STUDY ON THE GROUNDWATER POTENTIAL EVALUATION AND MANAGEMENT PLAN FOR THE SOUTHEAST KALAHARI (STAMPRIET) ARTESIAN BASIN IN THE REPUBLIC OF NAMIBIA

Japan International Cooperation Agency

Pacific Consultants International

BOREHOLE FINAL REPORT

Borehole

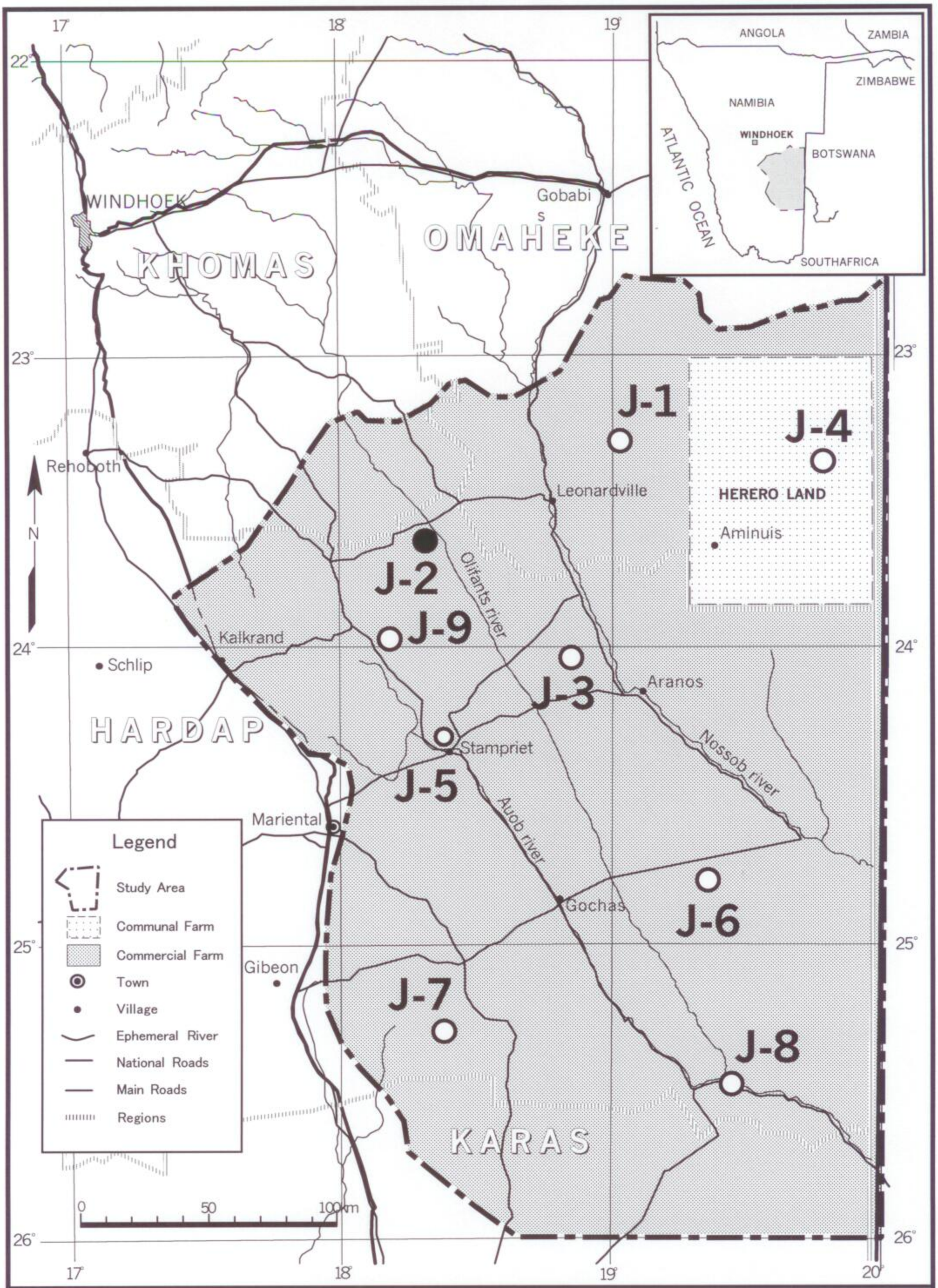
J2-A (WW 39840)

Olifantswater West

METZGER PM DRILLING
P.O.Box 11733
Windhoek
Namibia

Windhoek

October 2000



Location Map of Test Boreholes

THE STUDY ON THE GROUNDWATER IN THE STAMPRIET ARTESIAN BASIN | JICA

Contents per Chapter

1. Geological Borehole Log

THE STUDY ON THE GROUNDWATER POTENTIAL EVALUATION AND MANAGEMENT PLAN IN THE SOUTHEAST KALAHARI (STAMPRIET) ARTESIAN BASIN

GEOLOGICAL BOREHOLE LOG

Farm Olifantswater West M 102 **WW 39840**
Jica Reference: J - 2 - A **S 23, 64747°**
Date completed:21 May 2000 **E 18, 38873°**
Collar elev.: 1272 m

Depth below surface (m)	Section (m)	Lithology	Stratigraphy
0 - 1	1	Light orange to reddish **sand**, fine to coarse grained, unsorted and unconsolidated, as shallow cover over karsted calcrete.	**KALAHARI**
1 - 5	4	White **calcrete**, massive and karsted in upper horizons. Karst cavities filled with unconsolidated red sand.	
5 - 11	6	White massive **calcrete** and calcretized sandstone.	
11 - 13	2	Light purplish brown micaceous **sandstone**, calcareous, fine to medium grained.	**UPPER RIETMOND**
13 -14,5	1,5	Light yellowish brown micaceous **sandstone** (muscovite), calcareous in places.	
14,5 - 17	2,5	Light reddish brown (to pale brown at 17 m) medium grained micaceous **sandstone**, moderately porous and calcareous.	
17 - 20	3	Pale yellowish fine-grained **sandstone** with muscovite flakes. Oxidation on bedding planes.	
20 - 25	5	Orange to light red **sandstone**, medium grained, with micaceous bedding planes.	
25 - 30	5	Pale yellowish micaceous fine to medium grained **sandstone**, laminated.	
30 - 40	10	**Shale**, pale yellow with subordinate interbedded sandstone between 35 and 40 m.	
40 - 90	50	**Shale**, reddish brown at 40 m, gradually changing over reddish grey to a pale grey at 58 m. At 54 to 58 m this shale is sandy in texture. From 58 m downwards, colour of the shale grey to dark grey. Between 75 m and 82 m scattered white calcitic specks are recorded. Micaceous in horizons below 75 m.	**LOWER RIETMOND**
90 - 115	25	Pale brownish grey **sandstone**, medium grained, sub-rounded, fining downwards. Calcareous horizons throughout with calcareous concretions at 104 m to 108 m. Sandstone friable and generally very porous.	**AUOB**
115 - 124	9	Intercalated **shale** and very fine **sandstone / siltstone**, very light grey. From 120 m downwards sandstone / siltstone is calcite cemented, with disseminated muscovite flakes.	**MUKOROB**
124 - 131 EOH	7	Light grey **shale** with minor horizons of siltstone.	

Remarks:

1. This borehole was drilled by the mud-rotary method. Drill-cuttings often are severely ground and therefore careful washing is necessary before any interpretation is attempted.
2. Most helpful in interpreting drill-cuttings is the information obtained while attending drilling operations.
3. Only 25 m of Auob Sandstone was intersected in this borehole. As this location lies towards the northern edge of the sedimentary basin, and that the described sandstone is continuous with either, or even with all three of the elsewhere described sandstone layers, and that the two shales A2 and A4 are only developed more towards the center of the basin. It is therefore not possible to correlate this sandstone with either A1, A3 or A5.
4. This borehole was cased and pressure-grouted to a depth of 94,5 m.

This borehole was logged by F. Bockmuhl.

