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Investigation of Groundwater Resources and Airborne-Geophysical Investigation of Selected Mineral Targets in Namibia

Volume IV.GW.3.1

Groundwater Investigations in the Eiseb Graben

Main Hydrogeological Report

Windhoek

December 2004

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Main Hydrogeological Report

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Abbreviations

asl	above (mean) sea level
bgl	below ground level
B	Linear well-loss coefficient (h/m^2)
C	Non-linear well-loss coefficient (h^2/m^5)
CD	Constant discharge
D	deuterium excess
E	Well efficiency (%)
GMWL	global meteoric water line
K	hydraulic conductivity (m/d)
L	Leakage factor (m)
Lat	Latitude
Long	Longitude
RWL	Rest water level (m below datum)
P	Exponent in non-linear well loss term or
P	Factor in Stallman's evaluation method describing the distance to a boundary
PID	Pump intake depth (m bgl)
PWL	Pumped water level (m below datum)
Q	Pumping rate (m^3/h)
Q_n	Pumping (abstraction) rate during the n-th step
Q_{rec}	Recommended maximum abstraction (m^3/h)
S	Storage coefficient
s	drawdown (observed) (m)
s_n	Total (steady state) drawdown s_n during the n-th step (m)
s_{max}	Maximum drawdown during pumping test (m)
s_{res}	Residual drawdown after recovery (m)
SACS	South African Committee for Stratigraphy (Council for Geoscience of South Africa)
SRTM	Shuttle Radar Topography Mission
T	Transmissivity (m^2/d) or
T	Temperature
TD	Total depth
UTM	Universal Transverse Mercator

Foreword

This report is part of a series of Technical Reports published by the Technical Cooperation Project "Investigation of Groundwater Resources and Airborne-Geophysical Investigation of Selected Mineral Targets in Namibia", which is being implemented by the Federal Institute of Geosciences and Natural Resources (BGR), Germany, and the Department of Water Affairs (DWA), Windhoek, Namibia . This project started in October 2002 and ends with its first phase in March 2005.

This report documents the hydrogeological situation in the Eiseb Graben of the Omaheke region as it is known to date. Within the framework of the project 4 exploration boreholes have been drilled with the aim to tap the Eiseb Graben Aquifer, to determine the hydraulic properties of this aquifer, and to delineate the extent of the Eiseb Graben.

All basic data related to the drilling program are documented in Volume IV.GW.3.2: Groundwater Investigations in the Eiseb Graben – Documentation Compendium on the 2004 Drilling Campaign. The pumping test evaluations are documented in Volume IV.GW.3.3: Groundwater Investigations in the Eiseb Graben – Evaluation of Pumping Tests.

1 Summary

The Omaheke Region is one of the areas with the lowest population density in Namibia. The main reasons for this are the lack of infrastructure and the low availability of water resources. Due to the lack of surface water resources the Omaheke Region is largely depending on groundwater resources. So far, however, groundwater resources have shown low exploitation potential. In order to improve the living conditions of the local population the Namibian Government is looking into further possibilities of groundwater exploitation in certain areas which are considered promising, such as the Eiseb Graben.

The joint Namibian-German technical cooperation project ‘Investigation of Groundwater Resources and Airborne-Geophysical Investigation of Selected Mineral Targets in Namibia’ has conducted time-domain electromagnetic (TEM) geophysical measurements in the eastern part of the Eiseb Graben. Based on these measurements 4 boreholes have been sunk to a maximum depth of 378 m encountering freshwater of high yield at the northern margin of the Eiseb Graben in semi-consolidated to unconsolidated Kalahari sediments. It is assumed that the alluvial filling in this part of the Eiseb Graben reaches a thickness of more than 400 m.

Isotope and hydrochemical analyses proved that this aquifer system receives recent recharge and is of suitable quality for human consumption. Pumping tests show that the transmissivity of this aquifer is extraordinarily high, however, the exact extent of the high yielding aquifer zone is presently not sufficiently known. Therefore the exploitation potential of the aquifer can presently not be evaluated.

It is recommended to carry out further geophysical measurements and drill at least three more deep boreholes into this aquifer zone before starting to develop this aquifer.

2 Introduction

Shortly after independence the area around Gam was considered by the Namibian Government as an area of repatriation for Hereros, most of which live from cattle farming. This area is therefore in urgent need of sufficient water supplies for drinking purposes and livestock watering.

Since the mid 1970s the Eiseb Graben is considered to be one of the major aquifer systems in this area. The main aim of this project was to investigate the extent and potential of this aquifer system.

The project area comprises the assumed central part of the Eiseb Graben between:

UTM-E	400,000	–	520,000
UTM-N	7,640,000	–	7,750,000
	equivalent to (lower left – upper right)		
LAT	-21.33874	–	-20.34737
LONG	20.03680	–	21.19289

of UTM zone 34S.

The regional topographic conditions governing the project area are shown in Figures 1 and 2. These maps were prepared based on Shuttle Radar Topography Mission (SRTM) data which were recorded in February 2000. Data represent a 90 m grid and elevation accuracy is estimated at around 4 m. Topography in the project area varies between approximately 1300 and 980 m asl. Surface water drainage is generally directed from West to East and is controlled by the Omurambas Otjozondjou, Eiseb, Rooiboklaagte, Elandslaagte and Epukiro, all of which are incised into unconsolidated Kalahari sediments. The combined catchment area of the ephemeral rivers collecting surface water runoff to the Eiseb Graben has a size of approximately 43,800 km² (Figure 3). The Eiseb and Otjozondjou Rivers flow towards the Okavango Delta in Botswana connecting at some 80 km east of the border whereas the Epukiro River flows towards Ngami Lake, located south of the Okavango Delta.

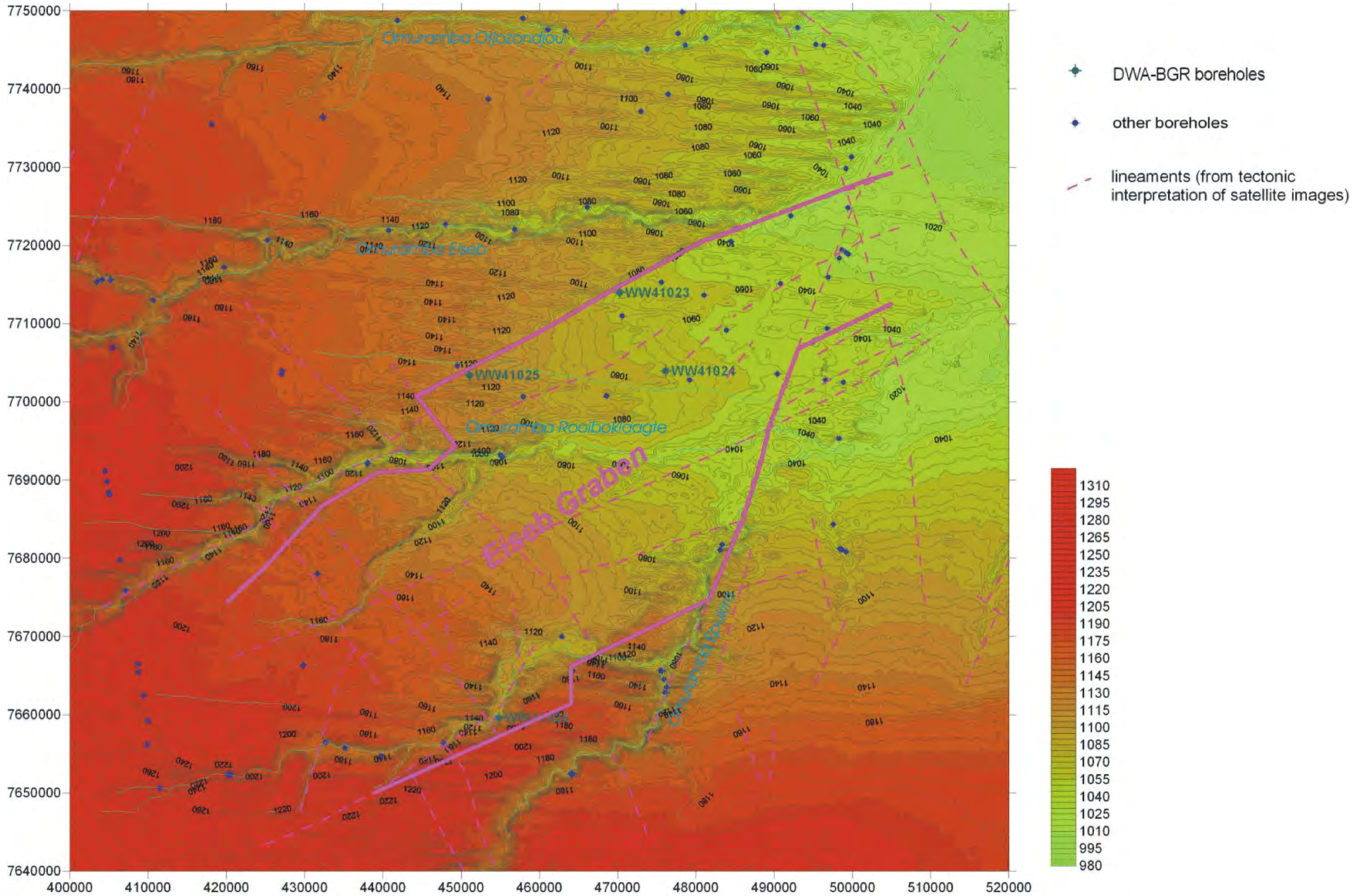
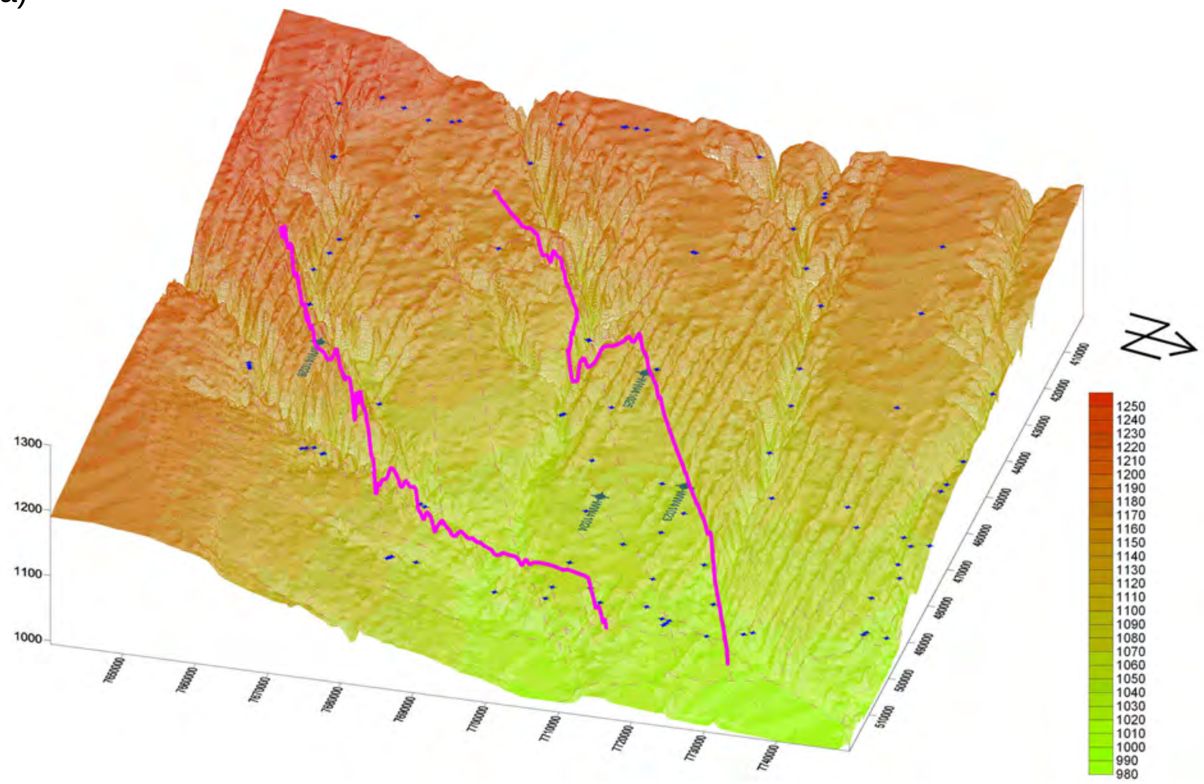


Figure 1: General Topography in the Eiseb Graben Region

a)



b)

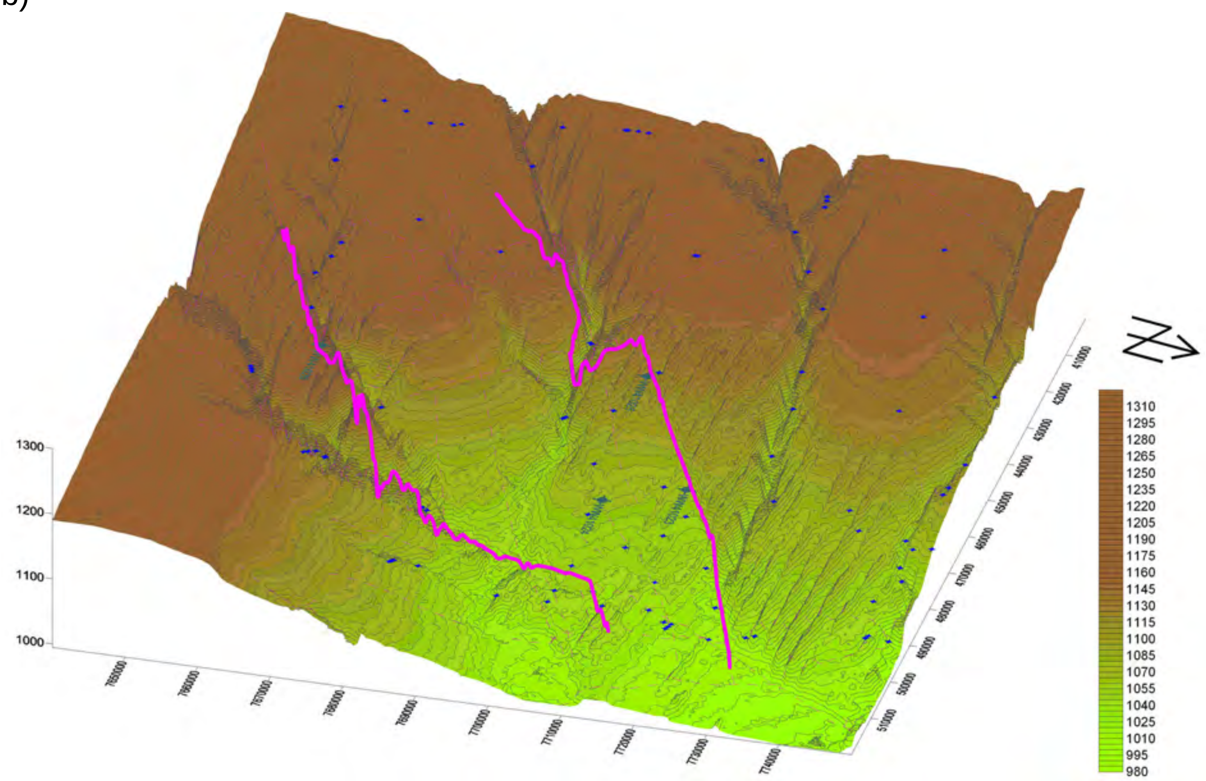


Figure 2: General Topography in the Eiseb Graben Region: a) based on Wireframe Feature (SURFER; 10 m intervals); b) based on Contours Feature (SURFER; 5m intervals); for Legend see Figure 1; vertical exaggeration: 100

The topographic maps as well as the satellite image reveal the presence of longitudinal dunes stretching in a W-E direction in most of the area (Figure 4).

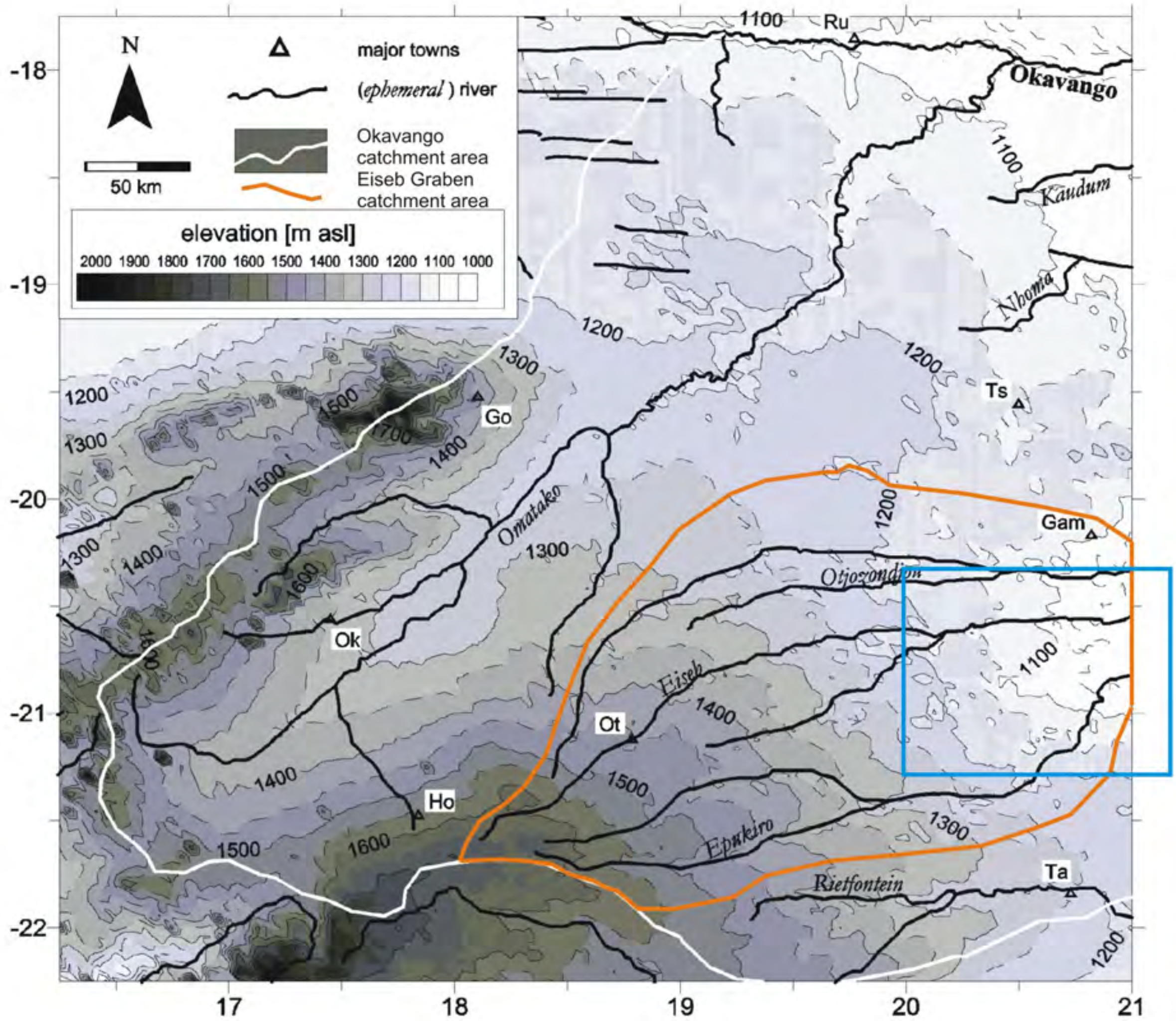


Figure 3: General Topographic Conditions in the Eiseb Graben Area
(modified after KLOCK, 2001; project area marked in light blue, Eiseb Graben Catchment Area marked in orange).

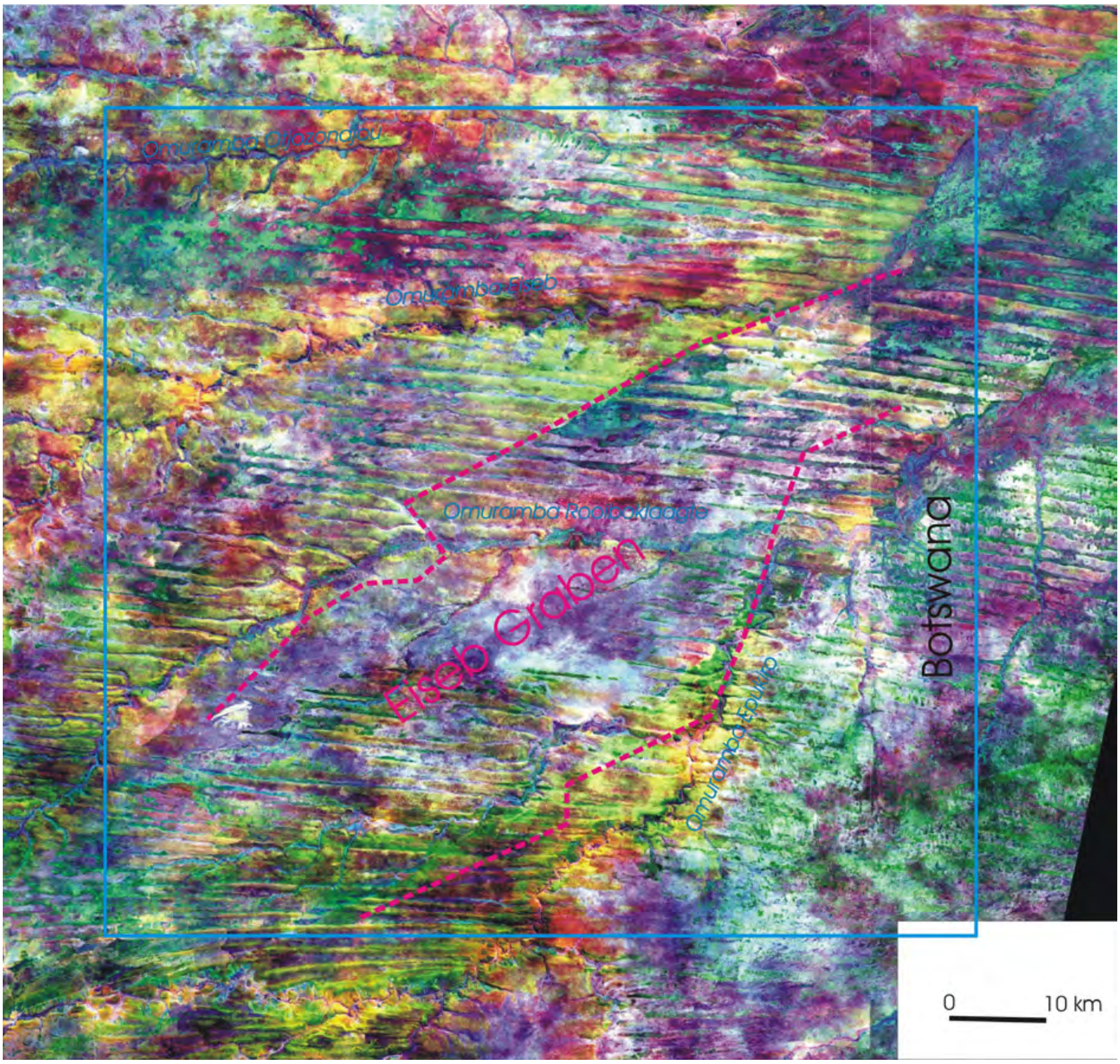


Figure 4: Landsat TM 7 Satellite Image of the Eiseb Graben Region showing Longitudinal W-E stretching Dunes (color composite of channels 7(red)-4(green)-1(blue); project area marked in blue)

During the field survey of INTERCONSULT (1996) the total population of this area was recorded as around 140 in 6 settlements and the number of cattle as around 1,800.

3 General Conditions

3.1 Climatic Conditions

The general distribution of precipitation in Namibia is shown in Figure 5.

