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

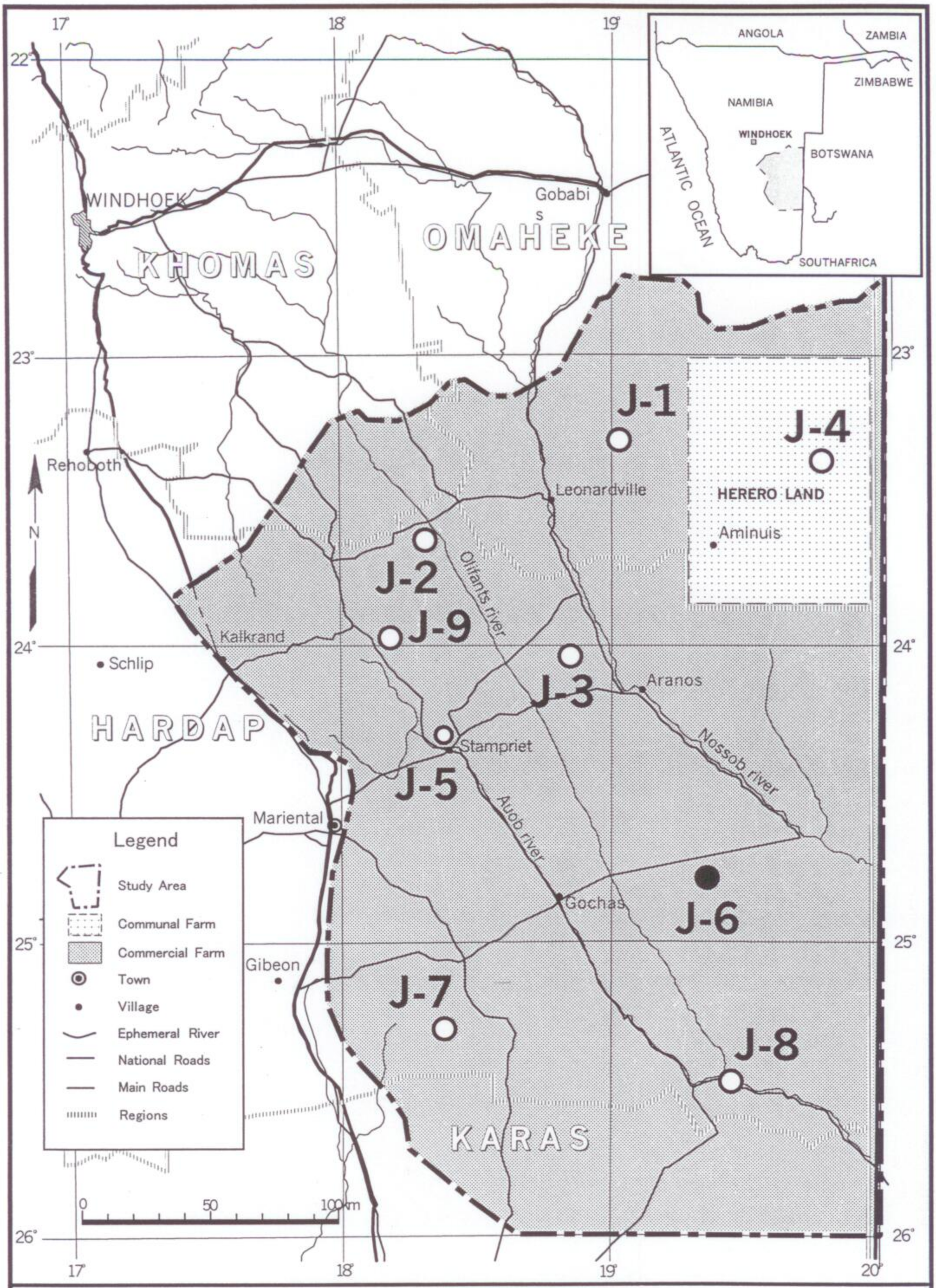
J6-K (WW 39849)

Cobra R 349

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 Cobra **WW 39850**
Jica Reference: J - 6 - K **S 24. 80009°**
Date completed: 28 July 2000 **E 19. 33483°**
(final casing installed), **Collar elev.: 1104 mamsl**

Depth below surface (m)	Section (m)	Lithology	Stratigraphy
0 - 4	4	Very coarse grained subsurface **sand**	**KALAHARI**
4 - 26	22	Calcareous **sandstone** with pebbles and granules, light pinkish to white.	
26 - 104	78	Calcareous **sandstone**, moderate brown, drill cuttings severely ground. Between 47 m and 51 a gravelly horizon was intersected.	
104 - 111	7	Light brown medium to coarse grained **sandstone**, calcite cemented.	
111 - 121	10	Calcareous **sandstone**, moderate brown, drill cuttings severely ground.	
121 - 141	20	Calcareous **sandstone**, medium grained quartz grains. Dispersed quartz granules ϕ 2 mm, sub-angular, purple to dark grey.	
141 - 153	12	As above, with colour change to moderate orange brown.	
153 - 158	5	As above, with intercalated bands of moderate red brown **sandstone**, medium to coarse grained, with some quartz granules ϕ 2 – 3 mm displaying FeO staining between 156 and 158 m.	
158 – 168.4 EOH	10.4	Prominent **sandstone** to 164 m, fining downwards to a shale at 168 m, colour dark yellowish brown.	

Remarks:

1. Drilling method mud-rotary results in severely ground drill-cuttings.

This borehole was logged by A. Wierenga and F. Bockmuhl.

2. Penetration Record

Penetration Record J 6 K			
Depth (m)	Pen. Rate (min/m)	Time (hrs:min)	Date (dd/mm/yy)
1			25/06/00
5			
	4		
	5.8		
10	4.35		
	4.4		
	5.65		
	6.6		
	6.6		
	6.3		
	6.55		
	7.1		
	8.25		
	7.95		
20	8.75		
	8.55		
	5.6		
	5.35		
	5.6		
	5.5		
	6.85		
	8.15		
	9.35		
	7		
30	6.8		
	6.95		
	7		
	8.3		
	8.1		
	7.55		
	5.3		
	8.65		
	6.35		
	4.55		
40	6.05		
	4.9		
	8.25		
	9.25		
	9.1		
	9.3		
	9.2		
	9.85		
	9.6		
	9.9		
50	14.3		
	17.8		
	13.8		
	12		
	11.3		

	12.2		
	13.2		
	11.1		
	11.5		
	14.95		
60	16.3		
	14.7		
	16.15		
	15.8		
	12.95		
	12		
	12.1		
	8.9		26/06/00
	9.7		
	11.35		
70	12.85		
	8.75		
	9		
	7.75		
	7.55		
	9		
	9.05		
	8.3		
	9.75		
	8.45		
80	11.15		
	10.7		
	12.1		
	10.85		
	10.55		
	10.3		
	10.85		
	11.5		
	10.6		
	9.4		
90	6.75		
	8.6		
	8.95		
	7.75		
	9.45		
	19.3		
	5.5		
	6.65		
	6.85		
	6.8		
100	6.1		
	5.3		
	4.7		
	6.9		
	9.5		
	9.35		
	11.85		
	8.4		
	9		
	3.4		
110	4		

	2.85		
	8.35		
	5.7		
	6.35		
	5.5		
	6.15		
	4.5		
	6.15		
	6.25		
120	6.2		
	6.1		
	5.7		
	6		
	6.4		
	5.35		
	4		
	3.8		
	2.55		
	5.15		
130	6.2		
	5		
	6.5		
	9.2		
	7.7		
	5.75		
	5.9		
	6.65		
	6.3		
140	5.05		
	4.05		
	7.1		
	3.8		
	7.85		
	5.55		
	8.5		
	7.65		
	5		
	6.65		
	7.75		
	11.25		
	10.9		
	6.3		
	8.1		
	13.3		
	10.2		
	16.75		
	15.6		
	9.25		
	7.25		
	11.15		
	5.3		
	8.95		
	2.3		
	4		