2. Penetration Record

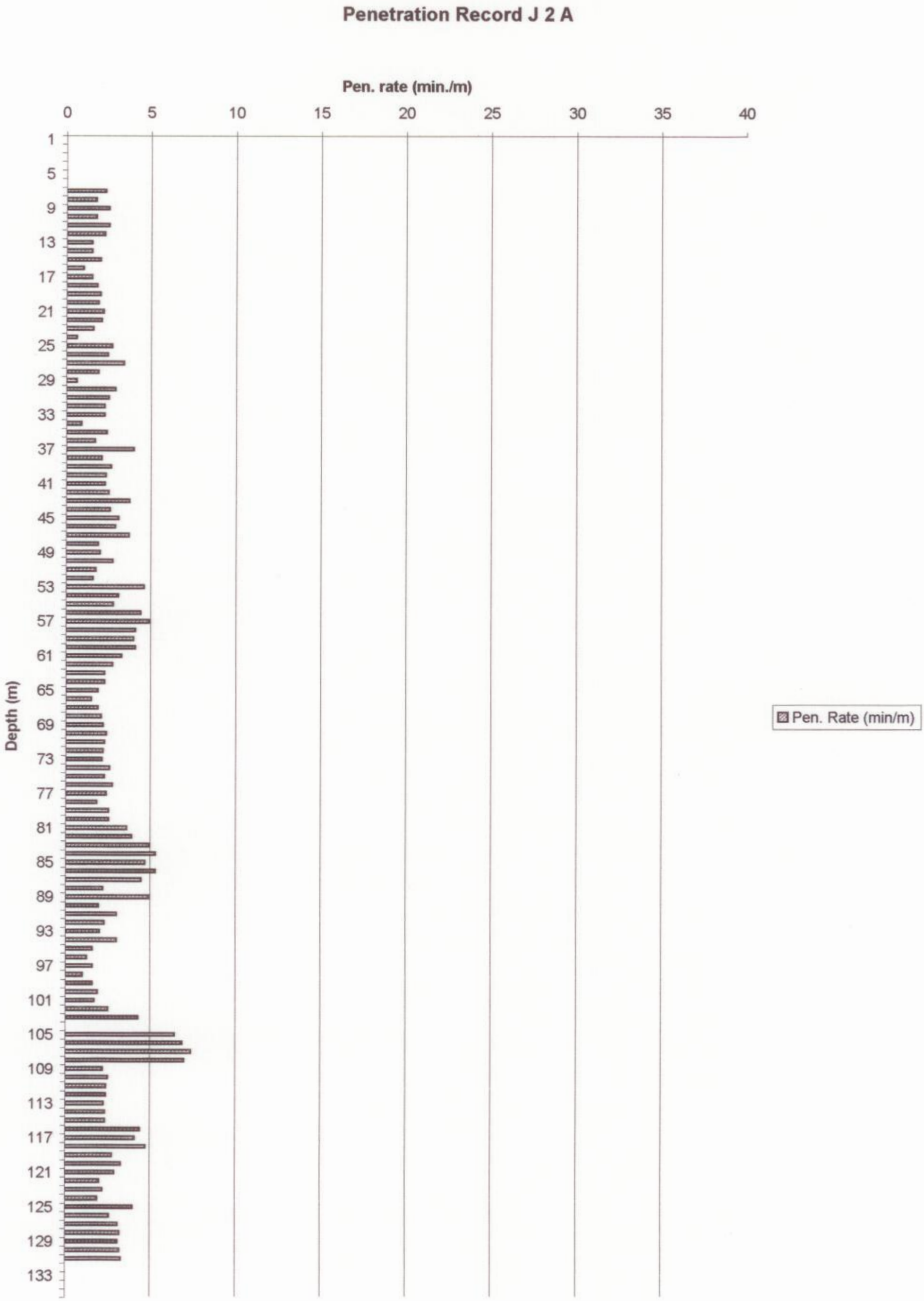
Penetration Record J 2 A	
Depth (m)	Pen. Rate (min/m)
5	
	2.32
	1.75
	2.5
10	1.75
	2.5
	2.25
	1.5
	1.5
15	2
	1
	1.5
	1.8
	2
20	1.9
	2.2
	2.1
	1.6
	0.6
25	2.7
	2.45
	3.4
	1.9
	0.6
30	2.9
	2.5
	2.25
	2.25
	0.9
35	2.4
	1.7
	4
	2.1
	2.65
40	2.35
	2.3
	2.5
	3.75
	2.6
45	3.1
	2.9
	3.7
	1.9
	2
50	2.75
	1.75

J 2 A Penetration Record

	1.6
	4.6
	3.1
55	2.8
	4.4
	4.9
	4.1
	4
60	4.1
	3.3
	2.75
	2.3
	2.3
65	1.9
	1.5
	1.9
	2.1
	2.2
70	2.4
	2.3
	2.2
	2.15
	2.6
75	2.3
	2.75
	2.4
	1.85
	2.55
80	2.55
	3.6
	3.9
	4.95
	5.3
85	4.7
	5.3
	4.45
	2.2
	4.9
90	1.95
	3
	2.3
	2
	3
95	1.6
	1.25
	1.6
	1
	1.6
100	1.9
	1.7
	2.5
	4.3

105	6.45
	6.9
	7.4
	7
	2.2
110	2.5
	2.4
	2.4
	2.25
	2.35
115	2.35
	4.4
	4.1
	4.75
	2.75
120	3.3
	2.9
	2
	2.2
	1.9
125	4
	2.6
	3.1
	3.2
	3.1
130	3.2
131	3.3

J2apen


Penetration Record J 2 A
Pen. rate (min./m)
0
5
10
15
20
25
30
35
40
Depth (m)
1
5
9
13
17
21
25
29
33
37
41
45
49
53
57
61
65
69
73
77
81
85
89
93
97
101
105
109
113
117
121
125
129
133
Pen. Rate (min/m)

3. Mud Rotary Drilling Log

THE STUDY ON THE GROUNDWATER POTENTIAL EVALUATION AND MANAGEMENT PLAN IN THE SOUTHEAST KALAHARI (STAMPRIET) ARTESIAN BASIN

MUD ROTARY DRILLING LOG

JICA REFERENCE: J 2 A LOCALITY: Olifantswater West WW 39840 DATE: 16 to 20 May 2000

TIME	DEPTH mbgl	MARSH FUNNEL TEST 1000 ml (sec)	MARSH FUNNEL TEST 500 ml (sec)	E. C. mS/cm	DENSITY	pH	TEMPERATURE ° C	COMMENT
17:40	6	30	20	5.84	≤ 1.2	8.5	23.3	Install conductor pipe. Wait for instructions regarding further drilling. Last measurement for 16/05/00.
11:05	10	31	20	5.80		8.5	24.4	
14:15	68	32	21	5.9		9	26.7	
17:00	95	30 *29*	20	5.84 *4.30*		8.5 *8.4*	23.3 *16.5*	Exchange drilling fluid ! Drill fluid before logging. *Water used for mixing drillfluid.* Last measurement for 17/05/00
07:30	96	30	20	5.35	≤ 1.2	8.5	18.3	
10:00	131	30 *29*	19	4.85 *4.30*		8.5 *8.5*	19.8 *16.8*	Drillfluid before logging. *Water used for mixing drillfluid.*

GENERAL REMARKS:

1. This borehole was geophysically logged at depths of 95 m and again at a final depth of 131 m.
2. Drilling diameter was 9 7/8" to 95 m, followed by 7 7/8" to 131 m.
3. Parameters of the drillfluid and for the water used for mixing were recorded from filtered samples. (Filtered through fine sieve.)
4. To determine the electrical resistivity of the samples as Ω-m., the E.C., expressed as S/m should be inversed.

4. Geophysical Log and Casing Design

Poseidon Geophysics

(Reg. No. 93550)

CO. Poseidon Geophysics
WELL J2A WW 39840
PROJ.
LCN. Olifantswater West
STE. J 2
FILING No. J2A

CONSULTANT PACIFIC CONSULTANTS INTERNATIONAL

COMPANY METZGER PM DRILLING

PROJECT The Study on the Groundwater Potential Evaluation and Management Plan in the Southeast Kalahari (Stampriet) Artesian Basin

WELL ID J2A WW39840

LOCATION OLIFANTSWATER WEST

COUNTRY REPUBLIC OF NAMIBIA

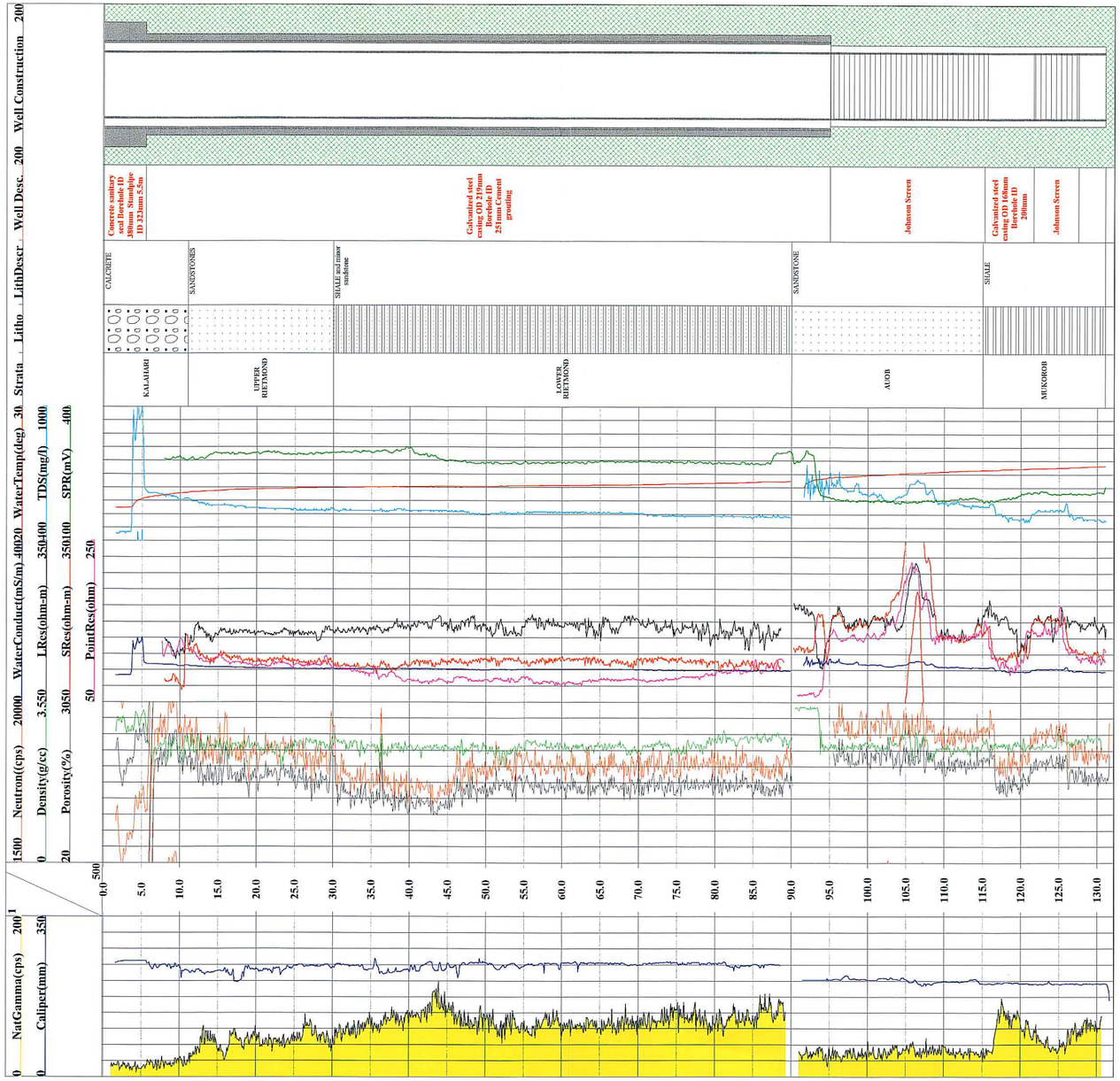
BH COORDINATES S 23.64747
E 18.38873

COLLAR ELEVATION 1272m
LOG MEAS. FROM Groundlevel

DRILLING MEAS. FROM Groundlevel

DATE	5 May 2000
TYPE LOG	Physical Properties
DEPTH-DRILLER	131m
DEPTH-LOGGER	131.2m
BTM LOGGED INTERVAL	131.2m
TOP LOGGED INTERVAL	0.60m
PERMANENT DATUM	Groundlevel
RECORDED BY	Clemence Kambewu
WITNESSED BY	Frank Bokmuhl