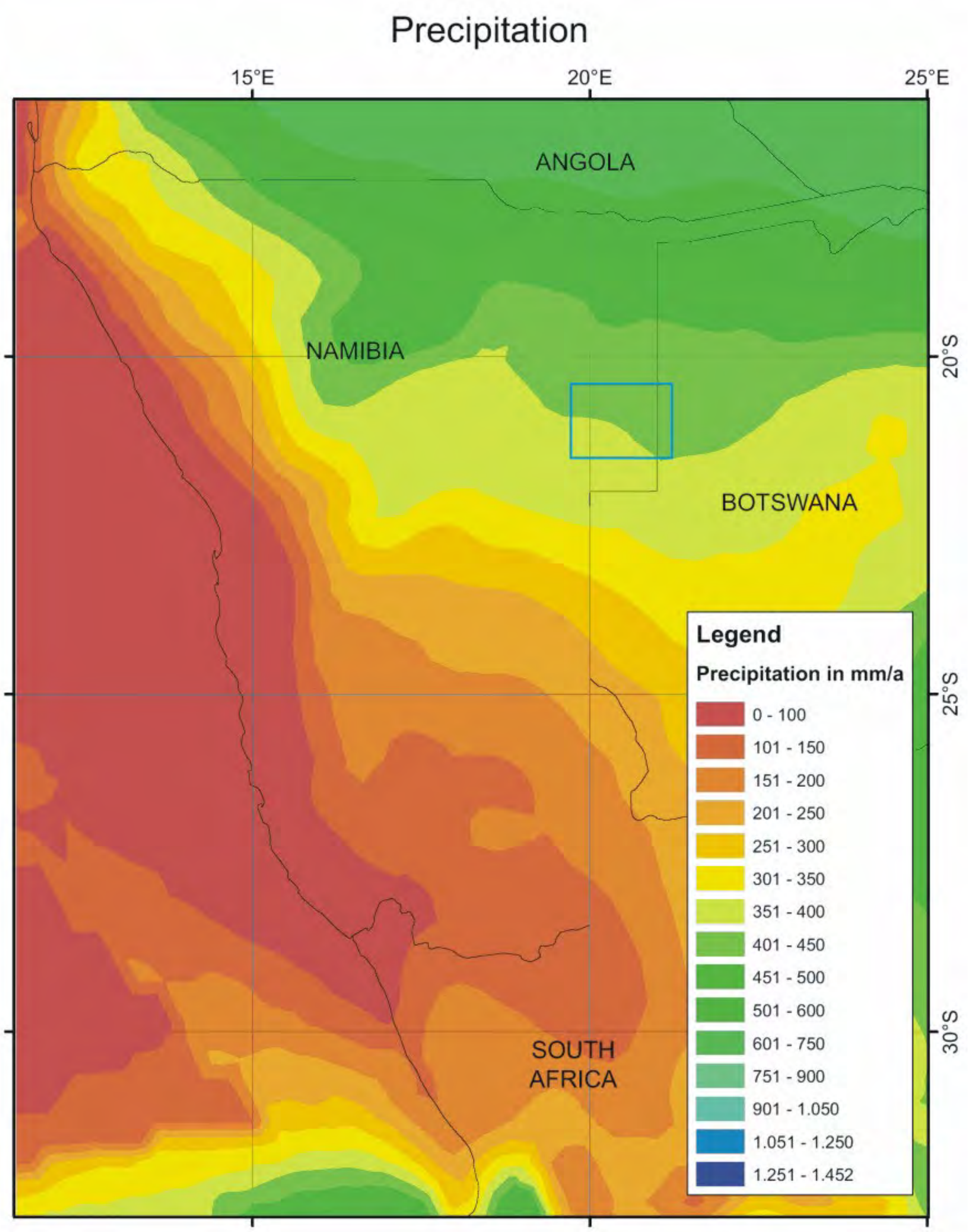


Figure 5: Spatial Distribution of Precipitation in Namibia (adopted from NEW et al., 1999; blue line: Investigation Area)

There are only few rainfall stations in the area. Rainfall is/was registered at :

- Epukiro Reserve (station 0833753; approx. 175 km towards SW) between 1927 and 1989 (average 1930-1989: 341 mm/a);
- Epukiro (station 0833222; approx. 175 km towards SW) between 1906 and recent (average 1944-2000: 414 mm/a);
- Tsumkwe (station 1015035; approx. 150 km towards N) between 1961 and recent (average 1961-2002: 460 mm/a);
- Frisgewagt (station 0834697; approx. 100 km towards SW) between 1983 and 1996 (average 1983-1996: 366 mm/a);
- Rietfontein/Talismanis (station 0836348; approx. 110 km towards S) between 1974 and 1979 (average 1974-1979: 388 mm/a);

Figure 6 shows the location of these stations. Because there is no matching time span with complete records over at least 20 years for these stations it is difficult to draw a meaningful rainfall distribution map for the area. Based on the available data annual rainfall in the project area is estimated to be in the order of 330-460 mm/a. As the graphs from Tsumkwe and Epukiro show, rainfall varies largely from year to year, from little over 100 mm (minimum: at Tsumkwe in 1964: 127 mm) to more than twice the long-term average (maximum: at Tsumkwe in 1977: 997 mm). The rainfall peak is commonly reached during the months of January and February. There is commonly no precipitation during the months of June to August. The station Epukiro shows a significant increase in its long-term trend.

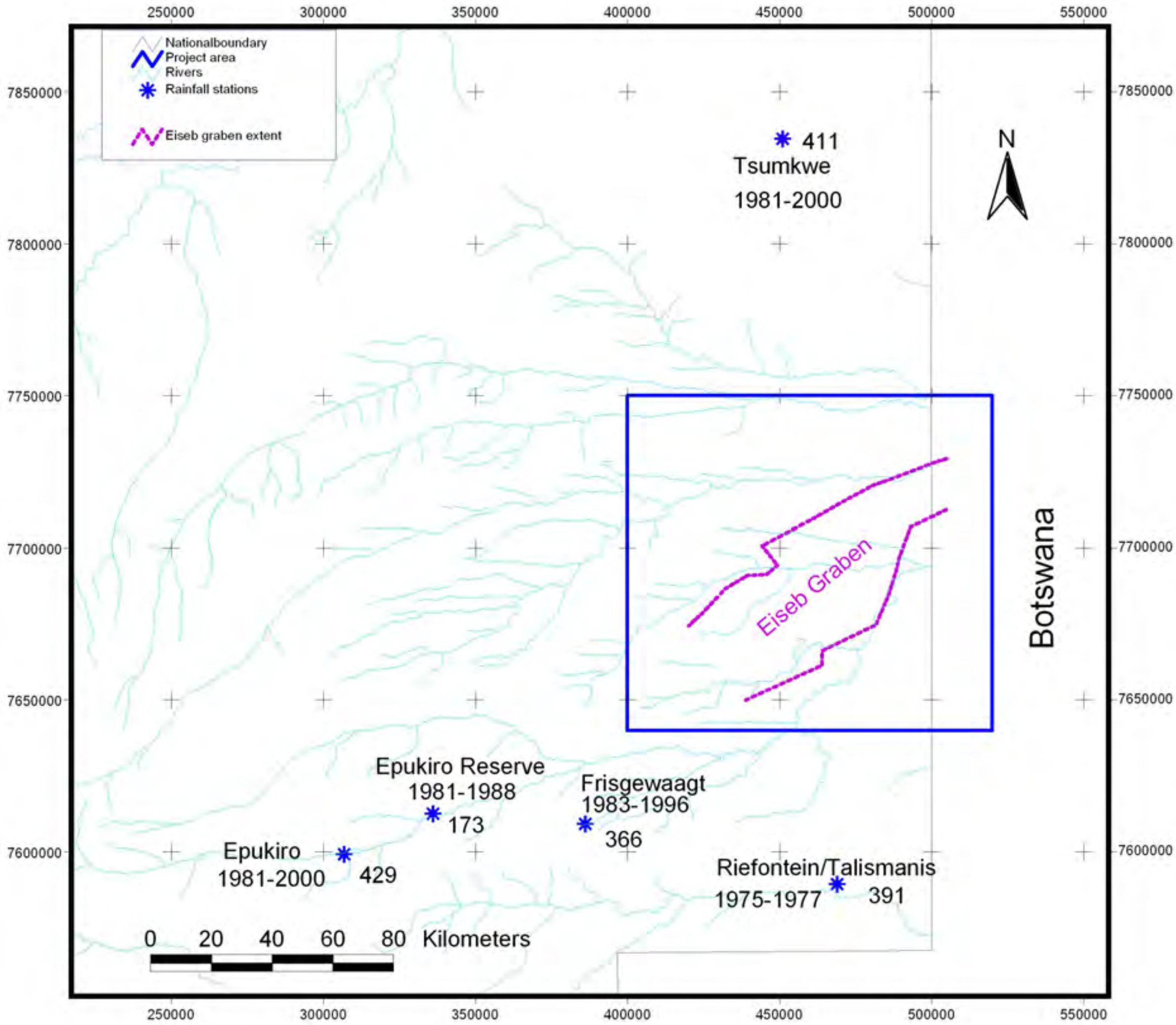


Figure 6: Location of Rainfall Stations in the Eiseb Region (name – time period – average rainfall)

(remark: the average of 173 mm at Epukiro Reserve seems unrealistically low since the average at Epukiro for the same time period is around twice as high)

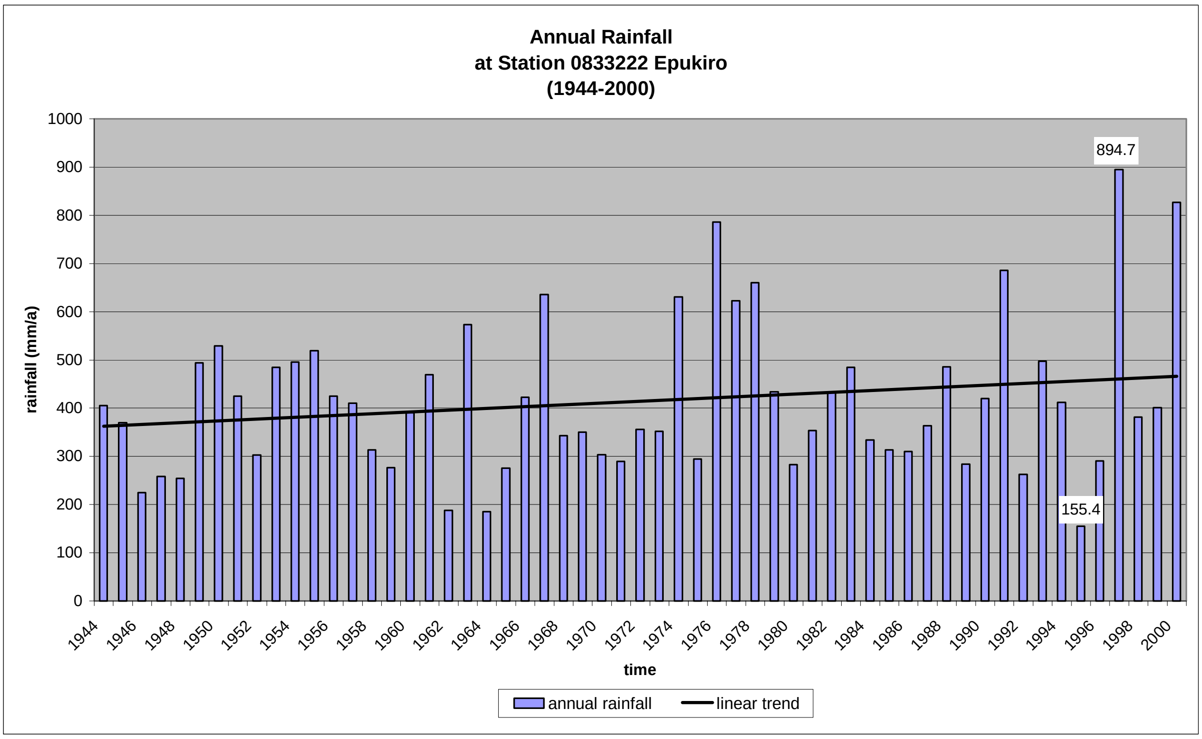


Figure 7: Annual Rainfall at Epukiro

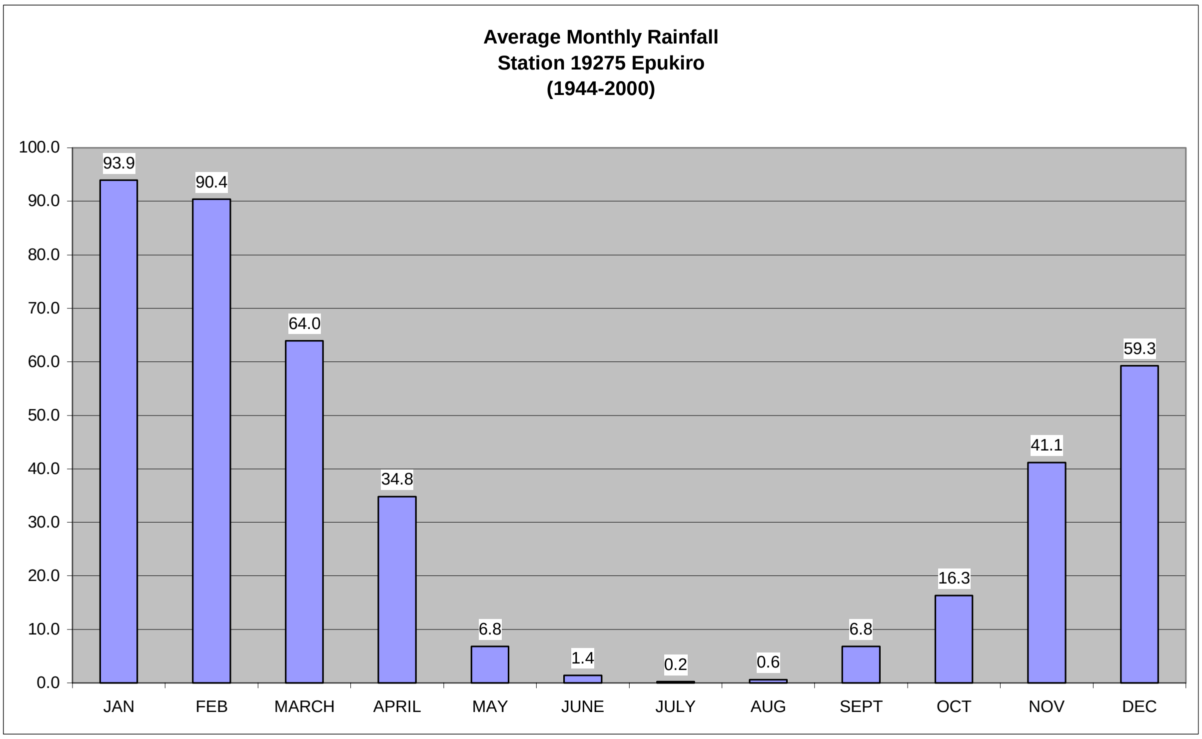


Figure 8: Average Monthly Rainfall at Epukiro

Some limited evaporation measurements are available from Ghanzi/Botswana, located some 100 km to the SSE of the project area. They indicate a relatively constant potential evaporation of around 3,000 mm/a (Figure 9), ranging between 180 mm/month in June and 320 mm/month in October (Figure 10).

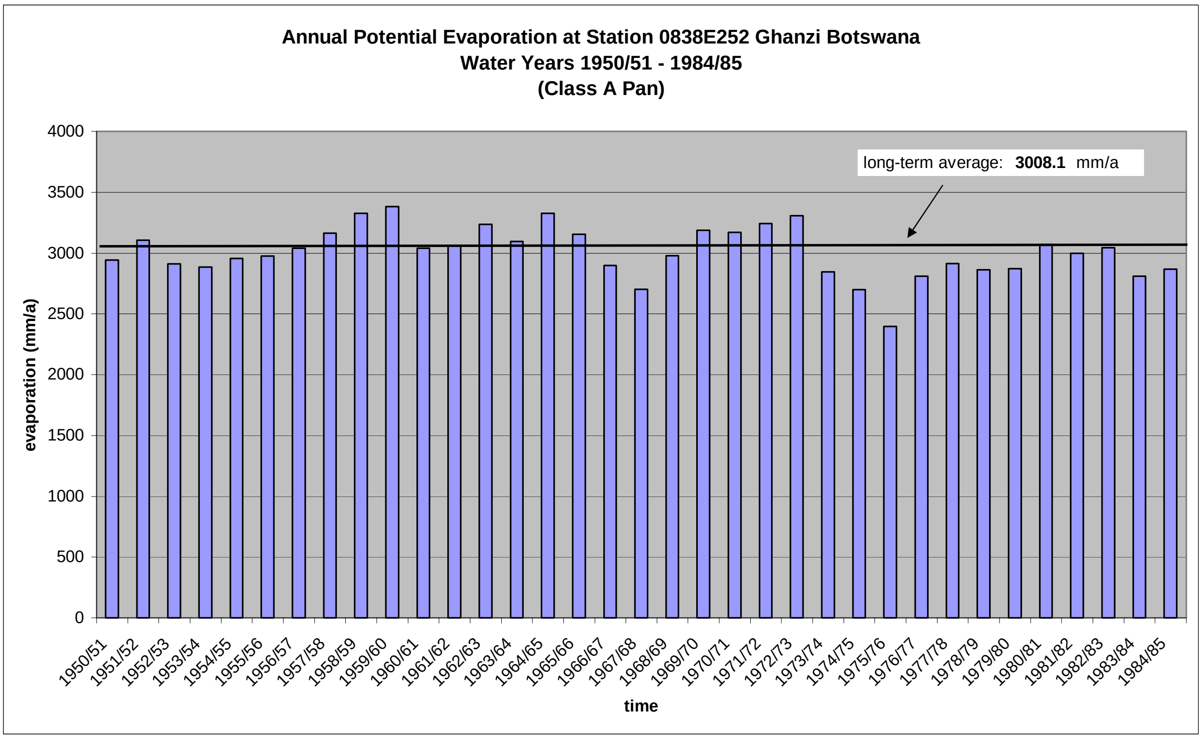


Figure 9: Annual Potential Evaporation at Ghanzi/Botswana

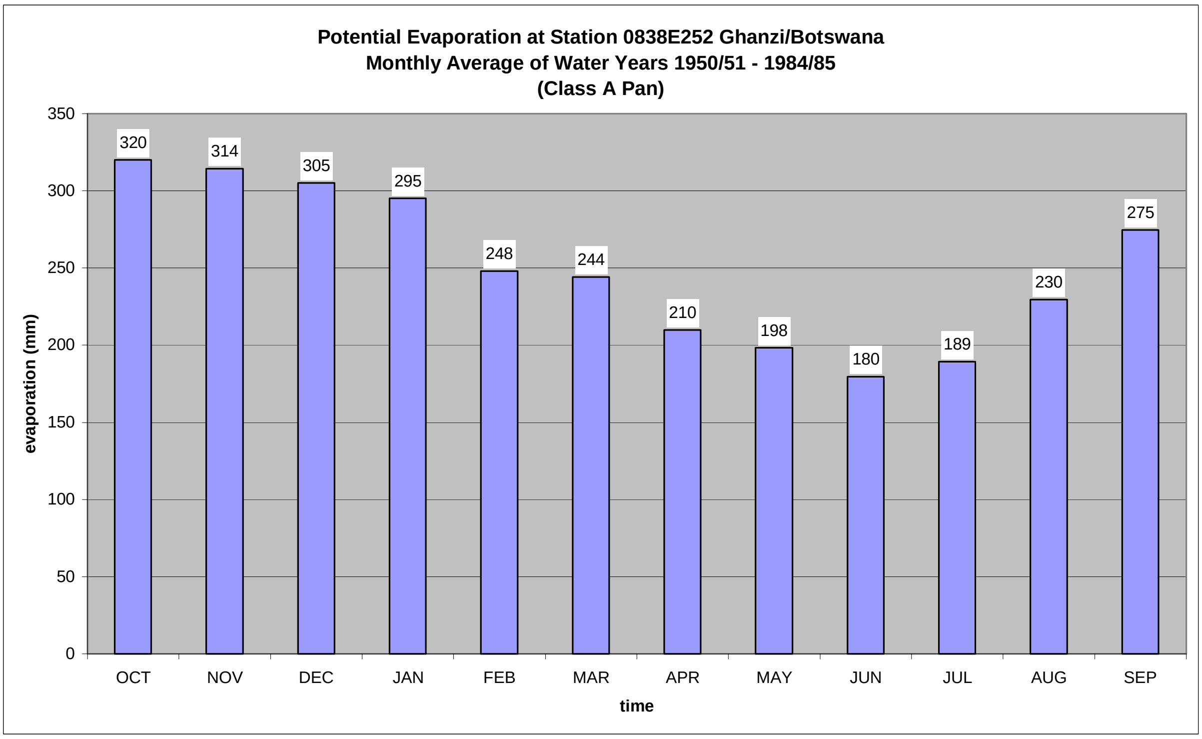


Figure 10: Monthly Potential Evaporation at Ghanzi/Botswana

Based on global data from Namibia (Figure 11) potential evaporation would be in the range of 2800 to 3200 mm/a.

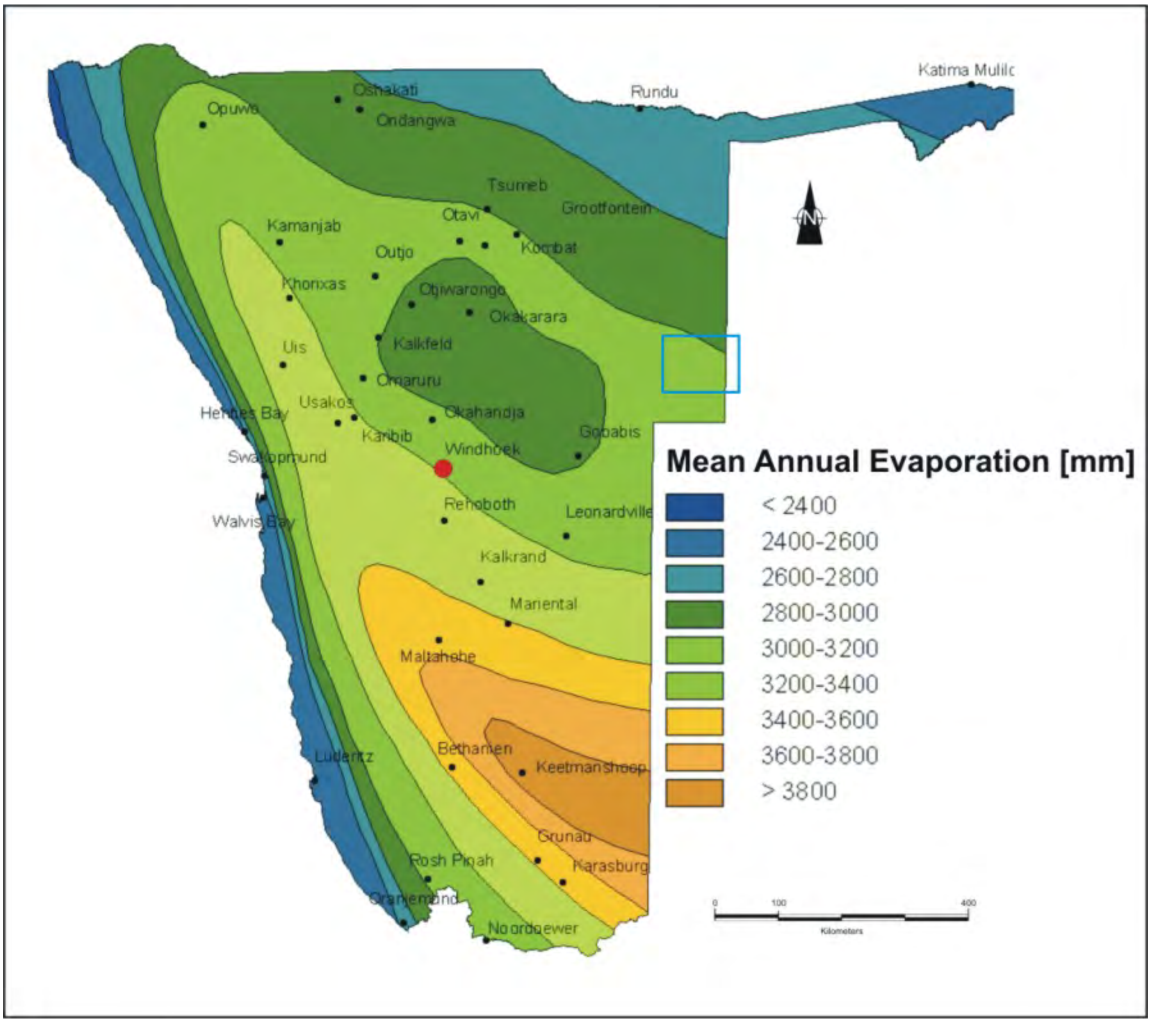


Figure 11: Spatial Distribution of Potential Evaporation in Namibia
(adopted from DWA, unpublished data)

3.2 Socio-Economic Conditions

A ‘Rural Water Supply Development Plan for the Omaheke Region’ was prepared in 2002 by AFRICON. For the establishment of this plan a socio-economic survey and water demand analysis and projection was carried out (compare chapter 5). The main findings of this study were:

- Population density is 0.8 capita per km²;
- The total population in 2001 in the entire Omaheke Region was 71,800 and is expected to increase to 106,400 until 2021;

- The population growth in the entire Omaheke Region is expected to decrease gradually from 3.21% in 2001 to 1.37% in 2021;
- The population growth in rural areas, however, is negative because most of the productive age groups have moved to urban areas, leaving behind the elderly and very young people (Figure 12);
- The chances for development are rather poor due to the low availability of clean water resources;
- The average monthly income per household is 697 N$ with 58% earning less than 400 N$;
- Income is mainly provided by extensive livestock farming, predominantly on a subsistence basis (present total number of large stock units (LSU): 193,100; total number of small stock units (SSU): 215,300);
- Education level is low with 46% of the population never having attended school.