	11.55		
	7.1		

j6kpen

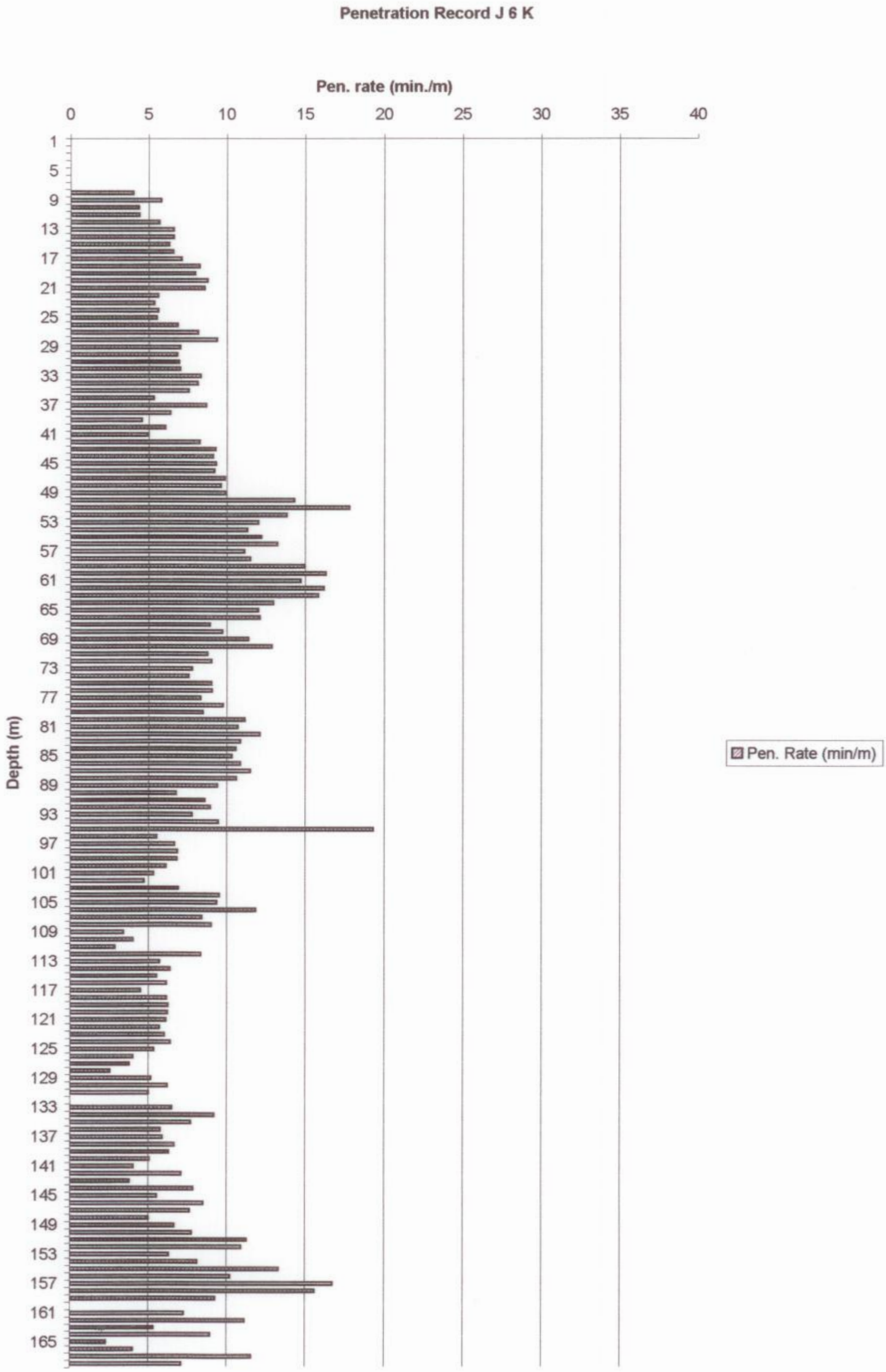


Chart2

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 6 K LOCALITY: Cobra R 349 WW 39849 DATE: 24/6 to 27/6 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
15:30	0	29	16	1.488	1.16 ≥	10	23	Water tanker, used for drilling fluid. Date 24/06/00
10:30	17	39	25	1.444	d.o.	9	17.7	Date 25/06/00
08:00	74	38	25	0.9	d.o.	9	19.7	Date 26/06/00
		28	16	0.99		8	8.0	Water tanker, used for mixing drill fluid.
14:00	110	32	20	2.16		9	31	
11:30	168	33	24	2.45		9	25.3	Date 27/06/00 end of borehole.

4. Geophysical Log and Casing Design

Poseidon Geophysics

(Reg. No. 93550)

CO. Poseidon Geophysics
WELL J6K WW 39851
PROJ.
LCN. Cobra
STE. J 6
FILING No. J6K

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 J6K WW39851

LOCATION COBRA

COUNTRY REPUBLIC OF NAMIBIA

BH COORDINATES

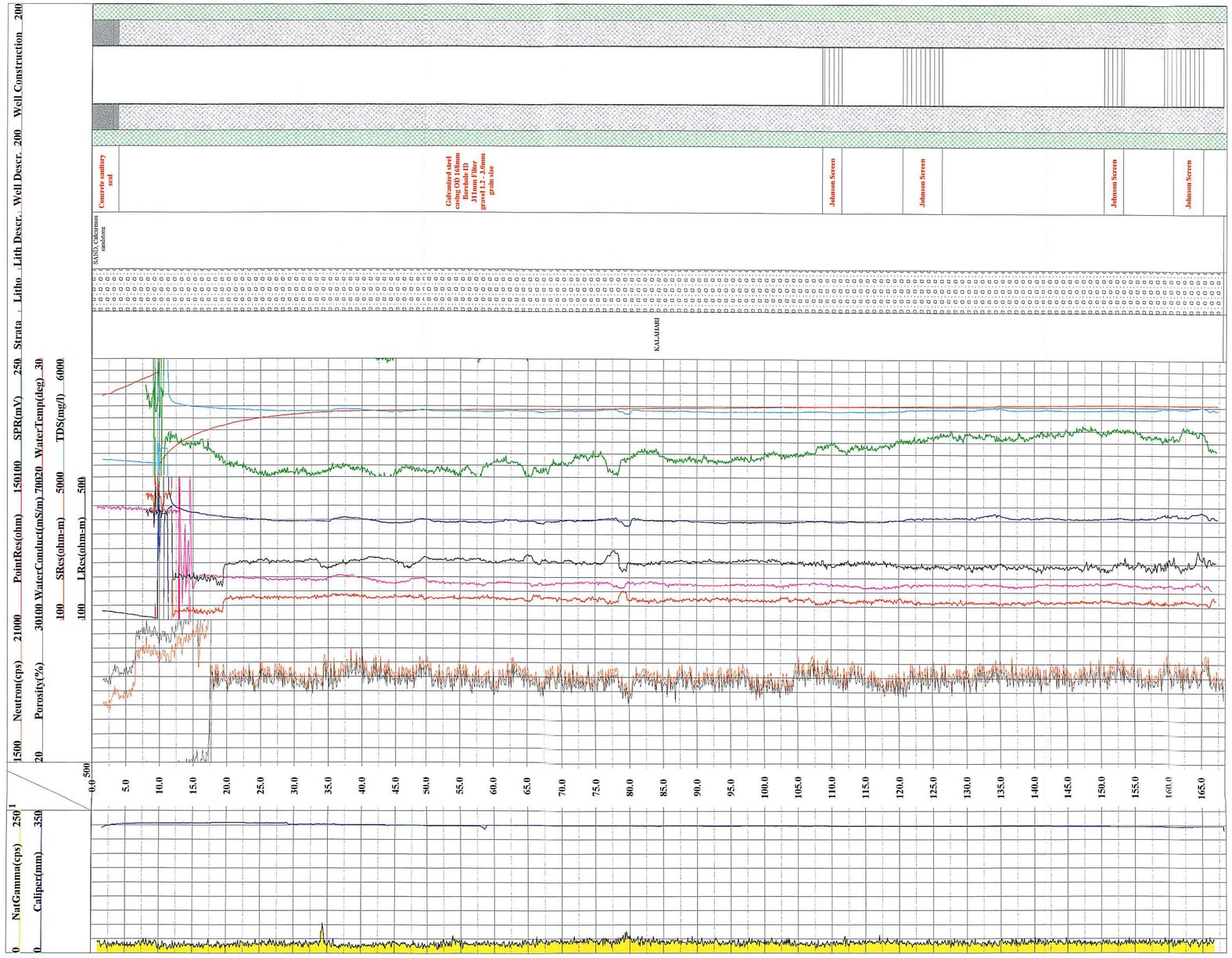
COLLAR ELEVATION

LOG MEAS. FROM Groundlevel

DRILLING MEAS. FROM Groundlevel

DATE	27 Jule 2000
TYPE LOG	Physical Properties
DEPTH-DRILLER	168.5m
DEPTH-LOGGER	168.3m
BTM LOGGED INTERVAL	168.3m
TOP LOGGED INTERVAL	0.60m
PERMANENT DATUM	Groundlevel
RECORDED BY	Wimpie Coetzer
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 6 K LOCALITY: Cobra R 349 WW 39849 DATE: 29/06/2000 (starting)

TIME (actual)	P.I.D. (mbsu)	½ 90° V-Notch (mm)	Yield (m^3/h)	E.C. (mS/m)	Water Level (mbsu)	Remarks
11:00					27,70	Date 29/06/00. **Cable Tool data.** Plunging through all the screens in order to settle and develop gravel. Add gravel as fines are washed out into the borehole.
23:00						Stop for the day.
08:00				241	42.75	Date 30/06/00. Bailing and plunging, alternating: Bail until 12:00
12:00			0.268			Remove 43 bailers @ 25 l, for a total of 1075 l.
14:00						Two hours of continuous plunging.
16:20			1.08	237	103.50	Bailing: remove 100 bailers @ 25 l for a total of 2500 l.
19:30						3 hours of continuous plunging and surging.
11:00	163	45			116.4	Date 2/7/00. **Airlifting.**
12:00		40			116.41	
13:00		43			114.10	
14:00		35			114.15	
15:00		30			113.10	
16:00		45			113.00	
17:00		30			113.98	
18:00		30			112.40	
19:00		29			112.45	Airlift through the night

TIME (actual)	P.I.D. (mbsu)	½ 90° V-Notch (mm)	Yield (m^3/h)	E.C. (mS/m)	Water Level (mbsu)	Remarks
07:45	163	34			113.14	Date 3/7/00.
08:15				>>>		pH 9.39; T 22.4°C. Water very saline.
09:10	151.3					
10:00		38	0.7		112.20	
11:00		38	0.7		112.27	
12:00					113.76	Remove pipes
13:20	124.50					Start again
17:10		20	0.144	2040	104.70	
17:50		20	0.144	2170	105.20	T 23.3°C
18:10	124.5	20	0.144	2180	105.30	Stop airlifting: water clear and free of sediment
08:15					103.28	Date 04/07/2000: Measure water level.

