deposits comprised a layered sequence of basaltic boulders interlayered with sand, gravel, silty sand and sandy gravel material. It was reported a hard layer was intersected between 84 m and 108 m depth and possibly comprised broken, fractured or vuggy basalt interlayered with sand.

It is understood Popondetta #2 was completed by installing an in-line string of sump, screen and casing into the bore. Class 12 PVC pipe, 150 mm diameter, supplied by Islex (Australia) Pty Ltd, was used as a casing and a sump (6 m long). A 150 mm diameter factory slotted screen, with 0.8 mm aperture and an open surface area of 8%, was installed from 76 m to 94 m depth. A filter pack consisting of 5-10 mm diameter gravel was placed in the annulus between the hole wall and casing/screen. The bore was developed by jetting, chemical treatment, and airlift surging until it produced clean, essentially sand free water. The top section of the annulus between the surface casing and the bore casing was cemented and bentonite sealed to prevent surface contamination from entering the bore.

The construction details provided by NBD for Popondetta #2 are summarised in Table 1 and are shown on the composite bore log in Appendix A.

Table 1: Bore Construction Details – Popondetta #2

Bore No.	Total Depth (mbgL)	Casing Diameter (mm)	Slotted Interval (mbgL)	Gravel Pack (mbgL)	Static Water Level (22/8/00) (mbgL)
Popondetta #2	100	150	76-94	60-108	5.55

Notes: mbgL - metres below ground level

NBD reported the yield whilst airlifting the bore, towards the completion of the development process, was about 15 L/s.

3.0 PUMPING TESTS AND ANALYSIS

Following completion of Popondetta #2, pumping tests were undertaken to assess the hydraulic parameters of the aquifer and long term yield of the bore. The pumping tests and analysis were carried out in accordance with Australian Standard AS2368-1990[1].

3.1 Pumping Test Set-Up

A Calpeda (4SD\23, 5.5 kW) multistage, electric submersible pump powered by a 60 kVA generator was used for the step drawdown and constant rate pumping tests. The pump intake was set at 32.5 m below ground level, about 27 m below the standing water level. Flow was controlled by an inline gate valve and was monitored using a 50 mm PMS inline flow meter.

Water level drawdown was manually measured in Popondetta #2 using electric dipmeters.

3.2 Step Drawdown Test

The step test was conducted in order to provide information on bore yield and efficiency in relation to the bore's construction and development. The data was analysed using the Eden and Hazel[2] method which gives an equation for the bore, enabling drawdown for the chosen flow rate over a given time period to be calculated, viz:

$$S_{wt} = (a + b \log t)\, Q + cQ^2$$

where:

S_{wt}	=	drawdown of the water table at a given time (t)
Q	=	pumping rate (m^3/day)
t	=	time in minutes
a,b,c	=	bore constants assessed from the step drawdown data

An assessment of the efficiency of the bore was made using the equation, viz:

$$\text{bore efficiency} = \frac{(a + b \log t)\, Q}{(a + b \log t)\, Q + cQ^2} \times 100$$

where:

$(a + b \log t)\, Q$ = drawdown due to formation loss

cQ^2 = drawdown due to bore loss

[1] *Standards Australia, 1990. Test Pumping of Water Wells AS2368-1990, Published by Standards Assoc. of Australia.*
[2] *Eden, R.N. and Hazel, C.P. (1973) "Computer and Graphical Analyses of Variable Discharge Pumping Test of Wells", Inst. Engrs. Australia, Civil Engng. Trans. pp 5-10*

This is considered to be the maximum long term safe yield for this bore based on the step test analysis of the data supplied to DP.

3.3 Constant Rate and Recovery Tests

A constant rate test is undertaken to assess the hydraulic parameters of the aquifer and the presence of boundary conditions which may increase or decrease the rate of drawdown. Boundaries may be in the form of a barrier (impermeable) boundary which will increase the rate of drawdown, or recharge boundaries which would reduce the rate of drawdown. The information, together with the hydraulic parameters, allows a more accurate assessment of the long term 'safe' yield of a bore or borefield.

A 24 hour constant rate pumping test was commenced at 0800 hours on 25 August 2000 and was completed at 0800 hours on 26 August 2000. The bore was pumped continuously at a rate of 540 m^3/day (6.25 L/s), and at completion of pumping a water level recovery test was undertaken.

The constant rate drawdown and recovery data by Popondetta #2 were analysed using the "Aquifer Test Version 2.0" software package[3].

The constant rate drawdown data was analysed using the Cooper-Jacob straight line analysis and curve matching techniques of the Neuman method for an unconfined aquifer. The recovery data was analysed using the Theis recovery method. Details of these analysis methods are outlined in Kruseman and de Ridder (1991)[4].

Analysis of the drawdown and recovery data provides an estimate of the hydraulic parameter of aquifer transmissivity. Transmissivity is the coefficient of hydraulic conductivity (permeability) multiplied by the aquifer thickness. The drawdown and recovery analysis sheets for Popondetta #2 are given in Appendix C and a summary of the analysis is provided in Table 3.

Table 3: Summary of Analysis of Pumping Test Data

Bore	Pumping Rate 'Q' (m^3/day)	SWL (mbgL)	Depth of Screen (mbgL)	Maximum Drawdown (m) During Test	Transmissivity 'T' (m^2/day)	Method of Analysis
Popondetta #2	540 (6.25 L/s)	5.55	76-94	7.39	94 87 100	Cooper/Jacob Neuman Theis Recovery

Note: mbgL – metres below ground level

[3] *Waterloo Hydrogeologic 1996, "Aquifer Test Version 2.0".*
[4] *Kruseman, G.P., and N.A. de Ridder, 1991. Analysis and Evaluation of Pumping Test Data. Second Edition, ILRI publication 47, Wageningen, The Netherlands.*

The constant rate test data and analysis indicate that the aquifer is unconfined and receives delayed yield as a result of the groundwater extraction. The delayed yield is indicated by a slight flattening of the drawdown curve, refer to Theis – Jacobs analysis plot in Appendix C, towards the end of the test.

The pumping test data indicates that the aquifer has a transmissivity of about 94 m^2/day at the drilling site.

No barrier or impermeable boundaries were reflected in the data recorded during the 24 hour constant rate test for Popondetta #2.

4.0 GROUNDWATER QUALITY

A groundwater sample collected during the pumping test was analysed on-site for water electrical conductivity (EC), salinity, pH and temperature with a standard hand held instrument. The results of the field measurements are summarised in Table 4.

Table 4: Results of Field Water Quality Analysis

Date	Analysis			
	pH	EC (µS/cm)	Salinity (ppk)	Temp (^{0}C)
29/8/2000	8.0	170	0.07	24.3

Note: µS/cm - micro siemens per centimetre
ppk - parts per thousand

The water is of a high quality with respect to EC and hence salinity or total dissolved solids. For comparison, the World Health Organisation (WHO) guidelines for total dissolved solids of 1000 mg/L in drinking water is approximately equal to an EC of 1500 µS/cm. The pH is slightly alkaline but is well within the WHO guidelines range of 6.5 to 8.5.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The groundwater exploratory drilling program was successful in locating a viable groundwater resource at the location of test bore Popondetta #2. The analysis of the pumping tests indicates the bore has intersected an unconfined aquifer with a transmissivity of about 94 m^2/day. Field water quality measurements indicated the water to be fresh with a slightly alkaline pH of 8.0.

The pumping test analysis indicates the long term 'safe' yield of Popondetta #2 is up to 1642 m^3/day or 19 L/s. A relatively steady state drawdown of about 53 m, about 59 m below ground level, is expected to result from long term pumping at this rate.

It is recommended the pump intake be set at 72 m below ground level to allow for seasonal water level fluctuations, deterioration of bore efficiency and drought conditions. Under no circumstances should the intake of the pump be installed within or close (<2 m) to the slotted screen section (refer composite log in Appendix A) of the bore as this will induce turbulent flow within the bore, thereby decreasing the bore efficiency.

Future pump testing of production bores in this area should be carried out with a pump that is capable of producing 16-20 L/s at least in order to confirm the long term safe (maximum) yields of the bores. Assessing the drawdown with the 'bore equation' (from the step test analysis) for pumping rates 3 times or greater than the test pumping rate (i.e. 6.25 L/s) is difficult and prone to error, especially when the bore efficiency is low.

In order to confirm the potential bore yields from this aquifer, future production bores should be constructed with 200 mm diameter (minimum) casing and 10 m of stainless steel screens in order to take full advantage of the potential bore yields. This should increase the bore's efficiency and allow the housing of a pump capable of pumping up to 25 L/s.

DOUGLAS PARTNERS PTY LTD

Reviewed by:

Carl Deegan
Associate/Hydrogeologist

Adrian Bulcock
Principal/Hydrogeologist

3.2.1 Popondetta #2 Analysis

A step drawdown test on Popondetta #2 comprising four, two hour steps, was undertaken on 22 August 2000. Prior to commencement of the test, the static water level was measured at 5.55 m below ground level (6.35 m below top of casing). The step test analysis sheets are given in Appendix B. The pumping rates were progressively increased as follows:

Step 1 - 172.8 m^3/day (2.0 L/s)
Step 2 - 259.2 m^3/day (3.0 L/s)
Step 3 - 345.6 m^3/day (4.0 L/s)
Step 4 - 540 m^3/day (6.25 L/s)

The step drawdown test data is summarised in Table 2.