Table 1: Estimated Population Numbers for the Omaheke Region (Central Bureau of Statistics)

Year	Population	Growth Rate
1991	52,700	
1996	61,300	3.07 %
2001	71,800	3.21 %
2006	82,000	2.70 %
2011	91,100	2.10 %
2016	99,400	1.78 %
2021	106,400	1.37 %

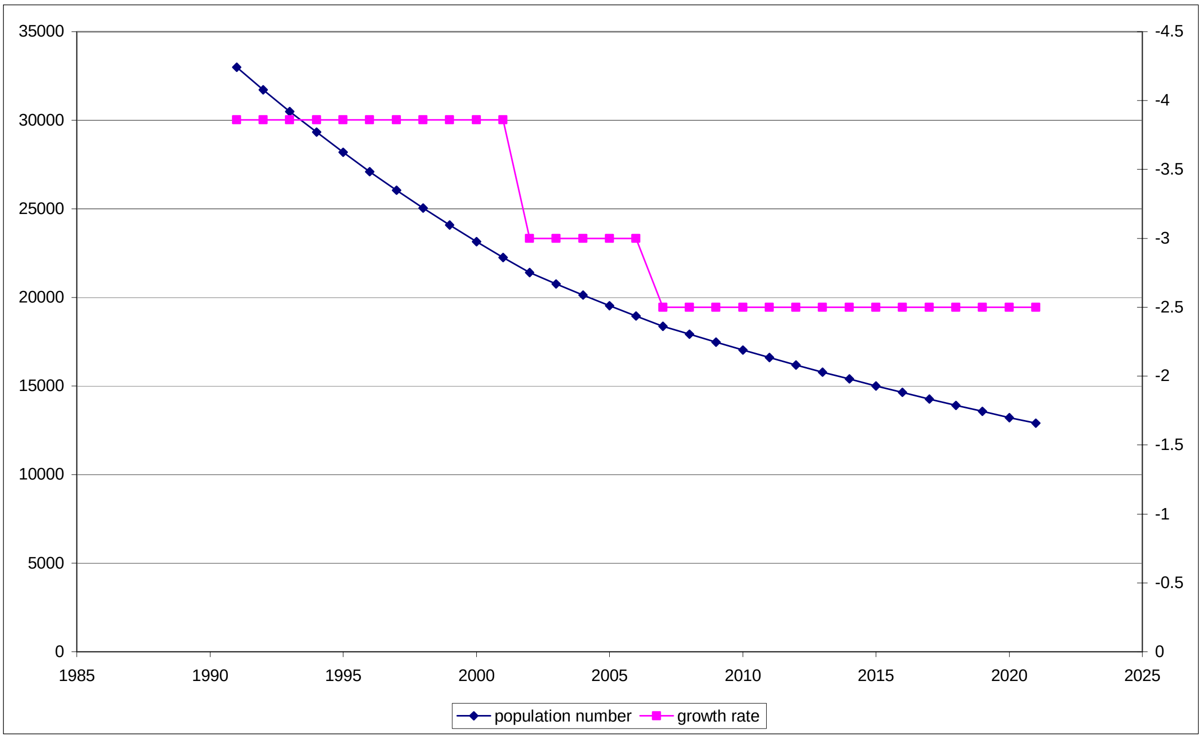


Figure 12: Projection of Rural Population in the Omaheke Region (adopted from AFRICON, 2002)

3.3 Hydrology

The surface water courses in the project area are part of the Okavango Delta surface water catchment area. There are four main ephemeral water courses in the area, the

- Omuramba Otjozondjou,
- Omuramba Eiseb,
- Omuramba Rooibooklagte and
- Omuramba Epukiro.

There are no streamflow monitoring gauges in the area and therefore there is no information available on the surface water runoff in these water courses.

3.4 Geological Setup

The geological setup in the project area is not very well known since most of the area is covered by Kalahari sediments and only few deeper penetrating wells exist. Based on the succession further to the West, the lithostratigraphic succession in the project area is expected to be as follows:

Table 2: Stratigraphy in NE-Namibia (modified after STRUCKMEIER & CHRISTELIS, 2001)

Group	**Formation**	**Age**	**Age (Ma)**
Kalahari		Recent – Tertiary/? Upper Cretaceous	0-65 (135)
	Disconformity (65-130 Ma)		
Karoo	Rundu Fm./Kalkrand Fm. (Basalt) Etjo Fm. (Sst) Omingonde Fm.	Jurassic - Permian	135-300
	Erosion (300-500 Ma)		
Damara	Mulden Group Otavi Group Nosib Group	Namibian – Early Cambrian	500-1000
Pre-Damara	Gamsberg Suite Abbabis Complex Grootfontein Complex Hohenwarte Complex	Cambrian - Precambrian	

Table 3: Lithostratigraphy of Northwest Ngamiland/Botswana (adopted from AQUALOGIC & WATER SURVEYS BOTSWANA, 2003)

Age	Supergroup	Group	Formation	Lithologies
Cretaceous to Recent		Kalahari		Aeolian sands, silcretes, calcretes. Sandstones, lacustrine and deltaic sediments.
Carboniferous to Jurassic	Karoo	Stormberg Lavas		Basalt (dolerite).
		Lebung	Bodibeng Marakwena Tale	Sandstones. Pebbly sandstones, mudstones. Mudstones, siltstones.
		Ecca		Arkoses, shales and mudstones.
711-649 Ma			Rooibok	Gneiss, amphibolite schist.
1020 - 530Ma	Ghanzi-Chobe	Xaudum + Koanaka	Aha Hills Fm (Chihabadum Complex)	Carbonates (marble), pelites. Marble and gneiss. Igneous and meta-igneous rocks.
1104 - 530Ma	Ghanzi-Chobe	Ghanzi	Mamuno	Sandstone, minor carbonate.
			D'kar	Shales, siltstone & arkoses.
			Ngwako Pan	Meta-arkoses, siltstone and minor limestone.
1106 Ma			Kgwebe	Rhyolites, basalts.
Mesoproterozoic ?		Tsodilo Hills		Quartzites, pelites, ironstones and migmatite.
Mesoproterozoic ?			Kwando Complex	Granite orthogneiss and migmatite.
2055-2044 Ma			Okwa and Quangwadum Complexes	Augen gneiss, granite, rhyolite.

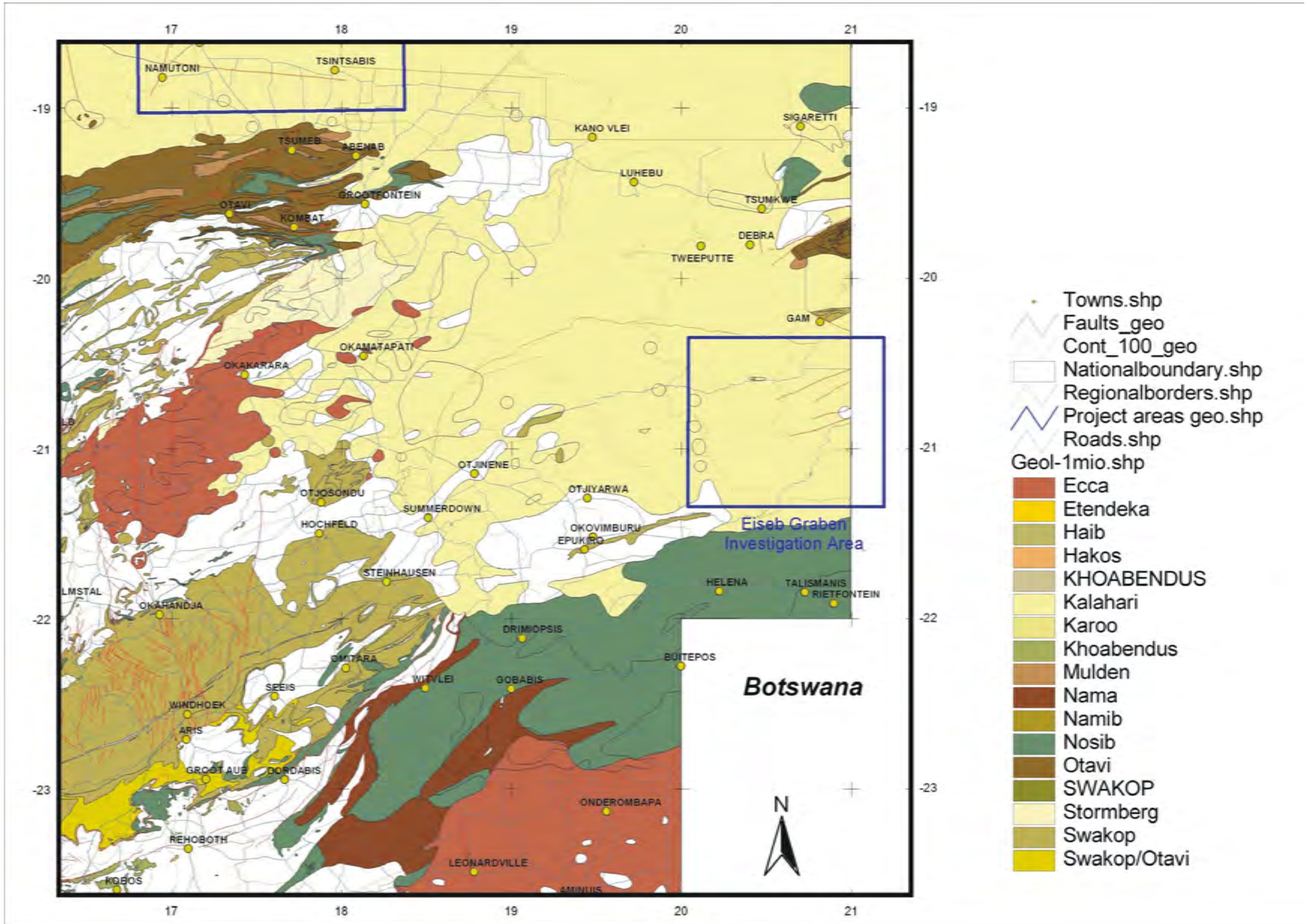


Figure 13: Map showing the Regional Geological Setup (based on 1:1,000,000 Geological Map of Namibia)

Most of the project area is believed to be underlain by formations of the Damara orogenic belt which trends ENE-WSW. These formations were deposited in an intercontinental environment (MILLER, 1983) and were later deformed and metamorphosed. Pre-Damara basement is included into the thrust belt, as are granites intruded during and after the main orogenetic events.

The red beds of the Lower Karoo were deposited during a period of uplifting. The Ecca Group, dominated by shales, was deposited during a marine transgression from the South. Sediments of the Beaufort Group and the Omingonde Fm. were deposited in a continental environment. The overlying Etjo Fm. documents a continental environment with dry climate. During late Karoo times the breakup of the Gondwana Continent took place evidenced by the occurrence of flood basalts (Kalkrand Fm.).

KLOCK (2001) has elaborated the thicknesses of the Karoo rock units as documented in Figures 14 and 15.

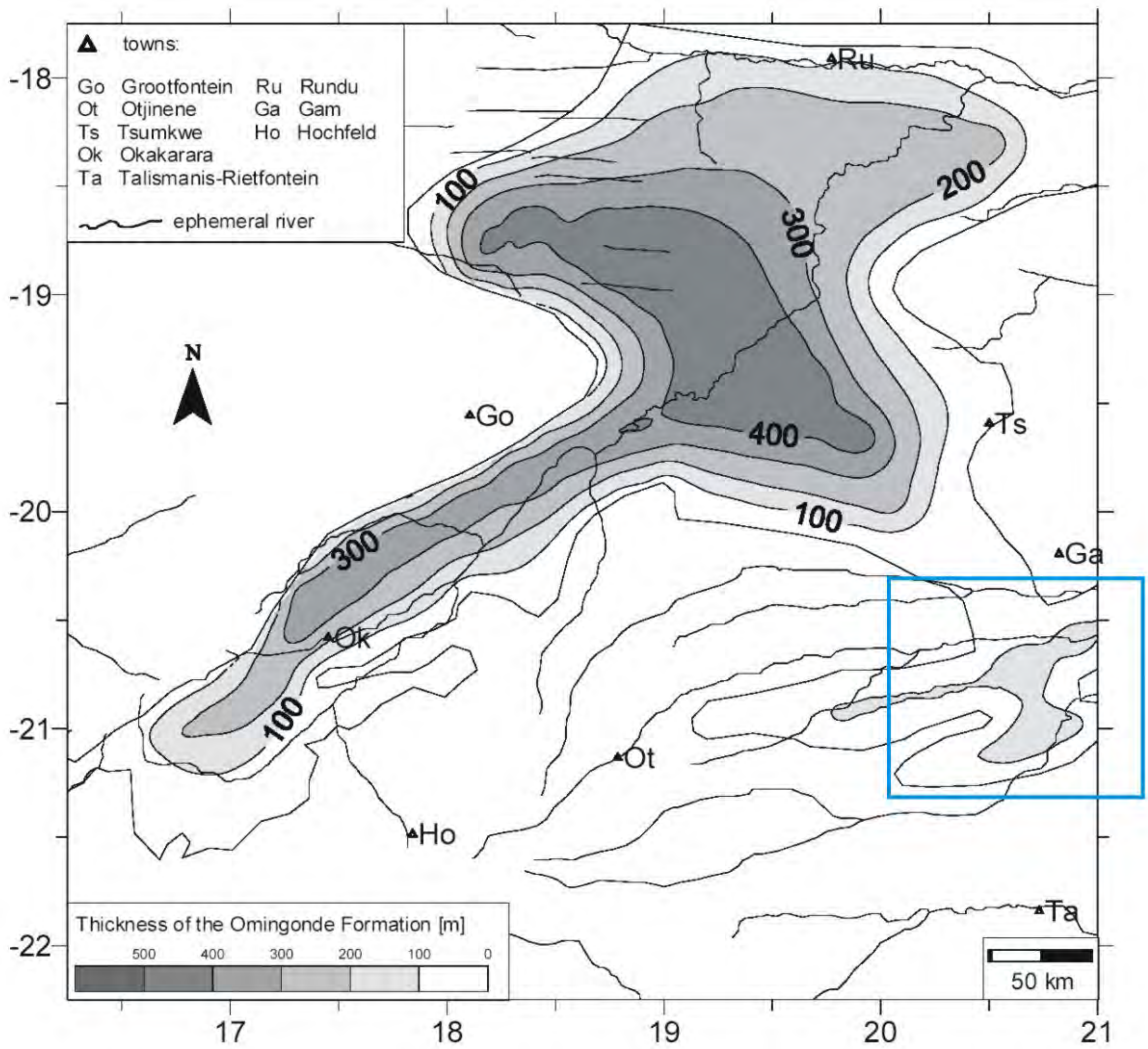


Figure 14: Thickness of Omingonde Formation (project area marked in blue)

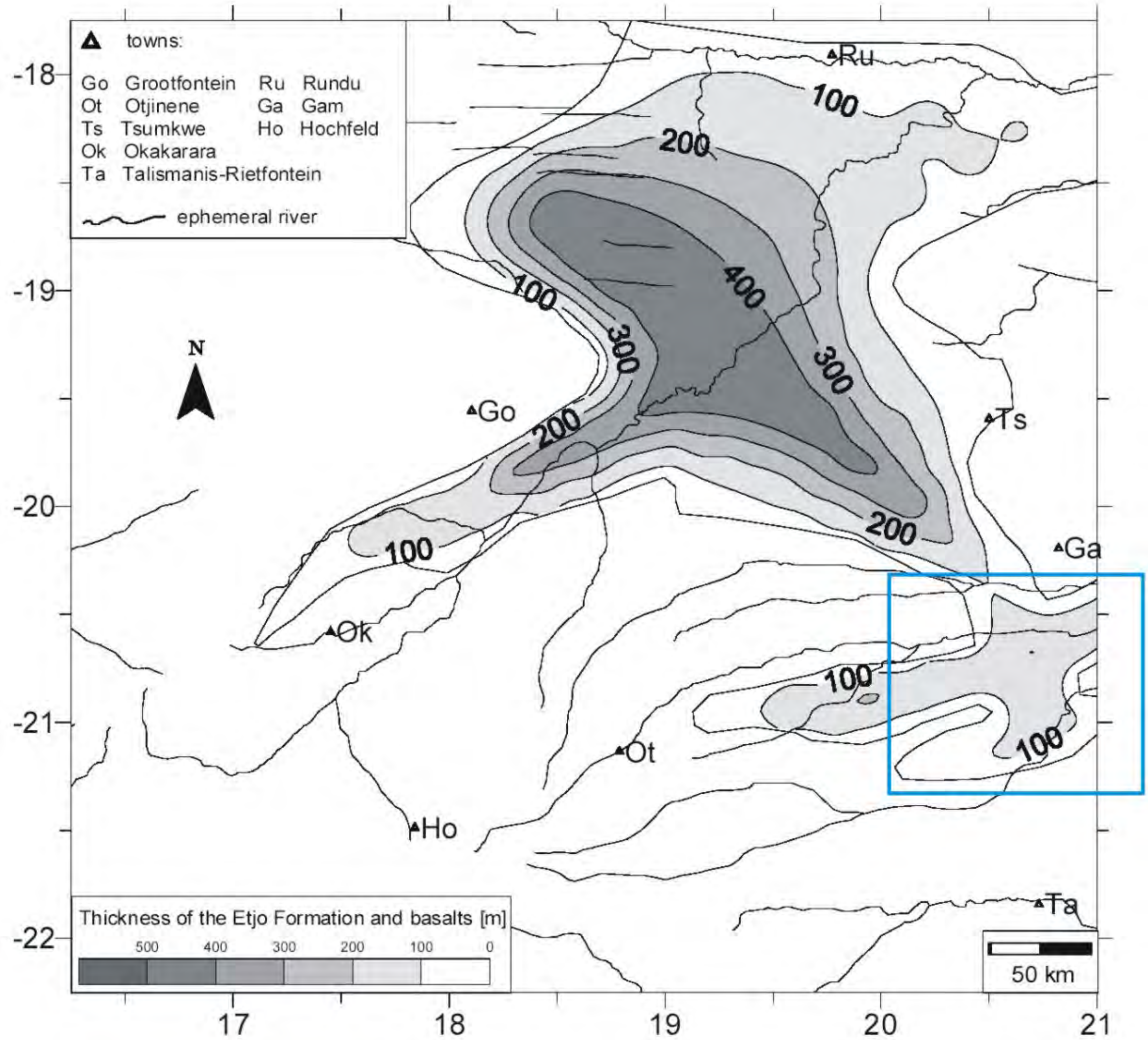


Figure 15: Thickness of Etjo and Rundu Formations (project area marked in blue)

At the base of the Kalahari sediments often conglomerates (e.g. carbonate cemented conglomeratic sandstones in the Tsumkwe district) and breccias (in the Eiseb Omuramba area) are found forming evidence of an extensive unconformity (KLOCK, 2001). At the Omuramba Epukiro alluvial breccias are found overlying the basement and overlain by fluvial deposits of a braided river system. These are termed Tsumkwe Fm., which at the same location is overlain by fluvial sand of the Eiseb Fm. The Tsumkwe Fm. may be equivalent to the Beiseb Fm. found in the Owambo Basin (MILLER, 1997).

As part of the Eiseb Fm., KLOCK mentions the occurrence of :

- Massive limestones, laminated limestones and limestones with a silici-clastic component, especially in the Omuramba Epukiro;

- Pebbly sandstones and immature sandstones (white to cream colored quartz sandstones; poorly sorted, angular to sub-rounded quartz grains, mostly clear quartz; exposed in the central part of Omuramba Eiseb);
- Pipe sandstone (sandstone with a network by interconnected pipes; e.g. at the upper cliff of the Omuramba Eiseb; light-grey or cream colored; comprises immature and sometimes pebbly, dominantly silica-cemented sandstones; sand component includes fine to coarse sub-rounded quartz grains; discontinuous, massive pebble bands occur sporadically (reddish sub-angular quartz-sandstone clasts or angular chert clasts); intense silicification);
- Silcretes with internal lamination.

According to the lithostratigraphy set up by SACS (1980), the Eiseb Fm. is overlain by the Omatako Fm., however, this unit does not occur within the project area but is restricted to the Omuramba Omatako, further to the North of it.

