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

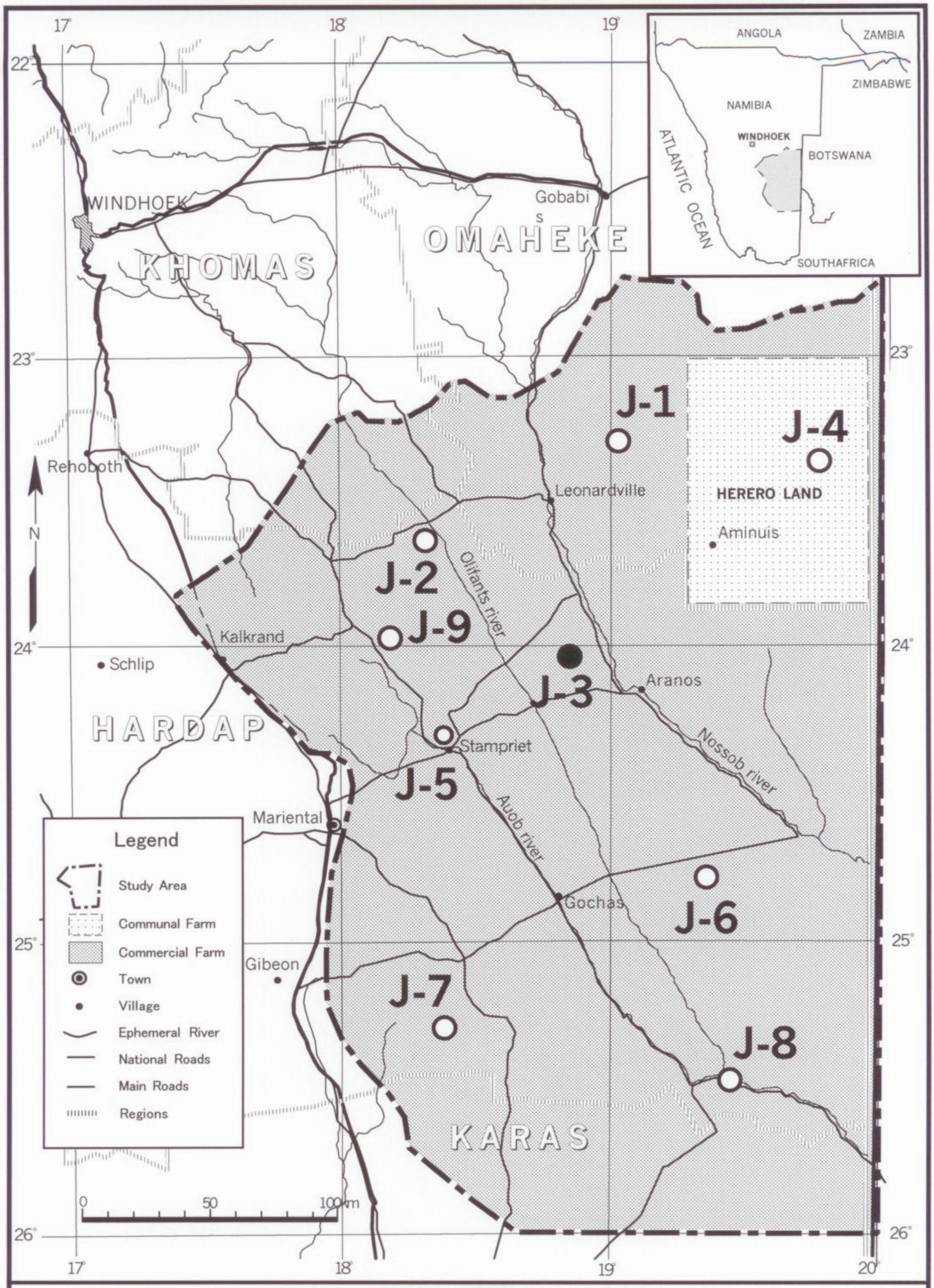
J3-K (WW 39842)

Choroaoheib R 300

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 Choroaoheib R 300 (Ptn Steynsrus) **WW 39842**
Jica Reference: J - 3 - K **S 24. 04592°**
Date completed: 8 June 2000 **E 18. 79340°**
Collar elev.: 1205 m

Depth below surface (m)	Section (m)	Lithology	Stratigraphy
0 - 5	5	Massive white sandy **calcrete**. Shallow cover of reddish brown medium to coarse sand.	
5 - 10	5	**Gravel**-bed : Coarsening downwards from slightly **calcareous** unsorted gravel to coarse, unsorted, partially calcretized pebbles up to 10 mm ∅.	
10 - 13	3	Sandy and gravelly **calcrete**.	
13 - 25	12	Poorly consolidated quartz **gravel**. With increasing depth gravel is progressively more cemented by a white calcrete	**KALAHARI**
25 - 28	3	Coarse **gravel** (quartz, rounded) in a yellowish orange clayey matrix.	
28 - 38	10	Pinkish white massive **calcrete**.	
38 - 43	5	Calcretized unsorted gravel bed: **conglomerate**.	
43 - 53	10	**Calcrete**, massive white to 49 m, then slightly clayey reddish brown to 53 m.	
53 - 58	5	Reddish brown calcareous, fine to coarse grained (unsorted) **sandstone**.	
58 - 64	6	Light reddish brown to (in places) light grey **sandstone**, calcareous and unsorted. Sample contaminated by washout from upper pebbly Kalahari beds.	**RIETMOND**
64 - 68	4	Fine to medium grained pale brownish **sandstone**, calcareous. Occasional larger pebbles embedded in sandstone.	
68 - 76	8	Slightly calcareous **gravel** in a fine grained **sandstone** matrix	
76 - 102 EOH	26	Fine to medium grained **sandstone**, calcareous. Colour light brownish, changing to light reddish-brown with depth. Intercalations of **shale**.	

Remarks:

1. The drilling method was mud-rotary, resulting in a highly ground mass of drill cuttings being retrieved.
2. The poorly consolidated upper Kalahari horizons through continuous collapse and wash out cause contamination of the samples collected from lower horizons. Description of samples should take this into account.
3. Hydrogeologically, in this case the Kalahari and Rietmond are considered to be one continuous unit.