JAPAN INTERNATIONAL COOPERATION AGENCY



5. Borehole Development Data

THE STUDY ON THE GROUNDWATER POTENTIAL EVALUATION AND MANAGEMENT PLAN IN THE SOUTHEAST KALAHARI (STAMPRIET) ARTESIAN BASIN

BOREHOLE DEVELOPMENT DATA

JICA REFERENCE: J 2 A LOCALITY: Olifantswater West M 102 WW 39840 DATE: 01/05/2000 (starting)
15/06/2000 (Subm. Pump)

TIME (actual)	Pump time (min)	Water Level (mbsu)	Yield (m^3/h)	E.C. (mS/m)	Remarks
12:41	1	24.25	3.1		Development by electrical submersible pump. 15/06/00
	2	25.38			Pump inlet depth 93.90 m
	3	26.44			Static Water Level 14.95 m
	4	27.56			
	5	28.34			
	6	29.21			
	7	30.02			
	8	30.79			
	9	31.38			
	10	32.01			
	12	33.12			
	14	34.04			
	16	35.00			
	18	36.29			
	20	36.83			
	23	37.58			
	26	38.23			
	30	39.46			
	35	40.27			

TIME (actual)	Pump time (min)	Water Level (mbsu)	Yield (m^3/h)	E.C. (mS/m)	Remarks
13:20	40	40.41			
	45	41.01			
	50	41.39			
	55	42.16			
13:40	60	42.43			
	61	45.16	6		
	62	46.64			
	63	48.83			
	64	49.92			
	65	51.02			
	66	52.64			
	67	54.07			
	68	55.12			
	69	56.16			
	70	57.07	6		
	72	58.71			
	74	60.49			
	76	61.57			
	78	62.92			
	80	63.58			
	83	64.88			
	86	66.37			
14:10	90	67.37			
	95	68.24			
	100	69.12			
	105	69.99			

TIME (actual)	Pump time (min)	Water Level (mbsu)	Yield (m^3/h)	E.C. (mS/m)	Remarks
	110	70.65			
	115	71.18			
14:40	120	71.10			
	121	72.91	8		
	122	74.00			
	123	75.48			
	124	76.37			
	125	77.20			
	126				Dipper stuck, pumping continues
	127				
	128				
	129				
	130				
	132				
	134				
	136				
	138	85.30			
	140	86.40			
	143	87.50			
	146	88.43			
15:10	150	88.95			
	155	89.95			
	160				Dipper stuck, pumping continues
	165				
	170				
	175				

TIME (actual)	Pump time (min)	Water Level (mbsu)	Yield (m^3/h)	E.C. (mS/m)	Remarks
15:40	180		8		Dipper stuck
	190				
16:05	205				End of development by submersible pump
	Recovery	Measured	Immediately		
16:06	1	90.00			Water Level assumed (?)
	2	85.10			
	3	81.90			
	4	77.20			
	5	72.60			
	6	68.80			
	7	66.10			
	8	63.00			
	9	59.90			
	10	57.80			
	12	53.10			
	14	49.22			
	16	45.16			
	18	42.56			
	20	39.74			
	23	36.80			
	26	34.22			
	30	31.34			
	35	28.79			
	40	26.87			
	45	25.58			
	50	24.39			

TIME (actual)	Pump time (min)	Water Level (mbsu)	Yield (m^3/h)	E.C. (mS/m)	Remarks
	55	23.48			
17:05	60	22.75			

Remarks:

This borehole was also developed by airlifting at various rates and from several depths.

1. **23. 05. 2000:** Airlift equipment was built into borehole. STPP (Sodium Tri Poly Phosphate) was introduced into the borehole. This was done in order to break down any possible wall cake consisting of highly ground shale and drilling mud.
2. **24. 05. 2000:** Via airlift pipes water from borehole (with dissolved STPP) was re-circulated, i.e. the water lifted from various depths from the various screen positions was collected in a V-Notch container and from there, through suitably positioned pipes, introduced back into the borehole. This resulted in a perfect washing of the wall cake and dissolving of the clay rich drill residues.
3. **25. 05. 2000:** 12 hours of pumping by airlift.
4. **27. 05. 2000:** 18 hours of pumping by airlift.
5. **28. 05. 2000:** 24 hours of pumping by airlift from the bottom of the borehole, until the water was clear.
6. **29. 05. 2000:** 2 hours of pumping by airlift.

6. Evaluation of Pumping Test

1. PUMPING TEST ANALYSIS

J2-A (WW39840) - Pumping well

J2-N (WW39841)- Observation well

1.1. Well Efficiency (Step draw down test) (Annex 1)

Well Efficiency was analysed by making use of the Jacob method for draw down data. Aquifer parameters used for the calculation of well efficiency were obtained from the evaluation results of the constant discharge test, which is discussed in **Section 1.2** below.

The well efficiencies at the range of pumping rates used during the step draw down test are summarised in **Table 1** below.

Table 1: J2-A: Borehole efficiency at various pumping rates

Borehole number	Step	Abstraction Rate [m^3/h]	Draw Down* [m]	Borehole Efficiency [%]
J2-A	1	2	8.1	86.6
	2	3	15.1	79.1
	3	4	22.1	72.8
	4	5	27.5	67.4
	5	6	35.3	62.8

* at cut-of time Δt, after which well bore storage has no affect on the well performance

Data on the linear and non-linear well losses and skin factors as well as the efficient well radius are presented in **Annex 1.**

1.2. Constant Discharge Test Analysis (Annex 2 - 6)

The constant discharge draw down curve of abstraction borehole **J2-A** indicates limited leaky conditions. For leaky aquifers, the Walton Hantush analysis method with draw down and recovery data was once again used to calculate the hydraulic conductivity of the aquifer and the aquitard **(Annex 2 & 3**).

Aquifer storativity was estimated due to the fact that observation borehole **J2-N** is located in the Nossob sandstone aquifer and not in the pumped Auob sandstone aquifer. During the duration of the constant discharge test, only minor fluctuations in the water level of **J2-N** is observed, which indicates that the underlying Nossob sandstone aquifer was not influenced by abstraction over the period of testing (See **Annex 5**).

The occurrence of leakage into the Auob aquifer during abstraction could be due to water derived from storage within the overlying aquitard (Dolerite) or aquifer (Kalahari). The results of the constant discharge analysis are summarised in **Table 2** below.

Table 2: Aquifer Parameters calculated for J2-A; Auob sandstone

Borehole number	Analysis Method	T	s	k	S	Simulation model	Comments
		[m^2/day]	[m]	[cm/sec]	[-]		
J2-A	Walton-Hantush - draw down	3.42	25	1.6×10^{-4}	*1×10^{-5}	Hantush	*Storativity estimated - Observation borehole not located in the tested aquifer
	Walton-Hantush - recovery	3.22	25	1.5×10^{-4}	*1×10^{-5}		

The Hantush model for leaky condition from aquitard storage was used to simulate and verify the actual data and analysis approach of the constant discharge test. Simulation parameters summarised in **Table 2** were used in simulation of the actual pumping test data (See **Annex 4** for simulation results).

Annex 6 compares the draw down results of the pumping borehole J2-A and observation borehole J2-N and it is clear that pumping from the Auob sandstone did not have any influence on the Nossob sandstone aquifer.

The radius of influence (R) was estimated after SICHARDT (1928) using the equation:

$R = 3000 \times s \times K_f^{1/2}$

$R = 3000 \times 38.3 \times 1.22 \times 10^{-3} = \underline{141\ m}$

where

R = Radius of influence

s = Draw down in abstraction borehole at end of pumping

K_f = Permeability of the aquifer

The equation is approximately correct for unconfined aquifers. In case of a confined aquifer the radius of influence most probably larger and the 141 m are considered to be the minimum value.