KLOCK (2001) presents the following typical section as generalized Kalahari Group profile in northeastern Namibia:

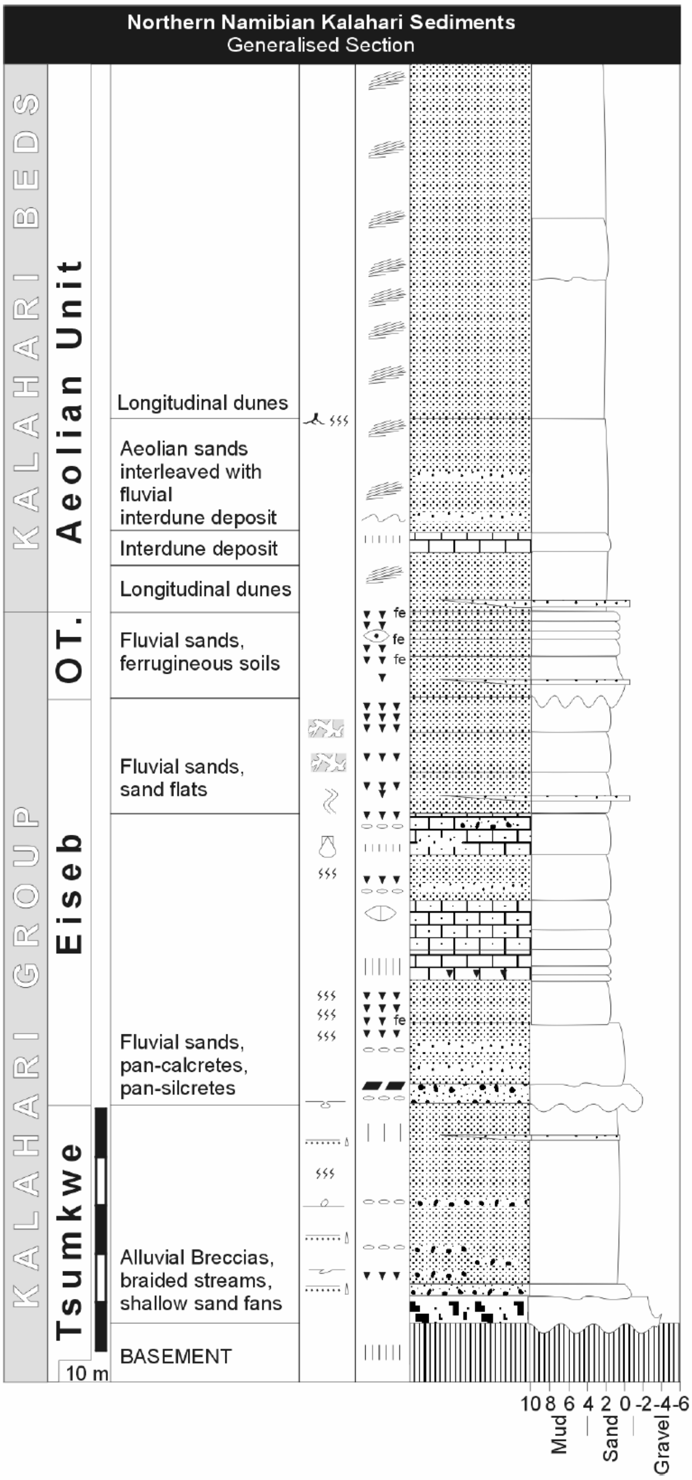


Figure 16: Generalized Profile of the Kalahari Group in Northeastern Namibia (adopted from KLOCK, 2001)

The thickness distribution of Kalahari sediments in NE-Namibia is shown in Figure 17. However, the therein depicted thickness distribution cannot be confirmed in the vicinity of the Eiseb Graben. Firstly, most boreholes in the vicinity of the graben did not reach the base of the Kalahari so that based on present data a thickness distribution map of Kalahari sediments in the project area cannot be drawn. Secondly, based on the TEM soundings conducted and boreholes drilled by the project it must be assumed that the graben structure is much more narrow than shown on Figure 17.

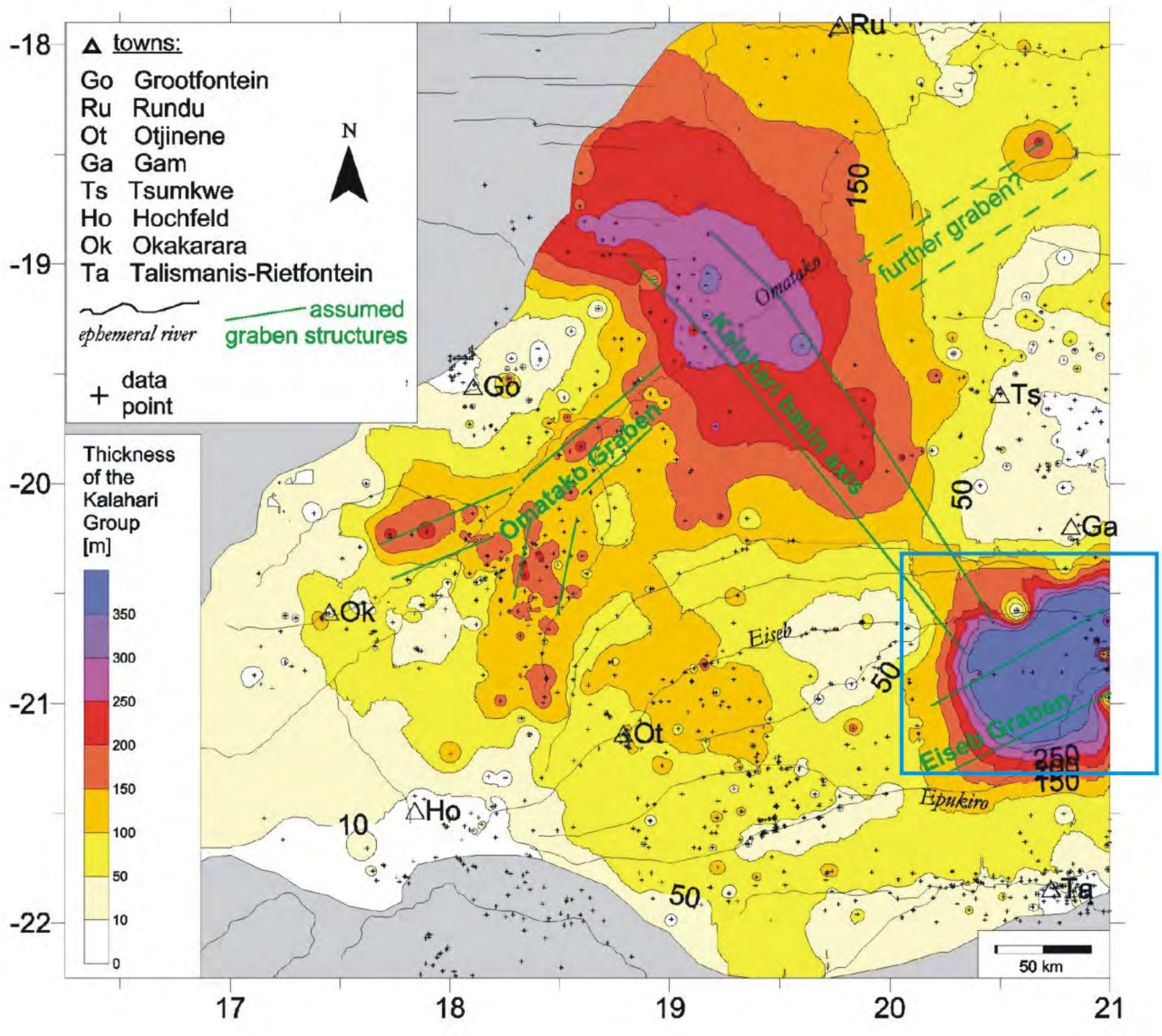


Figure 17: Isopachs of Kalahari Group sediments and Proposed Graben Structures in NE-Namibia (adopted from KLOCK, 2001; project area marked in blue)

According to AQUALOGIC & WATER SURVEYS BOTSWANA (2003) Karoo deposits underlie Kalahari sediments to the East of the Eiseb Graben Region in Botswana (Figure 18) and the Karoo is believed to form a major aquifer underneath the Kalahari sediment cover.

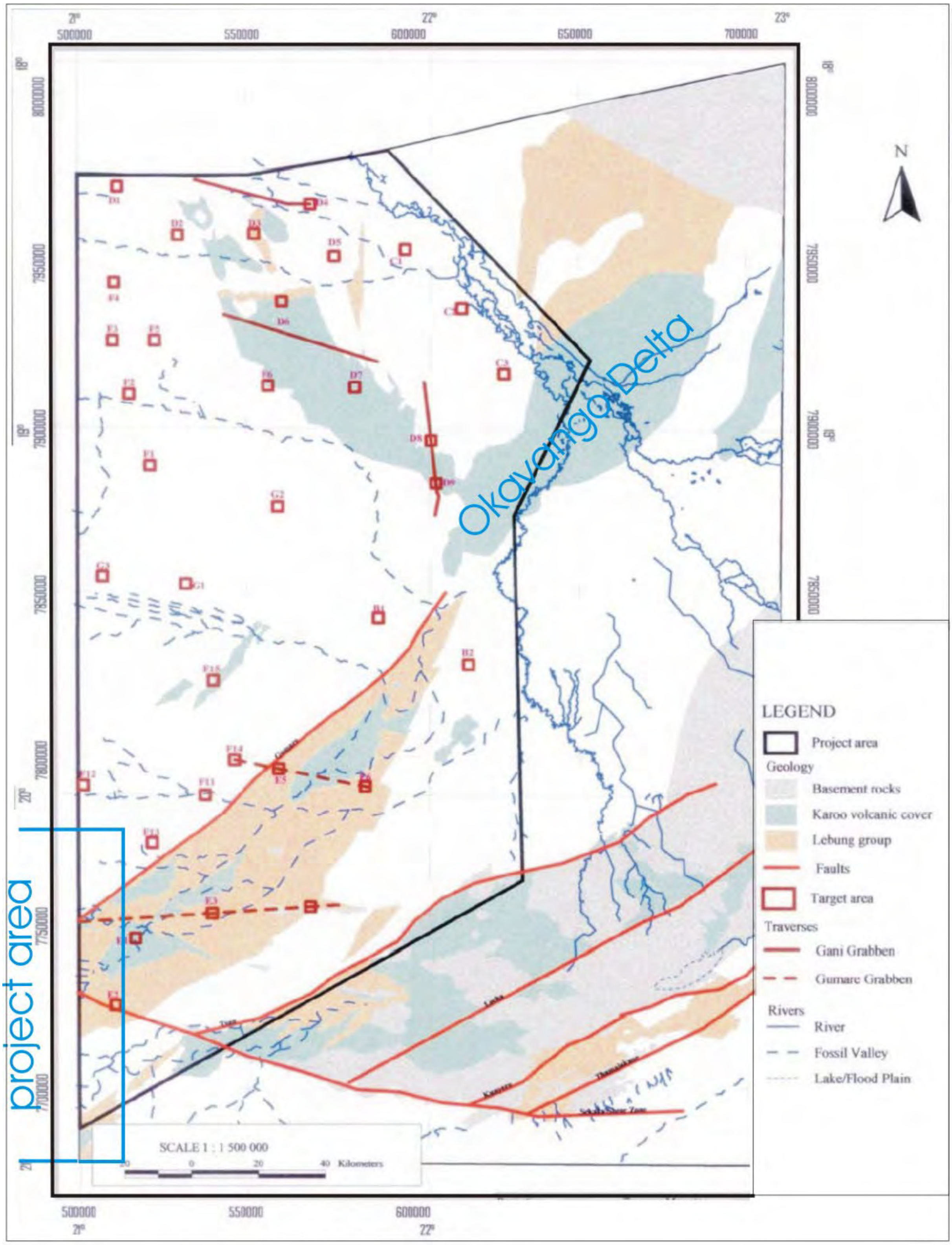


Figure 18: Occurrence of Karoo and Basement Rocks under Kalahari Cover in Northwestern Botswana

3.5 Structural Setup

A tectonic analysis of Landsat TM 7 image scenes, was carried out by BGR (SCHEAFFER, 2003). The result is depicted in Figure 19. It shows predominantly SW-NE (60°) trending lineaments intersected by a more or less perpendicular set of NW-SE (150°) trending lineaments. If considering the former as force of dilatation (σ_1 = 60°), the compressional force would be σ_3 = 150°. Another direction which is typically found is trending around 20° and may correspond to right lateral shear faults.

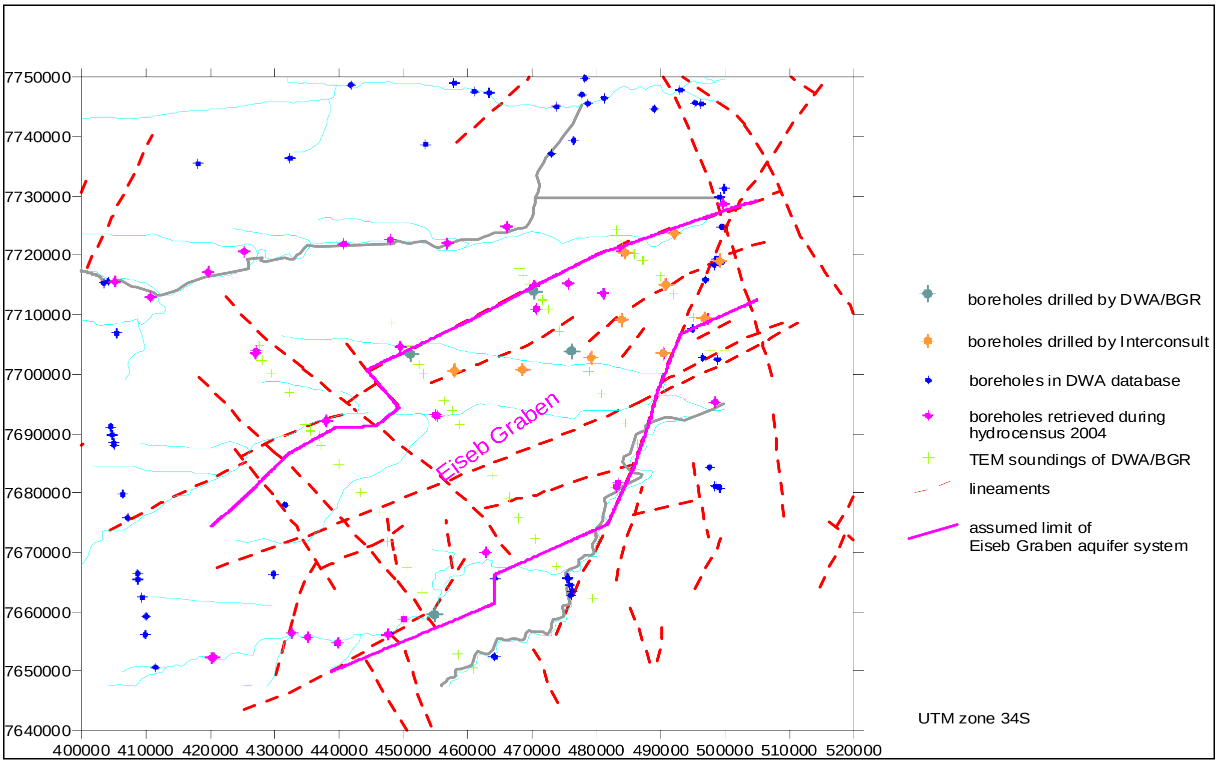


Figure 19: Tectonic Interpretation of Landsat 7 TM Satellite Image with assumed Limit of Eiseb Graben Aquifer System and Location of Boreholes

KLOCK (2001) assumes an overall tectonic setting as depicted in Figure 17. According to this hypothesis, the Eiseb Graben may be connected to a structure which extends perpendicular to the graben itself, forming the axis of the Kalahari Basin. This idea is mentioned in the report to a hydrogeological investigation conducted in northwestern Botswana (Figure 20; AQUALOGIC & WATER SURVEYS BOTSWANA, 2003). However, this so-called NE-Namibia Graben was not identified in the TEM soundings, but may coincide with a set of NW-SE trending lineaments identified by the project on satellite images in the western part of the graben (Figure 19). In respect of the hydrogeological significance of these features, it is likely, based on the results of the TEM soundings conducted within the framework of the project, that the deeply downlifted block, which was identified in the northern part of the Eiseb

Graben, does not continue south of the intersection with the assumed NW-SE fault zone or is downlifted in the southern part only to a much lesser extent.

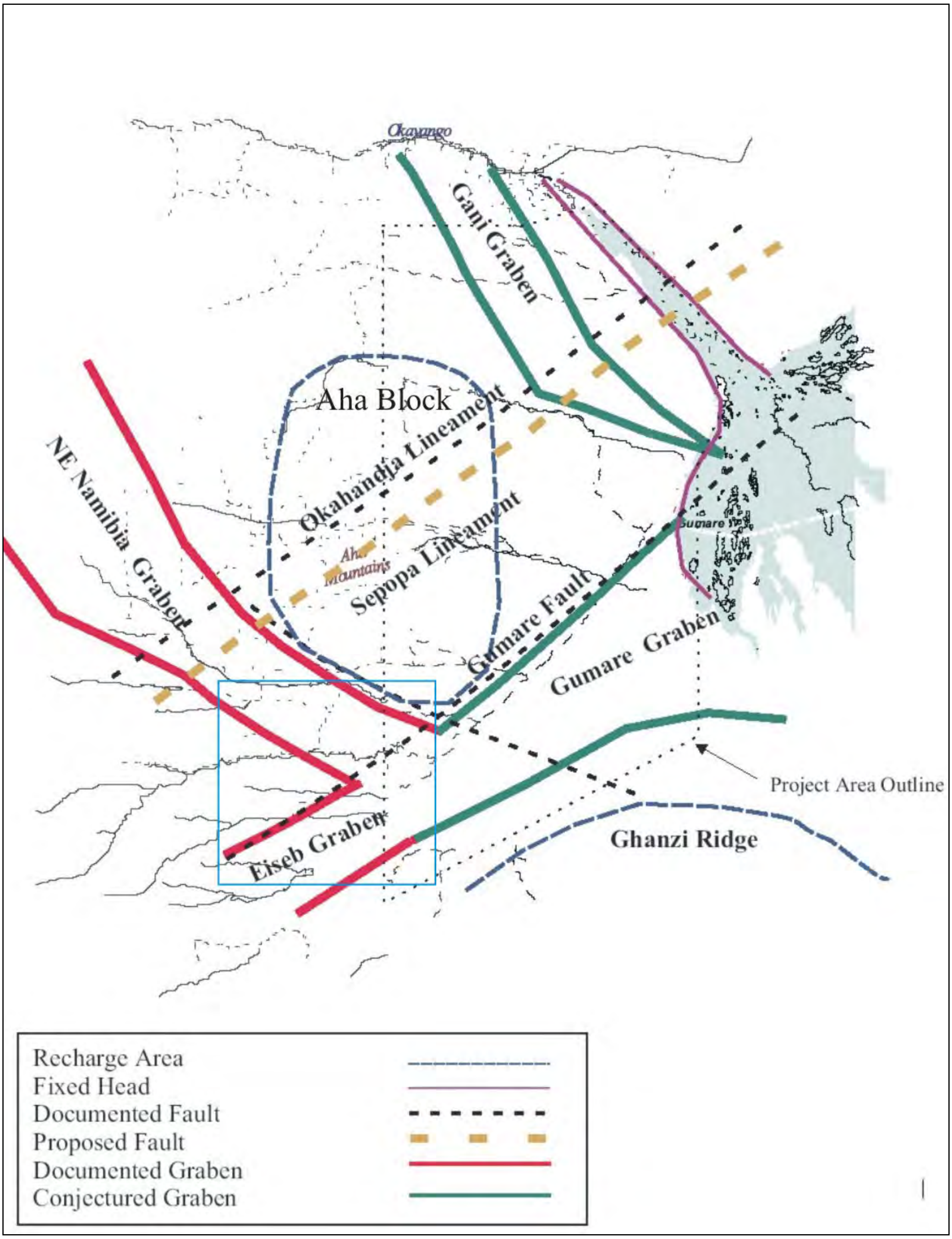


Figure 20: Generalized Tectonic Features in Northeastern Namibia and Northwestern Botswana (modified after AQUALOGIC & WATER SURVEYS BOTSWANA, 2003; light blue line: DWA-BGR project area Eiseb)

3.6 Previous Investigations

Few groundwater investigations have been conducted in this remote area until present. Investigations by SCHOLZ (1976) had suggested that a graben-like structure exists between two main faults, both trending in a NE-SW direction. These faults were believed to be connected to those in the Okavango Delta. In the late 1970s and early 1980s vertical electrical soundings (VES) for the siting of 6 boreholes along the Omuramba Eiseb were carried out by CSIR. Between the late 1980s and the early 1990s gravity and EM surveys were conducted by CSIR and consultants in the Epukiro and Omuramba Elandslaagte area for the siting of 9 boreholes.

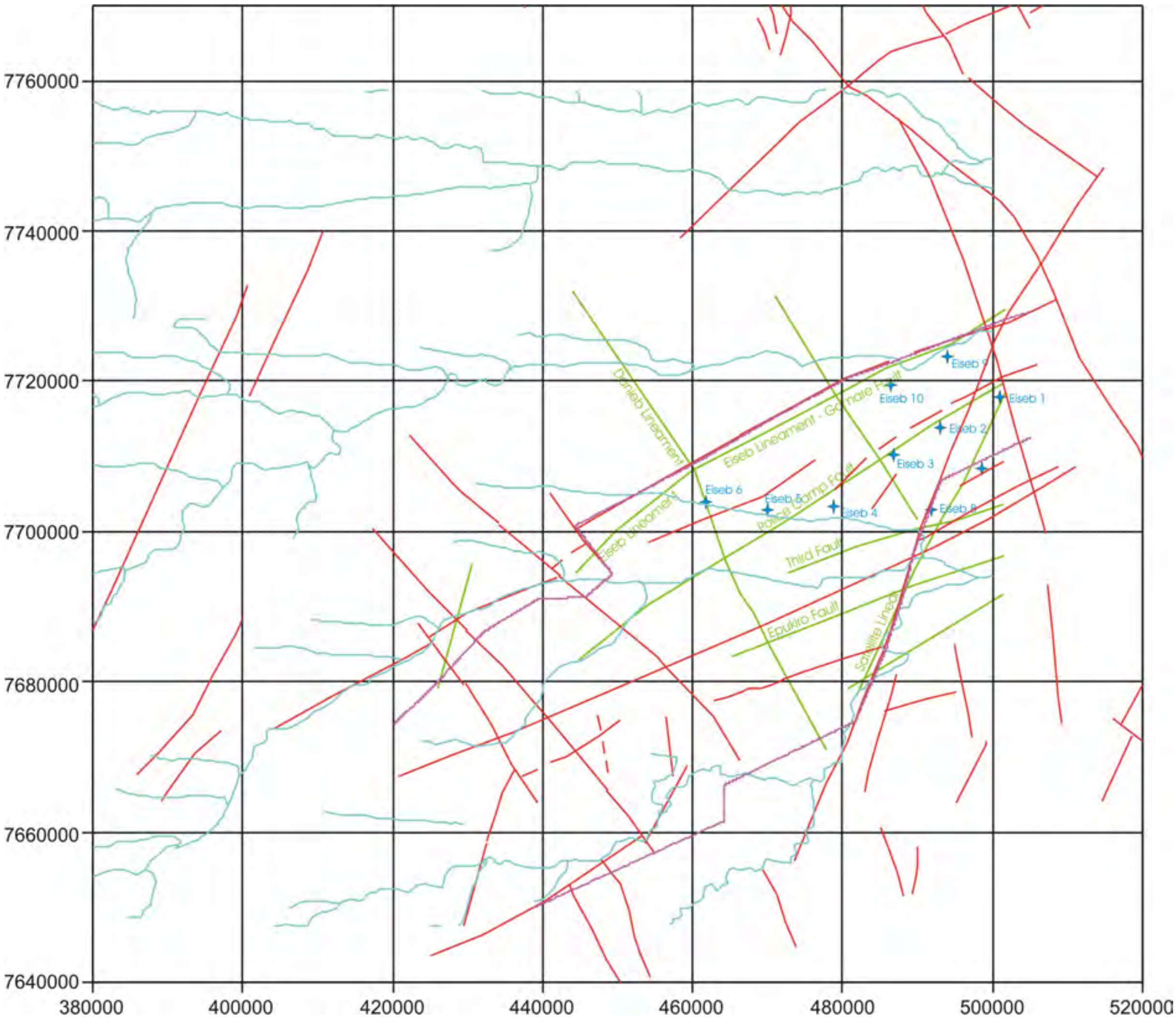


Figure 21: INTERCONSULT (1996) Satellite Image Interpretation (lineaments with names in green color) and Location of boreholes matched with BGR Satellite Image Interpretation (lineaments in red color; graben extent in purple color)

The most significant investigation was undertaken by INTERCONSULT (1996). Within this project 10 boreholes were drilled in the lower Eiseb Graben. The aim of this drilling program was to provide water for the resettlement of some 4000 Herero and Mbandero exiles from Botswana to the Gam area and south of it. Some 20 VES were performed during the investigation. Pumping tests (probably blow tests) and hydrochemical analyses for those boreholes were undertaken, however, no evaluation of the pumping tests was carried out.

