CHAPTER 11 GROUNDWATER POTENTIAL EVALUATION

11.1 Introduction

The groundwater potential of three aquifers, namely, the Kalahari, Auob and Nossob Aquifer is evaluated in this chapter using hydrogeological indices.

11.2 Storage of Groundwater

11.2.1 Volume of Aquifer

The volume of each aquifer was calculated using the maps of geological isopachs described in Chapter 8.

1) Kalahari Aquifer

The area, thickness and volume of the Kalahari Aquifer in the study area are shown in Table 11.2-1. It can be seen that more than 60% of the total area of Kalahari Aquifer has the thickness between zero and 100m. The table also shows that the total volume of the Kalahari Aquifer is around $4.75 \times 10^{12} m^3$.

Table 11.2-1 Volume of Kalahari Aquifer

Thickness (m)	**Area (m^2)**	**Area/total area (%)**	**Volume (m^3)**
0-50	1.86E+10	35.5%	4.66E+11
50-100	1.37E+10	26.0%	1.03E+12
100-150	9.89E+09	18.8%	1.24E+12
150-200	6.33E+09	12.0%	1.11E+12
200-250	3.79E+09	7.2%	8.53E+11
>250	2.27E+08	0.4%	5.67E+10
Total	**5.26E+10**		**4.75E+12**

However, this total volume is not equal to the total saturated volume of the aquifer since the Kalahari aquifer is an unconfined aquifer. The volume of Kalahari Aquifer above the water level therefore was calculated to estimate the saturated volume of the Kalahari Aquifer.

Table 11.2-2 Volume of Kalahari Aquifer above Water Level

Thickness (m)	**Area (m^2)**	**Volume (m^3)**
0-25	1.46E+10	1.82E+11
25-50	1.77E+10	6.65E+11
50-75	1.10E+10	6.88E+11
75-100	8.37E+09	7.32E+11
100-125	8.59E+08	9.67E+10
Total	**5.26E+10**	**2.36E+12**

Table 11.2-2 shows that the total volume above water level is $2.36x10^{12}m^3$. Thus, the total saturated volume of Kalahari Aquifer becomes $2.39x10^{12}m^3$. The result also shows that nearly 50% of the total volume of the Kalahari Aquifer is unsaturated.

2) Auob Aquifer

Table 11.2-3 shows the result of the volume calculation of the Auob aquifer.

Table 11.2-3 Volume of Auob Aquifer

Thickness (m)	**Area (m^2)**	**Area/total area (%)**	**Volume (m^3)**
0-25	5.77E+09	11.4%	7.21E+10
25-50	8.72E+09	17.2%	3.27E+11
50-75	1.09E+10	21.5%	6.82E+11
75-100	1.14E+10	22.5%	9.97E+11
100-150	4.93E+09	9.7%	6.16E+11
150-200	7.40E+07	0.1%	1.30E+10
50-150	8.92E+09	17.6%	8.92E+11
Total	**5.07E+10**		**3.60E+12**

The table indicates that the total volume of the Auob Aquifer is $3.60x10^{12}m^3$.

3) Nossob Aquifer

The result of the Nossob Aquifer's volume calculation is shown in Table 11.2-4.

Table 11.2-4 Volume of Nossob Aquifer

Thickness (m)	**Area (m^2)**	**Area/total area (%)**	**Volume (m^3)**
0-10	4.93E+09	9.8%	2.47E+10
10-20	5.88E+09	11.6%	8.82E+10
20-30	3.85E+10	76.1%	9.62E+11
30-40	8.18E+08	1.6%	2.86E+10
40-50	3.78E+08	0.7%	1.70E+10
50-60	8.21E+07	0.2%	4.52E+09
Total	**5.06E+10**		**1.13E+12**

It can be seen from the table that the total volume of the Nossob Aquifer is $1.13x10^{12}m^3$. It is noted that nearly 75% of the total Nossob Aquifer area is the area where the thickness is between 20 and 30m.

11.2.2 Aquifer Characteristic

Table 11.3-1 shows the porosity of each aquifer. The values of the porosity were calculated using the result of the neutron borehole logging and the lab experiment of core samples. The neutron logging was carried out using the JICA test boreholes in this study. Porosity data on the lab experiment was taken from the report (Vogel, J.C., Talma, A.S. and Heaton, T.H.E. 1982. The Age and Isotopic composition of Groundwater in the Stampriet Artesian Basin, SWA. Final report to the Steering Committee for Water Research in SWA).