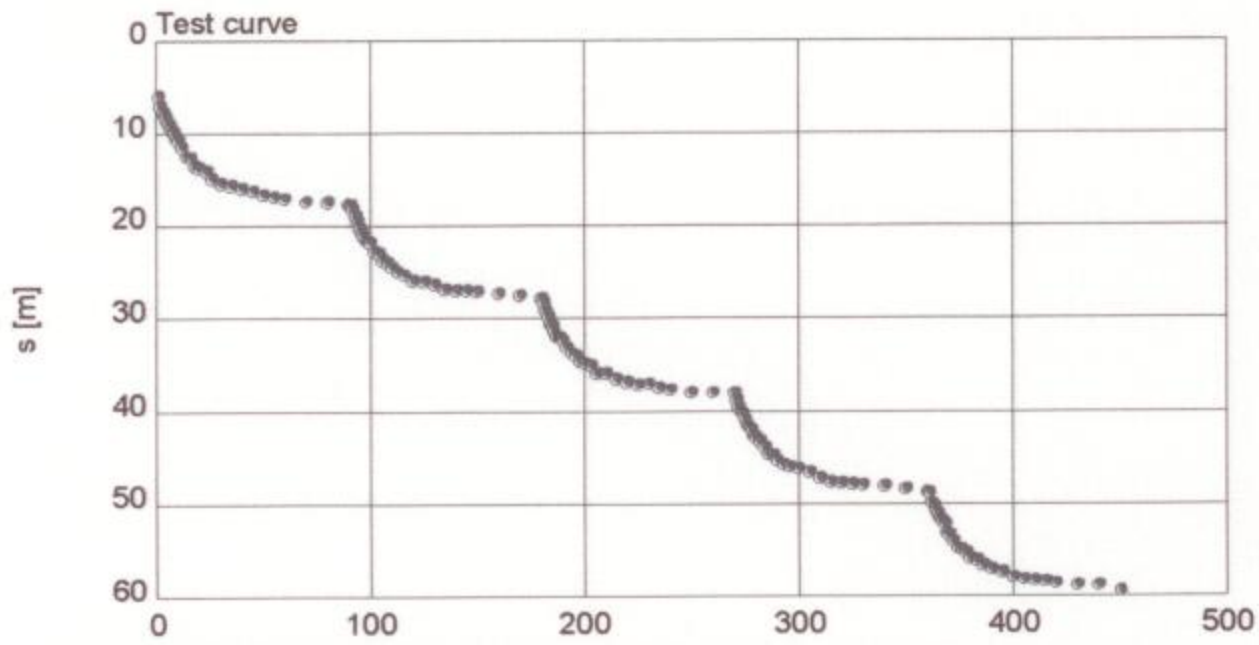
A proper evaluation of R (and storativity S) will only be possible once reliable data from observation wells, penetrating the same aquifer as the pumped well, are available.

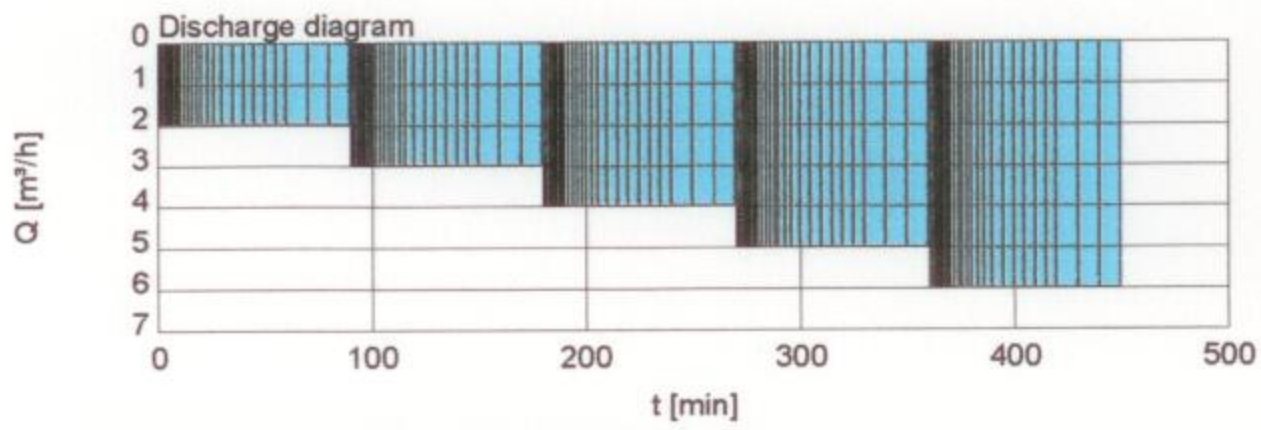
Groundwater Study in the Stampriet Artesian Basin

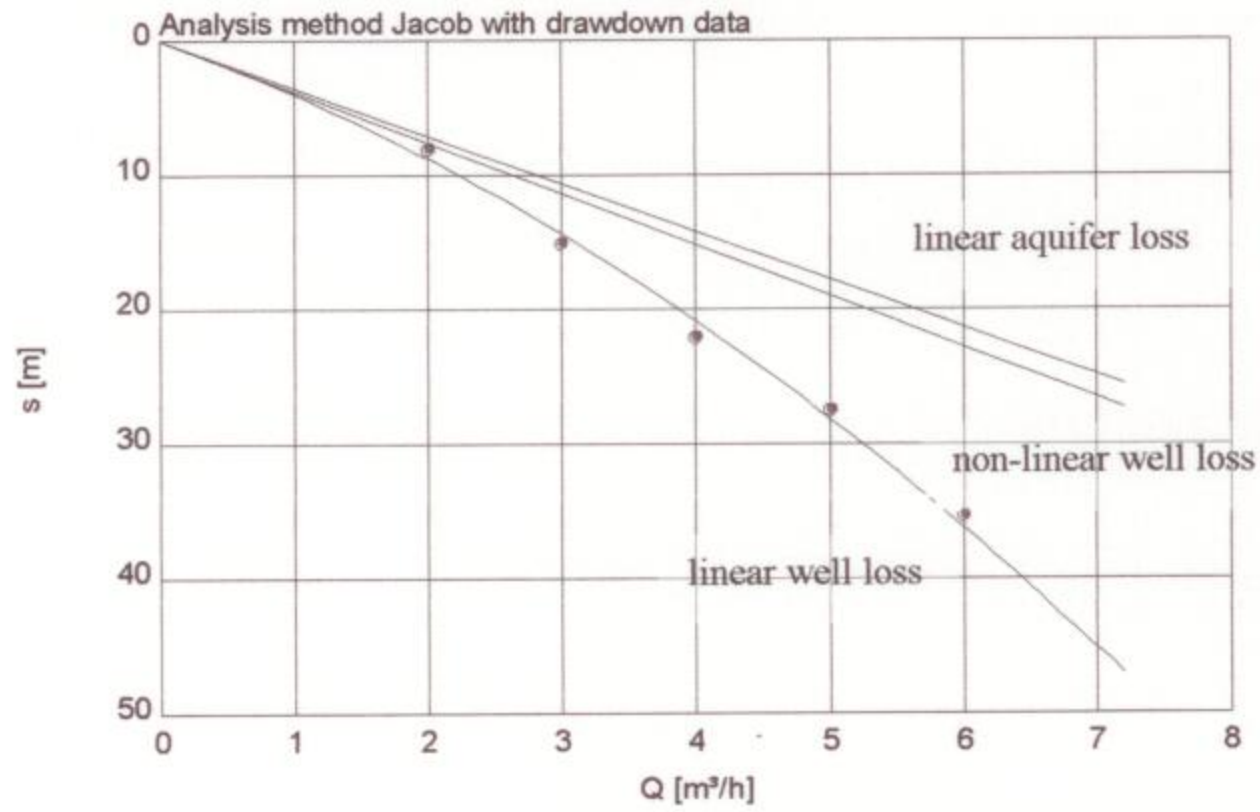
Evaluation of Test Pumping Data

Step test analysis

Pumped well J2-A







Borehole, well & aquifer

Drilled:	
Latitude:	
Longitude:	
Elevation:	1100 [m]
Depth:	
Stick up:	0.00 [m]
Bh. radius:	0.100 [m]
Casing radius:	0.075 [m]
RWL:	16.41 [m]
max.drawdown:	59.50 [m]
Aq.type:	confined
Aq.thickness:	100.00 [m]
Stratigraphy:	Aoub Sandstone
Lithology:	Sandstone

Test running

Start:03/07/2000 20:44:09	
Dis.dur.:	450 [min]
Av.dis.:	4 [m³/h]
Max.dis.:	6 [m³/h]
Min.dis.:	2 [m³/h]
Total dis.:	30 [m³]
Crew:	Metzger_PM
Supervisior:	PCI

Results

Well performance:

s: $(B1+B2)*Q+C*Q^2$

Linear aquifer loss B1:	3.79
Linear well loss B2:	-2.4E-01
Non-linear well loss C:	0.41

	Q [m³/h]	s [m]	Eff [%]
Step 1:	2.00	8.10	86.6
Step 2:	3.00	15.1	79.1
Step 3:	4.00	22.1	72.8
Step 4:	5.00	27.5	67.4
Step 5:	6.00	35.3	62.8

Linear skin factor:	-0.22 [-]
Non-linear skin factor:	8.86 [d/m³]
Effective well radius:	1.4E-2 [m]