The INTERCONSULT boreholes were mainly sited along SW-NE trending assumed faults (compare Figure 21), the so-called Eiseb Lineament – Gomare Fault and the Police Camp Fault, situated some 10 km to the South of the former.

Yields of the boreholes drilled by INTERCONSULT are relatively low, being in the range of 0.5 - > 3.5 m^3/h. Total depth of these boreholes is between 151 and 209 m. EC varied from 74 to 147 mS/m. Transmissivity values were not evaluated.

Another major investigation has been undertaken in the adjacent area in north-western Botswana (AQUALOGIC & WATER SURVEYS BOTSWANA, 2003). This study identified the Eiseb Graben as a possible groundwater resource of moderate potential. However, only one borehole has been drilled nearby the project area (borehole no. 9896: TD: 149 m; yield 0.5 m^3/h; TDS: 2,300 mg/l). Based on aeromagnetic and geomagnetic surveys it concludes that Karoo deposits underlie Kalahari sediments in this area (Figure 18). Borehole 9896, however, encountered biotite schist at a depth of 123 m. According to the regional groundwater flow pattern (Figure 27), it is assumed that a local groundwater recharge mound exists to the north of the project area in the Aha Mountains. Although this groundwater contour map is rather schematic, it seems possible that flow from this area is directed to the Eiseb Graben.

3.7 Summary of Drilling Results

Four boreholes were drilled within the framework of this project. Their location and some essential base data are documented in Figure 22 and Table 4.

Borehole WW41023 was exceptionally successful with a recommended yield of approximately 120 m^3/h, a transmissivity of 553 m^2/d and an electric conductivity of 43 mS/m. The aquifer consists of fine to coarse grained sandstone which is partly calcareous and partly gravelly, and conglomerate (247-257 m bgl). The pumping test clearly shows boundary effects, however, the distance to the boundary/-ies could not be defined yet. Based on the TEM findings, it is assumed that this borehole is located in a deep reaching trench along the northern margin of the graben. It is not clear yet whether this finding indicates an isolated resource resulting from coarse grained deposition in an alluvial fan or rather a more extended resource bound to an aquifer in a channel-like structure. However, isotope data (see below) indicate a relatively young water age so that the hypothesis of an extended trench being in connection with a source that receives present-day recharge seems quite likely.

Table 4: Basic Data of Boreholes Drilled within the Framework of the Project (CDT: constant discharge test)

WW-No	Geophysical_ Sounding	UTM-E	UTM-S	Lat	Long	Elevation_ TEM	TD	Started	Completed
		m	*m*	°	°	*m*	*m*		
WW41023	2_23	470250	7713970	20.67284	20.71558	1068	378	29-06-2004	05-07-2004
WW41024	2_50	476136	7703930	20.76365	20.77197	1072	300	09-07-2004	17-07-2004
WW41025	3_23	451067	7703396	20.76799	20.5311	1122	244	17-07-2004	27-07-2004
WW41026	4_110	454808	7659556	21.16423	20.5659	1125	230	30-07-2004	06-08-2004

WW-No	RWL_CDT	RWL_asl	Yield_CDT	EC_CDT	Transmissivity	Yield_recom
	m	*m*	*m³/h*	*µS/cm*	*m²/d*	*m³/h*
WW41023	150.00	918.00	49.7	430	553	123
WW41024	149.54	922.46	5.4	1380	52.1	2.5
WW41025	172.91	949.09		960		< 0.5
WW41026	137.65	987.35		750		< 0.5

Borehole WW41024 struck a 50 m thick aquiferous, predominantly fine to medium grained sandstone above thick clay deposits. Transmissivity is much less than in WW41023 and EC is considerably higher (138 mS/m), comparable to that of the boreholes drilled by INTERCONSULT (1996), all of which are in the range of 74 to 147 mS/m. The low EC in WW41023 may indicate that this water originates from a different source and was possibly recharged other than the more shallow aquifer struck at WW41024. Due to the fact that borehole WW41023 is screened or open between 148 and 378 m, it may also be that the water in the lower part of the aquifer has a different hydrochemical composition than in the upper part.

Borehole WW41025 which was also targeted at the assumed trench immediately south of the northern margin of the Eiseb Graben unfortunately did not tap the aquifer although it penetrated sediments which generally looked promising to constitute a suitable aquifer, i.e. fine to medium grained sandstone mostly with gravel but also commonly with a slightly clayey matrix. No pumping test could be carried out because the yield was below 1 m³/h. The well was drilled down to 244 m and stopped after entering a clay layer, believed to represent the Tsumkwe Fm.

Borehole WW41026 was targeted at a zone of high resistivity immediately north of the southern margin of the Eiseb Graben, believed to represent a freshwater bearing zone. This well encountered metamorphic schists below 115 m bgl and is believed to be already situated on the southern graben shoulder.

For further information it is referred to Volume IV.BG.3.2 of this series of reports.

4 Groundwater Resources

4.1 Description of Aquifer System

4.1.1 Information from Water and Exploration Wells (Hydrogeological Database)

A hydrocensus was conducted by A. Wierenga (AGES Consult) in order to improve the database for the project area. Altogether 43 wells were visited, 24 of which were previously not in the database. Altogether there are 83 boreholes in the project area (the entire database set up for the project purposes contains 153 wells and is documented in Annex 1). Of those, 43 are situated in the graben itself. During the hydrocensus 20 water samples were collected and later on analyzed.

Figure 22 shows the locations of all boreholes in the project area.

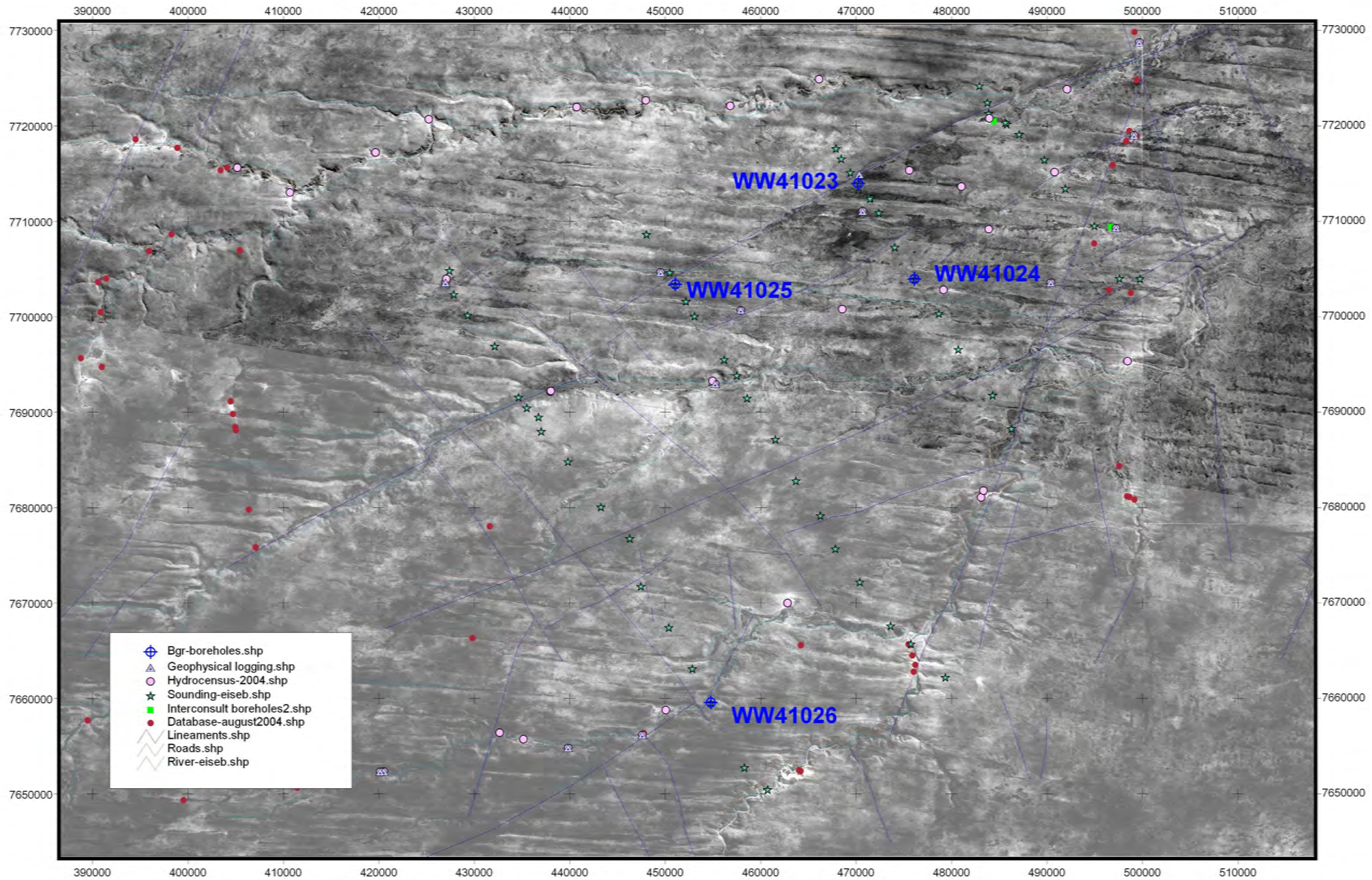


Figure 22: Borehole Location Map of the Eiseb Graben Region

4.1.2 Information from Geophysical Surveys

Ground geophysical surveys were conducted by INTERCONSULT (1996) to determine the depth to bedrock, especially in the Eiseb Graben using Schlummberger array and VES techniques. Based on the results, INTERCONSULT assumes that the thickness of Kalahari sediments in the center of the Graben exceeds 750 m. The interpreted sounding curves are documented in the INTERCONSULT report.

Previous investigations of CSIR and other consultants, which were described by INTERCONSULT, could not be made available.

Numerous geophysical investigations have been undertaken in northwestern Botswana (AQUALOGIC & WATER SURVEYS BOTSWANA, 2003) at a more regional scale. However, no detailed studies are available from the immediate vicinity of the project area.

On behalf of the DWA-BGR technical cooperation project POSEIDON/Botswana conducted a total of 54 time-domain electromagnetic (TEM) soundings across the Eiseb Graben, located on an array of four lines with a spacing of approximately 20 km between lines and a spacing ranging from 1.5 to 7.5 km between TEM measurements. Figure 23 shows the location of these measurements relative to the lineaments mapped by satellite image interpretation conducted by the project. The results of the TEM measurements are documented in FIELITZ et al. (2004) of this series of project reports.

Two boreholes were drilled on TEM line 2 (Figure 24). The third borehole (WW41025) was drilled towards the northern end of TEM line 3, whereas the forth borehole (WW41026) was drilled towards the southern end of TEM line 4. The aim of the first three boreholes was to tap an expected aquifer in a formation with relatively high resistivities (30 – 80 Ωm) at the northern margin of the Eiseb Graben. It was expected that Kalahari sediments had been deposited at the northern margin in a deeply downlifted trench. It was assumed that the forth borehole may penetrate a similar sequence of high resistive layers at the southern margin of the Eiseb Graben. The former assumption was confirmed by the first borehole (WW41023) which penetrated Kalahari sediments of high yield down to a depth of 378 m, while the latter assumption could not be confirmed. Borehole WW41026 entered into basement rocks (gneiss) at a depth of 115 m. It was furthermore assumed that the resistivities below 20 Ωm, which occur in the central and southern parts of the northern part of the Eiseb Graben as well as almost throughout the southern part of the Eiseb Graben with the exception of a very narrow stretch towards its southern margin, represent aquitards. This could be confirmed by borehole WW41024 which penetrated clays between a depth of 251 and 300 m after encountering a saturated aquifer between 149 and 251 m of sufficiently high yield.

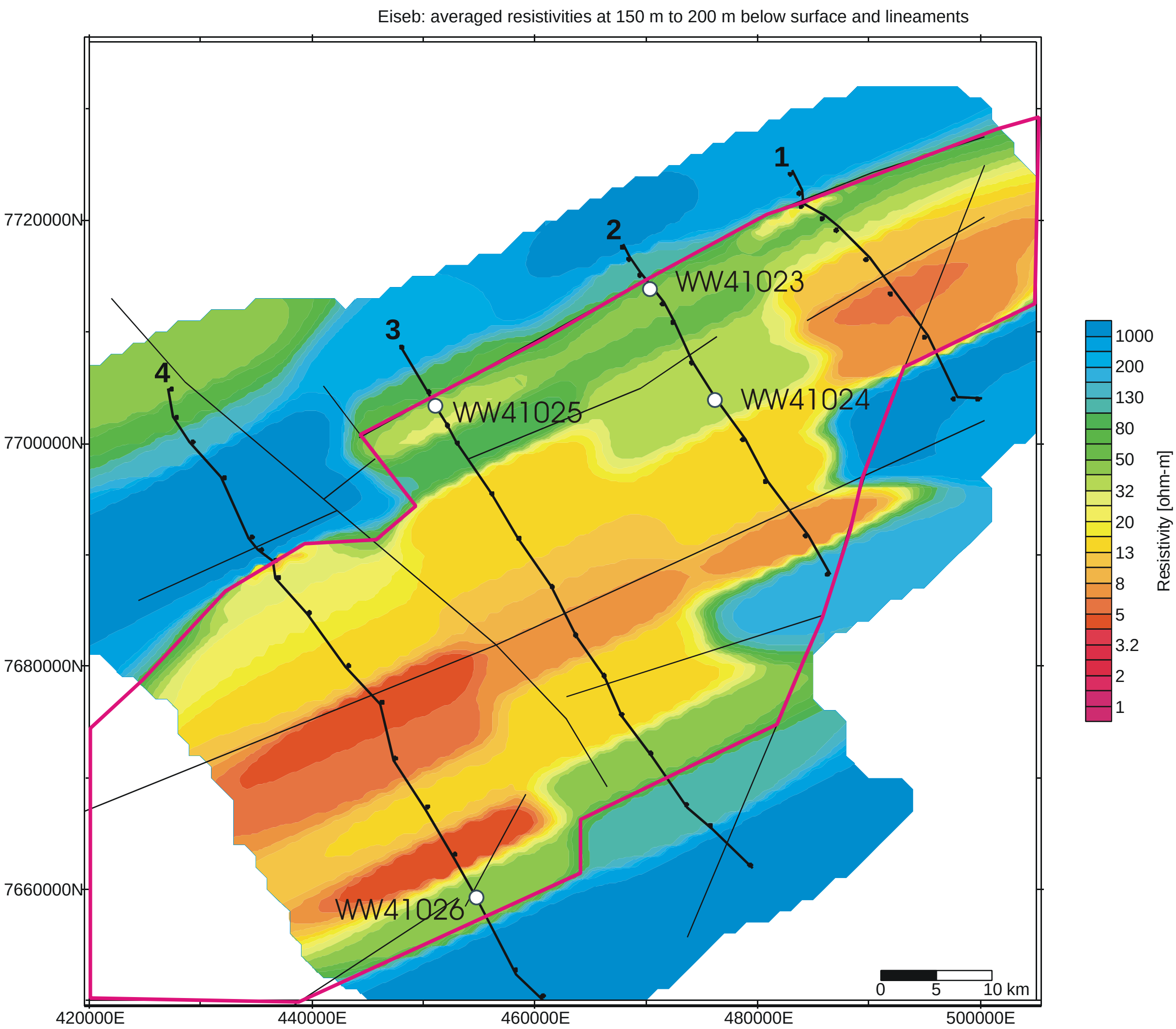


Figure 23: Location of TEM Soundings and Resistivities Interpolated for a Depth Interval of 150-200 m bgl (red line: assumed extent of Graben based on TEM soundings and satellite image lineament interpretation, circles: DWA-BGR boreholes)

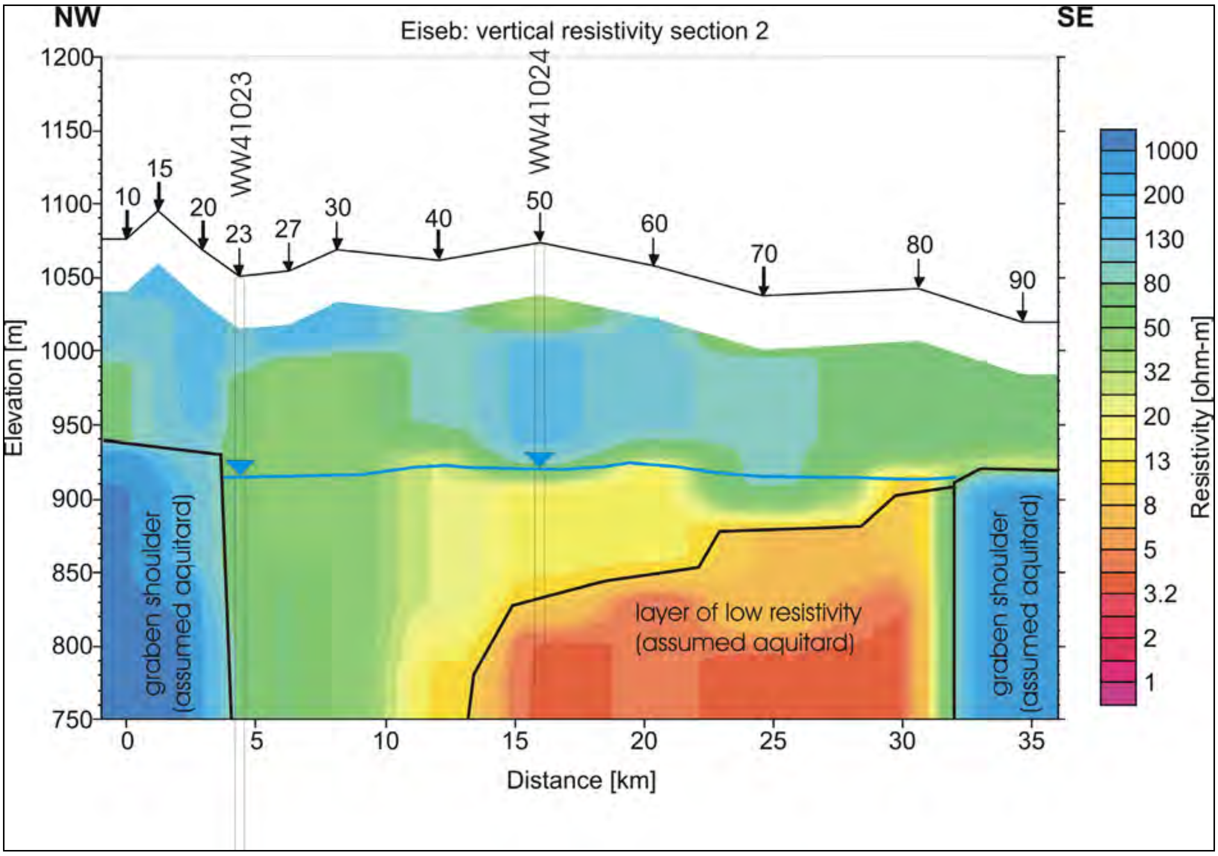


Figure 24: Cross Section along TEM Line 2 showing Locations of TEM Soundings and Interpolated Resistivities together with the Locations of Boreholes and the Distribution of Hydraulic Heads (blue line: assumed, blue triangles: measured)

Borehole geophysical logging was conducted in 17 boreholes in the project area, most of them being located in the graben. However, to only 5 of them there is a lithological borehole log available. Many of the logged boreholes were partly cased so that the geophysical log yields only information for lithological interpretation about the lower part of the borehole.

Lithological logs are available for 29 boreholes in the project area as depicted in Figure 25, most of which are located in the northern part of the graben. However, most of the boreholes in the graben are only 150 to 200 m deep so that a comparison with the new findings is difficult. Almost all of those were described as sandstone forming the main aquifer. From two boreholes, one at the northern (WW40393) and one at the southern margin (WW16653), metamorphic rocks were described to be present in the lower section, possibly constituting the graben shoulders.

It was not possible to make a meaningful correlation of lithological logs due to the strong lithological differences over short distances apart from some general doubts over the correctness of the lithological descriptions in general.

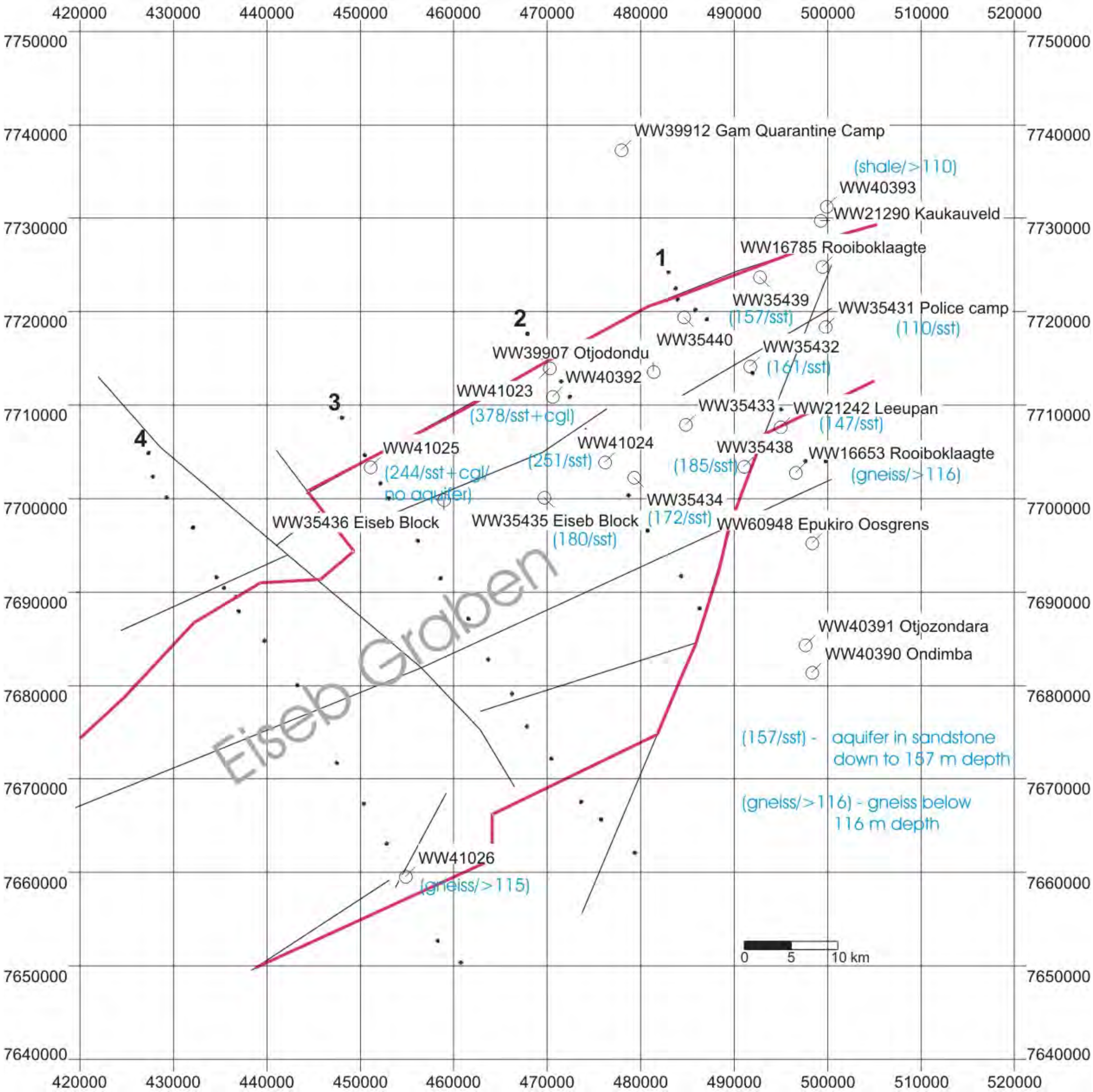


Figure 25: Boreholes with Lithological Logs, Lithology and Assumed Graben Extent

4.1.3 Lateral and Vertical Extent of the Eiseb Graben Aquifer System

The interpolated resistivity section in Figure 24 which was obtained from TEM soundings shows high resistivities exceeding 100 Ωm on the supposed graben shoulders. Based on the resistivity distribution, it could be assumed that within the graben there would be either layers of low resistivity or water with a high salinity. The latter was not confirmed and from the hydrogeological viewpoint not expected since all boreholes drilled by INTERCONSULT (1996) showed low salinities (EC ranging between 75 and 150 mS/m, equivalent to a TDS of between 500 and 1,000 mg/l). According to borehole WW41024, the low resistivities of between 5 and 20 Ωm, which were measured by borehole logging below 150 m bgl, represent a clay layer encountered below a depth of 205 m bgl (with around 10 Ωm in the borehole geophysical log). At borehole WW41026 the graben shoulder (metamorphic schist) was reached at a depth of 115 m bgl (having a resistivity of around 15 Ωm).