Table 11.2-5 Porosity of Aquifer

Aquifer	Porosity	
	Neutron log	Core sample
Kalahari	27%	28%
Auob	25%	23%
Nossob	25%	26%

The value of porosity obtained from neutron log ranges from 25 to 27%, whereas the values from core sample has the wide range from 23 to 28%. This may indicate that porosity values estimated from core samples are site-specific values and does not represent the aquifer itself. As a whole, the porosity of each aquifer is almost same value as approximately 25%.

11.2.3 Aquifer Storage

An effective porosity is necessary to estimate the amount of groundwater, which means available void space of each aquifer for water use. This value was estimated as 5 %. Their effective porosities of aquifers are regarded as the same since their porosities are same each other. Estimated groundwater storage of the aquifers was summarised in Table 11.2-6.

Table 11.2-6 Groundwater Quantities within the Aquifers

	Volume of Aquifer (m^3)	Effective Porosity	The amount of groundwater within the aquifer (m^3)
Kalahari	2.39E+12	5%	1.20E+11
Auob	3.60E+12	5%	1.80E+11
Nossob	1.13E+12	5%	0.57E+11

The table indicates that the Auob aquifer contains more groundwater than the Kalahari and the Nossob Aquifer. The amount of groundwater within the Auob aquifer is three times larger than that within the Nossob aquifer. It might be concluded that the Auob Aquifer is a better aquifer than the other aquifers in the study area in terms of the Nossob groundwater storage. These groundwater storages are huge volumes, however, it should be considered that very little of groundwater within the aquifers is virtually available for the extraction because of technical and economical reasons. Consequently, it is necessary to consider other indices instead of aquifer storage to evaluate the groundwater potential of the aquifers.

11.3 Groundwater Potential Evaluation

Four indices, water depth, water quality, depth of aquifer and specific yield were selected for this purpose as shown in Table 11.3-1. There are many manners to evaluate each item, however, the following way was adopted in this study.

The evaluation point is given to the maximum as 100 points and minimum as 0 point in each index and it distributes equally between them. For example, water depth of Aquifer varies G.L-172.3m to G.L.+23.9m (Artesian). The former is given 0 point as the minimum evaluation and the latter is given 100 points as the maximum evaluation. Total evaluation point (TP) is summed them up. Therefore the maximum total evaluation is given 400 points. The point in each index is calculated with a simple linear function as follows.

Table 11.3-1 Index for Evaluation of Aquifers

Items / Index		Maximum Evaluation		Minimum Evaluation		Related Factors
		Maximum Value (100 Point)	Aquifer	Minimum value (0 Point)	Aquifer	
I	Water Depth (B.G.L m)	-23.9	Nossob	172.37	Kalahari	Withdrawal cost, Operation cost
II	Water Quality (TDS mg/l)	354.6	Auob	39,428	Nossob	Human health, Productivity or quality of crops and stocks
III	Depth of Aquifer (B.G.L. m)	0	Kalahari	440	Nossob	Initial cost (Drilling cost)
IV	Specific Yield (m^3/hr/m)	15.92	Auob	0.0008	Nossob	Capacity of aquifer

I ,II, III: $$y = \frac{(x - Mm) \times 100}{Mx - Mm}$$

IV: $$y = \frac{100}{Mx - Mm} \times (x - Mm)$$

$$TP = \sum_{n=I}^{VI} y_n$$

Mx : Maximum Value
Mm : Minimum Value
y : Evaluation Value
x : Data Value
TP : Total Evaluation Point
n : Index No.

Since the statistical weight among indices is changeable for any purposes, they were treated evenhandedly in this study.

11.3.1 Groundwater Depth

The required capacity of the pump for withdrawal depends on the depth of the groundwater table from the ground surface in case of the same withdrawal volume. The depth of groundwater is also closely related to withdrawal cost, namely, operation cost of production wells. The groundwater depth of each aquifer is illustrated in Fig. 11.3-1 to 11.3-3.