Remarks:

1. This borehole was also developed by means of electrical submersible pump. Data from the development conducted on 22/07/2000 is tabulated below:

TIME (actual)	Pump time (min)	Water Level (mbsu)	Yield (m^3/h)	E.C. (mS/m)	Remarks
13:30	0	102.31	0		Rest water level
	1	105.55			
	2	107.54			
	3	108.64			
	4	109.52			
	5	110.18			

TIME (actual)	Pump time (min)	Water Level (mbsu)	Yield (m^3/h)	E.C. (mS/m)	Remarks
	6	110.95			
	7	111.49			
	8	112.15			
	9	112.79			
	10	113.32			
	12	113.65			
	14	113.70	1.656		
13.46	16	113.78			Change cable phases. Short recovery.
13.53	17	116.00	10.19		Tap full open
	18	122.03			
	19	128.59			
	20	132.00			
	21	138.40			
	22	141.80			Close the tap
	23	141.50	7.48		
	24	143.10			
	25	144.15			Close the tap
	26	144.25	5.9		
	28	144.21	5.7		
	30	144.48			
	32	144.29			Close the tap
	34	143.17	5.0		
	36	142.35			
	39	141.75	4.996		
	42	141.32			
	46	141.18	5.052		
	51	141.08			

TIME (actual)	Pump time (min)	Water Level (mbsu)	Yield (m^3/h)	E.C. (mS/m)	Remarks
	56	140.96	5.142		
	61	140.87			
	66	140.84	5.157		
	71	140.77			
	76	140.76	5.088		
	86	140.77			
	96	140.75	5.120		
	106	140.73			
	116	140.72	5.106		
	126	140.72			
	136	140.68	5.117		
	146	140.67			
	156	140.68	5.179		
	166	140.65			
	176	140.64	5.095		
	186	140.65			
	196	140.66	5.168	2350	pH 9.15; T 27.7°C
	206	140.66			
	216	140.61	5.110		
	226	140.53			
	236	140.51	5.142		
	246	140.46	5.088		
17:53	256	140.45	5.110		End of development

6. Evaluation of Pumping Test

1. PUMPING TEST ANALYSIS

J6-K (WW39849) - Pumping well

J6-A (WW39850) - Observation well

J6-N (WW39851) - Observation well

1.1. Well Efficiency (Step Drawdown 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 drawdown test are summarised in **Table 1** below.

Table 1: J6-K: Borehole efficiency at various pumping rates

Borehole number	Step	Abstraction Rate [m^3/h]	Draw Down* [m]	Borehole Efficiency [%]
J6-K	1	1.0	6.24	59.1
	2	2.1	12.40	56.7
	3	3.0	19.30	54.9
	4	4.0	26.50	53.0
	5	5.1	35.80	51.1

* at cut-off time t, 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 - 5)

The abstraction rate of the constant discharge test was 3 m^3/h. The constant discharge draw down curve of abstraction borehole **J6-K** indicates leaky conditions. For leaky aquifers, the Walton / Hantush I analysis method with draw down and recovery data was used to calculate the hydraulic conductivity of the aquifer and the aquitard as well as the leakage factor B **(Annex 2 & 3**). Using the normal Theis or Cooper-Jacob analysis will result in the over estimation of the hydraulic conductivity of the leaky aquifer and an under estimation of the hydraulic conductivity of the aquitard. (Kruseman, De Ridder, 1992).

The aquifer storativity had to be estimated due to the fact that the observation boreholes **J6-A** and **J6-N** do not penetrate the same aquifer as **J6-K**. During the duration of the constant discharge test, a rise in the water level of observation borehole **J6-N** is observed, while the water level of J6-A was stable over the period of testing. (See **Annex 5**).

The occurrence of leakage could be due to water derived from storage within the aquitard. The sandstone within the Rietmond Formation is confined and under higher hydraulic pressure and will also contribute to leakage occurring into the upper Kalahari aquifer. The results of the constant discharge analysis are summarised in **Table 2** below.

Table 2: Aquifer Parameters calculated for J6-K; Kalahari

Borehole number	Analysis method	T	s	k	S	Simulation model	Comments
		[m^2/day]	[m]	[cm/sec]	[-]		
J6-K	Walton / Hantush I - draw down	6,23	50	$1,4 \times 10^{-4}$	$*1 \times 10^{-5}$	Walton / Hantush I	*Storativity estimated - Observation boreholes are not located in the tested aquifer
	Walton / Hantush I- recovery	6.35	50	$1,5 \times 10^{-4}$	$*1 \times 10^{-5}$		

The Walton / Hantush I 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).

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

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

$R = 3000 \times 20.7 \times 1.21 \times 10^{-3} = \underline{75\ m}$

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 75 m are considered to be the minimum value.

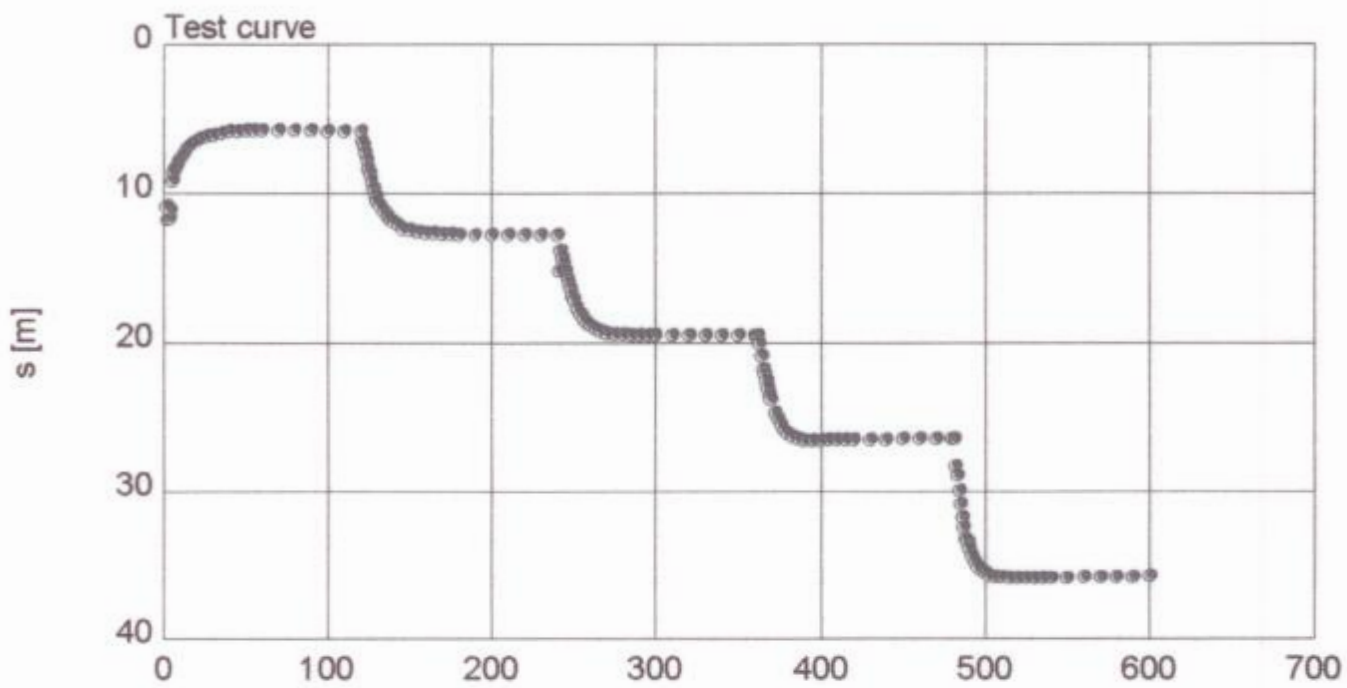
A proper evaluation of R (and storativity S) will only be possible once reliable data from observation wells, penetrating the same aquifer as the pumped well, are available.