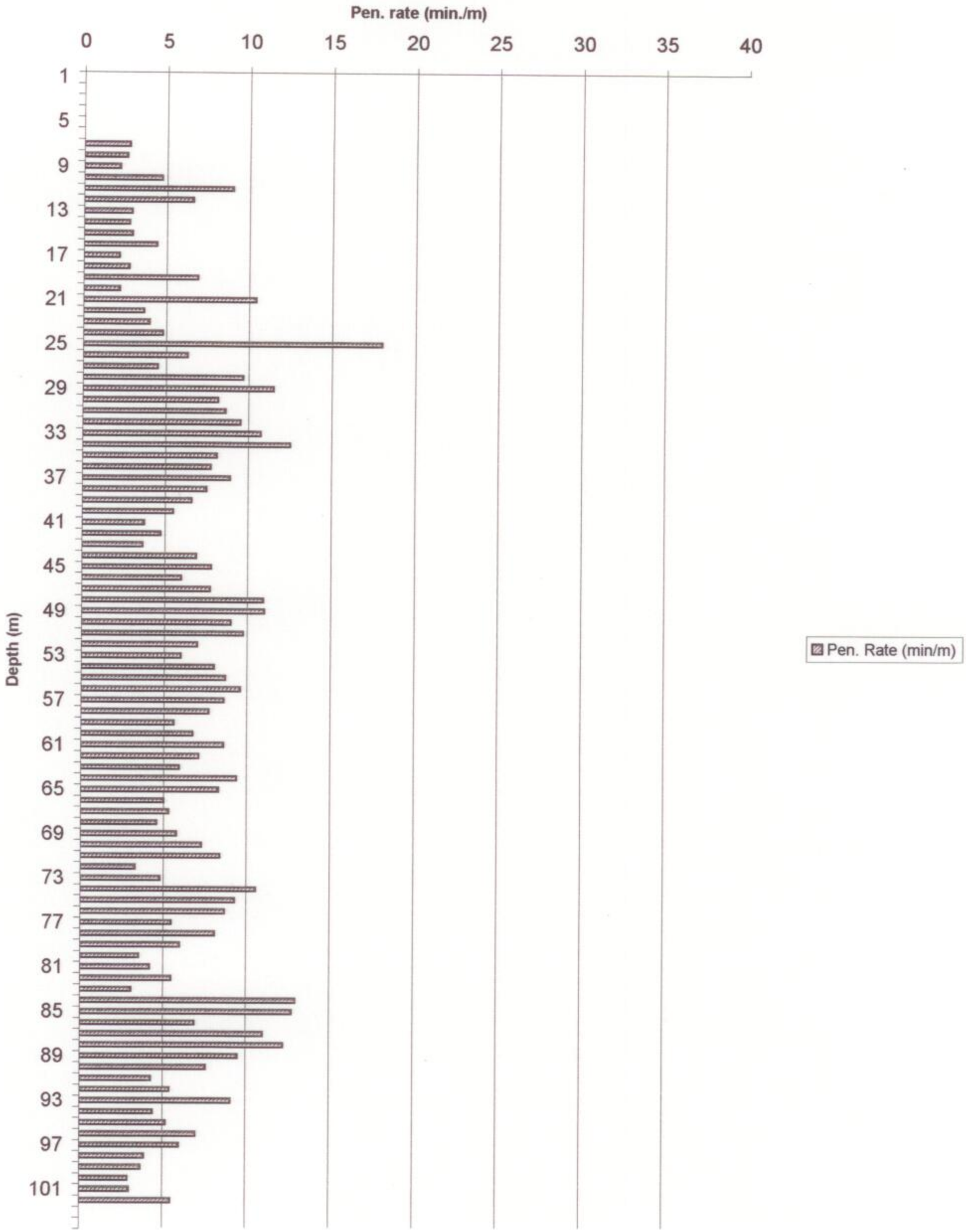
This borehole was logged by F. Bockmuhl.

2. Penetration Record

Penetration Record J 3 K	
Depth (m)	Pen. Rate (min/m)
5	
	2.75
	2.6
	2.2
10	4.7
	9
	6.6
	2.9
	2.75
15	2.95
	4.4
	2.15
	2.75
	6.9
20	2.2
	10.4
	3.65
	4
	4.8
25	18
	6.3
	4.5
	9.65
	11.5
30	8.15
	8.6
	9.5
	10.75
	12.5
35	8.1
	7.75
	8.9
	7.5
	6.6
40	5.5
	3.75
	4.75
	3.65
	6.9
45	7.8
	6
	7.75
	10.95
	11
50	9
	9.75

	7
	6
	8
55	8.7
	9.6
	8.6
	7.7
	5.6
60	6.75
	8.6
	7.1
	5.95
	9.4
65	8.3
	5
	5.3
	4.6
	5.8
70	7.3
	8.4
	3.3
	4.8
	10.55
75	9.3
	8.7
	5.5
	8.1
	6
80	3.55
	4.2
	5.5
	3.1
	12.95
85	12.75
	6.9
	11
	12.25
	9.5
90	7.6
	4.3
	5.4
	9.1
	4.4
95	5.2
	7
	6
	3.9
	3.7
100	2.9
	3
102	5.5

Pentration Record J 3 K



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 3 K **LOCALITY:** Choroaoheib **WW** 39842 **DATE:** 6 June 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
13:10	102	41 *29*	27	11.62 *11.2*		8 *8*	24.10 *22.4*	After trip at end of hole *Water from tanker*

GENEREAL REMARKS:

1. Only one measurement taken.
2. This borehole was drilled to a depth of 102 m at 12 ¼" ϕ.
3. Geophysical logging was done inone step.
4. To obtain the electrical resistivity of the samples expressed 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..J3K WW 39842
PROJ.
LCN. Choroaoheib
STE. J3
FILING No. J3K

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 J3K WW39842

LOCATION CHOROAOHEIB

COUNTRY REPUBLIC OF NAMIBIA

BH COORDINATES S 24.04592
E 18.79346

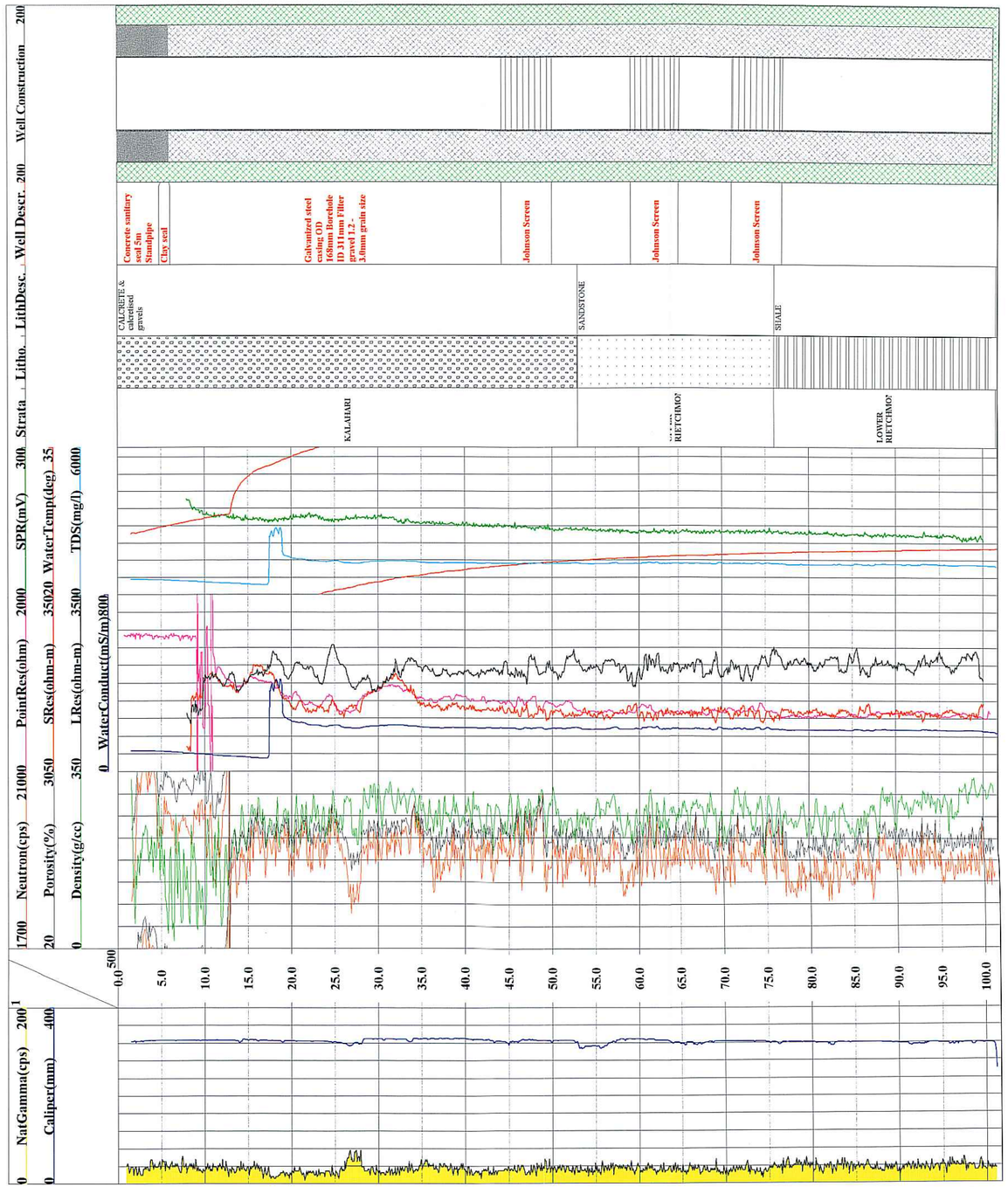
COLLAR ELEVATION 1205m

LOG MEAS. FROM Groundlevel

DRILLING MEAS. FROM Groundlevel

DATE	07 June 2000
TYPE LOG	Physical Properties
DEPTH-DRILLER	101m
DEPTH-LOGGER	101.20m
BTM LOGGED INTERVAL	101.20m
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 3 K LOCALITY: Choroaoheib R 300 WW 39842 DATE: 18/06/2000 (starting)