Table 2: Step Test Analysis

Step	Q (m^3/day)	Δs (m)	Δs/Q (m/m^3/day)	S_w(1min) (m)	S_w(1min)/Q (m/m^3/day)
1	172.8	0.17	9.84×10^{-4}	0.91	5.27×10^{-3}
2	259.2	0.33	1.27×10^{-3}	1.91	7.37×10^{-3}
3	345.6	0.41	1.19×10^{-3}	3.14	9.09×10^{-3}
4	540.0	0.65	1.20×10^{-3}	5.53	1.02×10^{-2}

By undertaking graphical analysis as shown in Appendix B, values for the bore constants were obtained as follows:

$a = 3.5 \times 10^{-3}$
$b = 1.16 \times 10^{-3}$
$c = 1.29 \times 10^{-5}$

Based on these, the 'bore equation' for test bore Popondetta #2 is assessed to be:

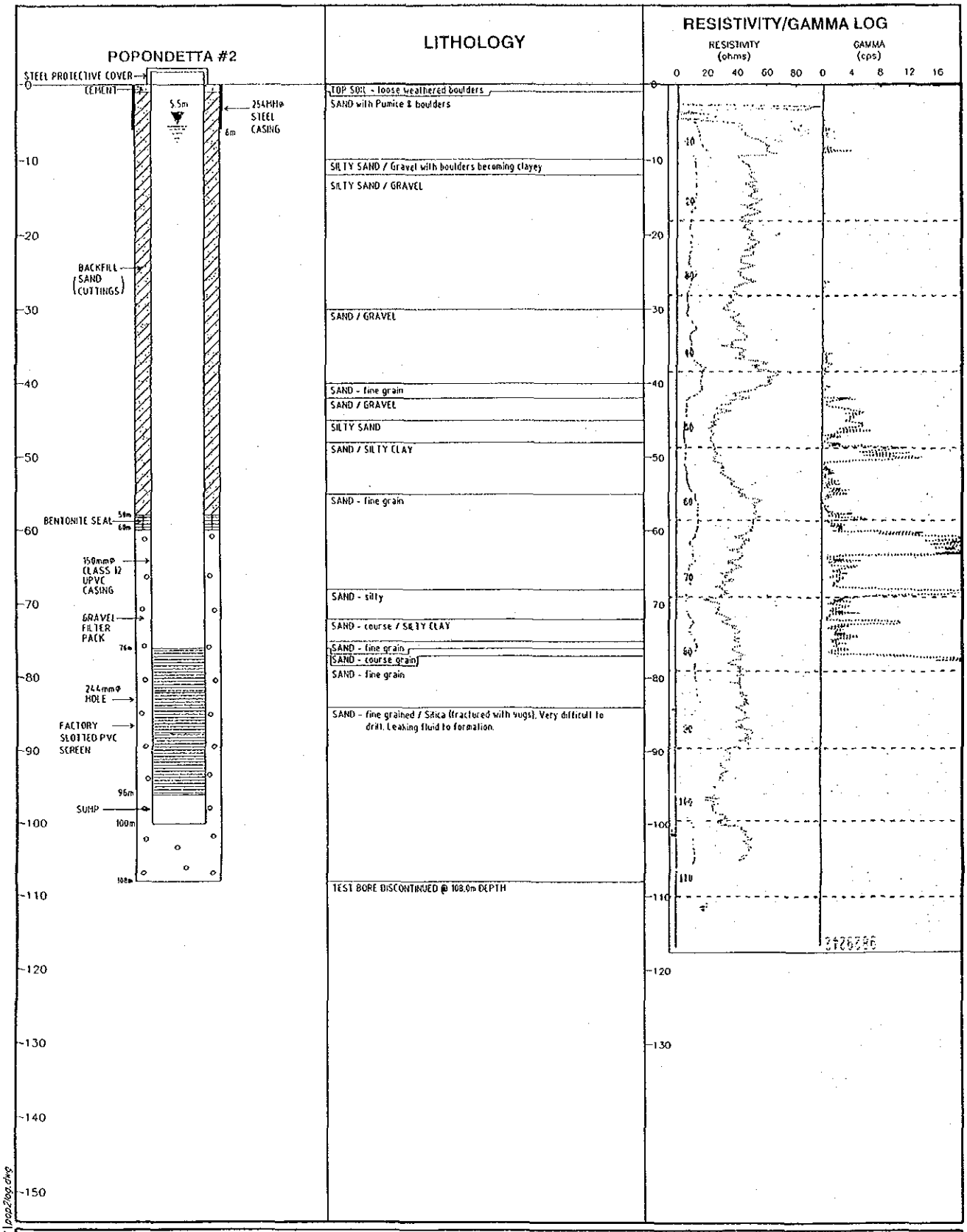
$$S_w = (3.5 \times 10^{-3} + 1.16 \times 10^{-3} \log t)\, Q + 1.29 \times 10^{-5}$$

This equation predicts a drawdown of 7.63 m after 24 hours pumping at a rate of 540 m^3/day (6.25 L/s) which compares favourably with a measured drawdown of 7.39 m during the 24 hour constant rate pumping test, undertaken at the same time.

Using this scenario, the 'bore equation' indicates that Popondetta #2 is about 51% efficient.

The bore equation indicates that pumping the bore at a constant rate of 1642 m^3/day (19 L/s) for ten years will give a drawdown of approximately 53 m, about 59 m below ground level (maximum available drawdown is 66.5 m about 72 m below ground level, i.e. recommended pump intake level).

COMPOSITE BORE LOG OF:
TEST BORE POPONDETTA #2



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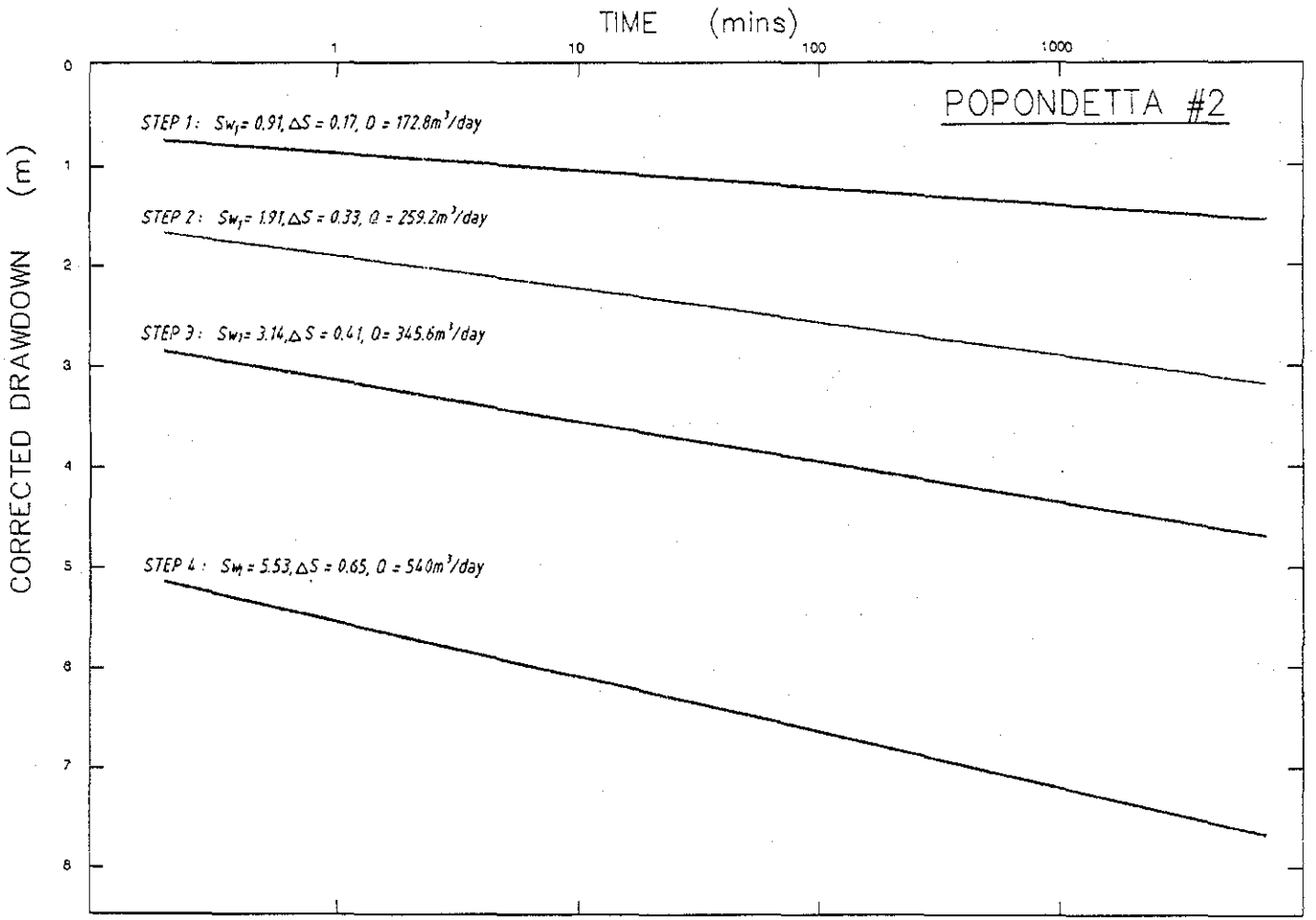
TITLE: **POPONDETTA #2 BORE COMPLETION REPORT**
POPONDETTA , PNG