Date 02/10/00 prepared by BIWAC

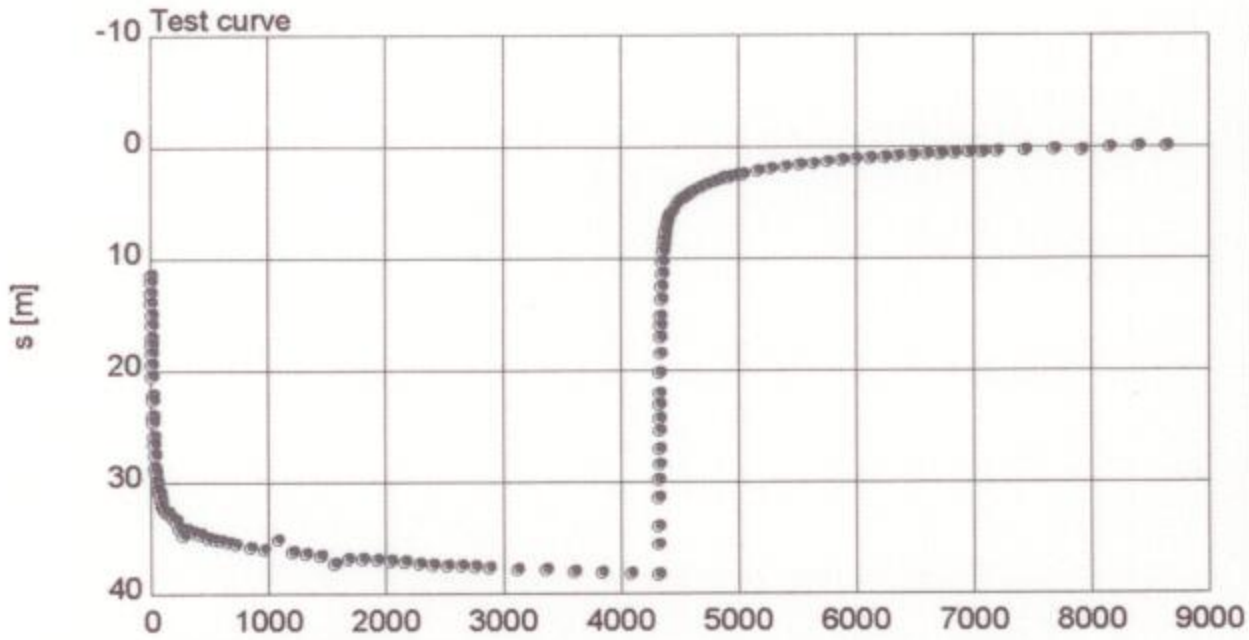
Annex 1

Groundwater Study in the Stampriet Artesian Basin

Evaluation of Test Pumping Data

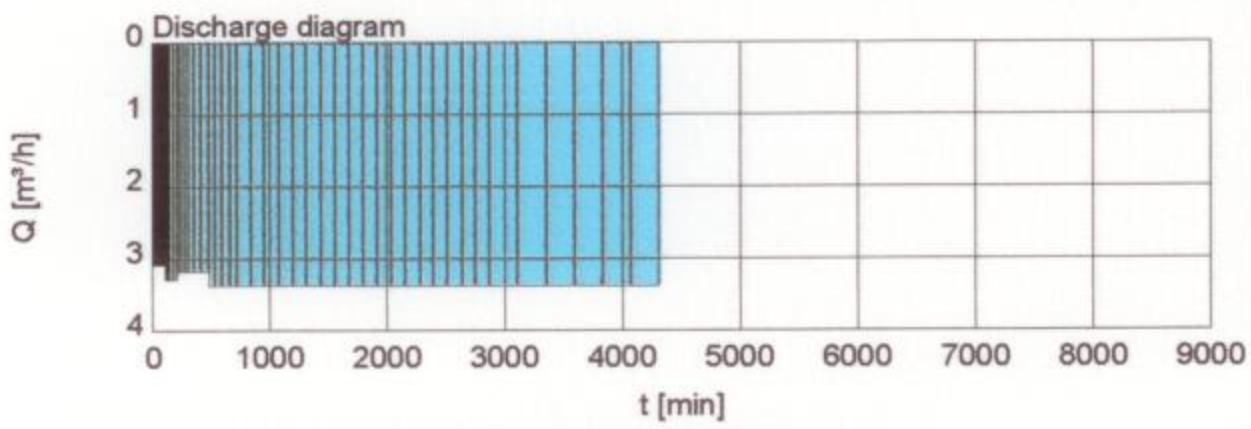
Test pumping analysis

Pumped well J2-A



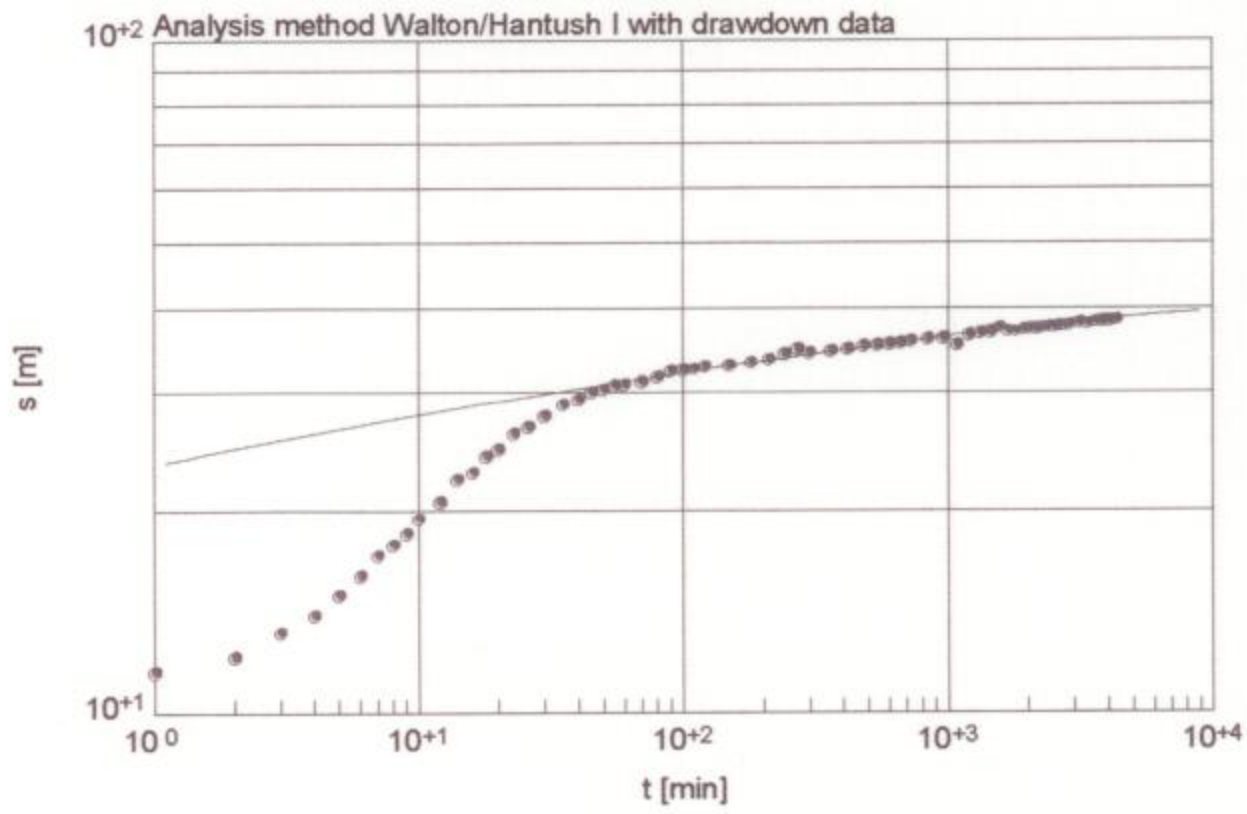
Borehole, well & aquifer

Drilled:	
Latitude:	
Longitude:	
Elevation:	1100 [m]
Depth:	
Stick up:	0.00 [m]
Bh. radius:	0.100 [m]
Casing radius:	0.075 [m]
RWL:	17.29 [m]
max.drawdown:	38.30 [m]
Aq.type:	confined
Aq.thickness:	100.00 [m]
Stratigraphy:	Aoub Sandstone
Lithology:	Sandstone



Test running

Start:	03/07/2000 20:08:52
Dis.dur.:	4320 [min]
Av.dis.:	3.38 [m³/h]
Max.dis.:	3.4 [m³/h]
Min.dis.:	3.1 [m³/h]
Total dis.:	243 [m³]
Crew:	Metzger_PM
Supervisior:	PCI



Results

Match parameter:	
Q:	3.38 [m³/h]
t:	374 [min]
s:	26.2 [m]
1/u:	1.69E8 [-]
W(u,r/B):	13.9 [-]
Aquifer parameter:	
T:	3.42 [m²/d]
k:	0.0342 [m/d]
Boundary parameter:	
B:	4E3 [m]
m´:	40 [m]
k´:	8.56E-6 [m/d]