TIME (actual)	P.I.D. (mbsu)	½ 90° V-Notch (mm)	Yield (m^3/h)	Water Level (mbsu)	Remarks
6:00	~49	60	2.16	19.85	Date 18/06/00. Continue until 14:30
7:00	~69	77	4.25	22.35	Date 19/06/00. Continue until 12:00
16:00	~80	55	1.75	33.20	
17:00		60	2.16	30.27	
20:00		60		30.26	
07:00		60		32.42	Date 20/06/00.
08:00		65	2.5	30.37	
09:00		60	2.16	33.82	
10:00		60		33.82	
11:00		60		32.90	
14:00		65 to 80			Varying airflow in order to surge borehole.
15:00		55	1.75	28.45	
16:00		50	1.44	30.13	Continue through the night.
07:00	~80	55	1.75	21.00	Waterlevel has recovered at the low yield. Date 21/06/00. Stop airlift test.

Remarks:

1. This borehole was also developed by cable tool. This was done primarily in order to settle and developed the gravel pack emplaced around the casing and screens.
2. Dates and times of the cable tool development are as follows:

Date	Hours	Work done
10/06/2000	11	Surge and plunge borehole. Add gravel as plunging results in settling of gravel.
11/06/2000	10.5	Bailing. Remove drilling mud and fine fraction of gravel accumulated in sump.
12/06/2000	10	Bailing and plunging.
13/06/2000	9	Plunging and bailing.
14/06/2000	1	Bailing to clean sand trap (= sump)

3. The total time for development by cable tool is 41,5 hours.
4. Finally this borehole was also developed by electrical submersible pump on 25/06/2000.

Time (actual)	Pump time (min)	Water Level (mbsu)	Yield (m^3/h)	E.C. (mS/m)	Remarks
12:45	0	19.89			Rest water Level
12:46	1	24.74			
	2	25.65	1.6	324	
	3	26.30			
	4	26.89			
	5	27.35			
	6	27.77			
	7	28.18			
	8	28.47			
	9	28.71			
	10	29.00			
	12	29.29			
	14	29.60			
	16	29.78			
	18	29.92			
	20	30.00			

Time (actual)	Pump time (min)	Water Level (mbsu)	Yield (m^3/h)	E.C. (mS/m)	Remarks
	23	30.11			
	26	30.18			
	30	30.22			
	35	30.28			
	40	30.34			
	45	30.40			
	50	30.41			
	55	30.41			
	60	30.42			
13:55	70	30.48			
	71	30.57			
	72	30.62			
	73	30.80			
	74	30.89			
	75	30.98	2		
	76	32.10			
	77	33.53			
	78	34.35			
	79	35.15			
	80	35.32			
	82	35.27			
	84	35.37			
	86	35.52			
	88	35.70			
	90	35.91			
	93	36.15			
	96	36.41			

Time (actual)	Pump time (min)	Water Level (mbsu)	Yield (m^3/h)	E.C. (mS/m)	Remarks
	100	36.73			
	105	37.24			
	110	37.50			
	115	37.70			
	120	37.91			
	125	37.99			
	130	38.01			
14:56	131	38.90			
	132	41.17	3.8		
	133	42.48			
	134	43.65			
	135	44.65			
	136	45.70			
	137	45.80			
	138	48.15			
	139	49.90			
	140	53.40			
	142	55.80			
	144	58.35			
	146	61.09			
15:14	148	63.21			Stop. Water level close to PID

6. Evaluation of Pumping Test

1. PUMPING TEST ANALYSIS

J3-K (WW39842) - Pumping well

J3-A (WW39843) - 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. The correlation between the pumping rates and draw down is however poor during simulation of the actual data and the correctness thereof is questioned. Only three of the four step could be evaluated, as step four was influenced by negative boundary conditions.

Table 1: J3-K; Borehole efficiency at various pumping rates

Borehole number	Step	Abstraction Rate [m^3/h]	Draw Down* [m]	Borehole Efficiency [%]
J3-K	1	0.98	5.99	78.7
	2	1.47	8.42	74.9
	3	1.96	13.1	71.6

* at cut-off 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 **J3-K** indicates leaky conditions. For leaky aquifers, the Walton Hantush analysis method with draw down and recovery data was used to calculate the hydraulic conductivity of the aquifer and the aquitard **(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)

Aquifer storativity was estimated due to the fact that observation borehole **J3-A** is located in the Auob sandstone aquifer and not in the pumped Kalahari and "Rietmond" aquifers. During the duration of the constant discharge test, a rise in the water level of observation borehole **J3-A** is observed, which indicates that the Auob sandstone aquifer was not influenced by abstraction 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 J3-K; Kalahari

Borehole number	Analysis Method	T	s	k	S	Simulation model	Comments
		[m^2/day]	[m]	[cm/sec]	[-]		
J3-K	Walton-Hantush - draw down	6,42	50	$1,5 \times 10^{-4}$	$*1 \times 10^{-6}$	Hantush	*Storativity estimated - Observation borehole not located in the tested aquifer
	Walton-Hantush - recovery	6.88	50	$1,6 \times 10^{-4}$	$*1 \times 10^{-6}$		

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 **J3-K** and observation borehole **J3-A** and it is clear that pumping from the Kalahari aquifer did not have any influence on the Auob sandstone aquifer.

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

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

$R = 3000 \times 11.3 \times 1.26 \times 10^{-3} = \underline{42\ m}$

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 42 m are considered to be the minimum value.

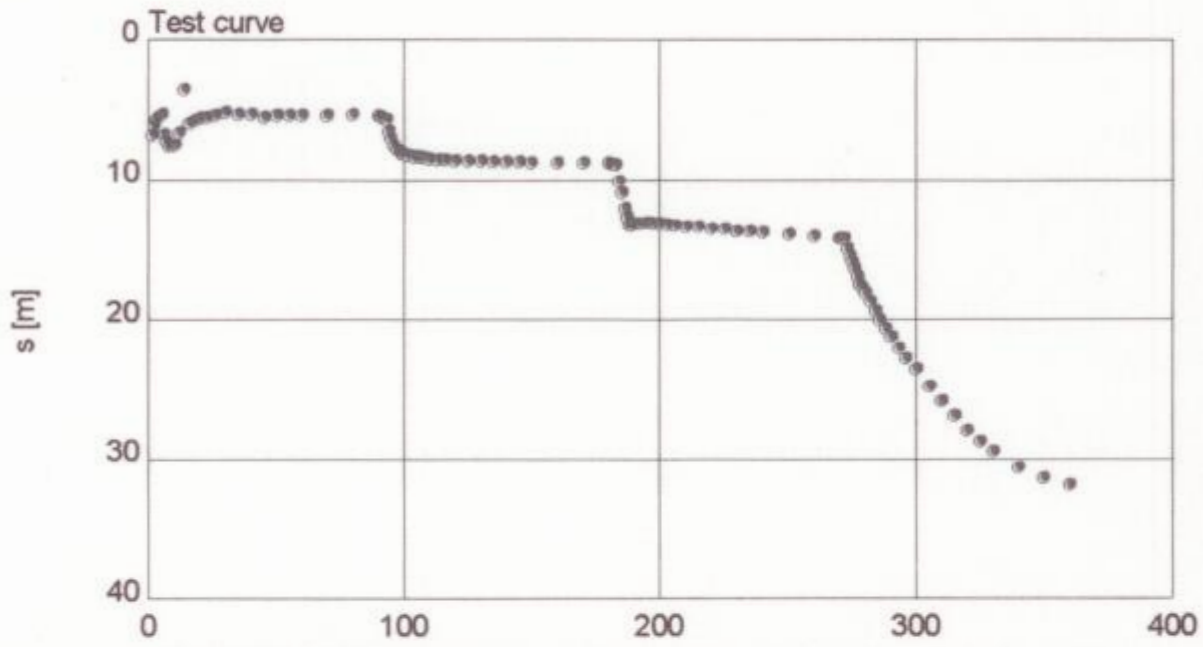
A proper evaluation of R (and storativity S) will only be possible once reliable data from observation wells, penetrating the same aquifer as the pumped well, are available.