CLIENT:	NEW BRITAIN DRILLING PTY LTD			OFFICE: BRISBANE	BORE: POPONDETTA #2
DRAWN BY:	FD	DATE: OCTOBER 2000	PROJECT No: 33121	APPROVED:	APPENDIX A

coorfile: c:\dwgs2000\33121\pop2log.dwg



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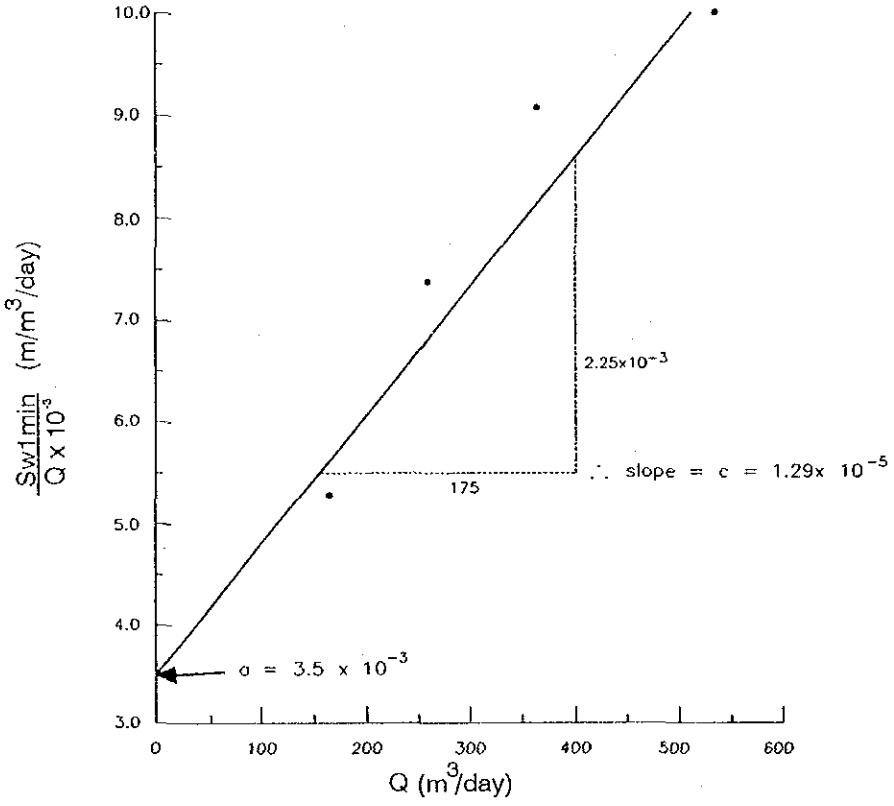
TITLE: POPONDETTA #2 BORE COMPLETION REPORT
POPONDETTA, PNG
STEP DRAWDOWN TEST – POPONDETTA #2

CLIENT:	NEW BRITAIN DRILLERS PTY LTD			OFFICE:	BRISBANE
DRAWN BY:	GAF	SCALE: AS SHOWN	PROJECT No: 33121	DRAWING No:	1
APPROVED BY:		DATE: OCTOBER 2000			

POPONDETTA #2



Since b = average $\frac{\Delta S}{Q}$ = 1.16 x 10^{-3}

∴ Bore Equation is :

Swt = (3.5 x 10^{-3} + 1.16 x 10^{-3} logt) Q + 1.29 x $10^{-5}Q^2$

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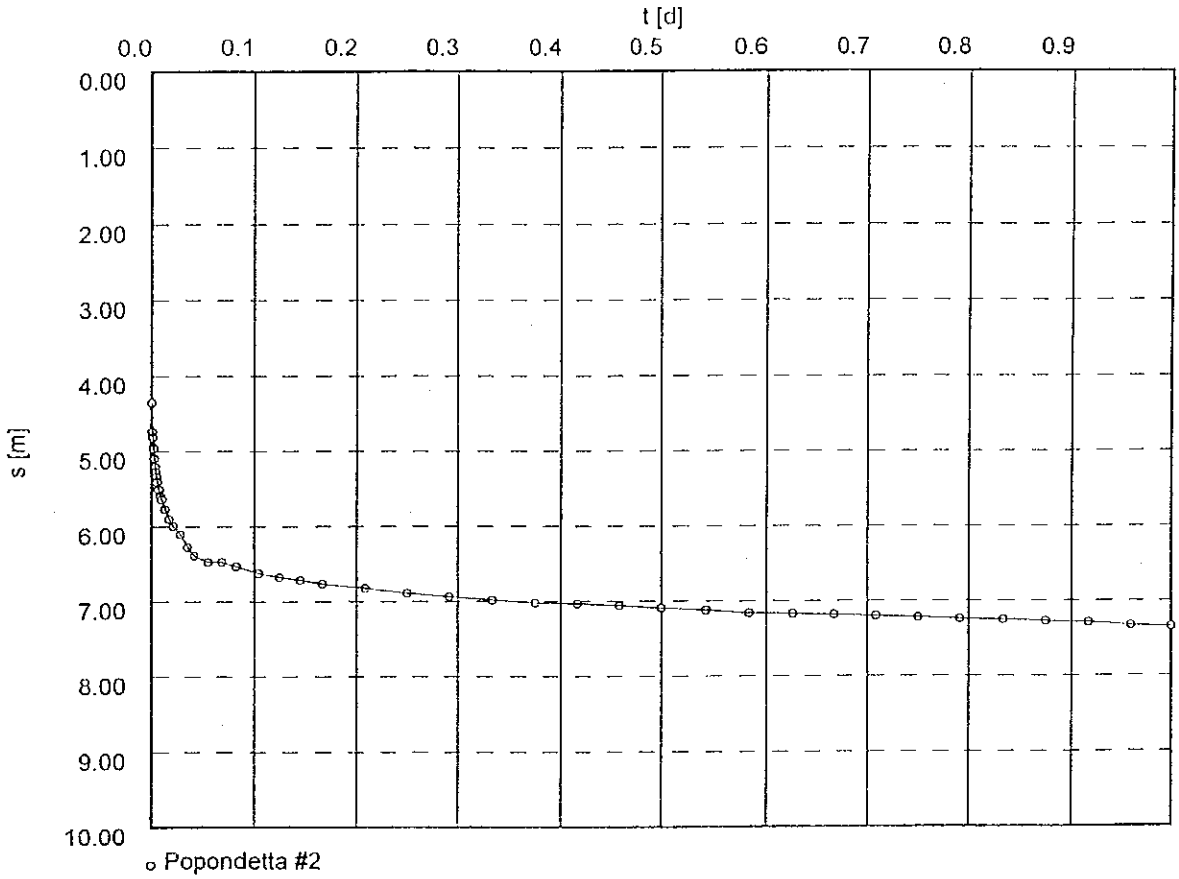
TITLE: POPONDETTA #2 BORE COMPLETION REPORT
POPONDETTA, PNG
STEP DRAWDOWN TEST - POPONDETTA #2

CLIENT: NEW BRITAIN DRILLERS PTY LTD			OFFICE: BRISBANE
DRAWN BY: GAF	SCALE: AS SHOWN	PROJECT No: 33121	APPENDIX B: 2
APPROVED BY: CD		DATE: OCTOBER 2000	

Douglas Partners Geotechnics · Environment · Groundwater	Pumping test analysis Time-Drawdown plot	Page 1 Project: Popondetta #1 Bore Report Evaluated by: CMD Date: 3/10/00
Pumping Test No. 1, 24 hour Constant Rate		Test conducted on: 25 August 2000
Popondetta #2		
Discharge 6.25 l/s		



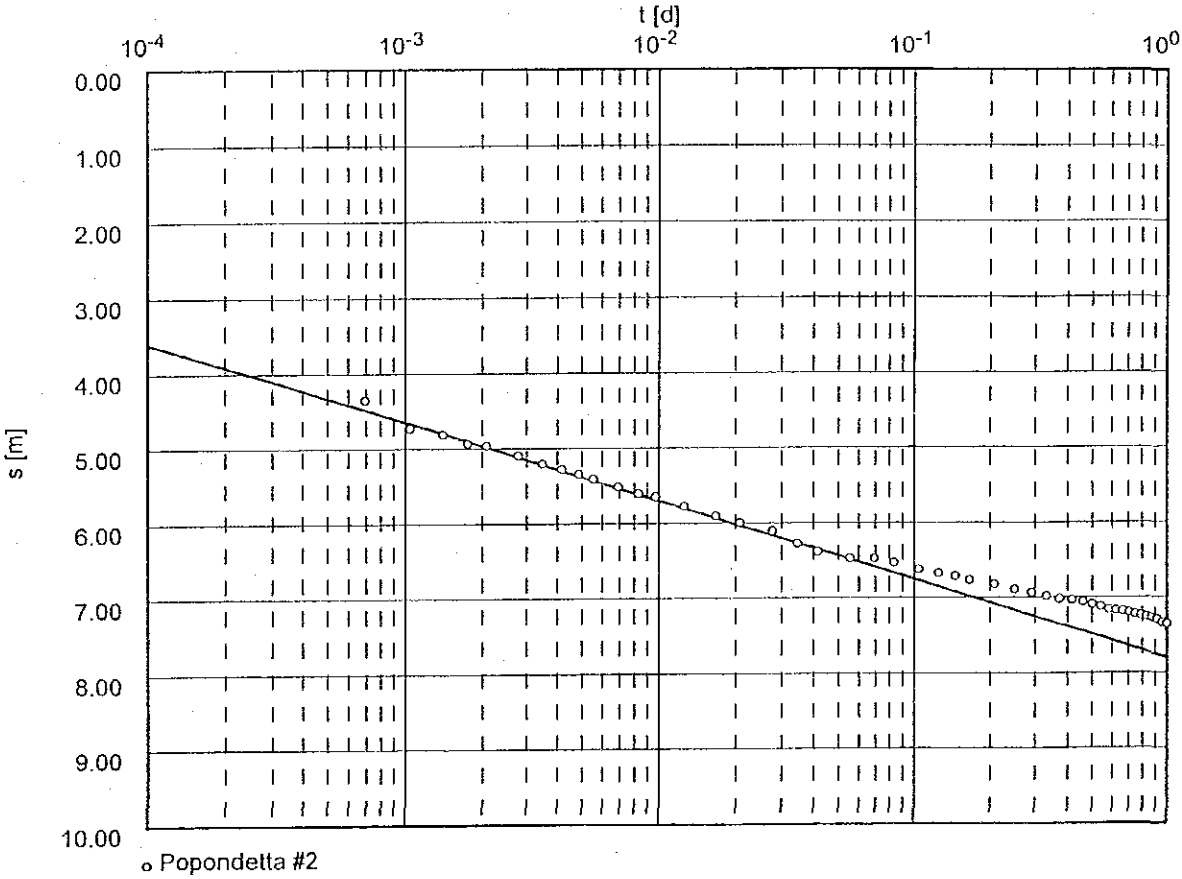
Douglas Partners Geotechnics · Environment · Groundwater	Pumping test analysis Time-Drawdown plot	Page 2 Project: Popondetta #1 Bore Report Evaluated by: CMD | Date: 3/10/00