Groundwater Study in the Stampriet Artesian Basin

Evaluation of Test Pumping Data

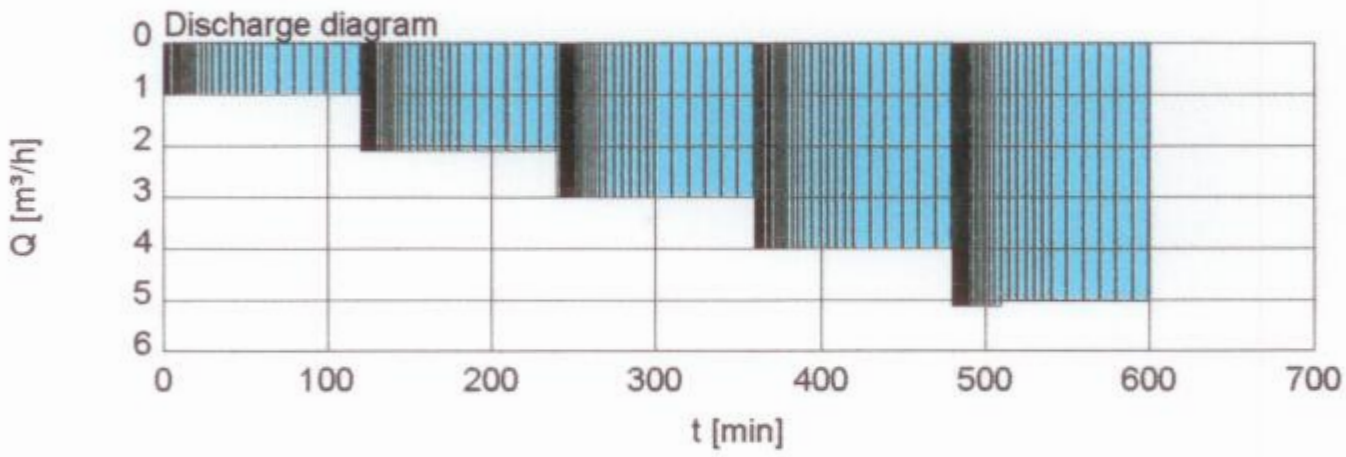
Step test analysis

Pumped well J6_K



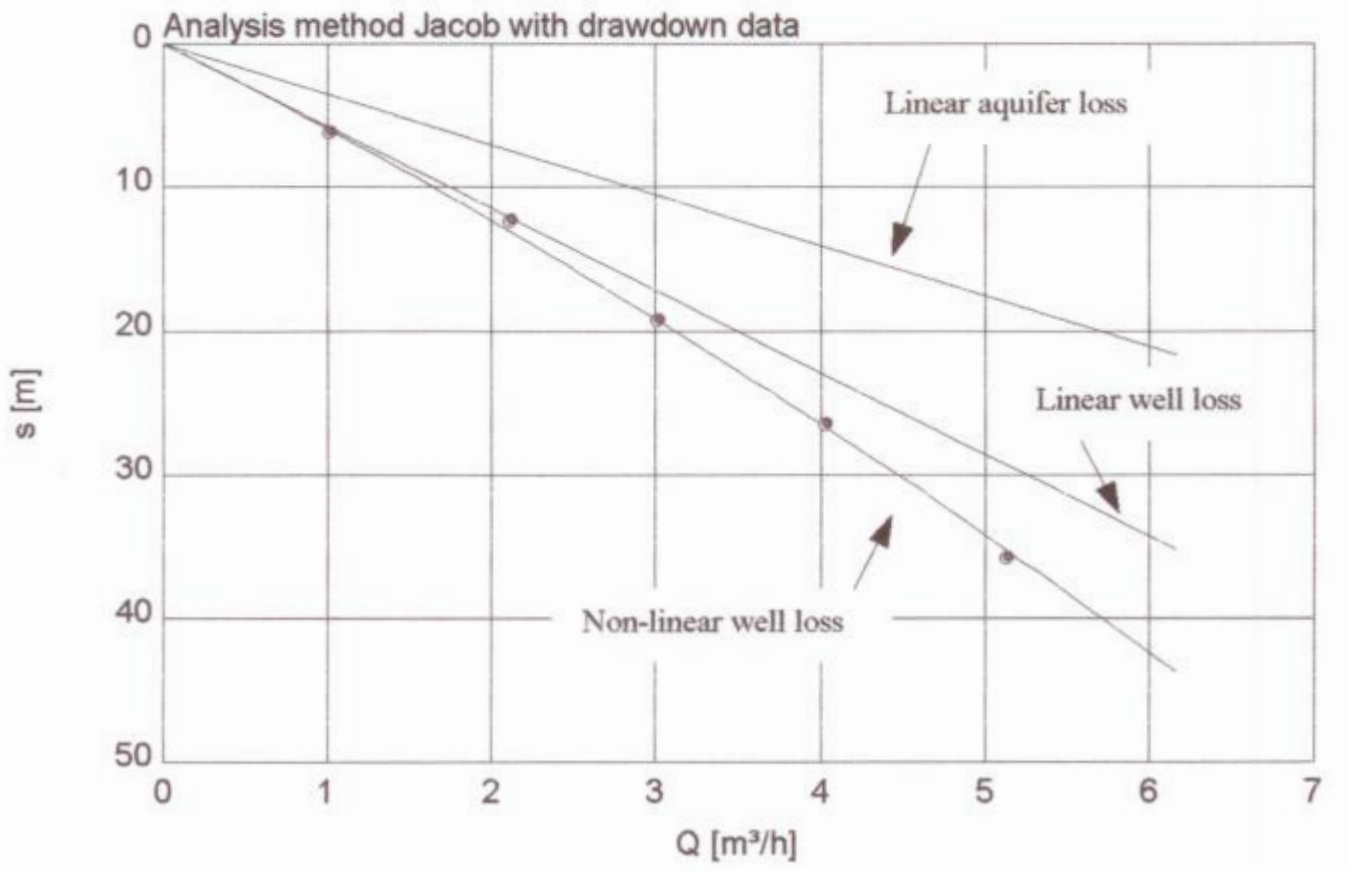
Borehole, well & aquifer

Drilled:	
Latitude:	
Longitude:	
Elevation:	300 [m]
Depth:	168.4 [m]
Stick up:	0.70 [m]
Bh. radius:	0.1555 [m]
Casing radius:	0.075 [m]
RWL:	102.68 [m]
max.drawdown:	35.88 [m]
Aq.type:	confined
Aq.thickness:	50.00 [m]
Stratigraphy:	Kalahari
Lithology:	



Test running

Start:	05/08/2000 14:41:42
Dis.dur.:	600 [min]
Av.dis.:	3.04 [m³/h]
Max.dis.:	5.13 [m³/h]
Min.dis.:	1.01 [m³/h]
Total dis.:	30.4 [m³]
Crew:	Metzger_PM
Supervisor:	PCI



Results

Well performance:

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

Linear aquifer loss B1:	3.53
Linear well loss B2:	2.18
Non-linear well loss C:	0.23

	Q [m³/h]	s [m]	Eff [%]
Step 1:	1.01	6.24	59.1
Step 2:	2.11	12.4	56.7
Step 3:	3.01	19.3	54.9
Step 4:	4.03	26.5	53.0
Step 5:	5.13	35.8	51.1