Groundwater Study in the Stampriet Artesian Basin

Evaluation of Test Pumping Data

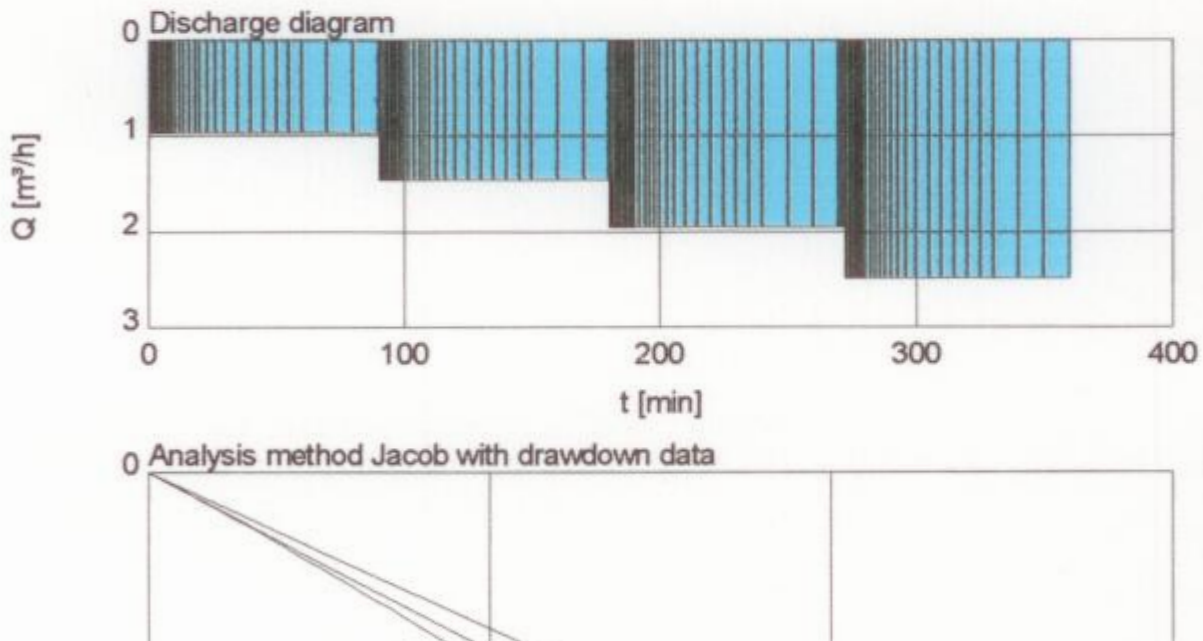
Step test analysis

Pumped well J3-K



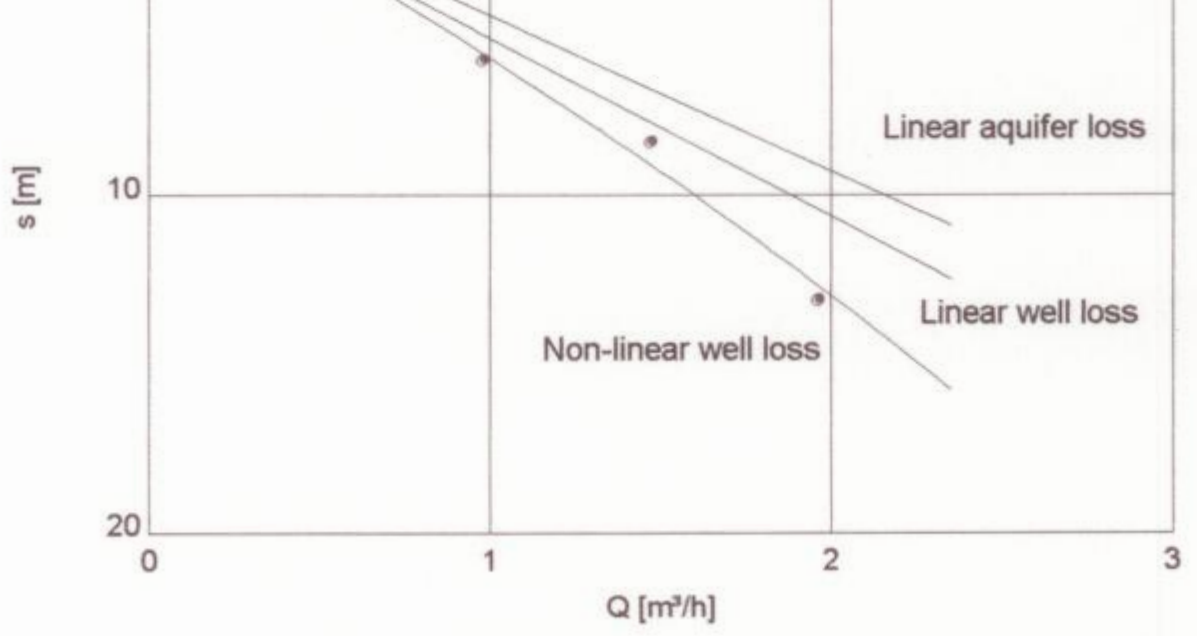
Borehole, well & aquifer

Drilled:	
Latitude:	
Longitude:	
Elevation:	1100 [m]
Depth:	
Stick up:	0.00 [m]
Bh. radius:	0.1 [m]
Casing radius:	0.75 [m]
RWL:	19.96 [m]
max.drawdown:	31.86 [m]
Aq.type:	confined
Aq.thickness:	50.00 [m]
Stratigraphy:	Kalahari
Lithology:	



Test running

Start:	10/07/2000 19:31:45
Dis.dur.:	360 [min]
Av.dis.:	1.72 [m³/h]
Max.dis.:	2.49 [m³/h]
Min.dis.:	0.98 [m³/h]
Total dis.:	10.3 [m³]
Crew:	Metzger_PM
Supervisior:	PCI



Results

Well performance:

s: (B1+B2)*Q+C*Q²

Linear aquifer loss B1:	4.31
Linear well loss B2:	0.99
Non-linear well loss C:	0.59

	Q [m³/h]	s [m]	Eff [%]
Step 1:	0.98	5.99	78.6
Step 2:	1.47	8.42	74.9
Step 3:	1.96	13.1	71.5

Linear skin factor:	1.82 [-]
Non-linear skin factor:	26.1 [d/m³]
Effective well radius:	1.9E-3 [m]