1) Kalahari Aquifer

Groundwater depth becomes deeper to the east side of the study area. In particular, the southeastern area around J-6, which is located in the Pre-Kalahari Valley, is the deepest place and its depth reaches to 100m more. (Fig. 11.3-1)

2) Auob Aquifer

A distribution of water depth is generally similar to that of the Kalahari Aquifer. The area whose water depth is more than 100m extends around J-6 and J-8 in the southeastern area of the basin. On the other hand, it becomes shallower in the western area of the basin around Stampriet and the artesian wells are located in the area. Though many artesian wells or springs are located along the Auob and Nossob River, they are not presented in Fig.11.3-2 except for the center of Stampriet because no data of piezometric head is available. Therefore, Stampriet is presented as a small red colored area in the figure.

3) Nossob Aquifer

Sufficient data is not available on this aquifer because of its characteristics. Therefore, it restricts the accuracy of the analysis. The Nossob Aquifer has a high piezometric

head in other words high pressure. Four areas in red around J-3, J-5, J-6 and Gochas respectively are noticed in Fig.11.3-3. If the data on this aquifer is increased, they will put together and show a large area in the center of the basin.

11.3.2 Groundwater Quality

A discussion of water quality is omitted in this section because it has been done in 8.5. The total dissolved solid (TDS) as a representative of water quality is an important factor for water quality standard, treatment cost for drinking water and productivity of live stocks and agricultural crops.