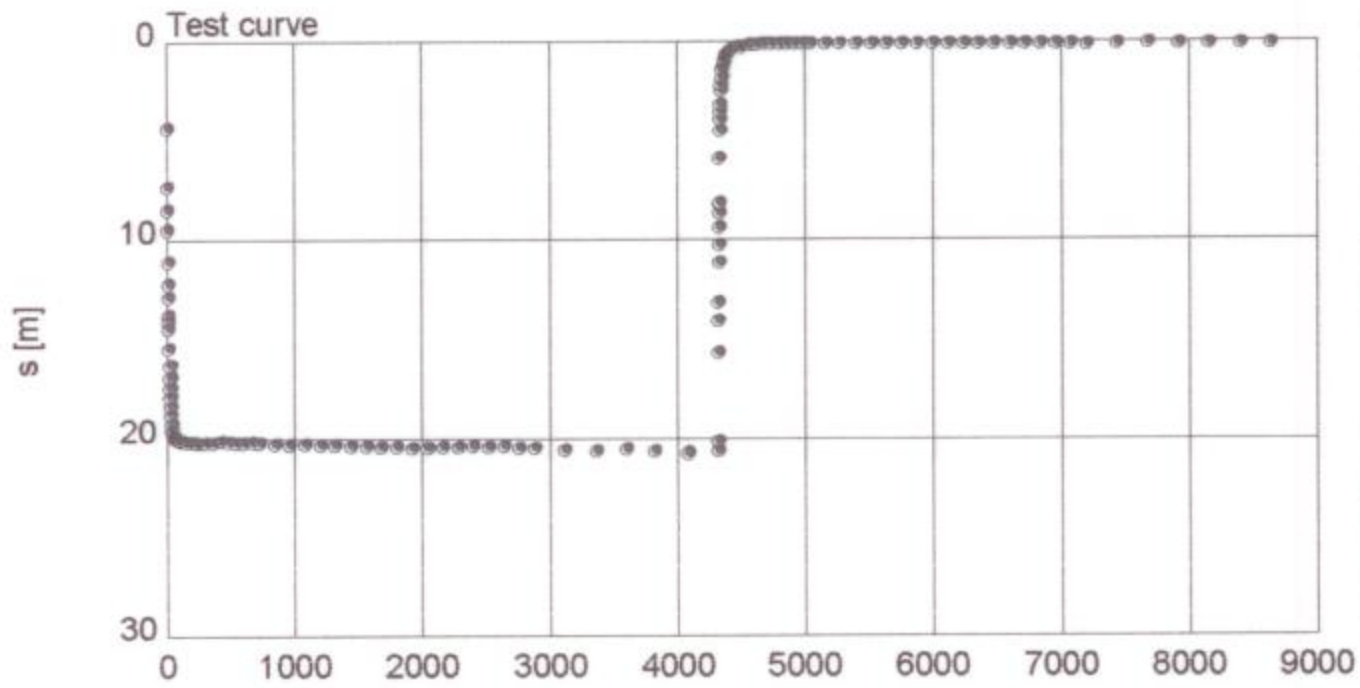
Linear skin factor:	3.59 [-]
Non-linear skin factor:	8.94 [d/m³]
Effective well radius:	6.4E-4 [m]

Groundwater Study in the Stampriet Artesian Basin

Evaluation of Test Pumping Data

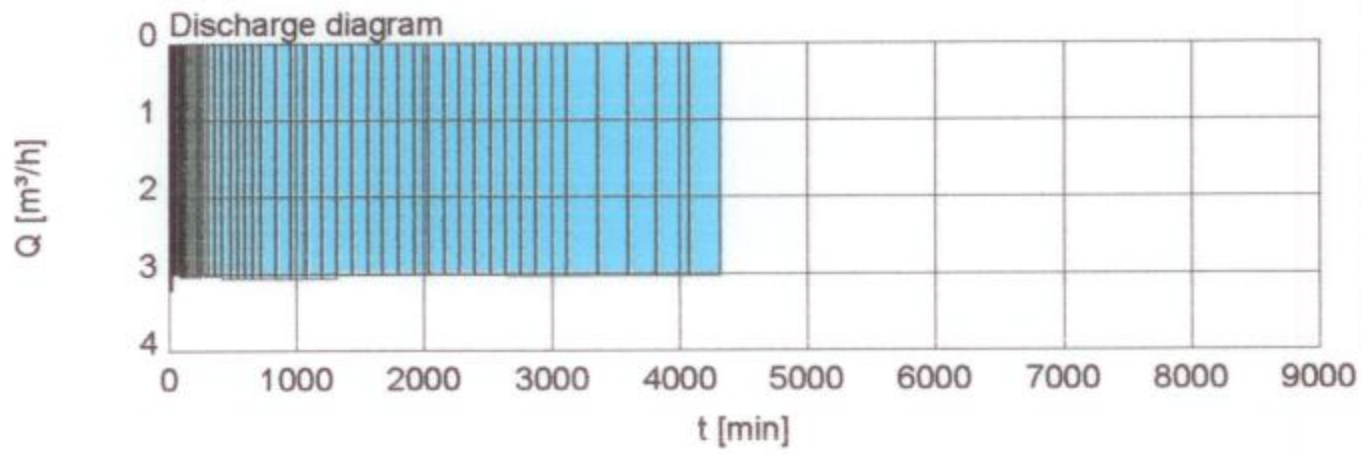
Test pumping analysis

Pumped well J6_K



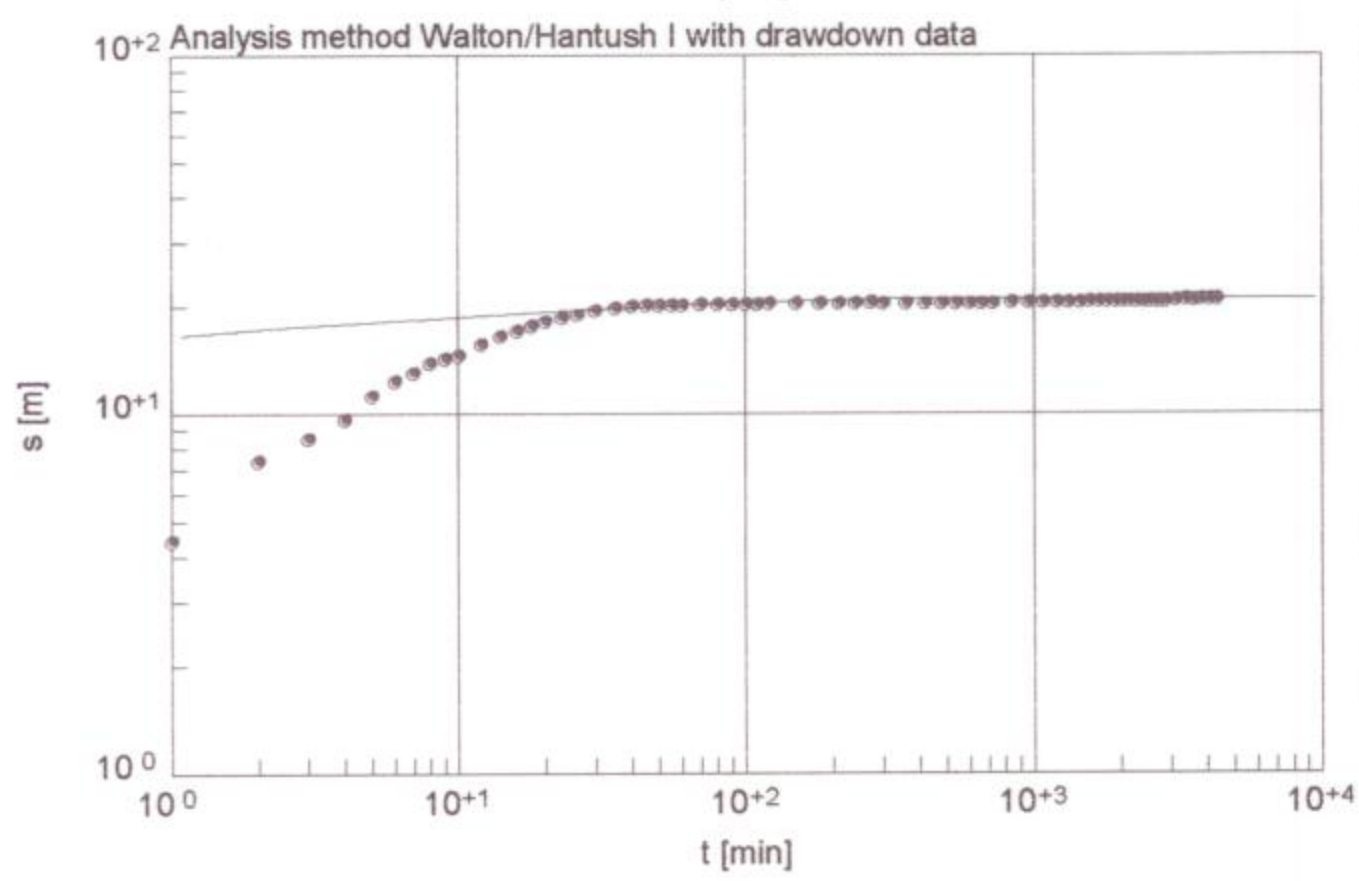
Borehole, well & aquifer

Drilled:	
Latitude:	
Longitude:	
Elevation:	300 [m]
Depth:	168.4 [m]
Stick up:	0.70 [m]
Bh. radius:	0.1555 [m]
Casing radius:	0.075 [m]
RWL:	102.69 [m]
max.drawdown:	20.73 [m]
Aq.type:	confined
Aq.thickness:	50.00 [m]
Stratigraphy:	Kalahari
Lithology:	



Test running

Start:	05/08/2000 14:40:18
Dis.dur.:	4320 [min]
Av.dis.:	3.05 [m³/h]
Max.dis.:	3.24 [m³/h]
Min.dis.:	3.01 [m³/h]
Total dis.:	219 [m³]
Crew:	Metzger_PM
Supervisor:	PCI



Results

Match parameter:	
Q:	3.05 [m³/h]
t:	8.34 [min]
s:	17.7 [m]
1/u:	6.98E8 [-]
W(u,r/B):	18.9 [-]
Aquifer parameter:	
T:	6.23 [m²/d]
k:	0.125 [m/d]
Boundary parameter:	
B:	1E4 [m]
m´:	20 [m]
k´:	1.25E-6 [m/d]