Pumping Test No. 1, 24 hour Constant Rate	Test conducted on: 25 August 2000
Popondetta #2	Popondetta #2
Discharge 6.25 l/s	*Distance from the pumping well 0.010 m*
Static water level: 6.390 m below datum	

	Pumping test duration [d]	Water level [m]	Drawdown [m]	
1	0.00069	10.740	4.350	
2	0.00104	11.120	4.730	
3	0.00139	11.200	4.810	
4	0.00174	11.320	4.930	
5	0.00208	11.350	4.960	
6	0.00278	11.480	5.090	
7	0.00347	11.590	5.200	
8	0.00417	11.660	5.270	
9	0.00486	11.730	5.340	
10	0.00556	11.790	5.400	
11	0.00694	11.900	5.510	
12	0.00833	11.990	5.600	
13	0.00972	12.030	5.640	
14	0.01250	12.160	5.770	
15	0.01667	12.290	5.900	
16	0.02083	12.380	5.990	
17	0.02778	12.490	6.100	
18	0.03472	12.660	6.270	
19	0.04167	12.770	6.380	
20	0.05556	12.860	6.470	
21	0.06944	12.860	6.470	
22	0.08333	12.920	6.530	
23	0.10417	13.010	6.620	
24	0.12500	13.060	6.670	
25	0.14583	13.100	6.710	
26	0.16667	13.150	6.760	
27	0.20833	13.210	6.820	
28	0.25000	13.280	6.890	
29	0.29167	13.320	6.930	
30	0.33333	13.370	6.980	
31	0.37500	13.410	7.020	
32	0.41667	13.420	7.030	
33	0.45833	13.450	7.060	
34	0.50000	13.480	7.090	
35	0.54167	13.510	7.120	
36	0.58333	13.550	7.160	
37	0.62500	13.560	7.170	
38	0.66667	13.570	7.180	
39	0.70833	13.590	7.200	
40	0.75000	13.610	7.220	
41	0.79167	13.630	7.240	
42	0.83333	13.640	7.250	
43	0.87500	13.660	7.270	
44	0.91667	13.680	7.290	
45	0.95833	13.720	7.330	
46	1.00000	13.740	7.350	

Douglas Partners Geotechnics · Environment · Groundwater	Pumping test analysis Time-Drawdown-method after COOPER & JACOB Confined aquifer	Page 1 Project: Popondetta #2 Bore Report Evaluated by: CMD Date: 3/10/00

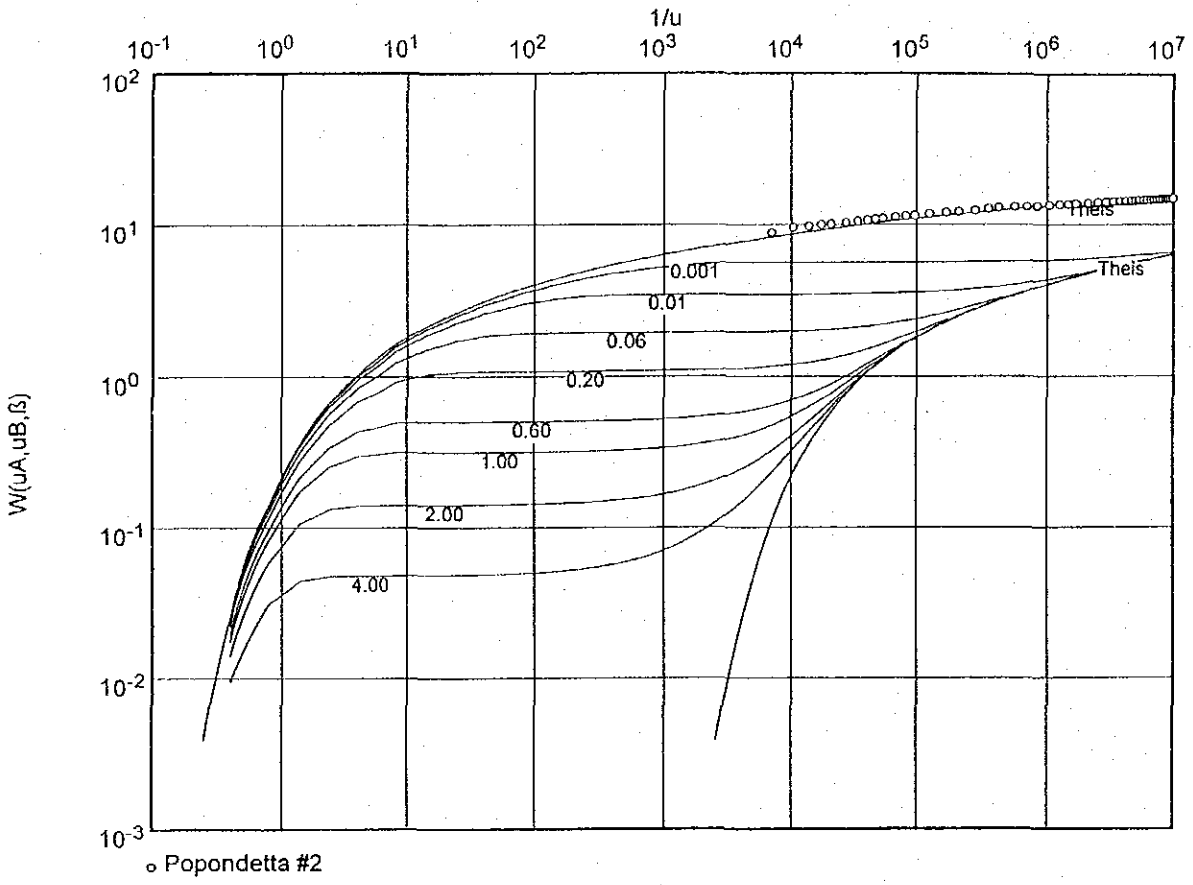
Pumping Test No. 1, 24 hour Constant Rate	Test conducted on: 25 August 2000
Popondetta #2	
Discharge 6.25 l/s	



Transmissivity [m²/d]: 9.40×10^{1}

Douglas Partners Geotechnics · Environment · Groundwater	Pumping test analysis NEUMAN's method Unconfined aquifer with delayed watertable response	Page 1 Project: Popondetta #2 Bore Report Evaluated by: CMD Date: 3/10/00