Date 02/10/00 prepared by BIWAC

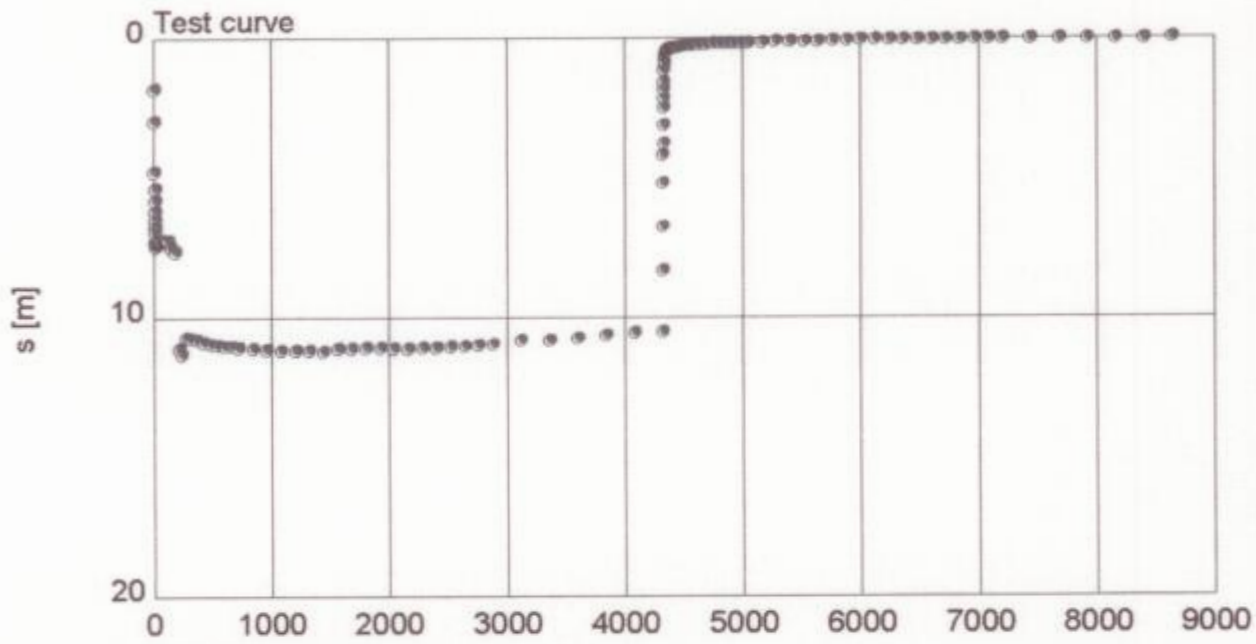
Annex 1

Groundwater Study in the Stampriet Artesian Basin

Evaluation of Test Pumping Data

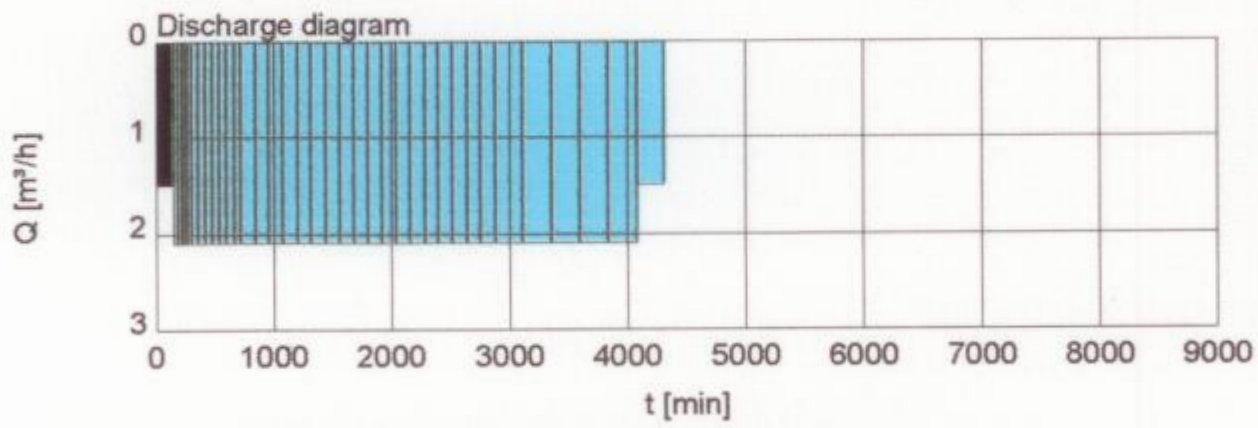
Test pumping analysis

Pumped well J3-K



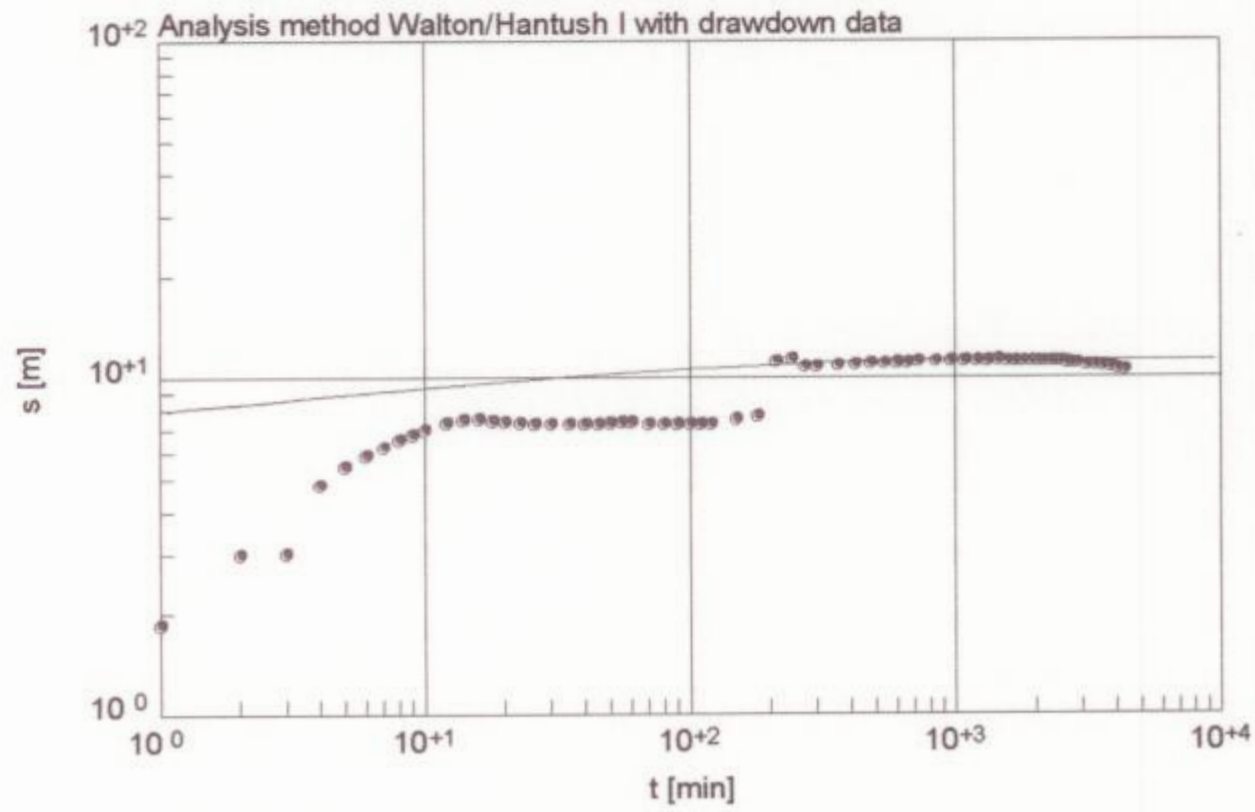
Borehole, well & aquifer

Drilled:	
Latitude:	
Longitude:	
Elevation:	1100 [m]
Depth:	
Stick up:	0.00 [m]
Bh. radius:	0.1 [m]
Casing radius:	0.75 [m]
RWL:	19.96 [m]
max.drawdown:	11.33 [m]
Aq.type:	confined
Aq.thickness:	50.00 [m]
Stratigraphy:	Kalahari
Lithology:	



Test running

Start:	10/07/2000 19:38:15
Dis.dur.:	4320 [min]
Av.dis.:	2.05 [m³/h]
Max.dis.:	2.1 [m³/h]
Min.dis.:	1.5 [m³/h]
Total dis.:	147 [m³]
Crew:	Metzger_PM
Supervisior:	PCI



Results

Match parameter:	
Q:	2.05 [m³/h]
t:	2.57E3 [min]
s:	5.62 [m]
1/u:	2.16E9 [-]
W(u,r/B):	9.24 [-]
Aquifer parameter:	
T:	6.42 [m²/d]
k:	0.128 [m/d]
Boundary parameter:	
B:	1E3 [m]
m´:	50 [m]
k´:	0.000321 [m/d]