Altogether the distribution of geophysical measurements is still insufficient so that it is presently difficult to truly delineate the graben area. Furthermore it is not known whether gneiss is forming the boundary of the graben throughout the area or if other rock units may also occur on the graben shoulders. Those other units may have considerably different resistivities. It is presently also not possible to describe the vertical and horizontal extent of aquifers and aquitards within the graben area due to the limited number and depth of boreholes.

4.2 Groundwater Flow Pattern

For most boreholes in the project area there was no reliable information concerning their elevation. Such data, if existing, was commonly compiled based on elevations estimated from topographic map information. Since elevation intervals usually are 20 m these data are in most cases inadequate for the establishment of a piezometric map.

A major problem that hampers the establishment of such a map is the non-existence of benchmarks in the area. A complete topographic survey of all water wells in the project area would have been too costly to conduct. Another problem is that such a map would require conducting a survey of water levels during a specific time period, which in such a remote area where almost no roads exist is extreme time consuming and costly. This idea was therefore not pursued.

A much better solution proved to be the use of elevation data based on SRTM data (compare above). The piezometric map shown in Figure 26 is therefore based on elevations taken from SRTM images. However, due to missing elevation or water level data, there are altogether only 49 piezometric heads so that the base for this piezometric map is rather weak. The piezometric heads in the Omuramba Otjozondjou are considerably higher than those in the Eiseb Graben. This is possibly due to the fact that groundwater resources are trapped in very local aquifers which are often of limited thickness, directly overlying bedrock, and are not connected to a main aquifer due to the undulating features of the non-aquiferous bedrock. In the Eiseb Graben there seems to be a coherent piezometric head in its lower part only.

Groundwater recharge to the Eiseb Graben Aquifer is assumed to take place through lateral inflow from localized aquifers in the main omurambas (Eiseb, Rooiboklaagte, Epukiro) and possibly through lateral inflow from localized aquifers in surrounding Kalahari deposits. However, little is known about the process in detail and the overall recharge amount.

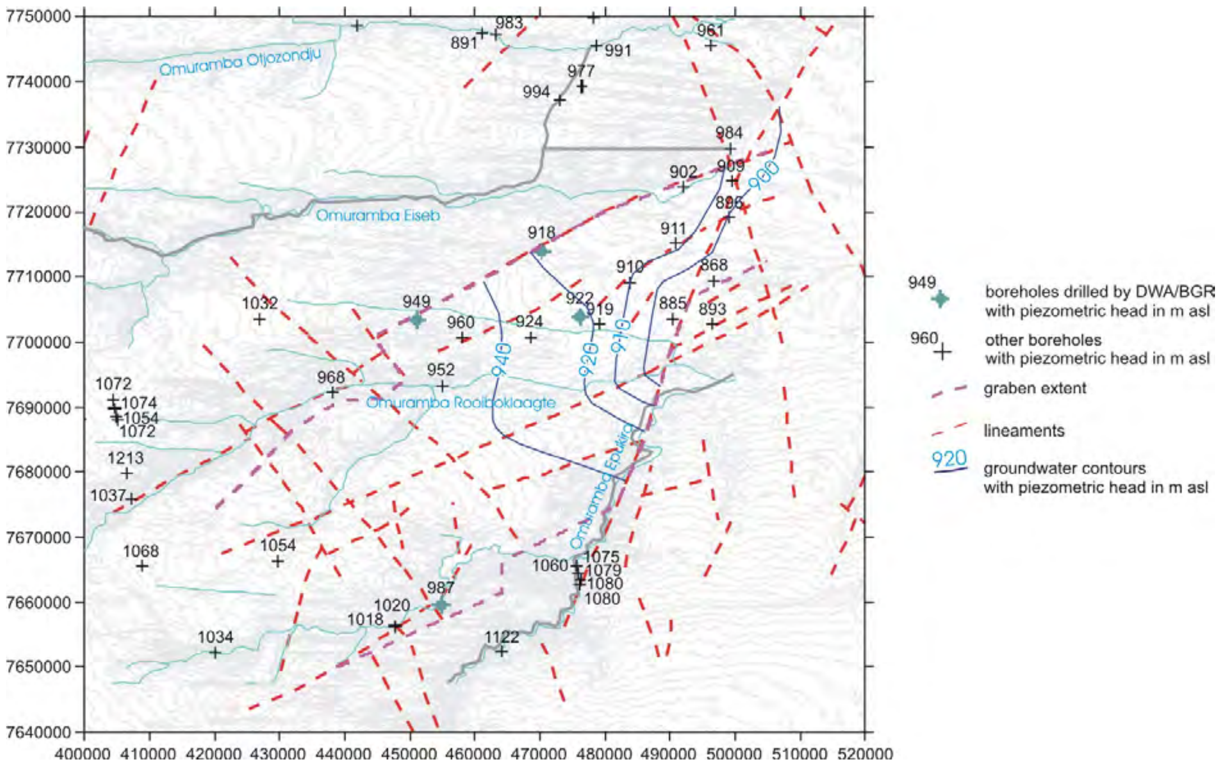


Figure 26: Groundwater Flow Pattern in the Eiseb Graben Region

In the lower part of the Eiseb Graben the hydraulic gradient is around 0.5 to 2 ‰.

The regional, strongly generalized piezometry is shown in Figure 27. According to this groundwater flow from the project area would be directed towards Lake Ngami in Botswana. Figure 27 indicates a local groundwater recharge mound in the Aha Mountains. Groundwater flow from this region may reach the Eiseb Graben.

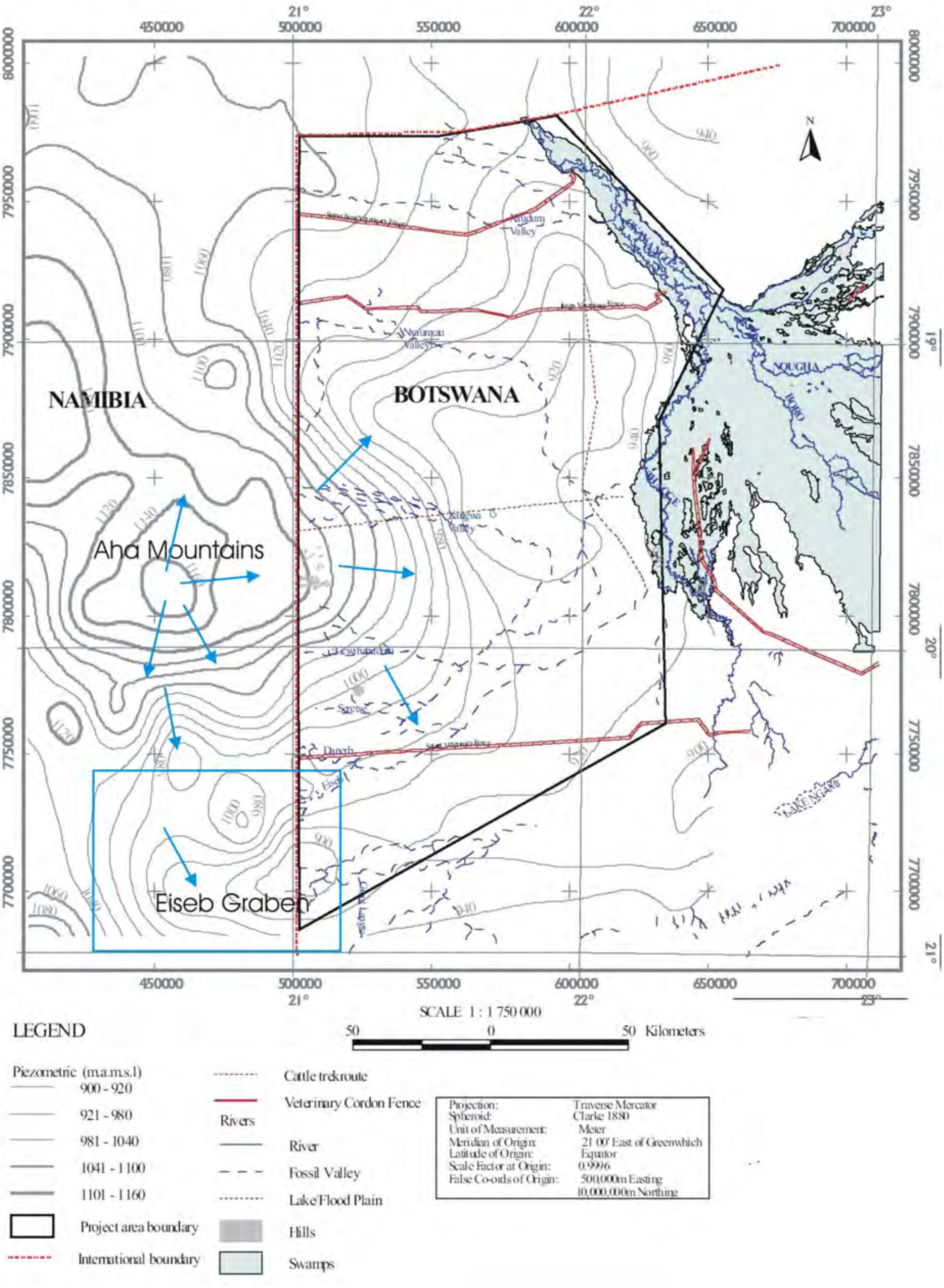


Figure 27: Generalized Regional Piezometric Map of Northwestern Botswana (adopted from AQUALOGIC & WATER SURVEYS BOTSWANA, 2003; project area marked in blue, blue arrows: direction of groundwater flow)

4.3 Hydraulic Parameters

No documents are available on pumping tests of previously drilled wells. Not even drawdowns during pumping tests are reported, so that not even maps showing the potential exploitation potential can be drawn. Therefore, the only hydraulic parameters available for this area are those recorded during the current project.

Only in two of the four drilled wells pumping tests could be carried out, in WW41023 and WW41024. The yields of WW41025 and WW41026 were too low, i.e. below 1 m³/h.

Pumping test data are documented in Volume IV.GW.3.2 of this series of reports. The evaluation of the pumping tests is documented in Volume IV.GW.3.3.

The results are summarized in Tables 5 to 8 and Figures 28 and 29. Since no observation boreholes were located close enough to the boreholes drilled within the framework of the project storage coefficients and distances to boundaries could not be determined. Only transmissivities could be evaluated.

Pumping test data at borehole WW41023 clearly shows boundary effects after a pumping duration of 600 minutes.

Table 5: Design of Step Tests

Pumped Well	**Aquifer**	**Date**	**No. of steps**	**Duration of steps [h]**	**Duration of recovery [h]**	**Range of pumping rate Q_n [m³/h]**	**Pump test crew**
WW41023	Kalahari	24-08-2004	5	1-3	1	10.3 – 49.3	DWA
WW41024	Kalahari	13-08-2004	6	1-2	6	1.1 – 7.7	Metzger
WW41025	-	not tested	-	-	-	yield too low	-
WW41026	-	not tested	-	-	-	yield too low	-

Table 6: Results of Step Tests

Pumped Well	**RWL [m]**	**Max. PWL [m]**	**s_{max} [m]**	**s_{res} [m]**	***B* [h/m²]**	***C* [h²/m⁵]**	***P* [-]**	**Q_{rec} [m³/h]**	**Evaluation Method**	**Determination of drawdown s_n**
WW41023	150.00	155.88	5.88	0.13	0.129	1.1E-4	2	123	Jacob (1947)	Observed steady state drawdown
WW41024	149.62	162.85	13.23	0.08	0.7	1.1E-1	2	2.5	Jacob (1947)	Hantush-Bierschenk (1964)
WW41025	-	-	-	-	-	-	-	< 0.5	-	-
WW41026	-	-	-	-	-	-	-	< 0.5	-	-

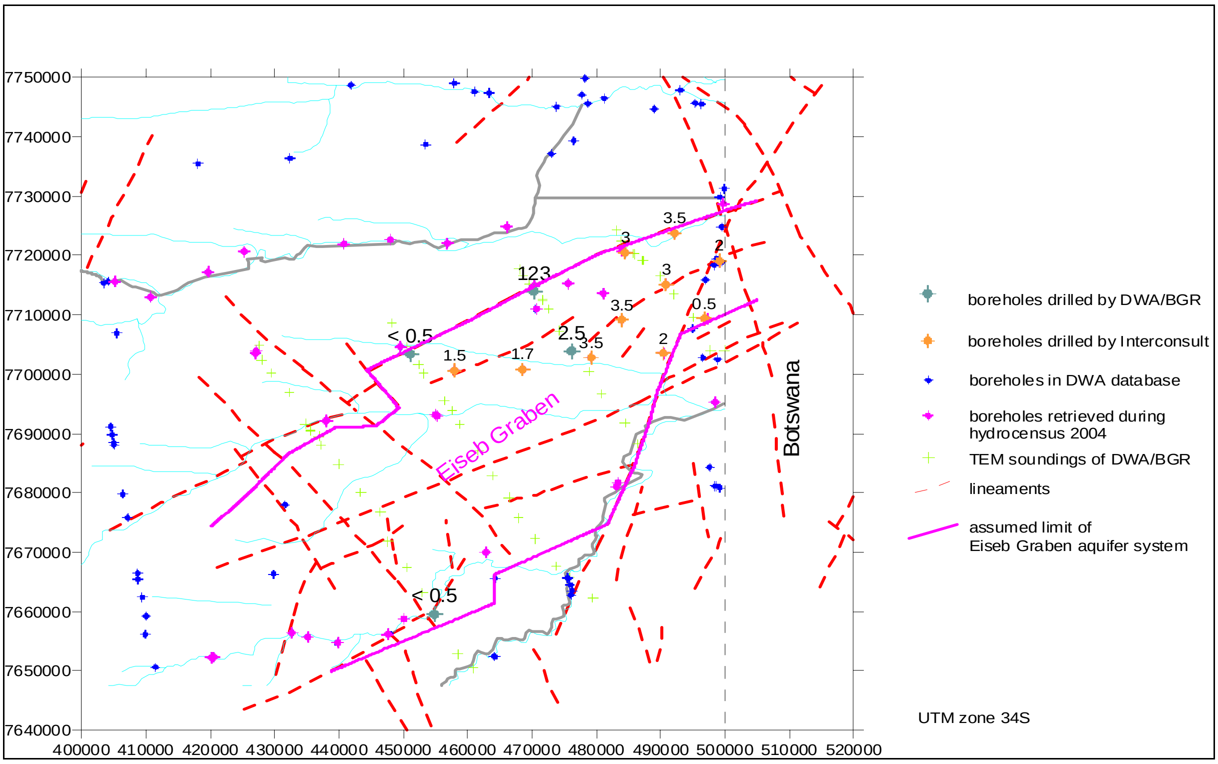


Figure 28: Recommended Yields (m³/h) of Boreholes drilled by DWA/BGR and those drilled by INTERCONSULT (1996) in the Eiseb Graben Aquifer System (values as reported by INTERCONSULT)

Table 7: Design of Constant Discharge Tests

Pumped Well	**Aquifer**	**Observation Well (s)**	**Date**	**Duration of pumping [h]**	**Duration of recovery [h]**	**Pumping rate *Q* [m³/h]**	**Pump test crew**
WW41023	Kalahari	-	25-08-2004	72	72	49.7	DWA
WW41024	Kalahari	-	15-08-2004	36	12	5.4	Metzger
WW41025	-	-	not tested	-	-	yield too low	-
WW41026	-	-	not tested	-	-	yield too low	-

Table 8: Results of Constant Discharge Tests

Pumped Well	**RWL [m]**	**Max. PWL [m]**	s_{max} **[m]**	s_{res} **[m]**	**EC [mS/m]**	***T* [m²/d]**	**Evaluation Method**	**Comments**
WW41023	150.00	156.50	6.50	0.12	43.7	553	Theis (1935)	boundary effects observed
WW41024	149.54	157.69	8.15	0.33	138	52.1	Theis (1935)	boundary effects likely – test too short
WW41025		-	-	-	-	-	-	yield too low
WW41026		-	-	-	-	-	-	yield too low

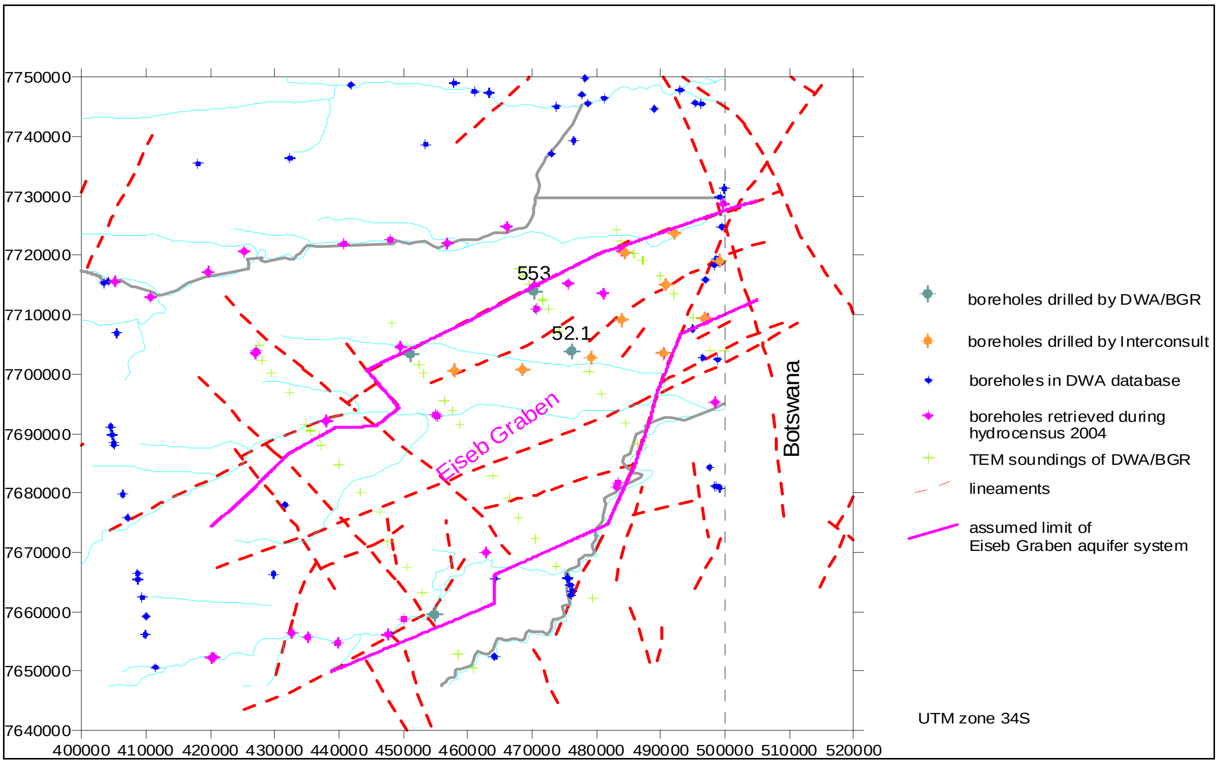


Figure 29: Transmissivities (m²/d) of Boreholes drilled by DWA/BGR

The combined saturated screened and open section of the aquifer at well WW41023 is 222.1 m long, so that the hydraulic conductivity of the aquifer is around 2.49 m/d (2.9E-5 m/s). The saturated screened section can therefore be characterized as a good aquifer. At WW41024 the aquifer thickness is around 81.6 m, so that the hydraulic conductivity is around 0.64 m/d (7.4E-6 m/s). The screened section can be characterized as a moderate aquifer.

No other hydraulic parameters are available for the area because no pumping tests for the boreholes in the area could be made available. Concerning the boreholes drilled by INTERCONSULT (1996), it seems that pumping tests (probably blow tests) were carried out but were not documented in the report. Since it was doubted that the yields reported by INTERCONSULT referred to true recommended yields, a step test was carried out at WW35432 (Pos. 2). This test showed that the recommended yield of this well is much higher (11 m³/h) than the reported value (3 m³/h). The yield would be even higher (around 20 m³/h) if the borehole would be deeper (around 200 m; compare Volume IV.GW.3.3). In view of these findings it is strongly recommended to conduct step tests and constant discharge tests at all INTERCONSULT boreholes drilled in the Eiseb Graben.

The two pumping tests carried out at the DWA-BGR boreholes in the framework of this investigation show that the hydraulic parameters vary considerably over short distances in the graben area.

4.4 Hydrochemical Characteristics

Water samples of 21 wells were analyzed within the framework of this project. Previously 19 analyses were available, however, only 7 of those are within the acceptable limit of 10% analytical error. The results of all analyses are listed in Annex 2. The locations of these samples are shown in Figure 30.

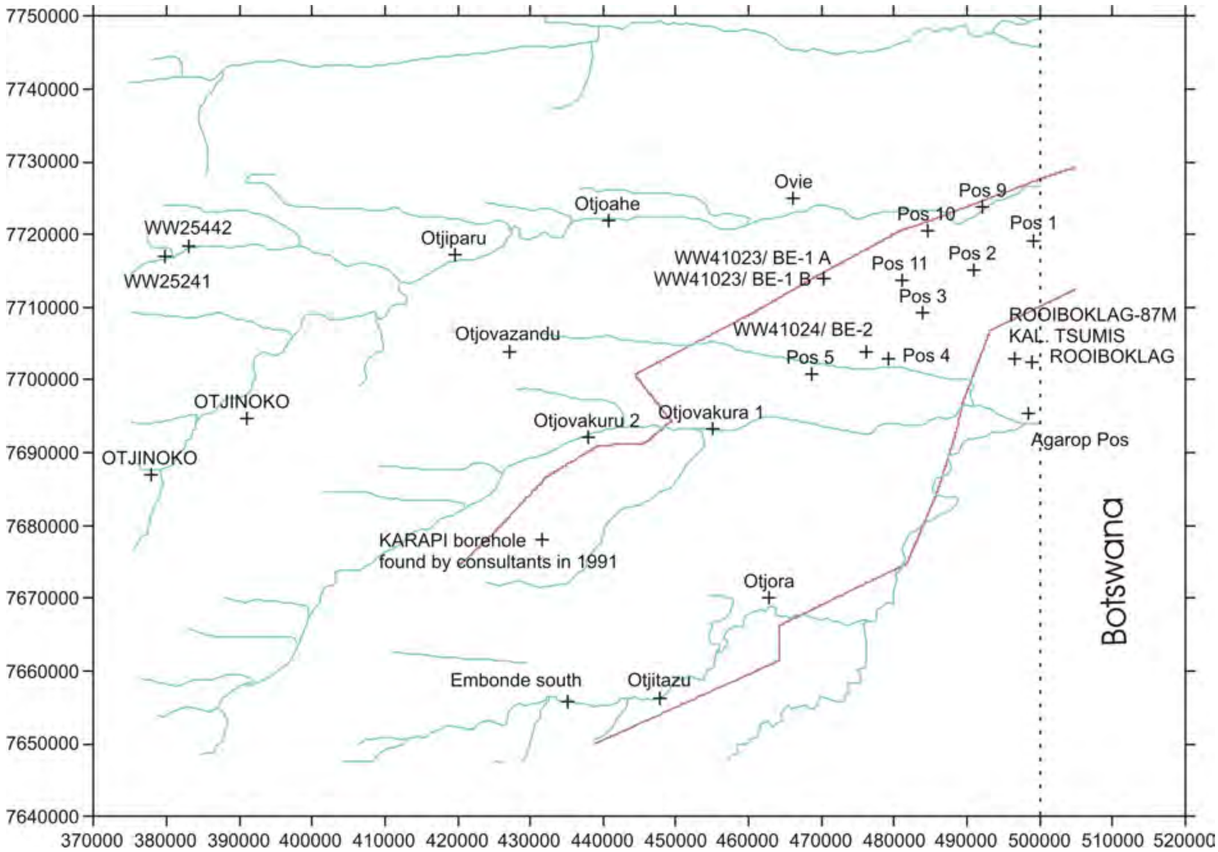


Figure 30: Locations of Boreholes with Chemical Analyses (<10% analytical error)

4.4.1 Groundwater Quality

Water quality varies strongly over the Eiseb Graben Region as depicted in Figure 31. In the lower part of the Omuramba Eiseb and Omuramba Epukiro TDS contents are mostly low, meeting class A standard (<1,500 mg/l) of the Namibian drinking water guideline. In the lower part of the Eiseb Graben class B standard (1,500-2,000 mg/l) is generally met. The lowest TDS value constitutes that of the newly drilled borehole WW41023 (230 mg/l). High salinities occur in the eastern part of Omuramba Eiseb, the eastern part of Omuramba Rooiboklaagte and north of the Epukiro/Rooiboklaagte confluence at the border to Botswana.