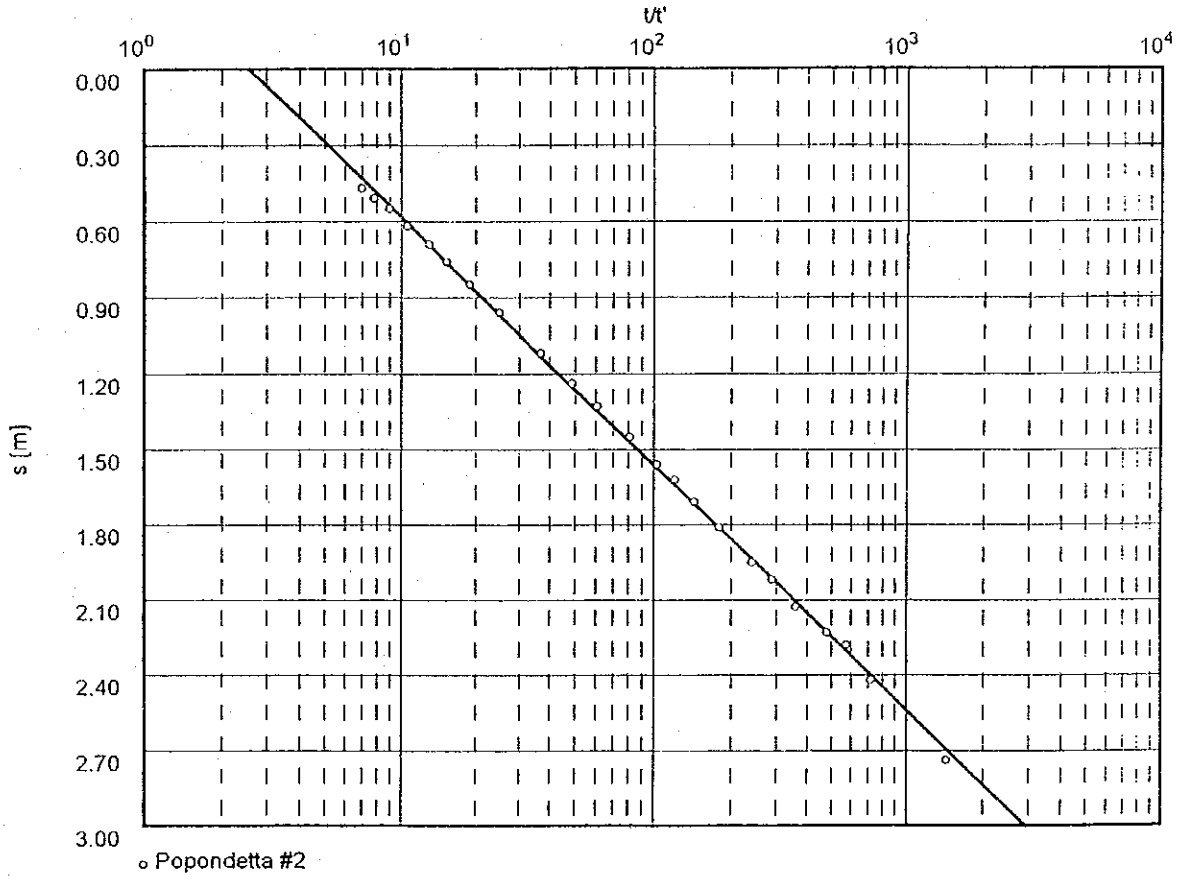
Pumping Test No. 1, 24 hour Constant Rate	Test conducted on: 25 August 2000
Popondetta #2	
Discharge 6.25 l/s	



Transmissivity [m²/d]: 8.71×10^{1}

Douglas Partners Geotechnics · Environment · Groundwater	Pumping test analysis Recovery method after THEIS & JACOB Confined aquifer	Page 1 Project: Popondetta #1 Bore Report Evaluated by: CMD | Date: 29/9/00

Pumping Test No. Recovery Test	Test conducted on: 24 August 2000
Popondetta #2	
Discharge 6.25 l/s	
	Pumping test duration: 1.00000 d



Transmissivity [m²/d]: 1.00×10^2

Douglas Partners Geotechnics · Environment · Groundwater	Pumping test analysis Recovery method after THEIS & JACOB Confined aquifer	Page 2 Project: Popondetta #1 Bore Report Evaluated by: CMD | Date: 29/9/00

Pumping Test No. Recovery Test	Test conducted on: 24 August 2000
Popondetta #2	Popondetta #2
Discharge 6.25 l/s	
Static water level: 6.390 m below datum	Pumping test duration: 1.00000 d

	Time from end of pumping [d]	Water level [m]	Residual drawdown [m]	
1	0.00069	9.130	2.740	
2	0.00139	8.810	2.420	
3	0.00174	8.670	2.280	
4	0.00208	8.620	2.230	
5	0.00278	8.520	2.130	
6	0.00347	8.410	2.020	
7	0.00417	8.340	1.950	
8	0.00556	8.200	1.810	
9	0.00694	8.100	1.710	
10	0.00833	8.010	1.620	
11	0.00972	7.950	1.560	
12	0.01250	7.840	1.450	
13	0.01667	7.720	1.330	
14	0.02083	7.630	1.240	
15	0.02778	7.510	1.120	
16	0.04167	7.350	0.960	
17	0.05556	7.240	0.850	
18	0.06944	7.150	0.760	
19	0.08333	7.080	0.690	
20	0.10417	7.010	0.620	
21	0.12500	6.940	0.550	
22	0.14583	6.900	0.510	
23	0.16667	6.860	0.470	

CD:gk(RD23)
Project 33121
October 2000

REPORT ON GROUNDWATER DEVELOPMENT FOR WATER SUPPLY SYSTEMS IN PAPUA NEW GUINEA - FINSCHHAFEN #2

1.0 INTRODUCTION

This report describes the test bore completion details and analysis of pumping test data for Finschhafen #2 that was recently installed in the primary school yard in the Finschhafen district. It is understood the bore was drilled and installed as part of the study on Groundwater Development for Water Supply Systems in Papua New Guinea, which is funded by JICA and being carried out by Japan Techno Co Ltd. Doulgas Partners Pty Ltd (DP) were commissioned by New Britain Drillers Ltd (NBD) to prepare this bore completion report.

The pumping test carried out on the bore by NBD included:

- a step drawdown test;
- a 24 hour constant rate test; and
- a water level recovery test.

The pumping test data, supplied by NBD, was analysed with the objective of assessing the long term 'safe' yield for the bore (i.e. Finschhafen #2).

DP did not supervise the drilling, construction, or pump testing of this test bore on-site. All information (i.e. bore construction, logging and pump test data) contained in this report was *obtained by third parties including NBD and sent to DP. Therefore DP cannot be held responsible* for the accuracy of the pump test data or the subsequent analysis contained in this report.

2.0 DRILLING AND BORE CONSTRUCTION

The exploratory drilling and bore construction was undertaken by NBD during the month of October 2000 using a Bournedrill THD25 truck-mounted drilling rig.

Test bore Finschhafen #2 was drilled initially with a 310 mm diameter hole to 6 m depth and installing 254 mm diameter steel casing (collar pipe). A 244 mm diameter hole was then drilled to 37 m depth using conventional rotary mud drilling techniques. As circulation loss was encountered whilst drilling, 203 mm (eight inch) diameter steel casing was required to be installed to 34 m in order to stabilise the borehole. Once the test bore had been installed this casing was removed. A biodegradable liquid polymer mud was used as drilling fluid to remove the cuttings from the borehole.

The rock cuttings were logged on-site by Jim Devlin of NBD. At completion of drilling a suite of geophysical logs consisting of natural Gamma and Resistivity were run, but were reported by NBD to be unsuccessful due to equipment failure. A composite bore log showing the lithological log is provided in Appendix A. The geological sequence encountered during the drilling of Finschhafen #2 consisted of brown coronous limestone and tuff to 6 m depth, underlain by grey coronous limestone with some silt to 28 m depth, which in turn is underlain by white coronous gravel and sand to the total depth drilled.

Finschhafen #2 was completed by installing an in-line string of screen and casing into the bore. Steel ultrapipe 152 mm (six inch) diameter nominal bore casing, 6.4 mm wall thickness, supplied by Tubemakers Australia Pty Ltd was used as the casing. A 152 mm diameter stainless steel screen, with 0.8 mm aperture and an open surface area of 20%, was installed from 30 m to 36 m depth. A filter pack consisting of 5-10 mm diameter gravel was placed in the annulus between the hole wall and casing/screen. The bore was developed by jetting, chemical treatment and airlift surging until it produced clean, essentially sand free water. The top section of the annulus between the surface casing and the bore casing was cemented and bentonite sealed to prevent surface contamination from entering the bore.

The construction details provided by NBD for Finschhafen #2 are summarised in Table 1 and are shown on the composite bore log in Appendix A.

Table 1: Bore Construction Details

Bore No.	Total Depth (mbgL)	Casing Diameter (mm)	Screen Interval (mbgL)	Gravel Pack (mbgL)	Static Water Level (29/8/00) (mbgL)
Finschhafen #2	36.2	152	30-36	10-37	5.90

NBD reported the yield whilst airlifting the bore, at the end of the development process, was about 15 L/s. This is considered to be the limit of the air compressor on the drilling rig airlifting from within a 152 mm (six inch) diameter bore casing, rather than a limit of the bore's yield.

3.0 PUMPING TESTS AND ANALYSIS

Following completion of Finschhafen #2, pumping tests were undertaken to assess the hydraulic parameters of the aquifer and long term yield of the bore. The pumping tests and analysis were carried out in accordance with Australian Standard AS2368-1990[1].

3.1 Pumping Test Set-Up

A Calpeda (4SD15\23, 5.5 kW) multistage, electric submersible pump powered by a 60 kVA generator was used for the step drawdown and constant rate pumping tests. The pump intake was set at 26.5 m below ground level, about 20 m below the standing water level. Flow was controlled by an in-line gate valve and was monitored using a 50 mm PMS in-line flow meter.

Water level drawdown was manually measured in Finschhafen #2 using electric dipmeters.

3.2 Step Drawdown Test

The step test was conducted in order to provide information on bore yield and efficiency in relation to the bore's construction and development. The data was analysed using the Eden and Hazel[2] method which gives an equation for the bore, enabling drawdown for the chosen flow rate over a given time period to be calculated, viz:

$$S_{wt} = (a + b \log t)\, Q + cQ^2$$

where:

S_{wt}	=	drawdown of the water table at a given time (t)
Q	=	pumping rate (m^3/day)
t	=	time in minutes
a,b,c	=	bore constants assessed from the step drawdown data

An assessment of the efficiency of the bore was made using the equation, viz:

$$\text{bore efficiency} = \frac{(a + b \log t)\, Q}{(a + b \log t)\, Q + cQ^2 \times 100}$$

[1] *Standards Australia, 1990. Test Pumping of Water Wells AS2368-1990, Published by Standards Assoc. of Australia.*
[2] *Eden, R.N. and Hazel, C.P. (1973) "Computer and Graphical Analyses of Variable Discharge Pumping Test of Wells", Inst. Engrs. Australia, Civil Engng. Trans. Pp 5-10*

where:

(a + b lot t) Q = drawdown due to formation loss

cQ^2 = drawdown due to bore loss

3.2.1 Finschhafen #2

A step drawdown test on Finschhafen #2 comprising four, two hour steps, was undertaken on 8 October 2000. Prior to commencement of the test, the static water level was measured at 6.90 m below top of casing which was 5.90 m below ground level. The step test drawdown versus time plot and step test data is given in Appendix B. The pumping rates were progressively increased as follows:

Step 1 - 172.8 m^3/day (2.0 L/s)
Step 2 - 259.2 m^3/day (3.0 L/s)
Step 3 - 345.6 m^3/day (4.0 L/s)
Step 4 - 540 m^3/day (6.25 L/s)

A step test analysis was not able to be carried out on the data provided due to the lack of drawdown observed whilst pumping at the rates mentioned above. The data shows rising water levels throughout steps 1, 2, 3 and 4 suggesting the variation in water levels was mainly due to tidal variations and ongoing bore development instead of the pumping. The maximum drawdown observed throughout the step drawdown test was 0.06 m during step 2.