Date 06/08/00 prepared by BIWAC

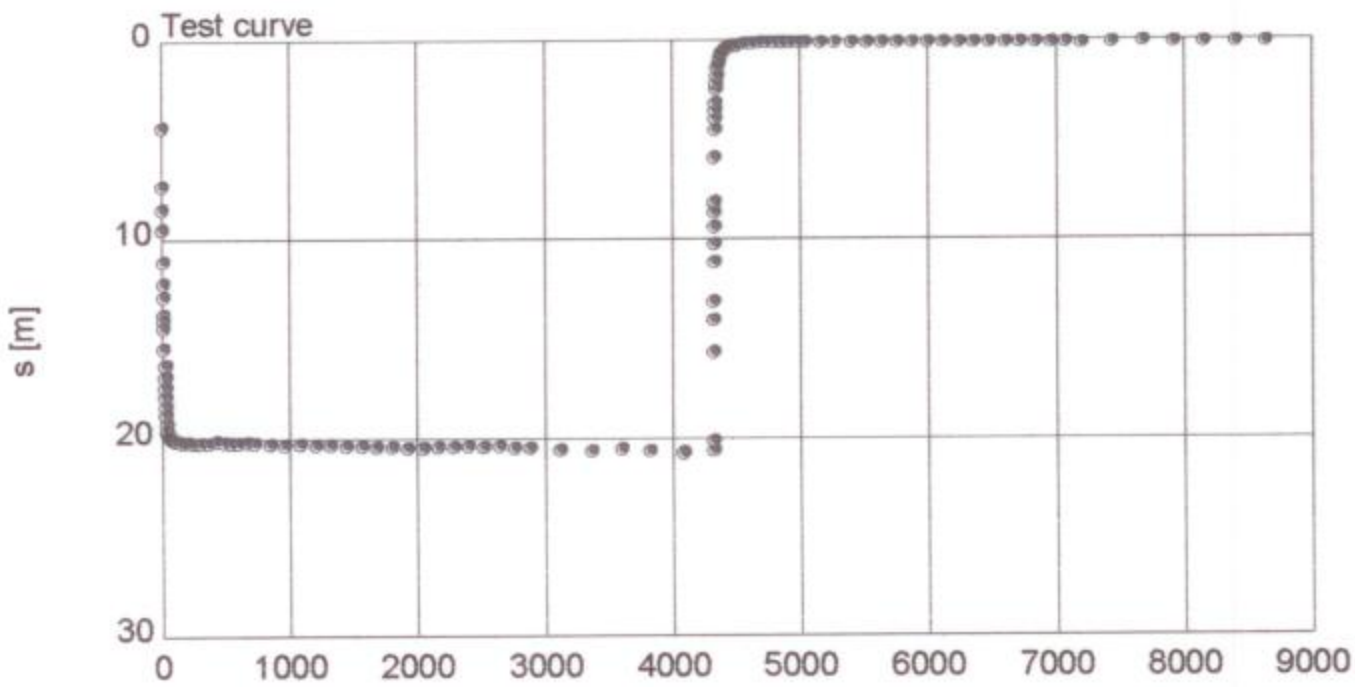
Annex 2

Groundwater Study in the Stampriet Artesian Basin

Evaluation of Test Pumping Data

Test pumping analysis

Pumped well J6_K



Borehole, well & aquifer

Drilled:	
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Elevation:	300 [m]
Depth:	168.4 [m]
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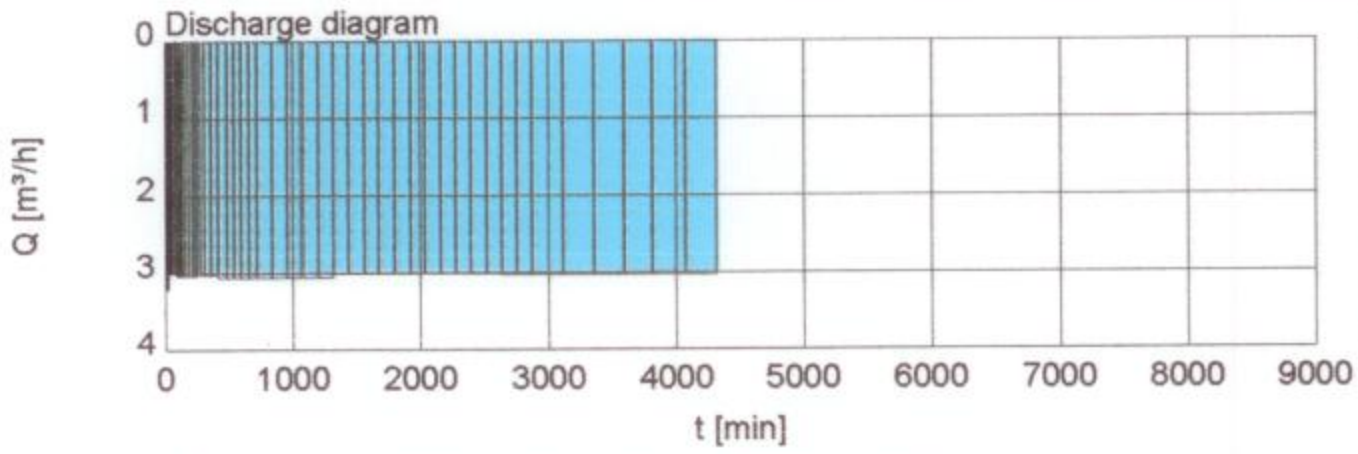
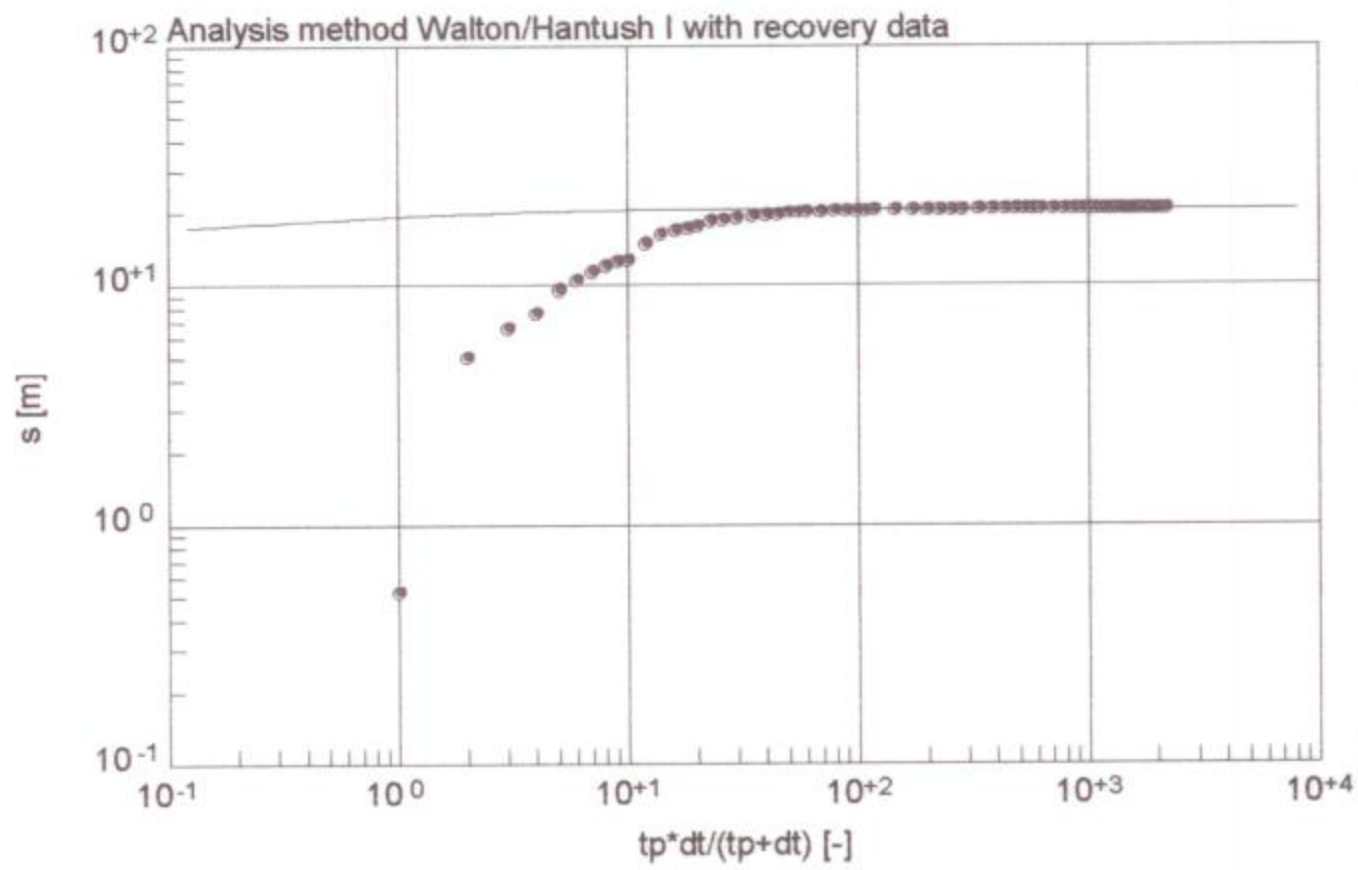
Bh. radius:	0.1555 [m]
Casing radius:	0.075 [m]
RWL:	102.69 [m]
max.drawdown:	20.73 [m]
Aq.type:	confined
Aq.thickness:	50.00 [m]
Stratigraphy:	Kalahari
Lithology:	