Concerning the water types, Figures 32 and 35 and Table 9 show that sodium type waters predominate. Bicarbonate and sulphate dominated waters seem to be equally distributed over the area (Figures 33, 38 and 39).

The main components which may constitute health risks are: nitrate, sodium and sulphate. Nitrate contents (as $N\text{-}NO_3$; Figure 34) entirely fall into categories A (<10 mg/l) and B (10-20 mg/l) and thus conform with the Namibian drinking water standard. However, especially in the lower part of the Eiseb Graben high nitrate contents have been encountered (WW35434: 72.2 mg/l and WW41024: 68.0 mg/l; as NO_3 !), far exceeding the maximum allowable limit of the European drinking water guidelines (50 mg/l). High values are also reported from the lower reaches of the Omuramba Eiseb (maximum of 75.3 mg/l in borehole Ovie; as NO_3).

Sodium contents are relatively high in some parts of the area, exceeding class C limits (400 mg/l) north of the confluence of the Epukiro/Rooiboklaagte Rivers, in the eastern part of the Eiseb Graben, in the eastern reaches of the Omuramba Eiseb, and in the Omuramba Otjozondjou. As can be seen on the Piper diagram and on Figures 35 and 36, sodium is the predominant cation especially in the Eiseb Graben.

Sulphate concentrations are relatively high throughout the area. Values exceeding class B limit (600 mg/l) are recorded at the area north of the confluence of the Epukiro/Rooiboklaagte Rivers, in the eastern part of the Eiseb Graben, in the eastern reaches of the Omuramba Eiseb, and in the Omuramba Otjozondjou (Figure 37). Figure 38 shows that sulphate exceeds 60% of the anions at many locations in the southeastern part of the project area and near the confluence of the Omurambas Epukiro/Rooiboklaagte.

Fluoride concentrations entirely fall into class A (<1.5 mg/l).

Iron contents are commonly below 0.5 mg/l, thus falling into class A (<0.1 mg/l) or B (0.1-1 mg/l).

Bicarbonate often constitutes more than 40% of the anions and therefore dominates many of the samples. The same is valid for Ca+Mg. This, together with the fact that nitrate contents are relatively high in the lower reaches of the Eiseb Graben can be seen as an indication of local groundwater recharge in this area.

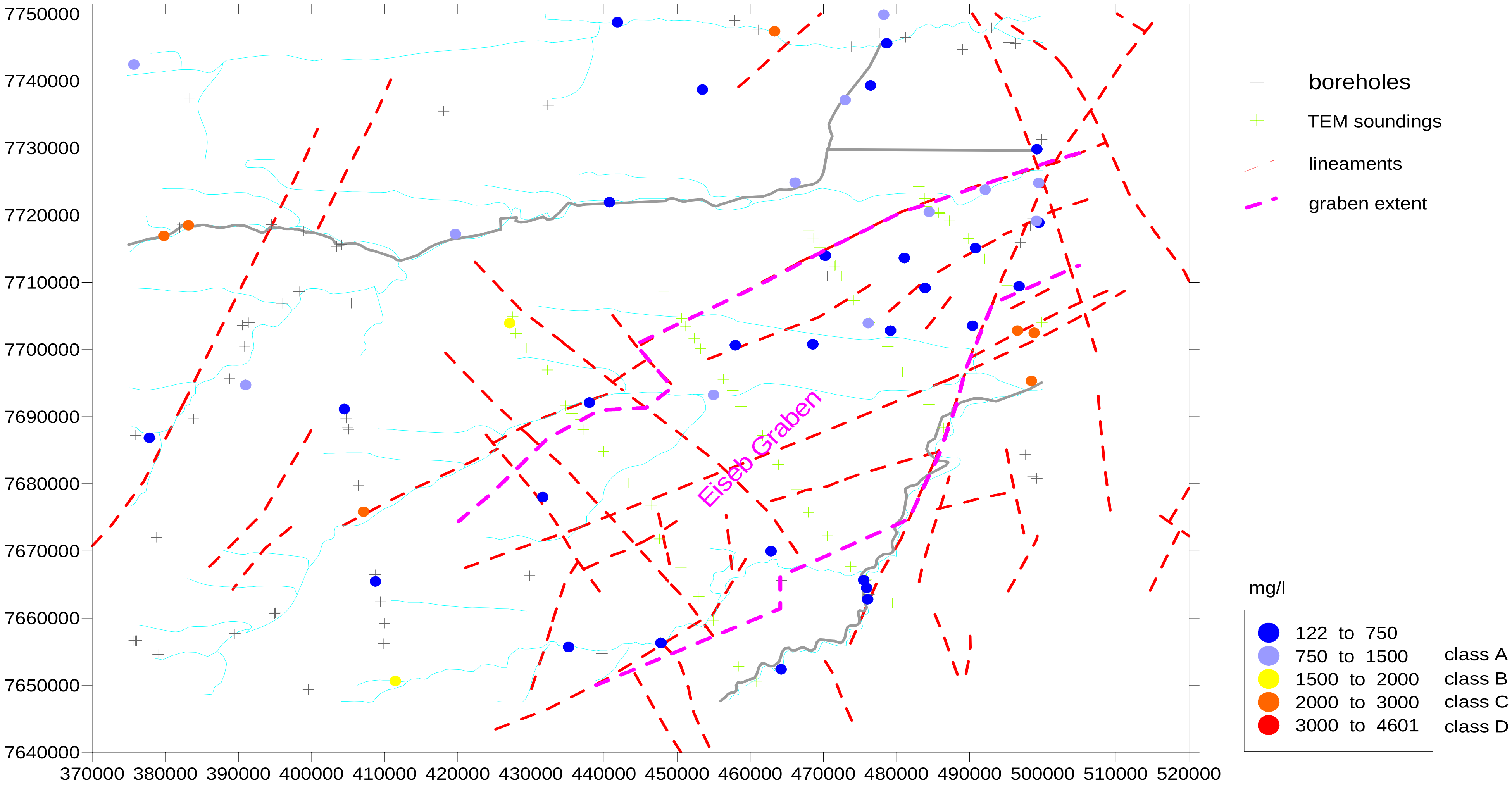


Figure 31: Spatial Distribution of TDS Contents

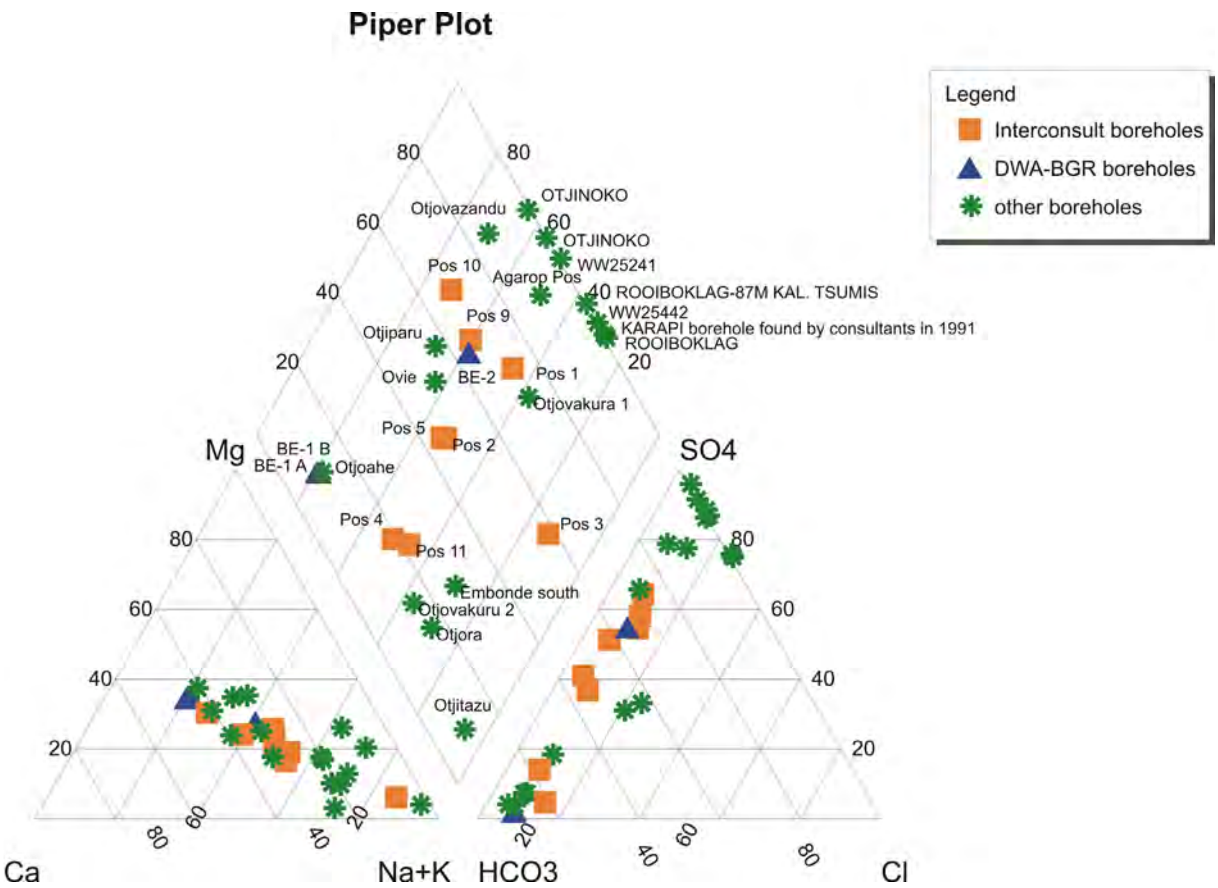


Figure 32: Piper Diagram of all Hydrochemical Analyses (samples with <10% analytical error only)

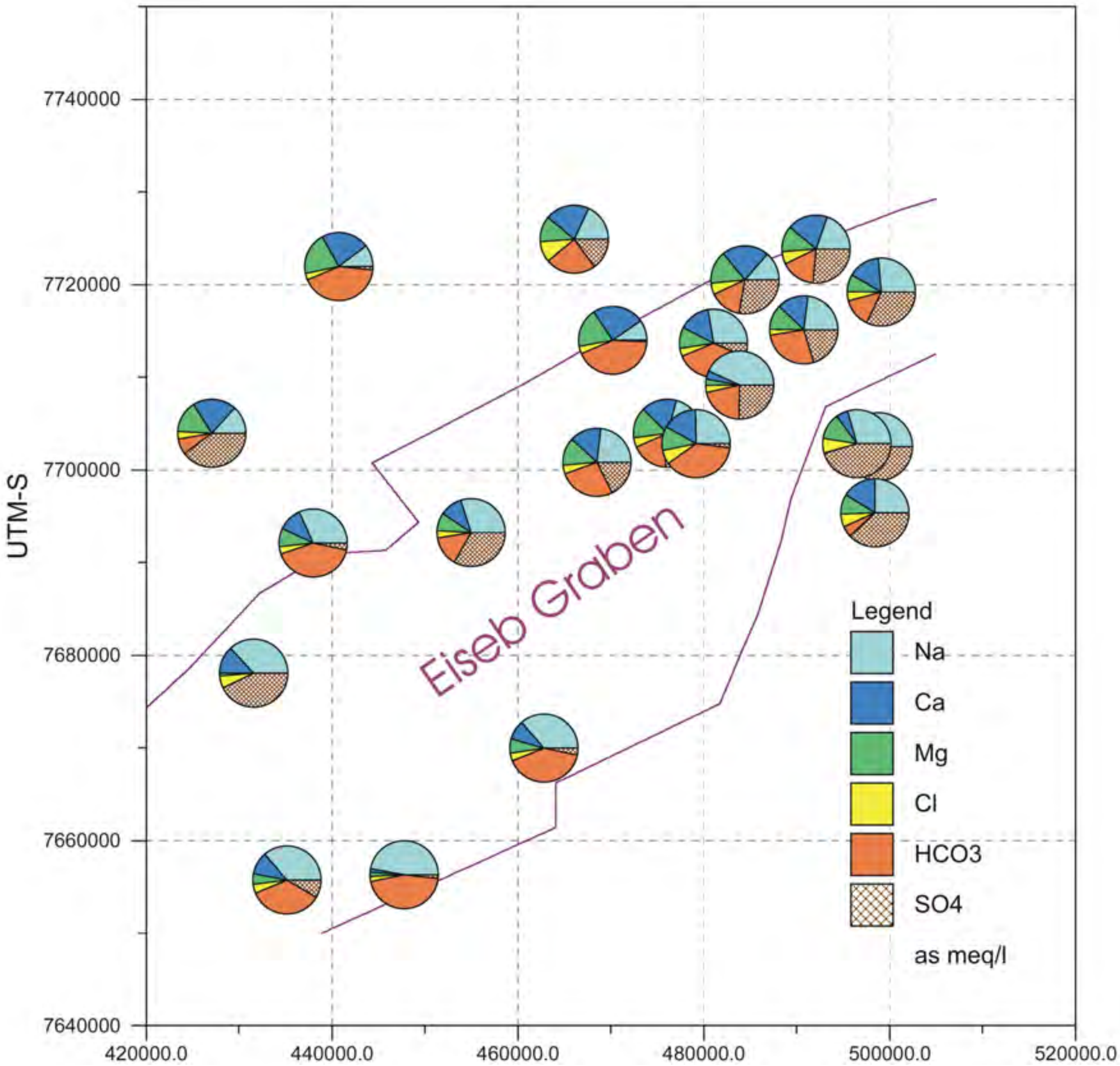


Figure 33: Spatial Distribution of Percentages of Selected Cations and Anions of the Total (samples with <10% analytical error only)

Table 9: Water Types (samples with <10% analytical error only)

Name	WW-No.	UTM-E	UTM-S	Water Type
Agarop Pos	WW 10413	498446.80	7695323.00	Na-Ca-SO4
BE-1 A	WW 41023	470250.00	7713970.00	Ca-Mg-HCO3
BE-1 B	WW 41023	470250.00	7713970.00	Ca-Mg-HCO3
BE-2	WW 41024	476136.00	7703930.00	Na-Ca-Mg-SO4-HCO3
Embonde south	-	435152.80	7655702.00	Na-Ca-HCO3
KARAPI borehole found by consultants in 1991	?	431624.40	7678018.00	Na-Ca-SO4
OTJINOKO	WW25462	377835.90	7686852.00	Mg-Na-Ca-SO4
OTJINOKO	WW25462	377835.90	7686852.00	Na-Ca-Mg-SO4
Otjiparu	-	419676.80	7717197.00	Ca-Mg-Na-HCO3-SO4-Cl
Otjitazu	WW 33168	447780.50	7656297.00	Na-HCO3
Otjoahe	-	440751.60	7721942.00	Ca-Mg-HCO3
Otjora	-	462839.30	7669966.00	Na-HCO3
Otjovakura 1	-	454973.80	7693232.00	Na-Ca-SO4-HCO3
Otjovakuru 2	-	437994.80	7692092.00	Na-Ca-HCO3
Otjovazandu	-	427107.30	7703931.00	Ca-Mg-Na-SO4
Ovie	-	466128.70	7724871.00	Ca-Na-Mg-HCO3-SO4
Pos 1	WW 35431	499122.90	7719143.00	Na-Ca-SO4-HCO3
Pos 10	WW 35440	484468.50	7720482.00	Ca-Mg-Na-SO4-HCO3
Pos 11	WW 39907	481064.20	7713630.00	Na-Ca-HCO3
Pos 2	WW 35432	490791.10	7715102.00	Na-Ca-Mg-HCO3-SO4
Pos 3	WW 35433	483906.20	7709158.00	Na-SO4-HCO3
Pos 4	WW 35434	479176.90	7702808.00	Na-Ca-Mg-HCO3
Pos 5	WW 35435	468547.30	7700781.00	Na-Ca-Mg-HCO3-SO4
Pos 9	WW 35439	492127.60	7723792.00	Na-Ca-Mg-SO4-HCO3
ROOIBOKLAG	WW16666	498829.10	7702481.00	Na-SO4
ROOIBOKLAG-87M KAL. TSUMIS	WW16653	496539.50	7702813.00	Na-Mg-SO4
WW25241	WW25241	379815.60	7716928.00	Na-Ca-SO4-Cl
WW25442	WW25442	383169.90	7718501.00	Na-Ca-SO4-Cl

(remark: blue: $Ca\text{-}HCO_3$ or $Ca\text{-}Mg\text{-}HCO_3$ type waters; orange: waters with SO_4 predominance; green: waters with Na and HCO_3 predominance)