3.3 Constant Rate and Recovery Tests

A constant rate test is undertaken to assess the hydraulic parameters of the aquifer and the presence of boundary conditions which may increase or decrease the rate of drawdown. Boundaries may be in the form of a barrier (impermeable) boundary which will increase the rate of drawdown, or recharge boundaries which would reduce the rate of drawdown. The information, together with the hydraulic parameters, allows a more accurate assessment of the long term 'safe' yield of a bore or borefield.

A 24 hour constant rate pumping test was commenced at 0800 hours on 9 October 2000 and was completed at 0800 hours on 10 October 2000. Prior to commencement of the test the static water level was measured at 7.05 m below top of casing or 6.05 m below ground level. The bore was pumped continuously at a rate of 540 m^3/day (6.25 L/s), and at completion of pumping a water level recovery test was undertaken.

The constant rate drawdown and recovery data for Finschhafen #2 were attempted to be analysed using the "Aquifer Test Version 2.0" software package[3]. The data and drawdown versus time plots are given in Appendix C.

[3] *Waterloo Hydrogeologic 1996, "Aquifer Test Version 2.0".*

Pumping the bore at a rate of 540 m^3/day (6.25 L/s) caused an insufficient drawdown of the static water level for the data to be analysed with the industry accepted methods. As such, no analysis of the constant rate or the recovery data to obtain the aquifer's hydraulic parameters could be carried out.

The constant rate and recovery test data showed the maximum drawdown throughout the test was 0.19 m indicating the aquifer intersected by the bore has a very high permeability or transmissivity. The water level was observed to rise and fall over a range of 0.23 m, reflecting the tidal variations in the nearby ocean. It is understood the bore is approximately 600 m from the coastline.

The maximum drawdown of 0.19 m was recorded at the end of the test which coincided with low tide. The water level recovered during the recovery test to only 7.19 m or by 0.05 m, suggesting the drawdown due to pumping was only 0.05 m.

In conclusion, no barrier or impermeable boundaries were able to be observed in the data recorded during the 24 hour constant rate test for Finschhafen #2. However, the data indicated the bore is affected by tidal influences.

4.0 GROUNDWATER QUALITY

A groundwater sample collected during the pumping test was analysed on-site for water electrical conductivity (EC), salinity, pH and temperature with a standard hand held instrument. The results of the field measurements are summarised in Table 2.

Table 2: Results of Field Water Quality Analysis

Date	Analysis			
	pH	EC (µS/cm)	Salinity (ppk)	Temp (^{0}C)
29/8/00	7.9	190	0.06	24.3

Note: µS/cm - micro siemens per centimetre
ppk - parts per thousand

The water is of a high quality with respect to EC and hence salinity or total dissolved solids. For comparison, the World Health Organisation (WHO) guidelines for total dissolved solids of 1000 mg/L in drinking water is approximately equal to an EC of 1500 µS/cm. The pH is slightly alkaline (at 7.9) due to the carbonate nature of the aquifer matrix but is well within the WHO guidelines range of 6.5 to 8.5.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The groundwater exploratory drilling program was successful in locating a viable groundwater resource at the location of test bore Finschhafen #2. The pumping tests indicate the bore has intersected an aquifer with a very high transmissivity. Field water quality measurements indicated the water to be fresh and slightly alkaline (pH of 7.9).

The pumping test data for Finschhafen #2 was unable to be analysed due to tidal influences and insufficient drawdown achieved by pumping the bore at 540 m^3/day or 6.25 L/s. As a result of this it is impossible to recommend a long term 'safe' yield for this test bore without another pumping test being undertaken at a greater extraction rate. Pumping rates of 3500-4320 m^3/day or 40-50 L/s may be sustainable but cannot be confirmed without the additional pump testing.

It is recommended the pump intake for this bore be set at 27 m below ground level. Under no circumstances should the intake of the pump be installed within or close (<1 m) to the stainless steel screen section (refer composite log in Appendix A) of the bore as this will induce turbulent flow within the bore, thereby decreasing the bore efficiency.

Future pump testing of this test bore and future production bores in this area should be carried out with a pump that is capable of producing 25-30 L/s at least in order to confirm the long term safe (maximum) yields of the bores.

To confirm the potential bore yields from this aquifer, future production bores should be constructed with 200 mm diameter (minimum) casing and 6 m of stainless steel screens in order to take full advantage of the potential bore yields. This should increase the bore's efficiency and allow the housing of a pump capable of pumping 40-50 L/s. As the test bore Finschhafen #2 is in close proximity to the coast and is affected by tidal fluctuations, it is recommended any future groundwater resource investigation comprises an assessment of the potential for salt water intrusion.

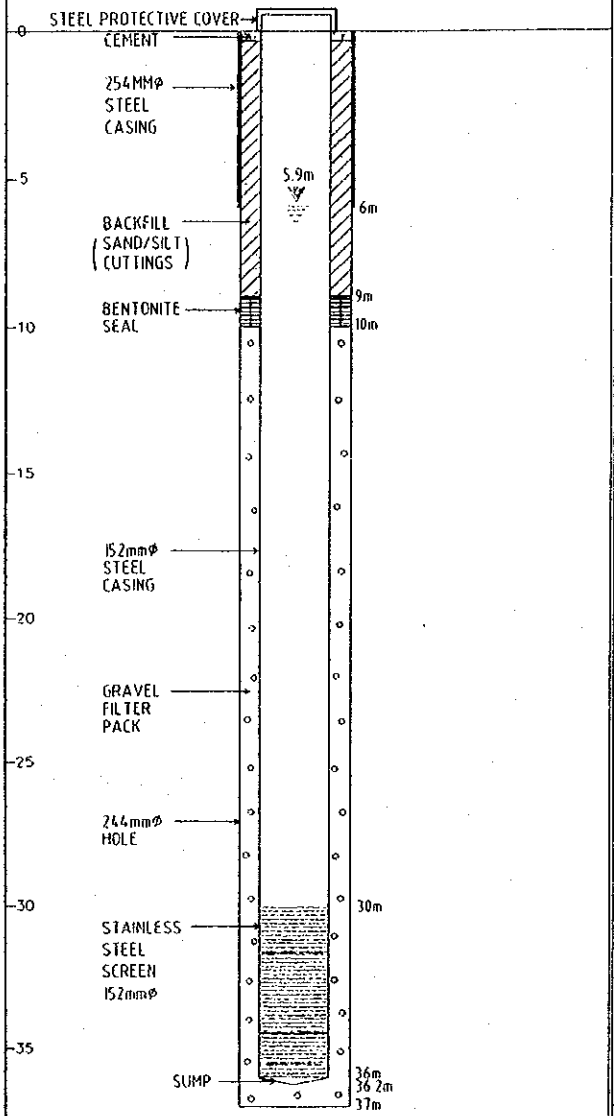
DOUGLAS PARTNERS PTY LTD

Reviewed by:

Carl Deegan
Associate/Hydrogeologist

Adrian Bulcock
Principal/Hydrogeologist

COMPOSITE BORE LOG OF:
TEST BORE FINSCHHAFEN #2



LITHOLOGY
TOP SOIL
BROWN CORONOUS LIMESTONE WITH TUFF
GREY CORONOUS LIMESTONE WITH SILT
WHITE CORONOUS LIMESTONE GRAVEL WITH SAND
TEST BORE DISCONTINUED @ 37m DEPTH

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TITLE: **FINSCHHAFEN #2 BORE COMPLETION REPORT**
FINSCHHAFEN , PNG

CLIENT:	NEW BRITAIN DRILLING PTY LTD			OFFICE:	BRISBANE	BORE:	FINSCHHAFEN #2
DRAWN BY:	FD	DATE:	OCTOBER 2000	PROJECT No:	33121	APPROVED:	APPENDIX A