Test running

Start:	05/08/2000 14:40:18
Dis.dur.:	4320 [min]
Av.dis.:	3.05 [m³/h]
Max.dis.:	3.24 [m³/h]
Min.dis.:	3.01 [m³/h]
Total dis.:	219 [m³]
Crew:	Metzger_PM
Supervisor:	PCI



Results

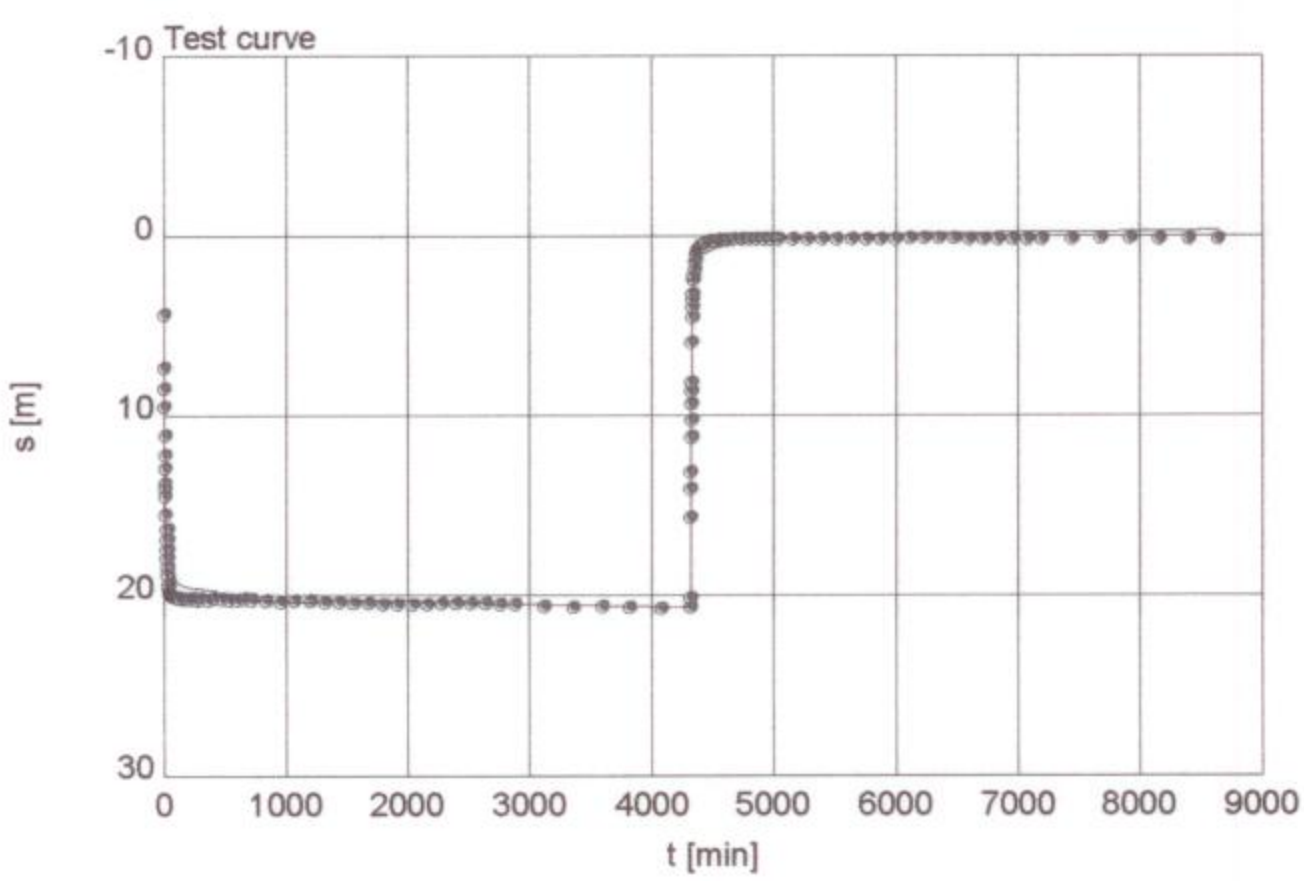
Match parameter:	
Q:	3.05 [m³/h]
t:	593 [min]
s:	20.1 [m]
1/u:	1.49E12 [-]
W(u,r/B):	21.9 [-]
Aquifer parameter:	
T:	6.35 [m²/d]
k:	0.127 [m/d]
Boundary parameter:	
B:	1E4 [m]
m´:	20 [m]
k´:	1.27E-6 [m/d]

Groundwater Study in the Stampriet Artesian Basin

Evaluation of Test Pumping Data

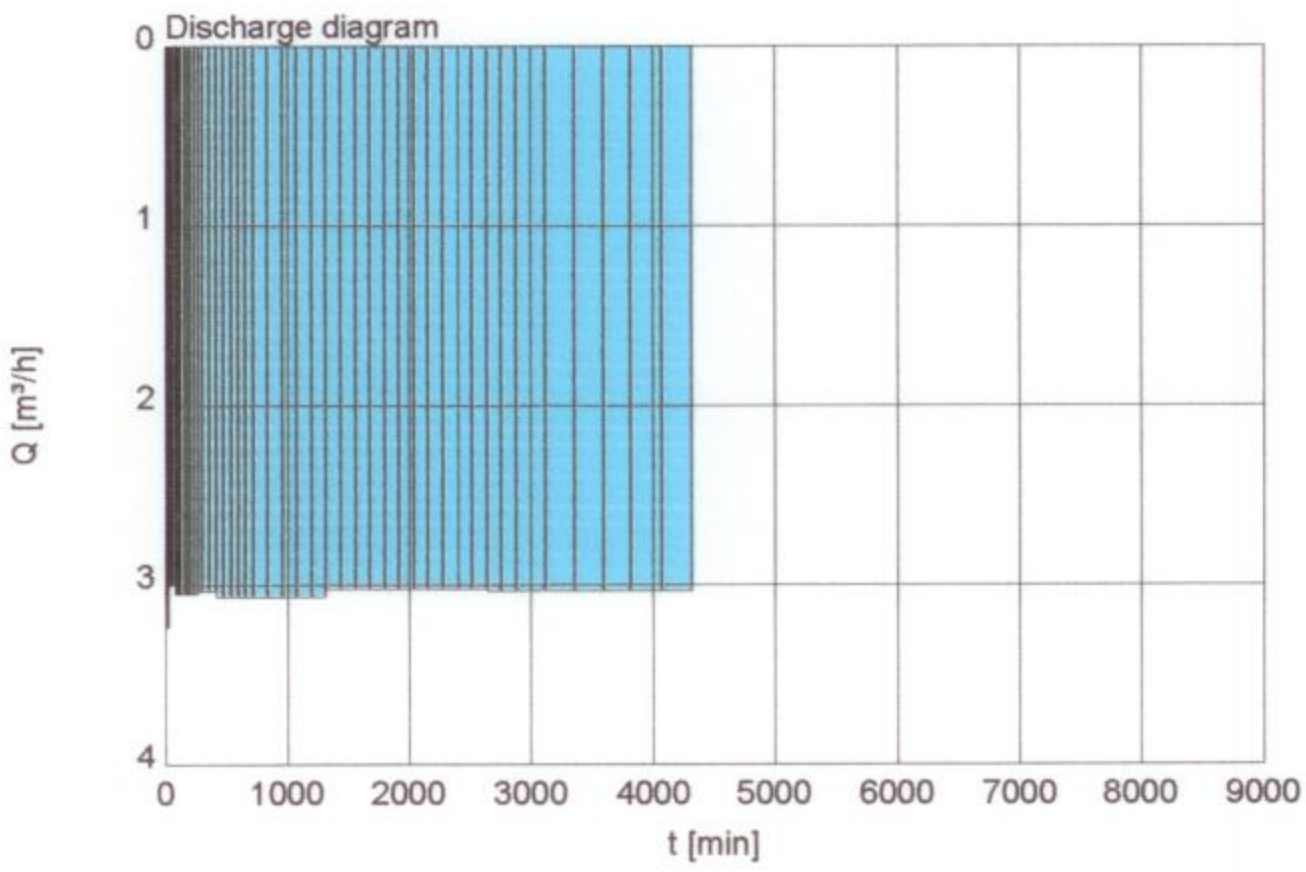
Test pumping diagnosis

Pumped well J6_K



Remarks

Simulation of the actual draw down during the constant discharge test using the Hantush model for leaky aquifers