Date 02/10/00 prepared by BIWAC

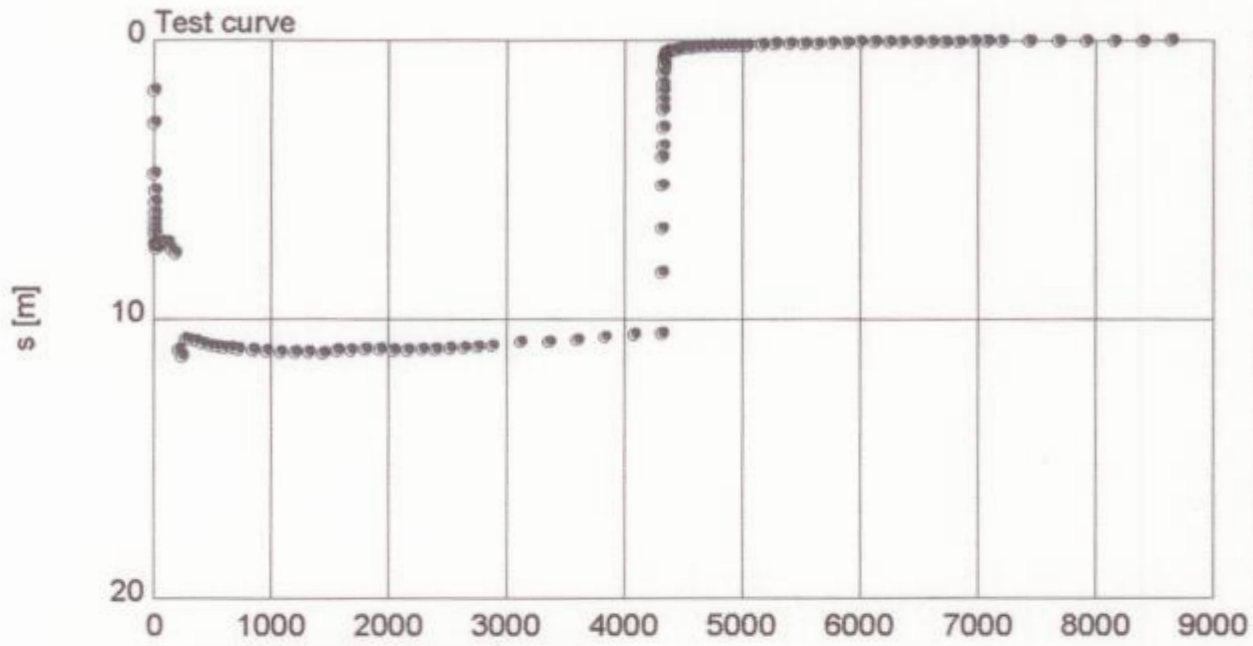
Annex 2

Groundwater Study in the Stampriet Artesian Basin

Evaluation of Test Pumping Data

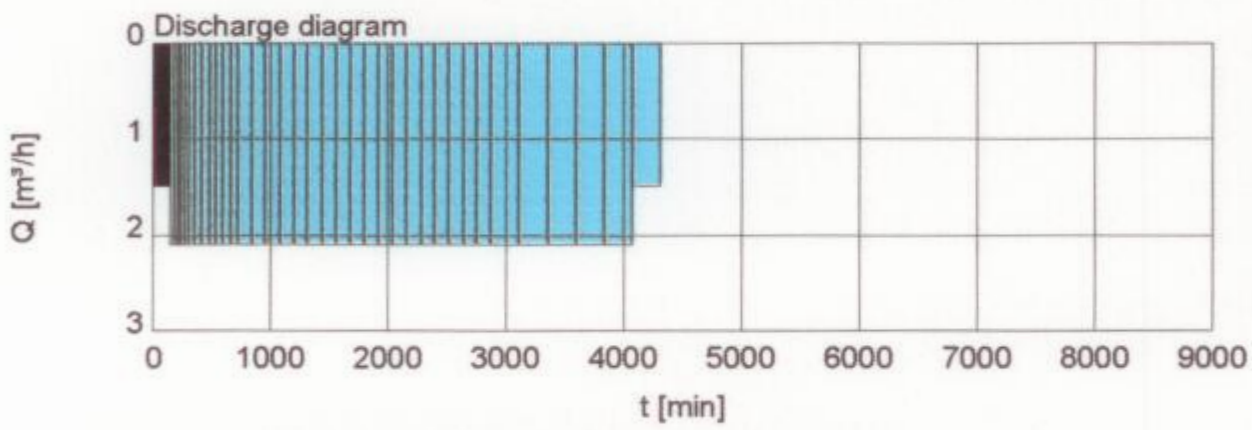
Test pumping analysis

Pumped well J3-K



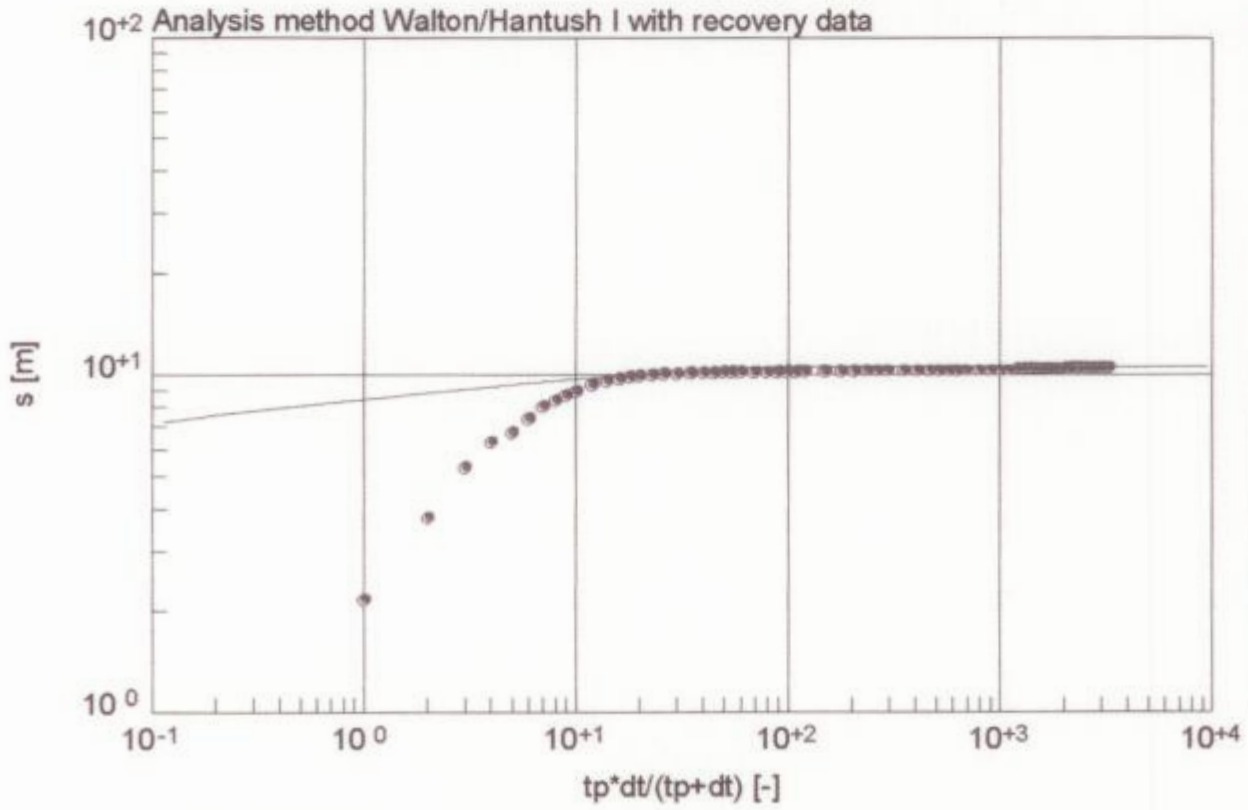
Borehole, well & aquifer

Drilled:	
Latitude:	
Longitude:	
Elevation:	1100 [m]
Depth:	
Stick up:	0.00 [m]
Bh. radius:	0.1 [m]
Casing radius:	0.75 [m]
RWL:	19.96 [m]
max.drawdown:	11.33 [m]
Aq.type:	confined
Aq.thickness:	50.00 [m]
Stratigraphy:	Kalahari
Lithology:	