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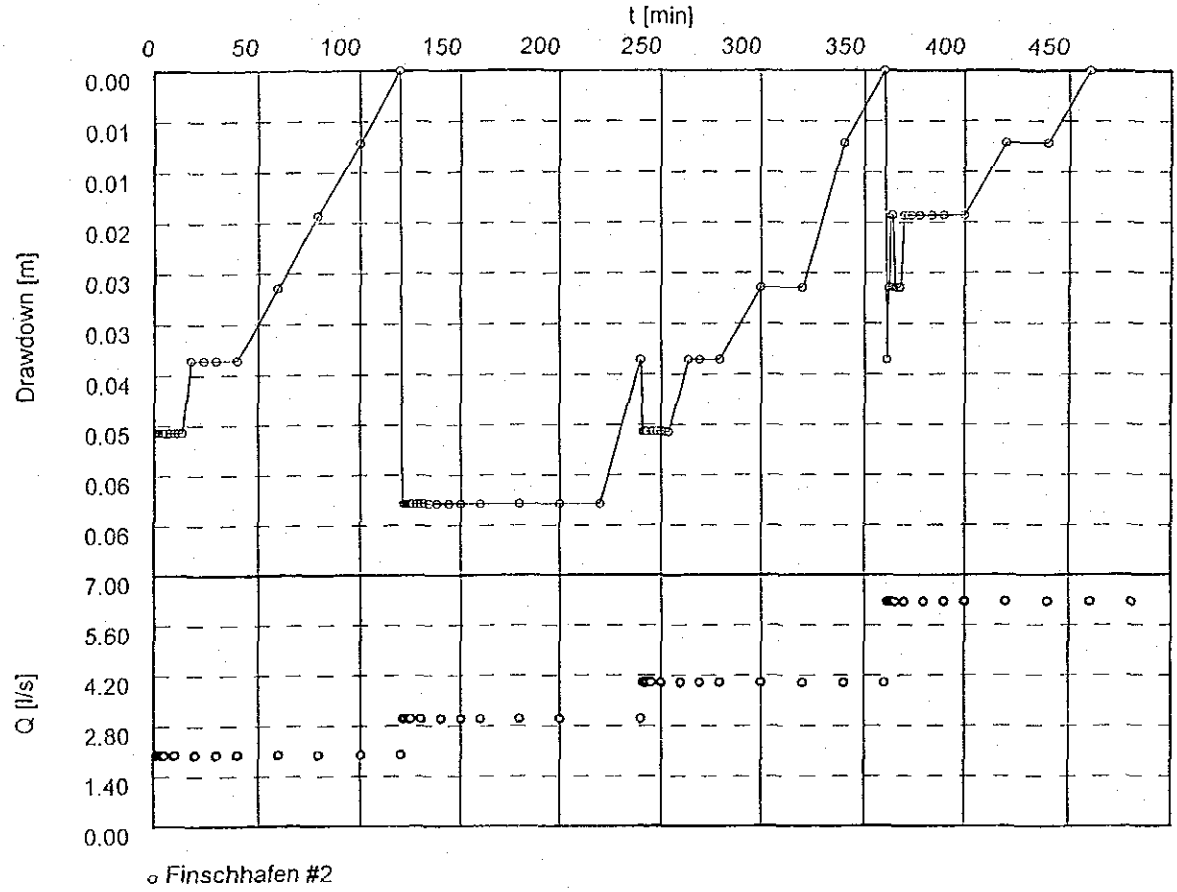
Douglas Partners Geotechnics · Environment · Groundwater	Pumping test analysis Time-Drawdown plot with discharge	Page 1 Project: Finschhafen #2 Bore Report Evaluated by: CMD Date: 26/10/00

Pumping Test No. Step Drawdown Test	Test conducted on: 8 October 2000
Finschhafen #2	



Douglas Partners Geotechnics · Environment · Groundwater	Pumping test analysis Time-Drawdown plot with discharge	Page 2 Project: Finschhafen #2 Bore Report Evaluated by: CMD Date: 26/10/00

Pumping Test No. Step Drawdown Test	Test conducted on: 8 October 2000
Finschhafen #2	Finschhafen #2

Static water level: 6.900 m below datum

	Pumping test duration [min]	Water level [m]	Drawdown [m]	
1	1.00	6.950	0.050	
2	1.50	6.950	0.050	
3	2.00	6.950	0.050	
4	2.50	6.950	0.050	
5	3.00	6.950	0.050	
6	4.00	6.950	0.050	
7	5.00	6.950	0.050	
8	6.00	6.950	0.050	
9	8.00	6.950	0.050	
10	10.00	6.950	0.050	
11	12.00	6.950	0.050	
12	14.00	6.950	0.050	
13	18.00	6.940	0.040	
14	24.00	6.940	0.040	
15	30.00	6.940	0.040	
16	40.00	6.940	0.040	
17	60.00	6.930	0.030	
18	80.00	6.920	0.020	
19	100.00	6.910	0.010	
20	120.00	6.900	0.000	
21	121.00	6.960	0.060	
22	122.00	6.960	0.060	
23	123.00	6.960	0.060	
24	124.00	6.960	0.060	
25	125.00	6.960	0.060	
26	126.00	6.960	0.060	
27	128.00	6.960	0.060	
28	130.00	6.960	0.060	
29	132.00	6.960	0.060	
30	134.00	6.960	0.060	
31	138.00	6.960	0.060	
32	144.00	6.960	0.060	
33	150.00	6.960	0.060	
34	160.00	6.960	0.060	
35	180.00	6.960	0.060	
36	200.00	6.960	0.060	
37	220.00	6.960	0.060	
38	240.00	6.940	0.040	
39	241.00	6.950	0.050	
40	242.00	6.950	0.050	
41	243.00	6.950	0.050	
42	245.00	6.950	0.050	
43	246.00	6.950	0.050	
44	248.00	6.950	0.050	
45	250.00	6.950	0.050	
46	252.00	6.950	0.050	
47	254.00	6.950	0.050	
48	264.00	6.940	0.040	
49	270.00	6.940	0.040	
50	280.00	6.940	0.040	

Douglas Partners Geotechnics · Environment · Groundwater	Pumping test analysis Time-Drawdown plot with discharge	Page 3 Project: Finschhafen #2 Bore Report Evaluated by: CMD Date: 26/10/00

Pumping Test No. Step Drawdown Test	Test conducted on: 8 October 2000
Finschhafen #2	Finschhafen #2

Static water level: 6.900 m below datum

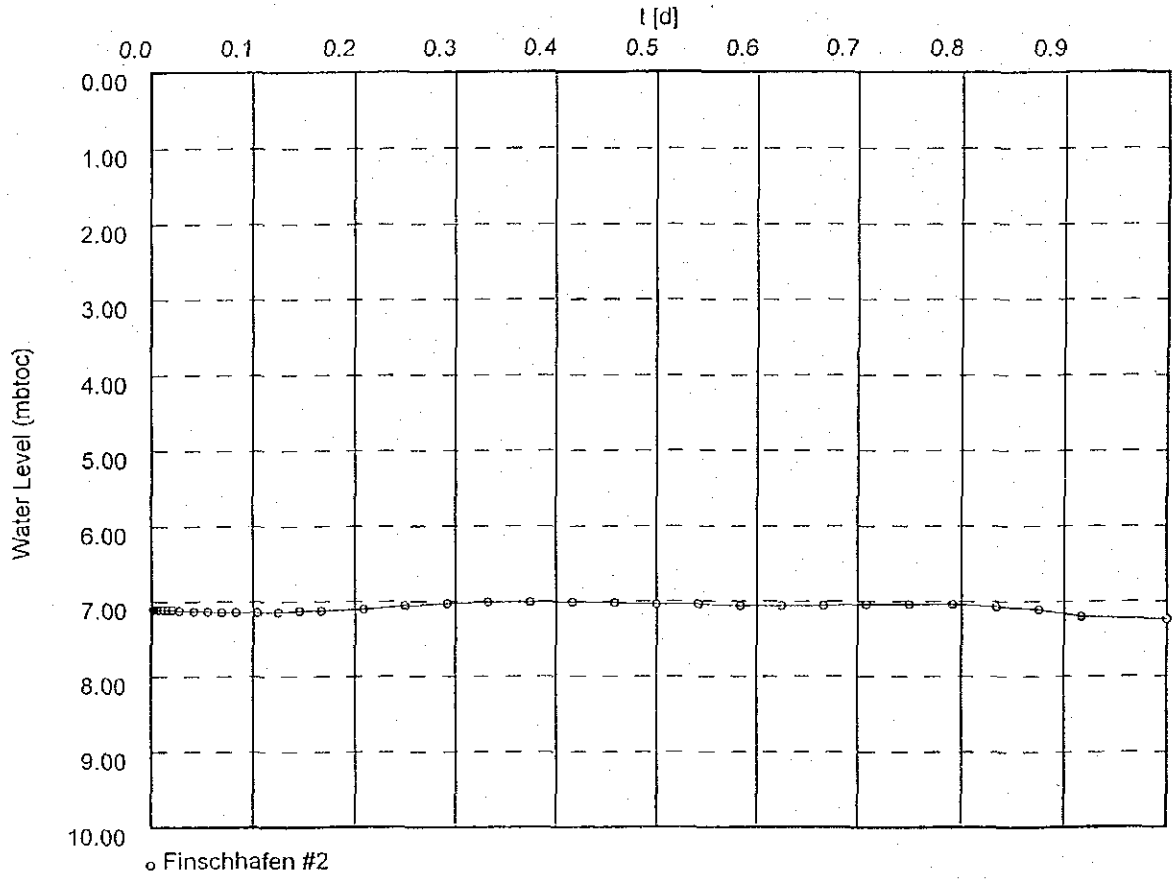
	Pumping test duration [min]	Water level [m]	Drawdown [m]	
51	300.00	6.930	0.030	
52	320.00	6.930	0.030	
53	340.00	6.910	0.010	
54	360.00	6.900	0.000	
55	361.00	6.940	0.040	
56	362.00	6.930	0.030	
57	363.00	6.920	0.020	
58	364.00	6.920	0.020	
59	365.00	6.930	0.030	
60	366.00	6.930	0.030	
61	368.00	6.930	0.030	
62	370.00	6.920	0.020	
63	372.00	6.920	0.020	
64	374.00	6.920	0.020	
65	378.00	6.920	0.020	
66	384.00	6.920	0.020	
67	390.00	6.920	0.020	
68	400.00	6.920	0.020	
69	420.00	6.910	0.010	
70	440.00	6.910	0.010	
71	460.00	6.900	0.000	
72	480.00	6.890	-0.010	