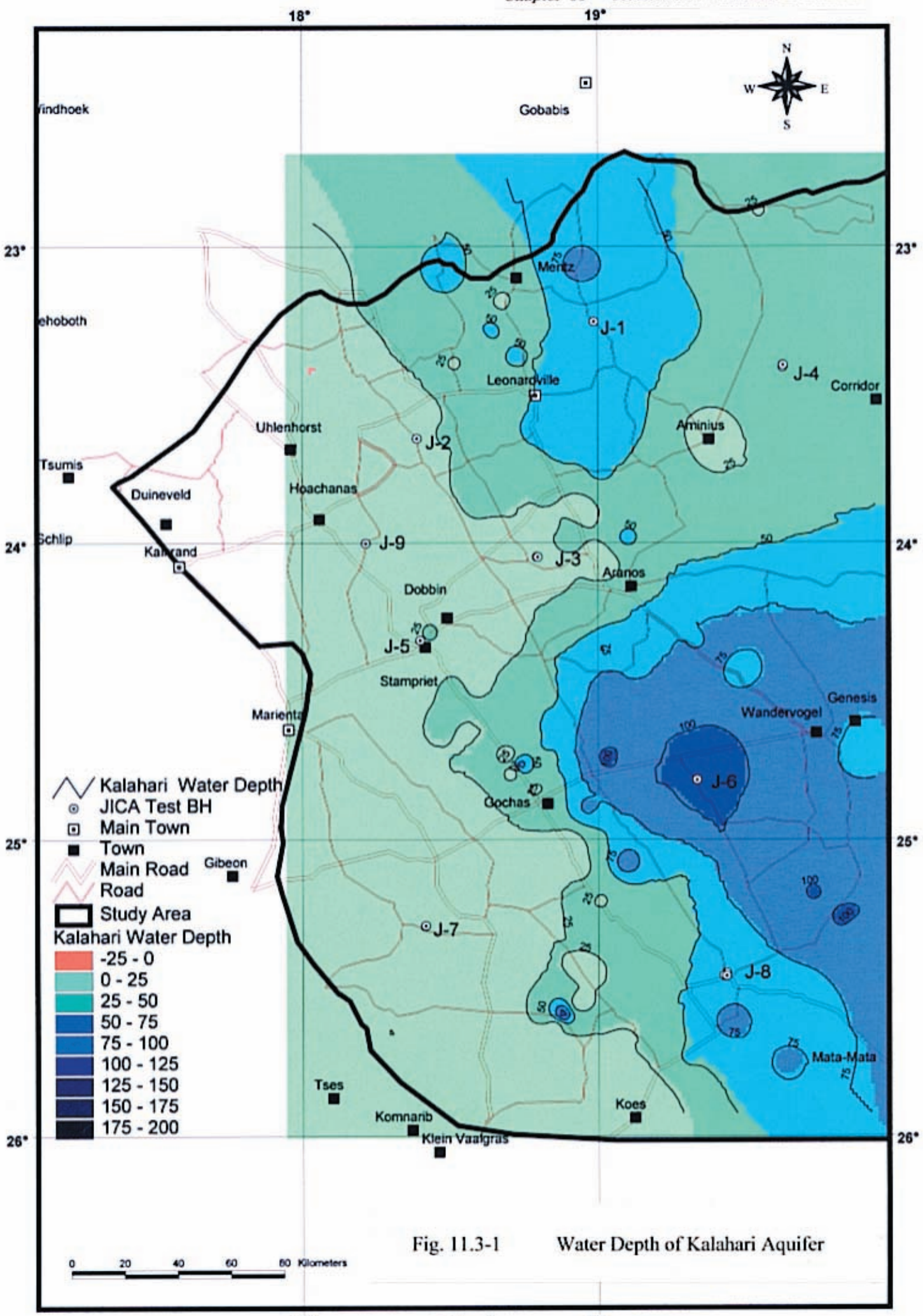

Fig. 11.3-1 Water Depth of Kalahari Aquifer

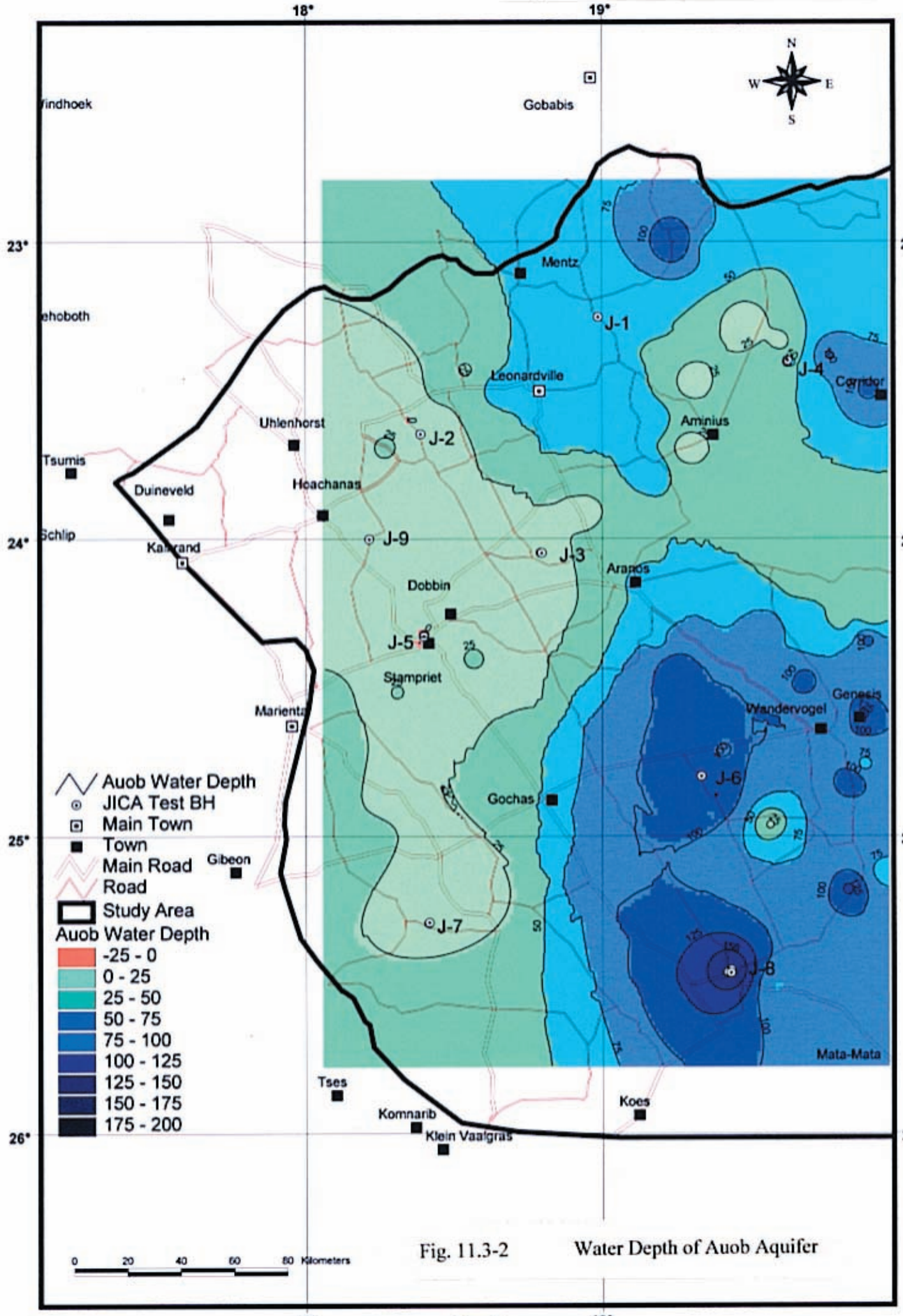