Test running

Start:	10/07/2000 19:38:15
Dis.dur.:	4320 [min]
Av.dis.:	2.05 [m³/h]
Max.dis.:	2.1 [m³/h]
Min.dis.:	1.5 [m³/h]
Total dis.:	147 [m³]
Crew:	Metzger_PM
Supervisior:	PCI



Results

Match parameter:	
Q:	2.05 [m³/h]
t:	444 [min]
s:	4.85 [m]
1/u:	2.38E9 [-]
W(u,r/B):	8.54 [-]
Aquifer parameter:	
T:	6.88 [m²/d]
k:	0.138 [m/d]
Boundary parameter:	
B:	1E3 [m]
m´:	50 [m]
k´:	0.000344 [m/d]

Date 02/10/00 prepared by BIWAC

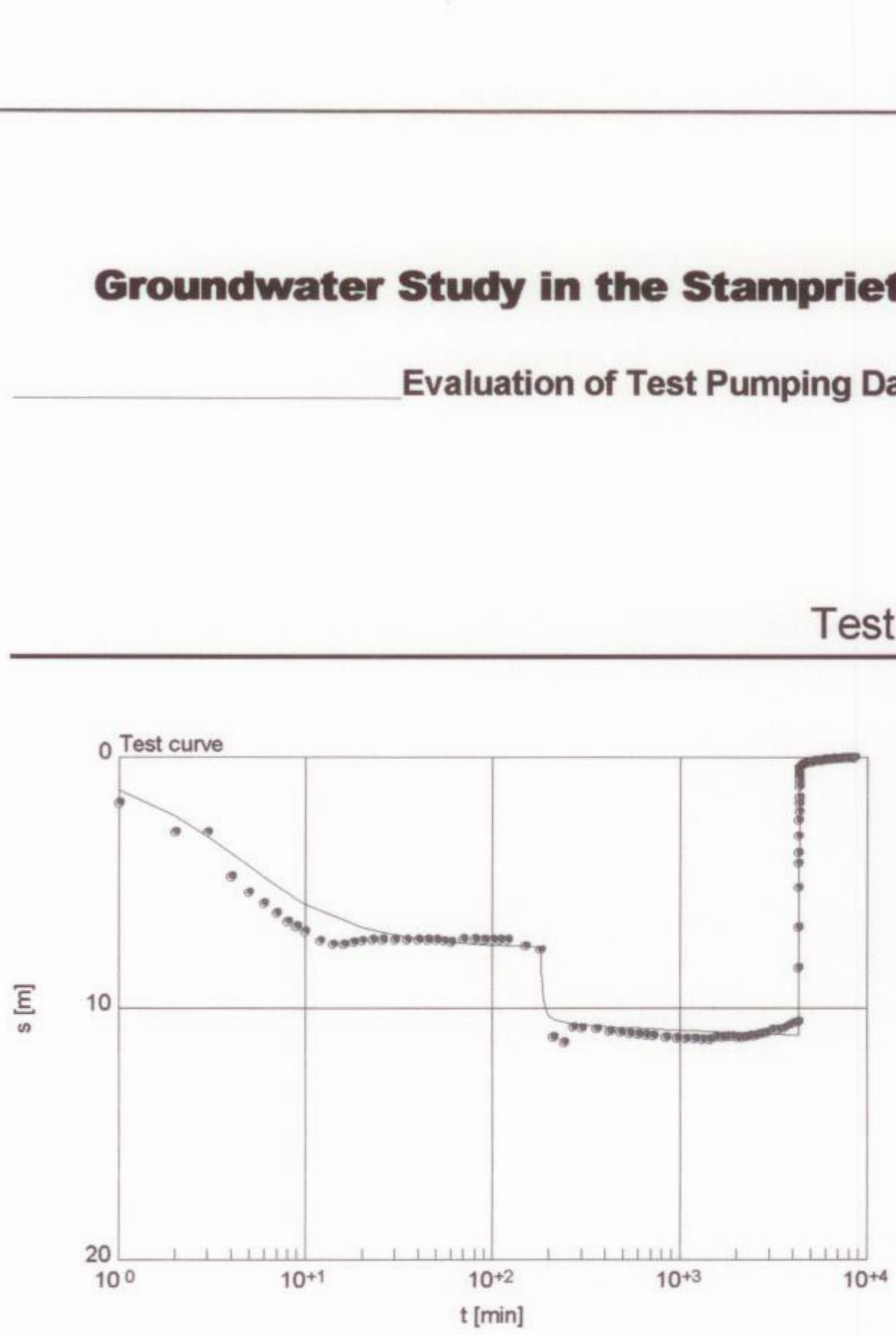
Annex 3

Groundwater Study in the Stampriet Artesian Basin

Evaluation of Test Pumping Data

Test pumping diagnosis

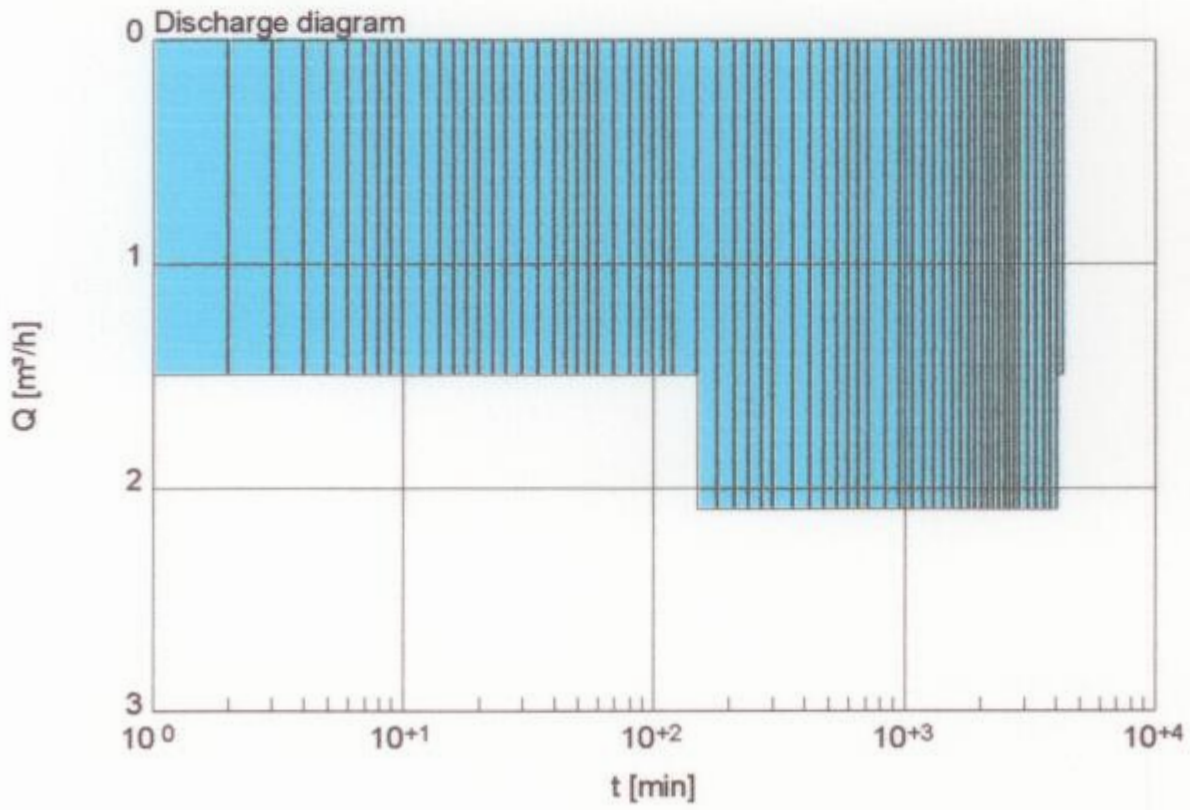
Pumped well J3-K



Remarks

Hantush model for leaky leaky aquifers used to the simulate the actual data.