Douglas Partners Geotechnics · Environment · Groundwater	Pumping test analysis Time-Drawdown plot with discharge	Page 4 Project: Finschhafen #2 Bore Report Evaluated by: CMD Date: 26/10/00

Pumping Test No. Step Drawdown Test	Test conducted on: 8 October 2000
Finschhafen #2	

	Pumping test duration [min]	Discharge [l/s]		
1	1.00	2.00		
2	3.00	2.00		
3	4.00	2.00		
4	5.00	2.00		
5	10.00	2.00		
6	20.00	2.00		
7	30.00	2.00		
8	40.00	2.00		
9	60.00	2.00		
10	80.00	2.00		
11	100.00	2.00		
12	120.00	2.00		
13	121.00	3.00		
14	122.00	3.00		
15	124.00	3.00		
16	125.00	3.00		
17	130.00	3.00		
18	140.00	3.00		
19	150.00	3.00		
20	160.00	3.00		
21	180.00	3.00		
22	200.00	3.00		
23	240.00	3.00		
24	241.00	4.00		
25	242.00	4.00		
26	243.00	4.00		
27	245.00	4.00		
28	250.00	4.00		
29	260.00	4.00		
30	270.00	4.00		
31	280.00	4.00		
32	300.00	4.00		
33	320.00	4.00		
34	340.00	4.00		
35	360.00	4.00		
36	361.00	6.25		
37	362.00	6.25		
38	363.00	6.25		
39	365.00	6.25		
40	370.00	6.25		
41	380.00	6.25		
42	390.00	6.25		
43	400.00	6.25		
44	420.00	6.25		
45	440.00	6.25		
46	460.00	6.25		
47	480.00	6.25		

Douglas Partners Geotechnics · Environment · Groundwater	Pumping test analysis Time-Drawdown plot	Page 1 Project: Finschhafen #2 Bore Report Evaluated by: CMD Date: 26/10/00
Pumping Test No. 24 Hour Constant Rate Test		Test conducted on: 9-10 October 2000
Finschhafen #2		



Douglas Partners Geotechnics · Environment · Groundwater	Pumping test analysis Time-Drawdown plot	Page 2 Project: Finschhafen #2 Bore Report Evaluated by: CMD Date: 26/10/00

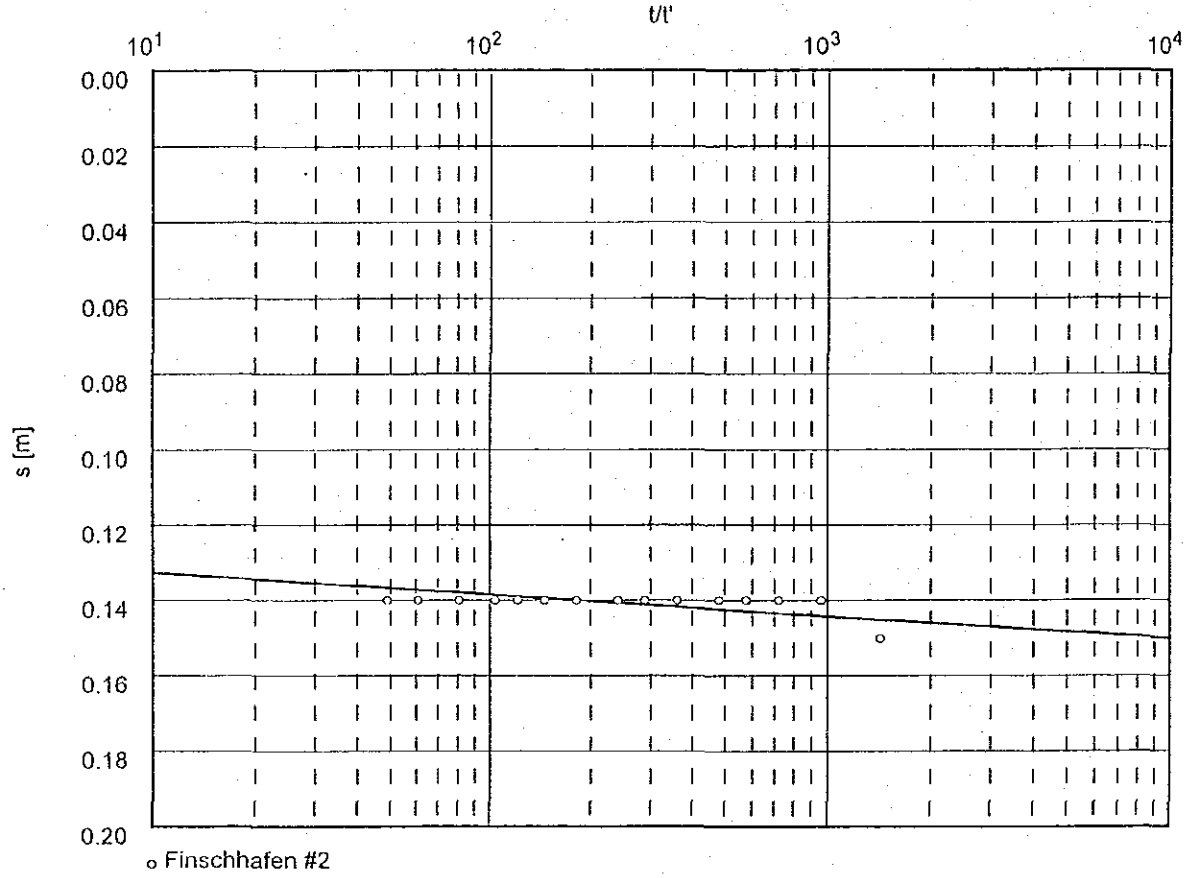
Pumping Test No: 24 Hour Constant Rate Test	Test conducted on: 9-10 October 2000
Finschhafen #2	Finschhafen #2
	Distance from the pumping well 0.010 m

Static water level: 0.000 m below datum

	Pumping test duration [min]	Water level [m]	Drawdown [m]	
1	1.00	7.100	7.100	
2	2.00	7.100	7.100	
3	3.00	7.110	7.110	
4	4.00	7.110	7.110	
5	5.00	7.110	7.110	
6	6.00	7.110	7.110	
7	7.00	7.110	7.110	
8	8.00	7.110	7.110	
9	10.00	7.110	7.110	
10	12.00	7.110	7.110	
11	14.00	7.110	7.110	
12	18.00	7.110	7.110	
13	24.00	7.110	7.110	
14	30.00	7.110	7.110	
15	40.00	7.120	7.120	
16	60.00	7.130	7.130	
17	80.00	7.130	7.130	
18	100.00	7.140	7.140	
19	120.00	7.140	7.140	
20	150.00	7.140	7.140	
21	180.00	7.140	7.140	
22	210.00	7.120	7.120	
23	240.00	7.120	7.120	
24	300.00	7.100	7.100	
25	360.00	7.060	7.060	
26	420.00	7.030	7.030	
27	480.00	7.010	7.010	
28	540.00	7.010	7.010	
29	600.00	7.010	7.010	
30	660.00	7.020	7.020	
31	720.00	7.040	7.040	
32	780.00	7.040	7.040	
33	840.00	7.060	7.060	
34	900.00	7.060	7.060	
35	960.00	7.060	7.060	
36	1020.00	7.040	7.040	
37	1080.00	7.040	7.040	
38	1140.00	7.040	7.040	
39	1200.00	7.070	7.070	
40	1260.00	7.110	7.110	
41	1320.00	7.200	7.200	
42	1440.00	7.240	7.240	

Douglas Partners Geotechnics · Environment · Groundwater	Pumping test analysis Recovery method after THEIS & JACOB Confined aquifer	Page 1 Project: Finschhafen #2 Bore Report Evaluated by: CMD Date: 26/10/00

Pumping Test No. Recovery Test	Test conducted on: 10 October 2000
Finschhafen #2	
Discharge 6.25 l/s	
	Pumping test duration: 1.00000 d



Transmissivity [m²/d]: 1.71×10^4

Douglas Partners Geotechnics · Environment · Groundwater	Pumping test analysis Recovery method after THEIS & JACOB Confined aquifer	Page 2 Project: Finschhafen #2 Bore Report Evaluated by: CMD Date: 26/10/00

Pumping Test No. Recovery Test	Test conducted on: 10 October 2000
Finschhafen #2	Finschhafen #2
Discharge 6.25 l/s	
Static water level: 7.050 m below datum	Pumping test duration: 1440.00 min

	Time from end of pumping [min]	Water level [m]	Residual drawdown [m]	
1	1.00	7.200	0.150	
2	1.50	7.190	0.140	
3	2.00	7.190	0.140	
4	2.50	7.190	0.140	
5	3.00	7.190	0.140	
6	4.00	7.190	0.140	
7	5.00	7.190	0.140	
8	6.00	7.190	0.140	
9	8.00	7.190	0.140	
10	10.00	7.190	0.140	
11	12.00	7.190	0.140	
12	14.00	7.190	0.140	
13	18.00	7.190	0.140	
14	24.00	7.190	0.140	
15	30.00	7.190	0.140	