Date 02/10/00 prepared by BIWAC

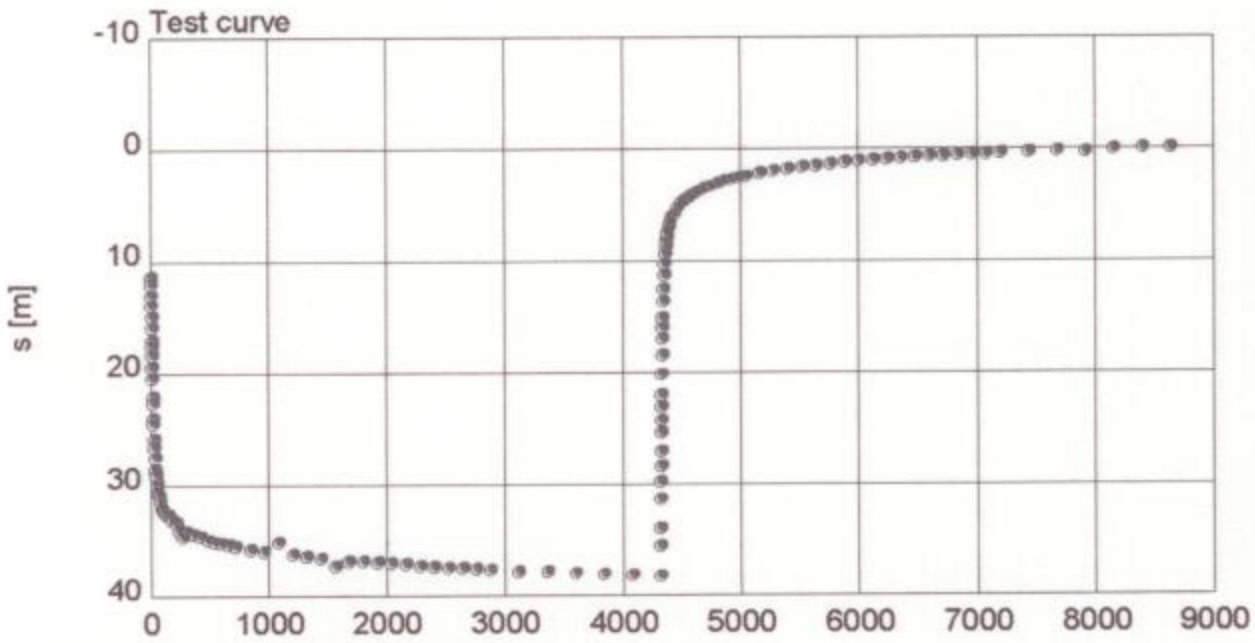
Annex 2

Groundwater Study in the Stampriet Artesian Basin

Evaluation of Test Pumping Data

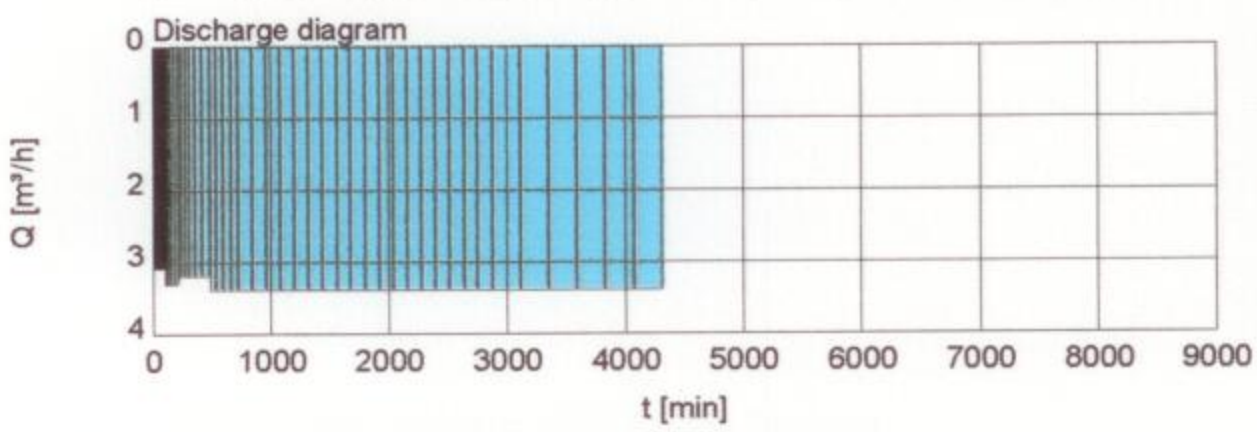
Test pumping analysis

Pumped well J2-A



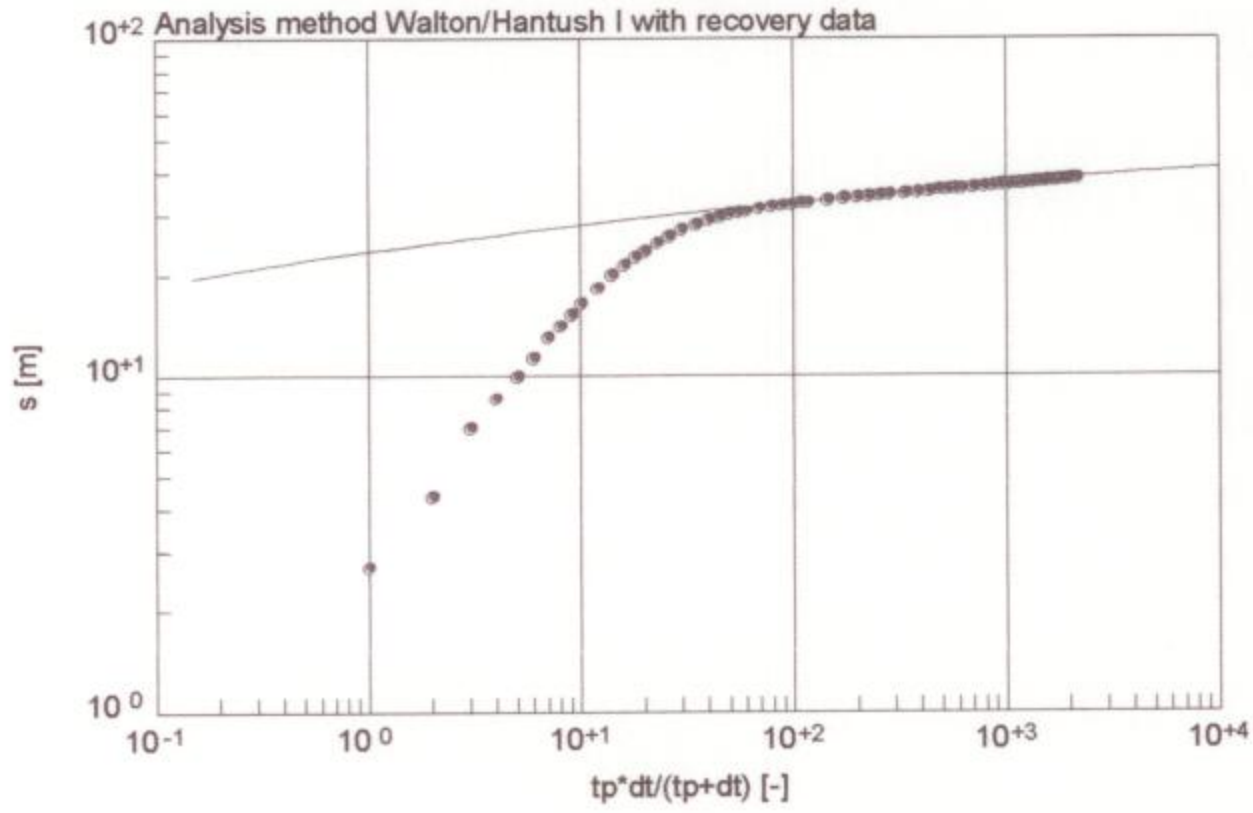
Borehole, well & aquifer

Drilled:	
Latitude:	
Longitude:	
Elevation:	1100 [m]
Depth:	
Stick up:	0.00 [m]
Bh. radius:	0.100 [m]
Casing radius:	0.075 [m]
RWL:	17.29 [m]
max.drawdown:	38.30 [m]
Aq.type:	confined
Aq.thickness:	100.00 [m]
Stratigraphy:	Aoub Sandstone
Lithology:	Sandstone



Test running

Start:	03/07/2000 20:08:52
Dis.dur.:	4320 [min]
Av.dis.:	3.38 [m³/h]
Max.dis.:	3.4 [m³/h]
Min.dis.:	3.1 [m³/h]
Total dis.:	243 [m³]
Crew:	Metzger_PM
Supervisior:	PCI



Results

Match parameter:	
Q:	3.38 [m³/h]
t:	456 [min]
s:	12 [m]
1/u:	9.29E7 [-]
W(u,r/B):	5.99 [-]
Aquifer parameter:	
T:	3.22 [m²/d]
k:	0.0322 [m/d]
S:	
Boundary parameter:	
B:	4E3 [m]
m':	40 [m]
k':	8.06E-6 [m/d]