Discharge info

Dis.dur.:4320 [min]
tcorr: 4327 [min]

Av.dis.: 3.05 [m³/h]
max.dis.:3.24 [m³/h]
min.dis.:3.01 [m³/h]
Qn: 3.04 [m³/h]

Dis.sum: 219 [m³]

Date 06/08/00 prepared by BIWAC

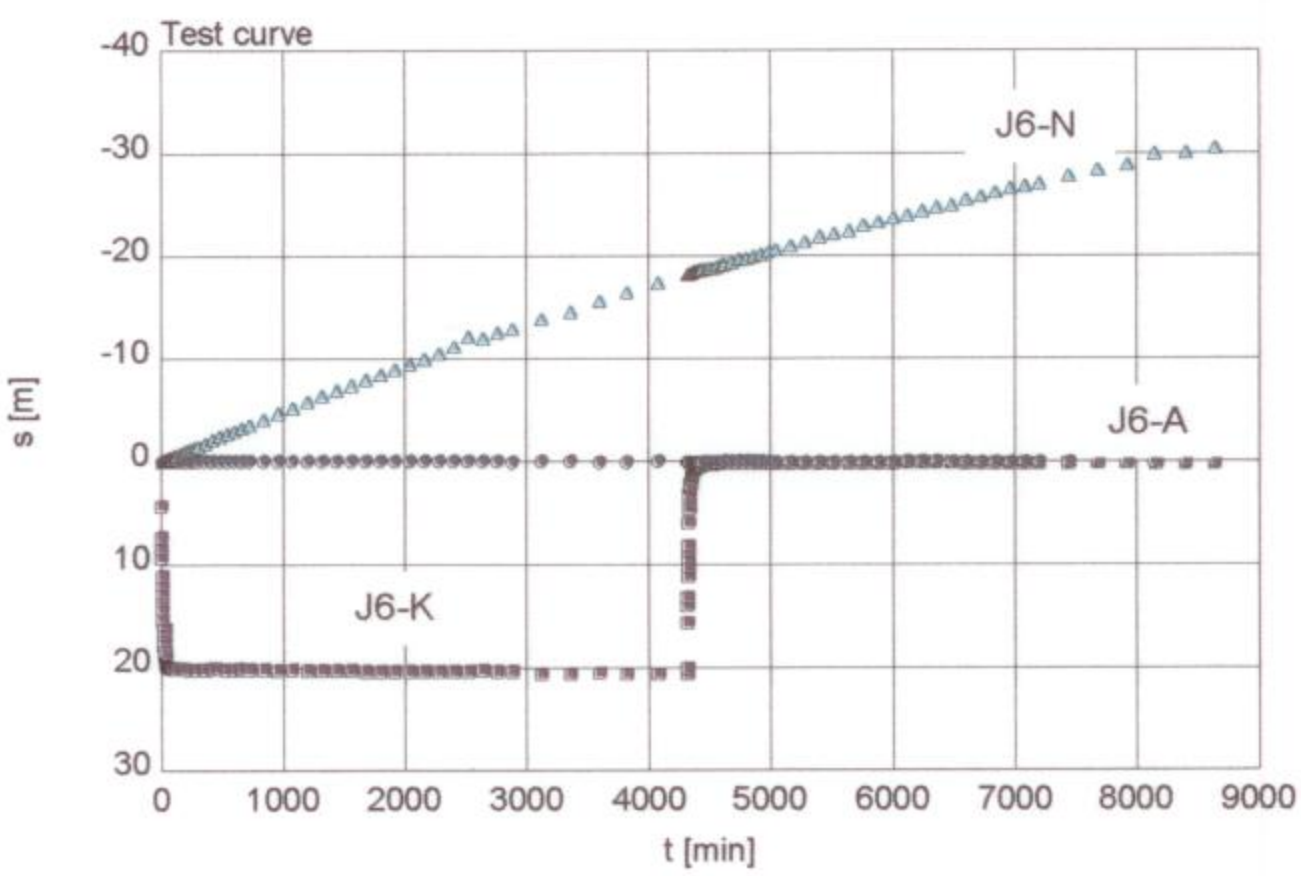
Annex 4

Groundwater Study in the Stampriet Artesian Basin

Evaluation of Test Pumping Data

Test pumping diagnosis

Pumped well J6_K

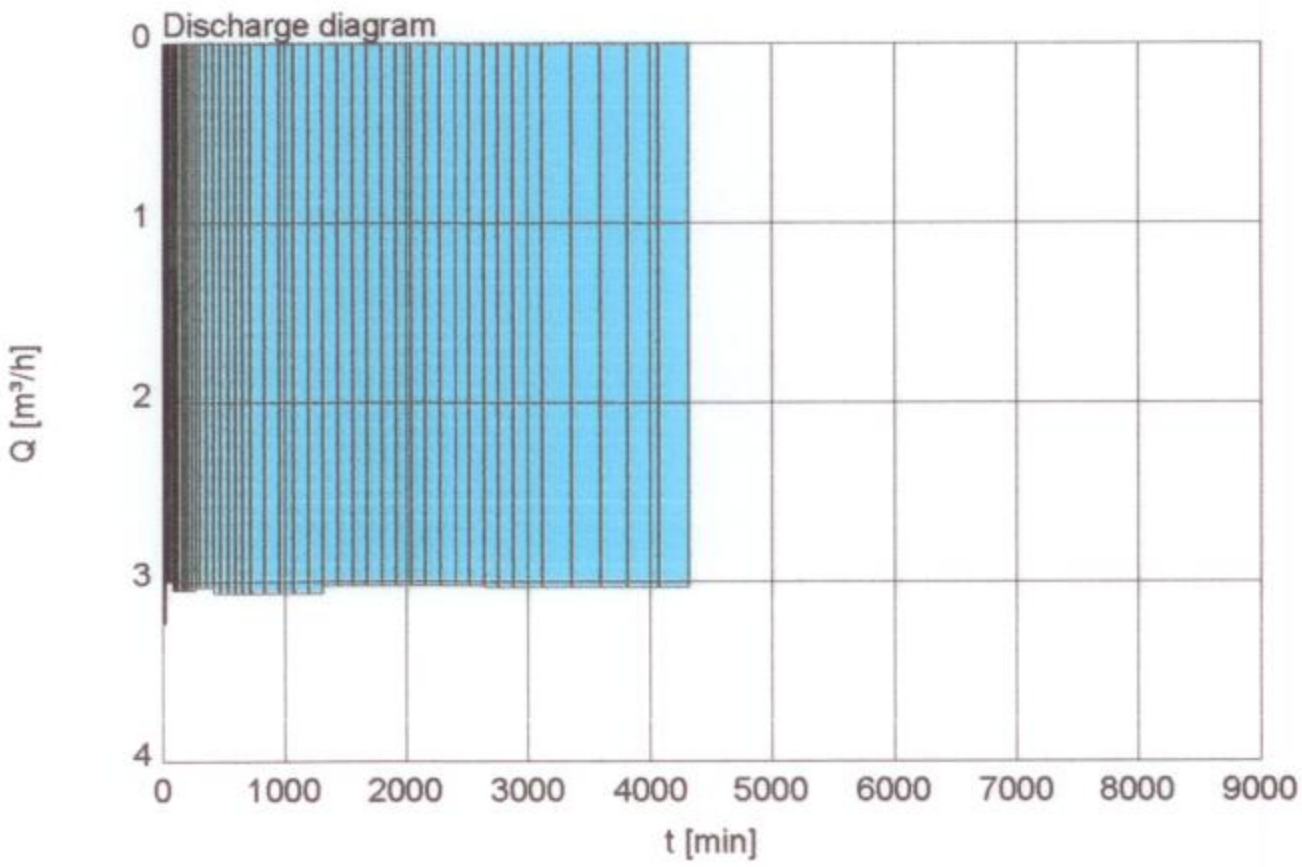


Remarks

Merged data from observation boreholes J6_A and J6_N and abstraction borehole J6_K

Both observation boreholes are not influenced by the pumping of J6_K

The water level of J6_N rises 30 m during the test



Discharge info

Dis.dur.:4320 [min]
tcorr: 4327 [min]

Av.dis.: 3.05 [m³/h]
max.dis.:3.24 [m³/h]
min.dis.:3.01 [m³/h]
Qn: 3.04 [m³/h]

Dis.sum: 219 [m³]

Distance of observation boreholes: J6-A = 63.5 m; J6-N = 58.5 m

Date 06/08/00 prepared by BIWAC

Annex 5

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 6 K LOCALITY: Cobra R 349

WW 39849

1. **Serial Number of floater**: 4540
2. **Date installed**: 20/09/00
3. **Rest Water Level when installed**: 103.50 mbsu
4. **Distance from stick-up to logger**: 99.0 m
5. **Distance from logger to water level**: 4.50 m
6. **Cut off**: 99.0 m (0.91 + 98.11)