Fig. 11.3-2 Water Depth of Auob Aquifer

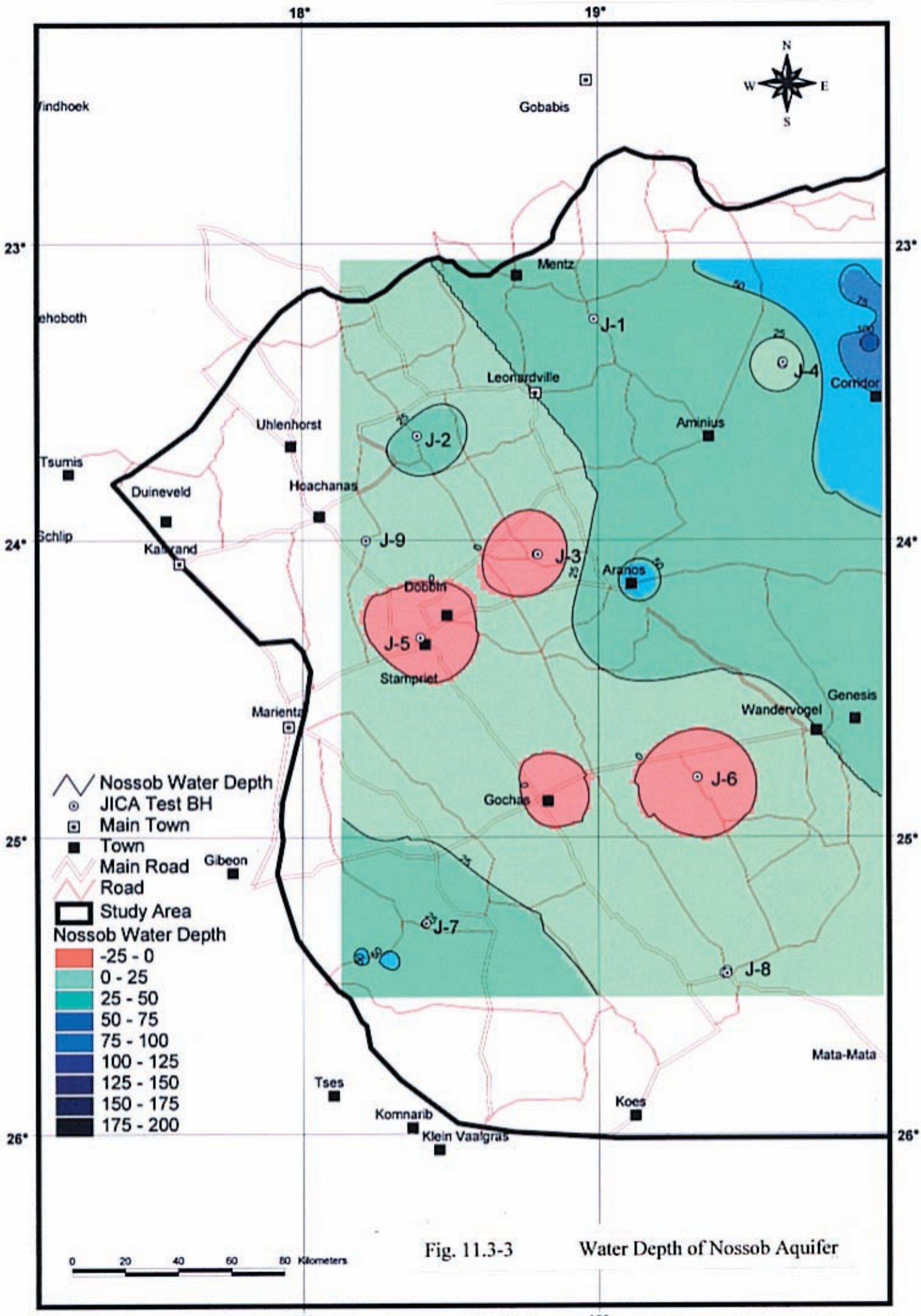

Fig. 11.3-3 Water Depth of Nossob Aquifer