Date 02/10/00 prepared by BIWAC

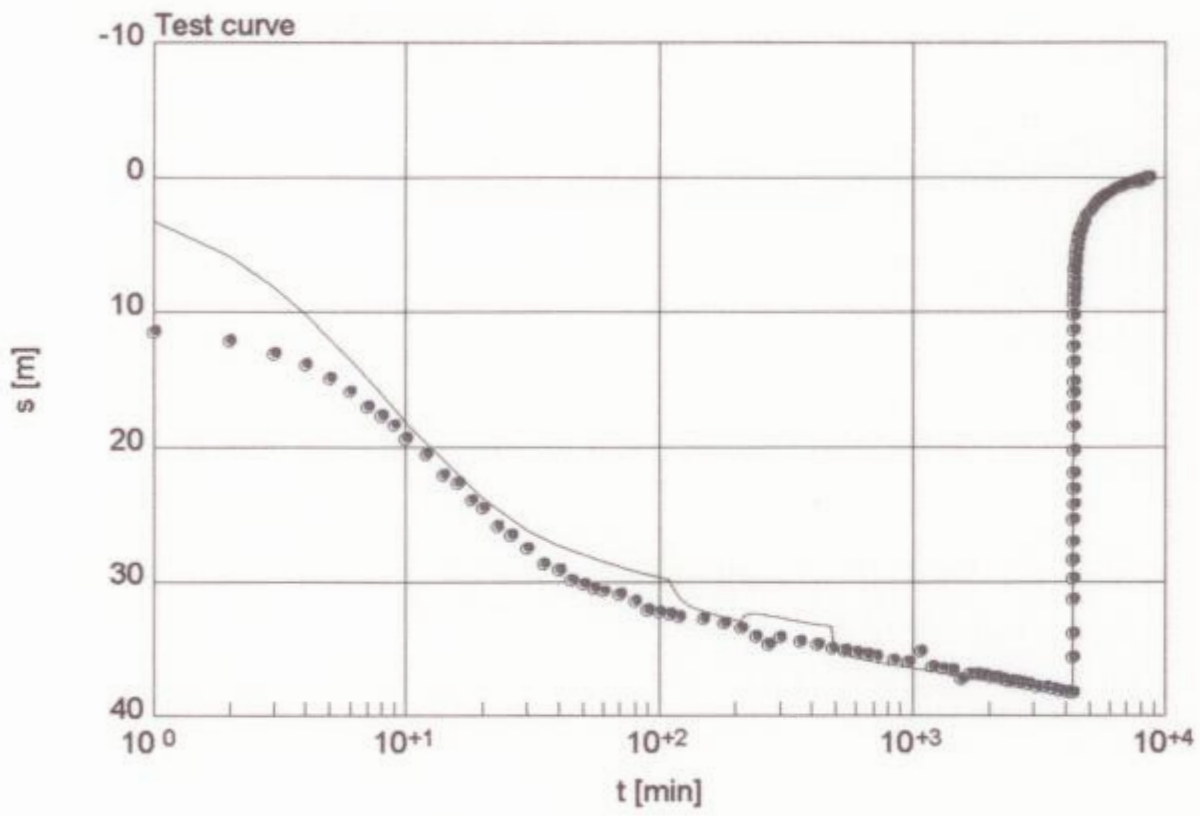
Annex 3

Groundwater Study in the Stampriet Artesian Basin

Evaluation of Test Pumping Data

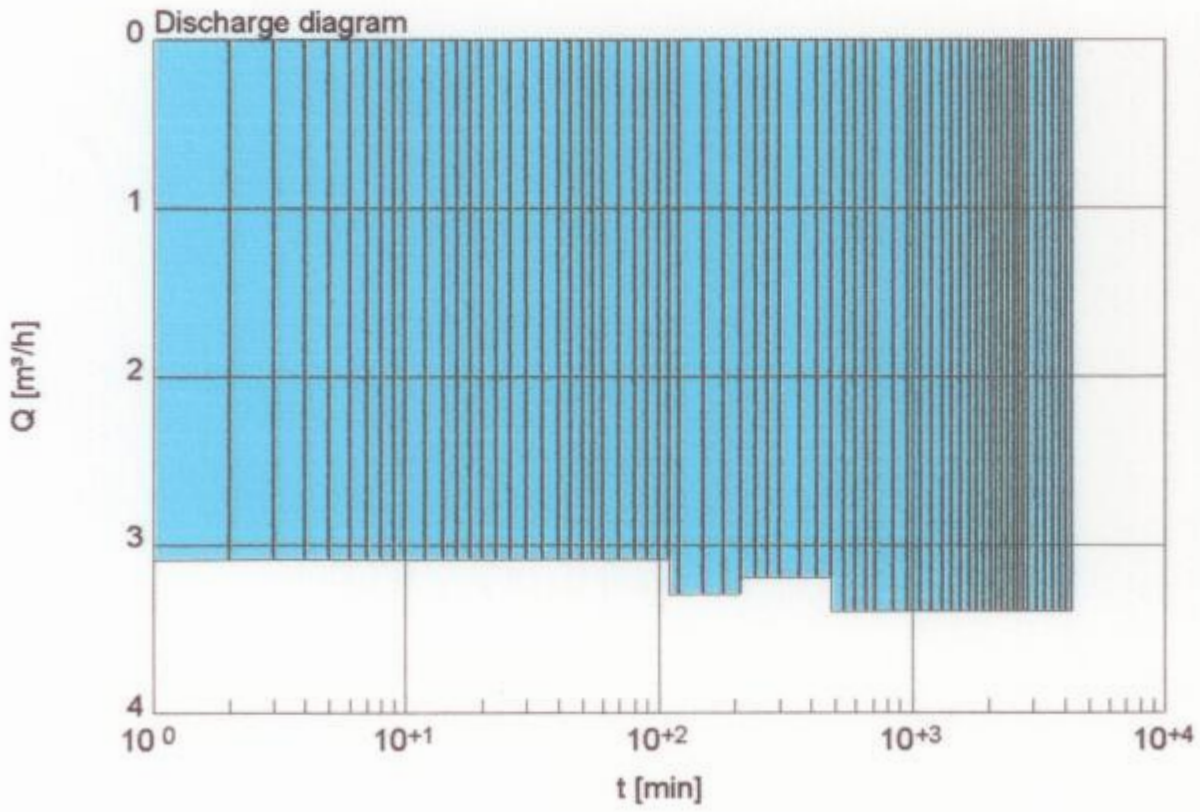
Test pumping diagnosis

Pumped well J2-A



Remarks

Simulation of the actual recorded draw down during the constant discharge test applying the Hantush model for leaky aquifers.



Discharge info

Dis.dur.:4320 [min]
tcorr: 4290 [min]

Av.dis.: 3.38 [m³/h]
max.dis.:3.40 [m³/h]
min.dis.:3.10 [m³/h]
Qn: 3.40 [m³/h]

Dis.sum: 243 [m³]