Initial well loss due to well bore storage is in the order of 2,4 m.



Discharge info

Dis.dur.:4320 [min]
tcorr: 13533 [min]

Av.dis.: 2.05 [m³/h]
max.dis.:2.10 [m³/h]
min.dis.:1.50 [m³/h]
Qn: 1.50 [m³/h]

Dis.sum: 147 [m³]

Date 02/10/00 prepared by BIWAC

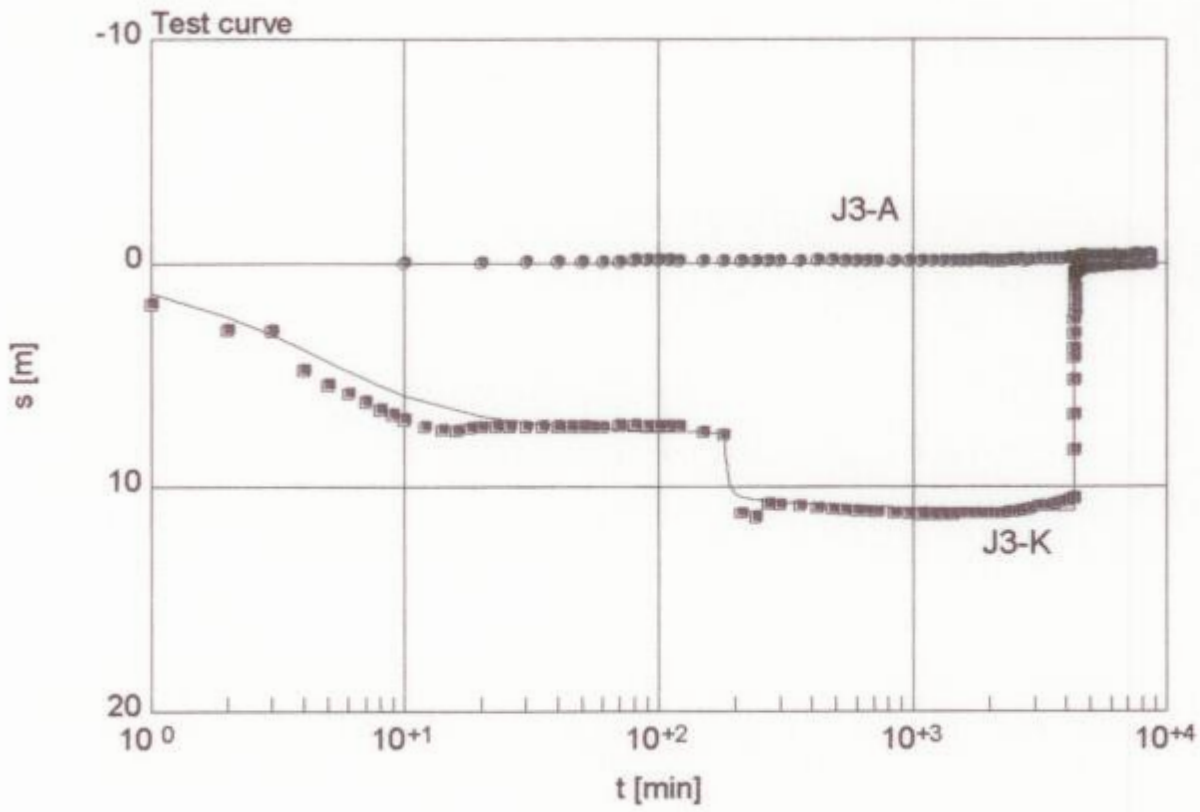
Annex 4

Groundwater Study in the Stampriet Artesian Basin

Evaluation of Test Pumping Data

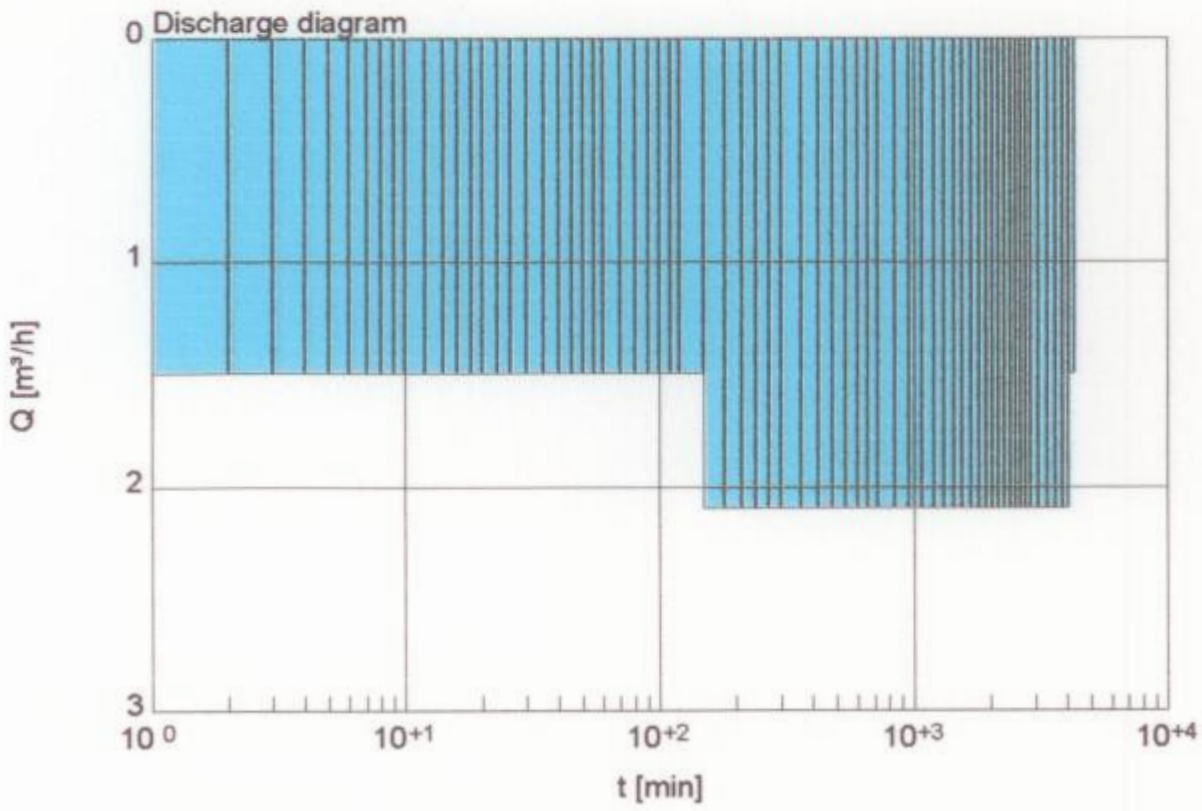
Test pumping diagnosis

Pumped well J3-K



Remarks

Merged data from observation borehole J3-A and abstraction borehole J3-K



Discharge info

Dis.dur.:4320 [min]
tcorr: 13533 [min]

Av.dis.: 2.05 [m³/h]
max.dis.:2.10 [m³/h]
min.dis.:1.50 [m³/h]
Qn: 1.50 [m³/h]

Dis.sum: 147 [m³]

Distance to observation borehole: J3-A = 216 m

Date 02/10/00 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 3 K LOCALITY: Choroaoheib R 300

WW 39842

1. **Serial Number of floater**: 4554
2. **Date installed**: 6/09/00
3. **Rest Water Level when installed**: 20.53 mbsu
4. **Distance from stick-up to logger**: 11.0
5. **Distance from logger to water level**: 9.53
6. **Cut off**: 11.0 (0.91 + 10.11)