Date 02/10/00 prepared by BIWAC

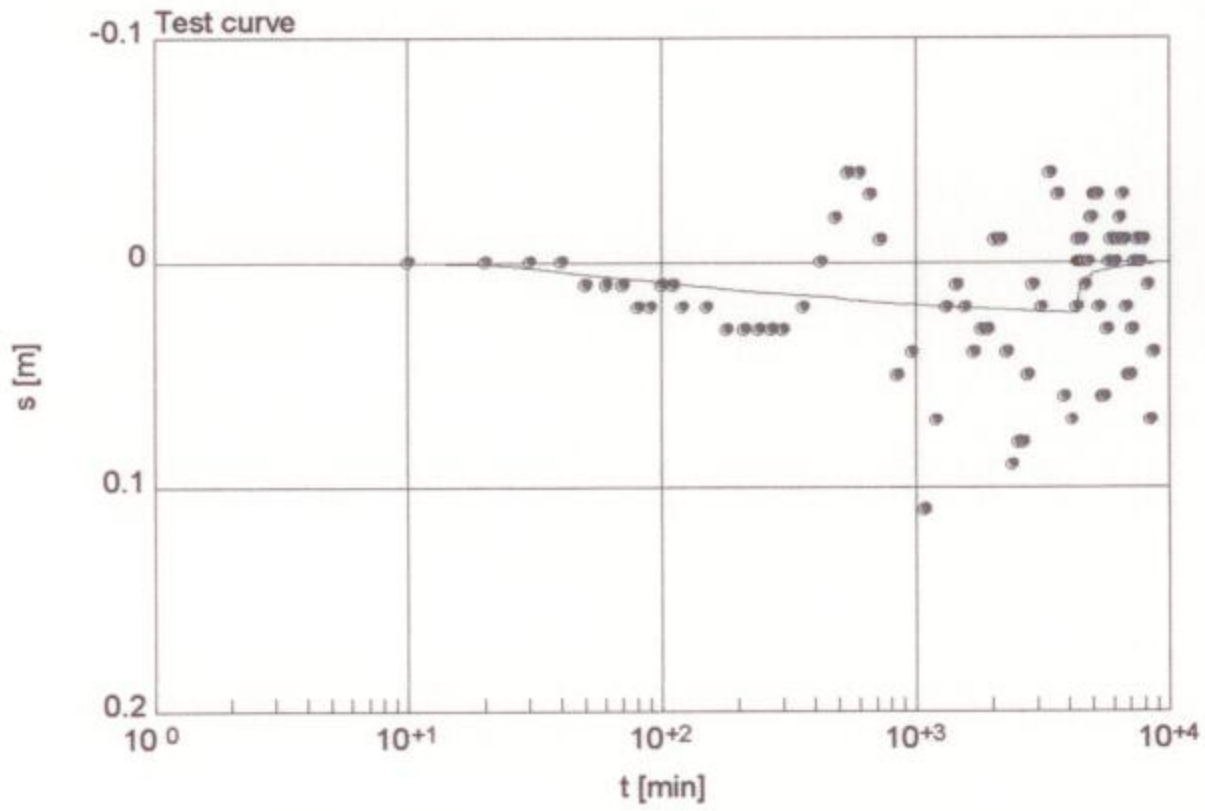
Annex 4

Groundwater Study in the Stampriet Artesian Basin

Evaluation of Test Pumping Data

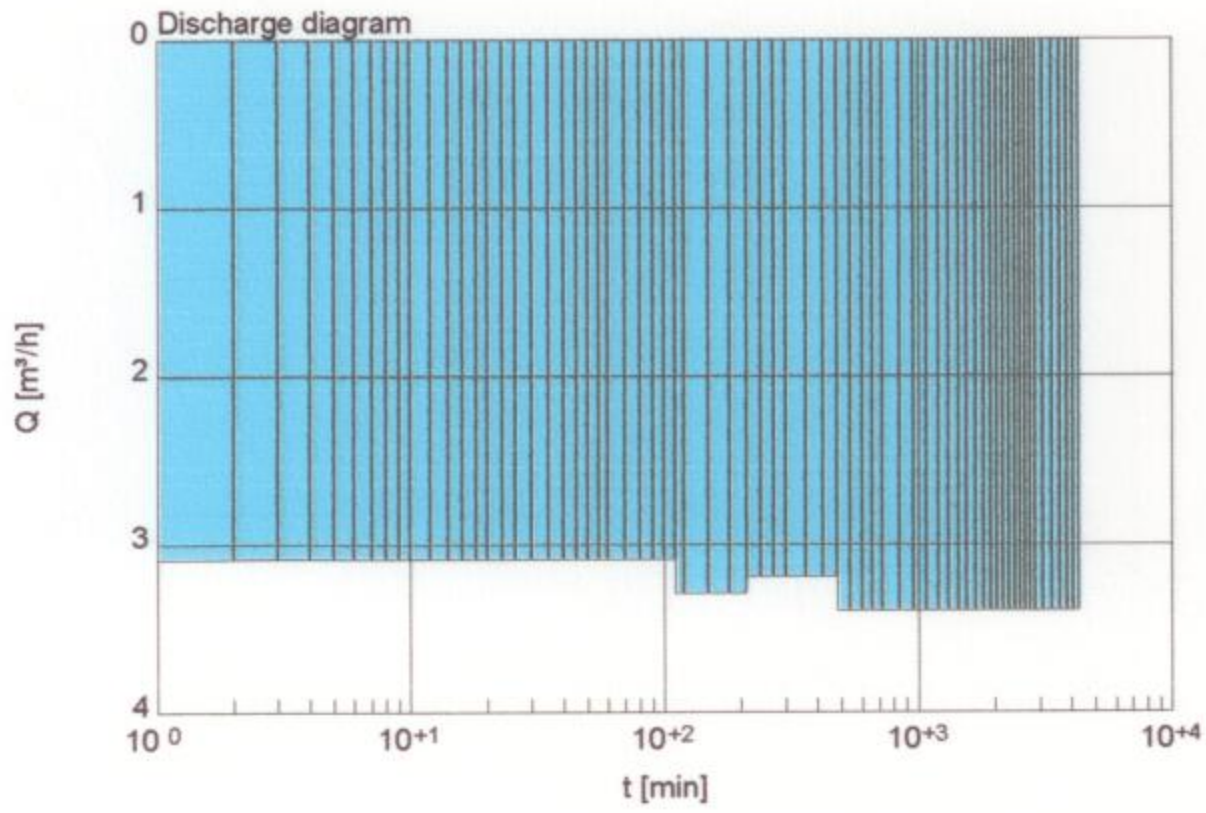
Test pumping diagnosis

Observation well J2-N



Remarks

Data from observation borehole J2-N could not be used to calculate aquifer parameters due to the fact that the borehole is not located in the pumped aquifer and



Discharge info

Dis.dur.:4320 [min]
tcorr: 4290 [min]

Av.dis.: 3.38 [m³/h]
max.dis.:3.40 [m³/h]
min.dis.:3.10 [m³/h]
Qn: 3.40 [m³/h]

Dis.sum: 243 [m³]

Date 02/10/00 prepared by BIWAC

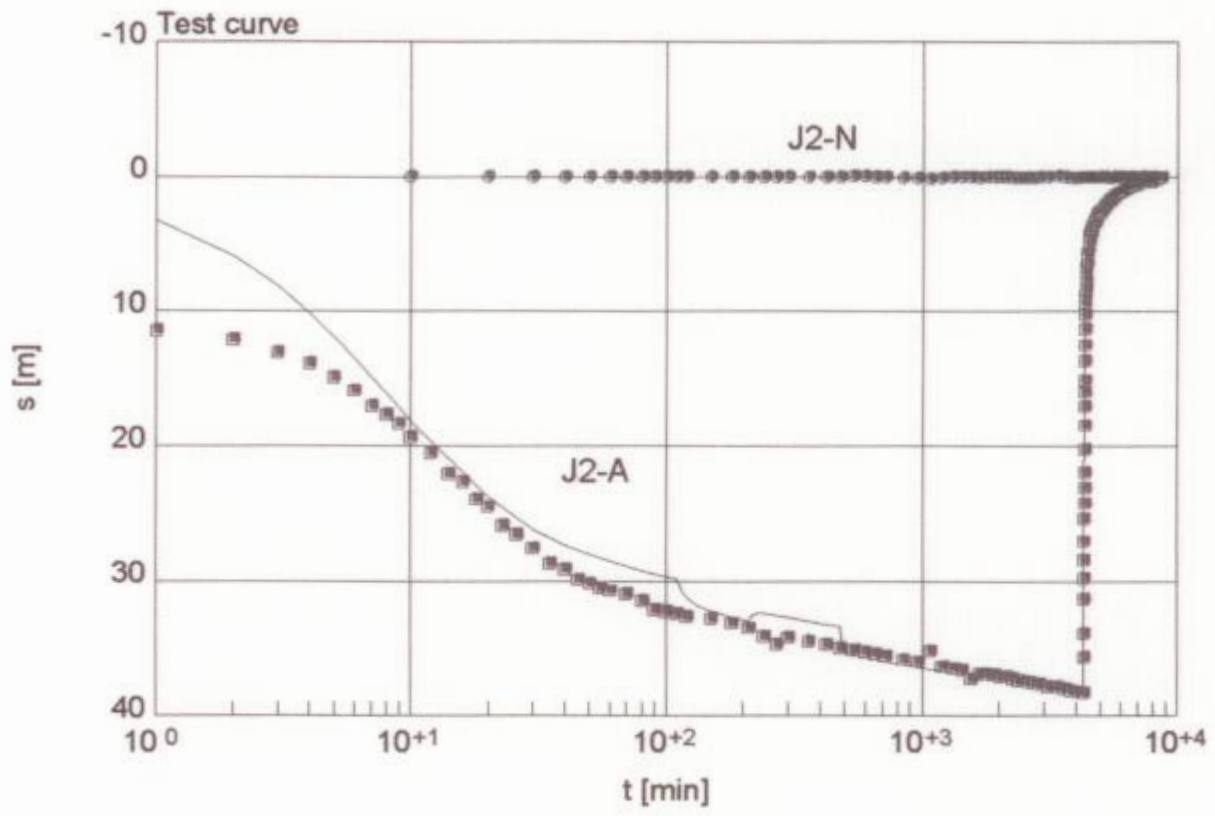
Annex 5

Groundwater Study in the Stampriet Artesian Basin

Evaluation of Test Pumping Data

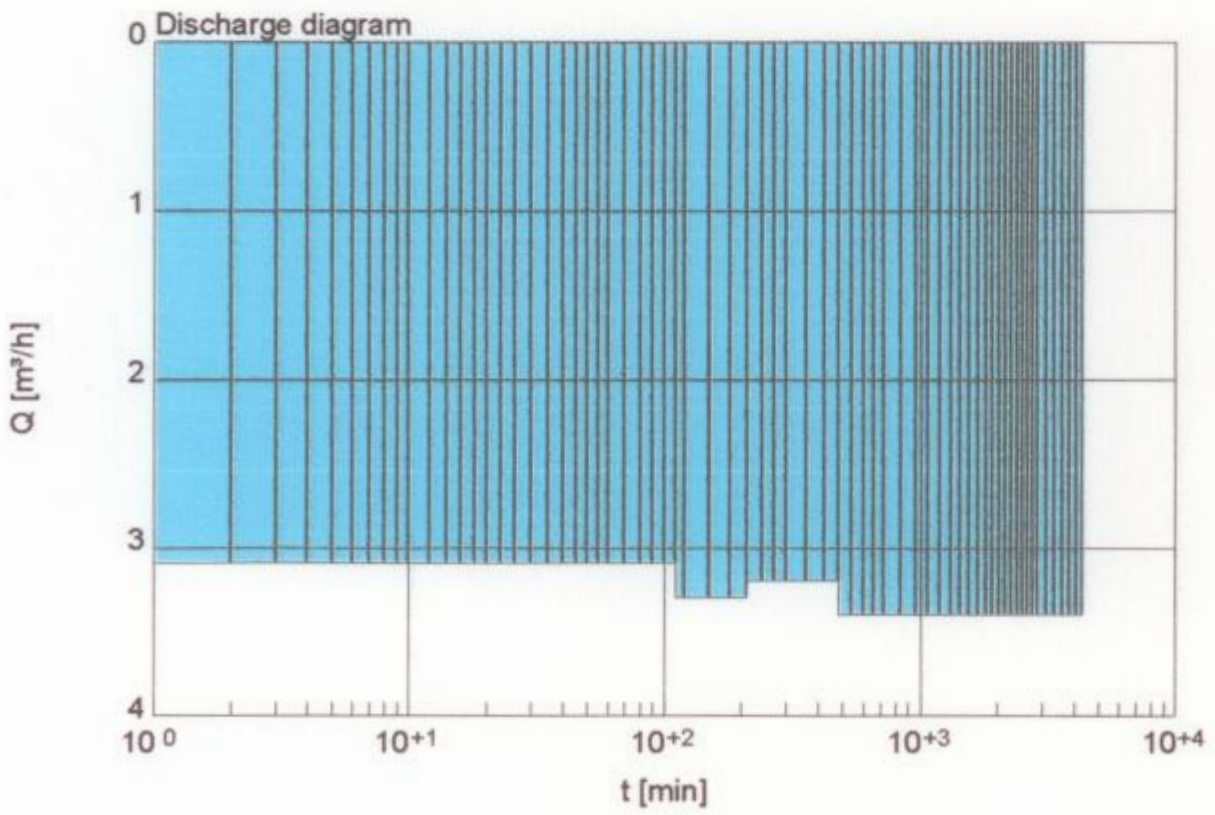
Test pumping diagnosis

Pumped well J2-A



Remarks

Merged draw down data from observation borehole J2-N and abstraction borehole J2-A.



Discharge info

Dis.dur.:4320 [min]
tcorr: 4290 [min]

Av.dis.: 3.38 [m³/h]
max.dis.:3.40 [m³/h]
min.dis.:3.10 [m³/h]
Qn: 3.40 [m³/h]

Dis.sum: 243 [m³]

Distance to observation borehole: J2-N = 71.2 m

Date 02/10/00 prepared by BIWAC

Annex 6

7. Water Level Recorder Installation

THE STUDY ON THE GROUNDWATER POTENTIAL EVALUATION AND MANAGEMENT PLAN IN THE SOUTHEAST KALAHARI (STAMPRIET) ARTESIAN BASIN

INSTALLATION OF SEBA FLOATERS

JICA REFERENCE: J 2 A LOCALITY: Olifantswater West M 102

WW 39840

1. **Serial Number of floater**: 4492
2. **Date installed**: 19/09/00
3. **Rest Water Level when installed**: 16.47 mbsu
4. **Distance from stick-up to logger**: 14.00 m
5. **Distance from logger to water level**: 2.47 m
6. **Cut off**: 14.00 (0.91 + 13.11)