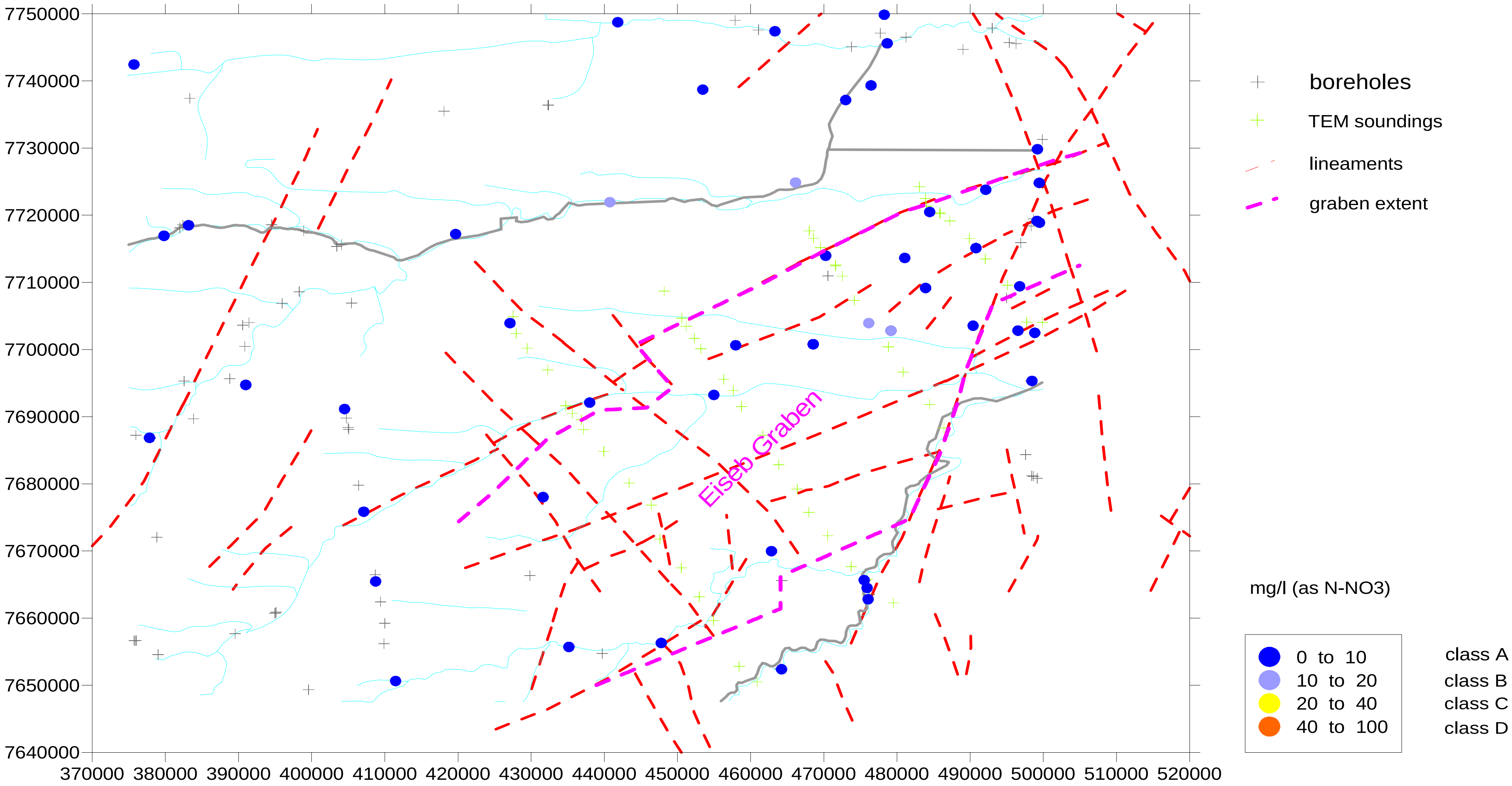


Figure 34: Spatial Distribution of Nitrate Contents

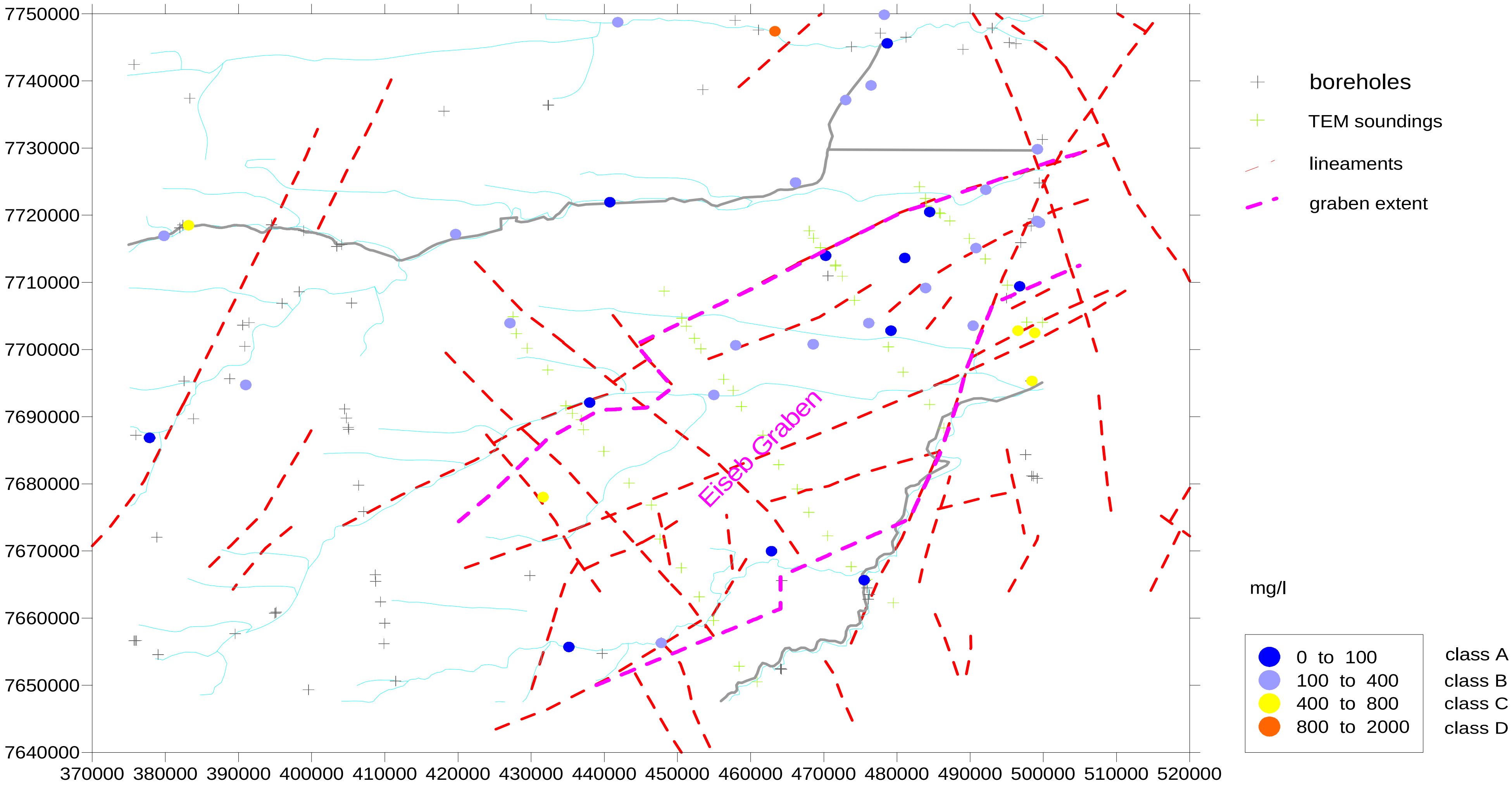


Figure 35: Spatial Distribution of Sodium Contents

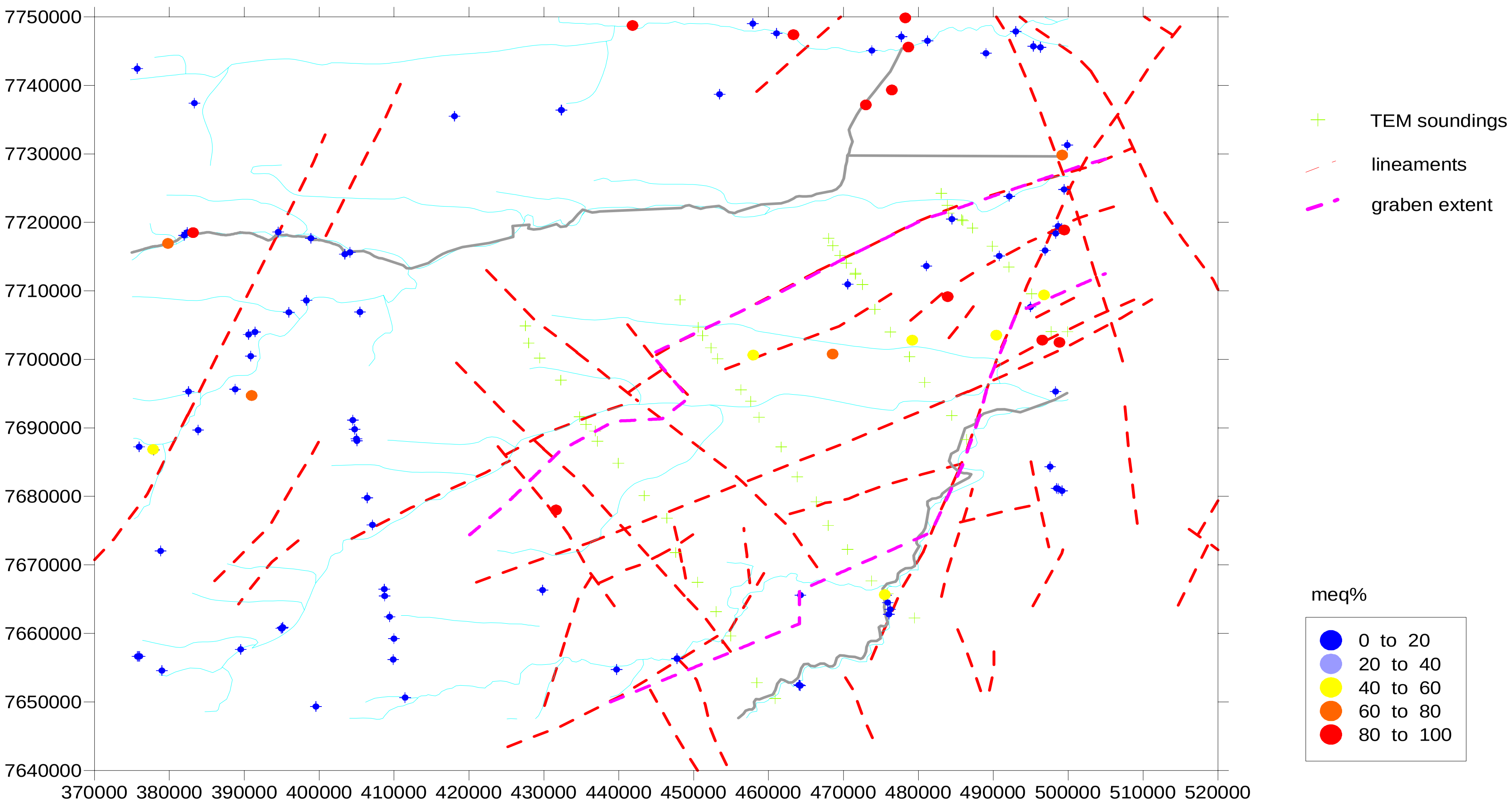


Figure 36: Predominance of Sodium (meq%)

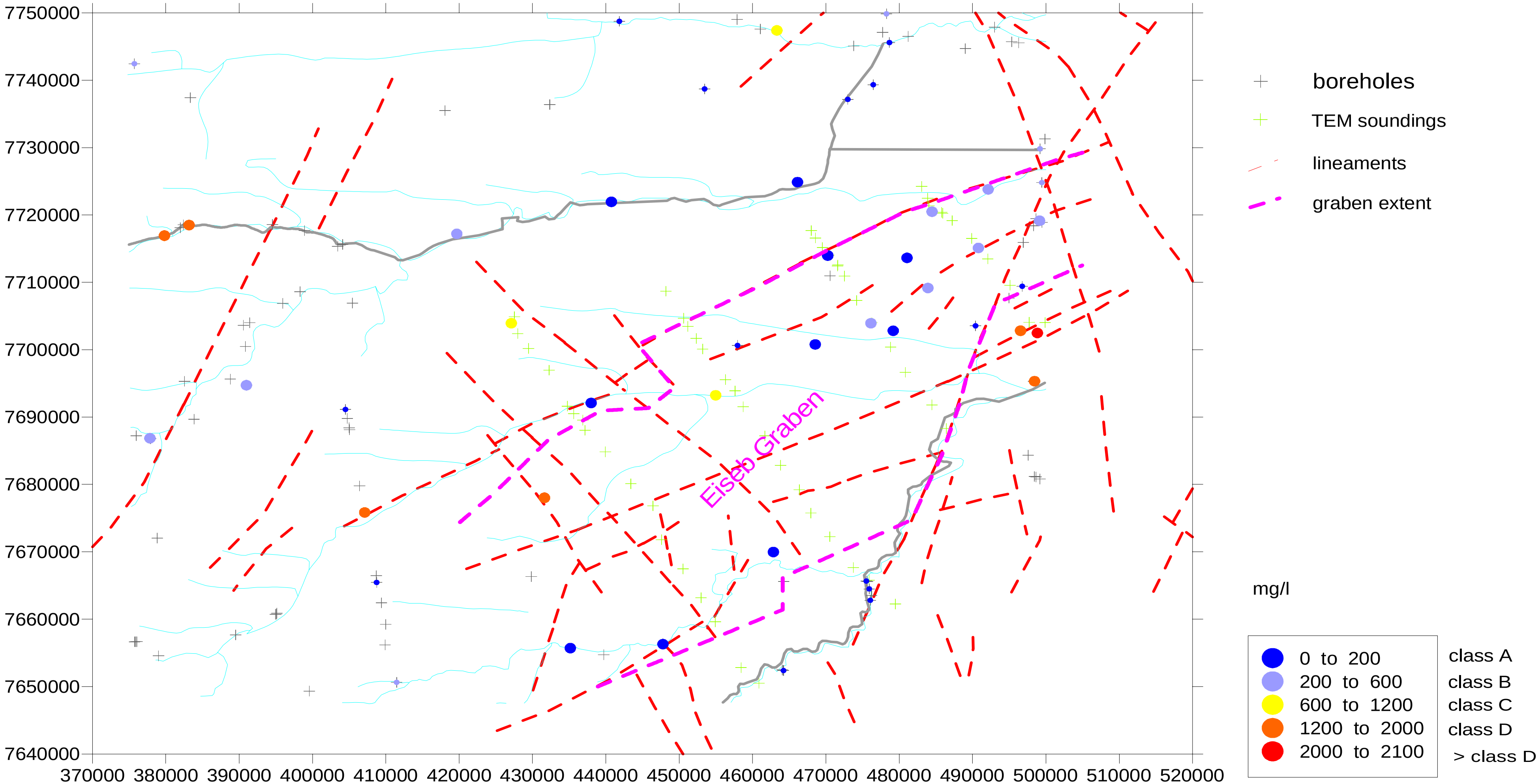


Figure 37: Spatial Distribution of Sulphate Contents

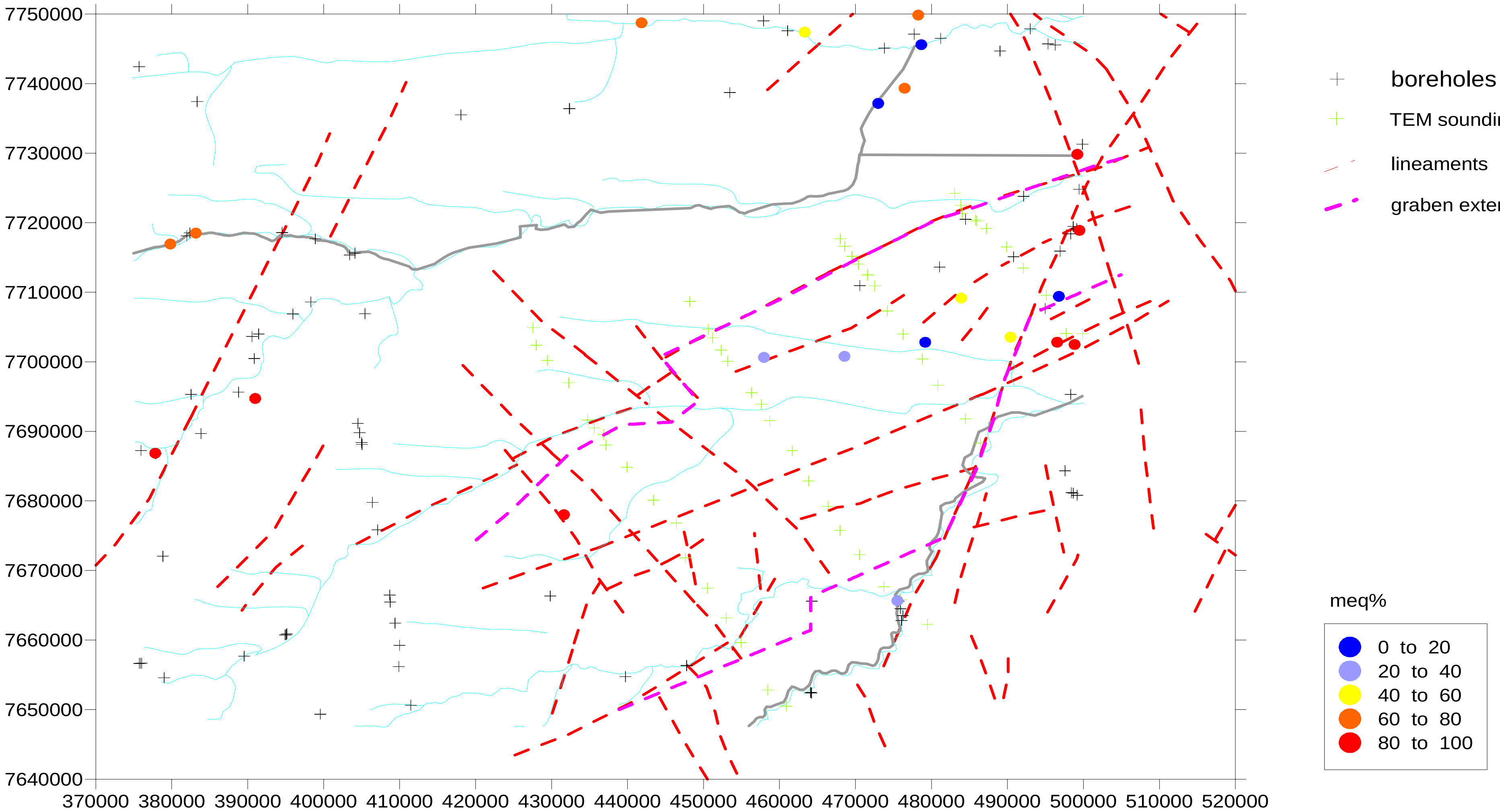


Figure 38: Predominance of Sulphate (meq%)

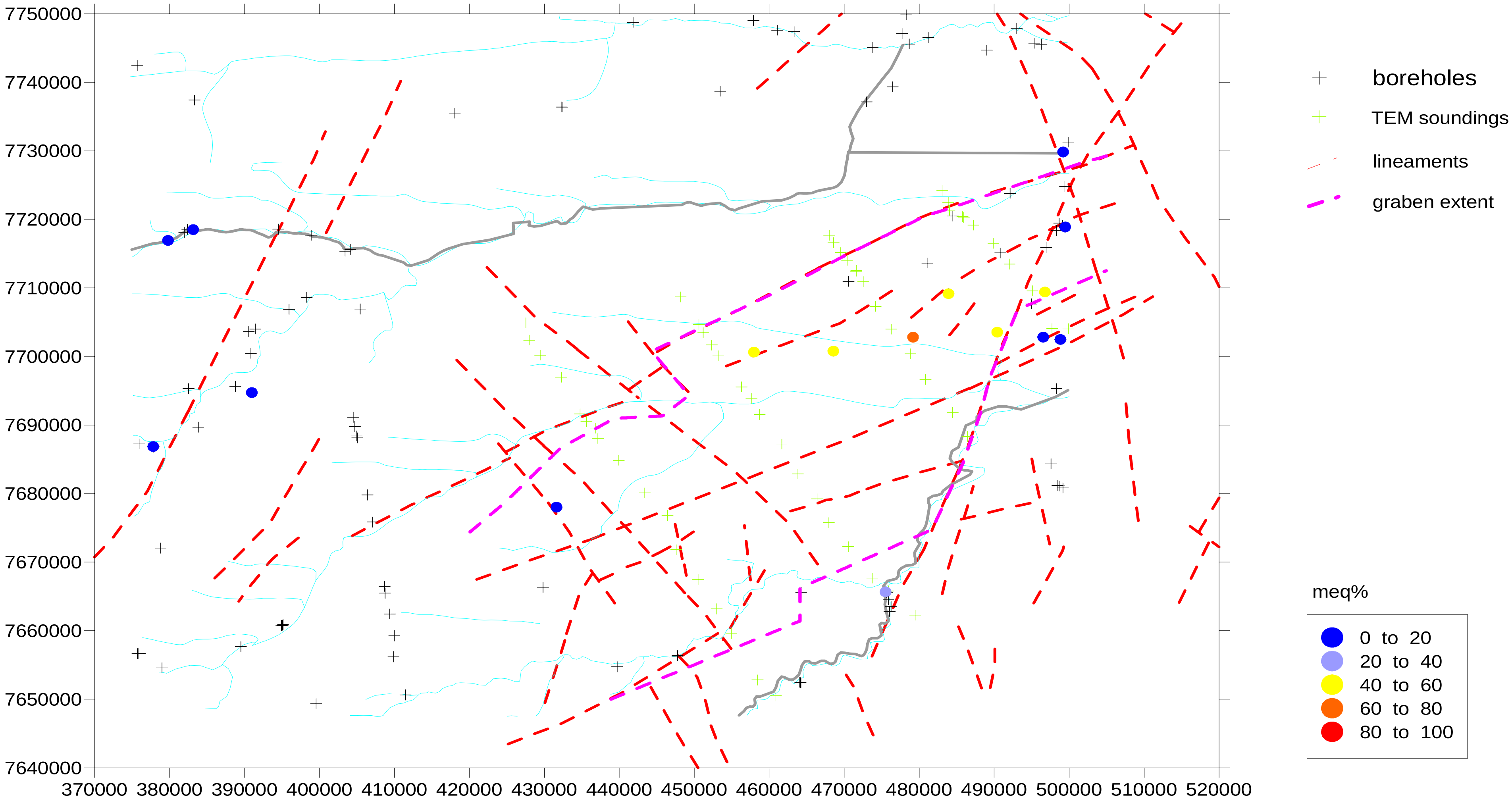


Figure 39: Predominance of Hydrogen Carbonate (meq%)

4.4.2 Isotopic Composition

Twenty-one groundwater samples from the project area were analyzed for stable and radioactive isotopes (deuterium, oxygen-18, tritium, carbon-14 and carbon-13) at Schonland Research Institute for Nuclear Sciences of the University of the Witwatersrand, South Africa. The results are compiled in Table 10 and Figures 40 to 48.

Table 10: Results of Isotope Analyses in the Eiseb Graben Region

IDN	Name	Latitude	Longitude	UTM-E	UTM-S	d D (‰)	d^{18}O (‰)	Tritium (TU)	accuracy	Carbon-14 (pmc)	accuracy	d^{13}C (‰)
WW39907	Pos 11	-20.67613	20.81942	481064.16	7713621.69	-54.6	-7.93	0.0	±0.2	30.9	±1.9	-9.46
WW35433	Pos 3	-20.71652	20.84666	483905.18	7709155.07	-55.0	-7.90	0.2	±0.2	12.5	±1.6	-6.87
WW35434	Pos 4	-20.77389	20.80109	479168.55	7702801.34	-54.3	-7.53	0.2	±0.2	53.9	±2.1	-9.52
WW10413	Agaroppos (Nam/Botswana Border)	-20.84159	20.98632	498446.75	7695322.31	-53.2	-7.56	0.0	±0.2	40.2	±2.0	-8.74
WW35431	Pos 1	-20.62806	20.99292	499132.30	7718951.49	-54.7	-7.81	0.0	±0.2	15.8	±1.7	-7.08
WW35432	Pos 2	-20.66277	20.91318	490827.59	7715108.13	-53.3	-7.62	0.5	±0.2	63.3	±2.2	-9.72
WW35439	Pos 9	-20.58423	20.92551	492107.77	7723799.87	-53.3	-7.90	0.0	±0.2	19.6	±1.7	-10.24
WW35440	Pos 10	-20.61157	20.84741	483972.35	7720768.80	-54.8	-7.87	0.2	±0.2	10.7	±1.6	-10.33
WW35435	Pos 5	-20.79203	20.69919	468567.12	7700777.54	-49.8	-7.03	0.0	±0.2	62.1	±2.2	-9.50
	Rooiboklaagte Omuramba - Otjovakuru	-20.85994	20.56837	454973.77	7693231.52	-53.5	-7.28	0.1	±0.2	47.5	±2.0	-8.67
	Rooiboklaagte Omuramba - Otjovakuru No.2	-20.86975	20.40510	437994.83	7692091.72	-44.9	-6.15	0.1	±0.2	47.4	±2.0	-9.70
	Ovie	-20.57427	20.67622	466128.72	7724870.28	-59.6	-8.76	0.6	±0.2	60.9	±2.2	-7.81
	Otjoahe	-20.60011	20.43261	440751.57	7721941.40	-58.8	-8.49	0.0	±0.2	49.0	±2.1	-10.18
	Otjiparu	-20.64220	20.23014	419676.75	7717196.85	-59.5	-8.57	0.3	±0.2	62.0	±2.2	-9.65
	Ojovazandu	-20.76238	20.30092	427107.27	7703930.41	-54.4	-7.94	0.2	±0.2	49.7	±2.5	-9.60
WW33168	Ojtitazu	-21.19489	20.49659	447624.29	7656142.08	-54.2	-7.92	0.7	±0.2	13.5	±1.7	-9.17
	Embonde (South)	-21.19847	20.37641	435152.85	7655701.53	-54.2	-8.12	0.1	±0.2	18.7	±1.7	-9.35
	Otjora	-21.07035	20.64349	462839.32	7669965.82	-48.4	-6.94	0.1	±0.2	0.0	±1.5	-7.32
WW41023	BE-1	-20.67284	20.71558	470249.52	7713970.26	-55.1	-7.87	0.3	±0.2	60.7	±2.2	-9.88
WW41023	BE-1	-20.67284	20.71558	470249.52	7713970.26	-54.0	-7.85	0.1	±0.2	55.2	±2.1	-9.73
WW41024	BE-2	-20.76365	20.77197	476136.32	7703930.50	-52.8	-7.62	0.0	±0.2	51.1	±2.1	-9.65

Tritium values above 0.2 (accuracy) have been found at 5 locations in the area, three of them inside the graben area, the remainder outside. They indicate that some level of recent recharge reaches the graben area. Important in this regard is the detection of 0.3 TU in borehole WW41023.

The ^{14}C values cover a wide range, from 0 pMC to 63 pMC, i.e. from completely static (old) to dynamic (sub-recent) groundwater. There is no clear correlation with $\delta^{13}C$ values (Figure 45). Old water is present at the southern margin of the graben, around borehole WW41026 (Figure 43). However, at the same time tritium is recorded in some of these wells. Difficult to explain is the presence of old water near the point where the Omuramba Eiseb reaches the Eiseb Graben. Some of these boreholes are even devoid of tritium, despite the fact that recharge must take place in the Omuramba Eiseb as evidenced by the tritium content there (Figure 42). The tritium – ^{14}C correlation (Figure 46) shows that mostly high carbon-14 levels coincide with high tritium levels, indicating relatively young groundwater that was sub-recently recharged. On the other hand low carbon-14 values commonly coincide with tritium contents around the detection level. There are, however, four samples containing low amounts of carbon-14 but some tritium, in one case even 0.7 TU. It is assumed that mixing of old and sub-recent groundwater takes place in these wells (WW41023, WW33168, WW35432).

Most of the δ^2H / $\delta^{18}O$ values fall in a fairly narrow range and can be divided into two categories: those lying close to or on the Global Meteoric Water Line (GMWL: $\delta D=8*\delta^{18}O+10$) with a deuterium excess (D) of +10 and those with a lower D value and generally following a regression of slope of approximately 5.5 (Figure 47). This is evidence of various degrees of evaporative loss prior to infiltration. Both samples from the currently drilled boreholes (WW41023, WW41024) plot on this evaporation line. A similar slope is seen for both shallow and deep groundwater at Stampriet in a similar dune landscape.

The plot of $\delta^{18}O$ against ^{14}C (Figure 48) does no show any correlation. However, lower ^{14}C (older) groundwater has a narrow range of values around approximately -7.9‰ $\delta^{18}O$ whilst the more recent groundwater scatters considerably – a classic "homogenizing" effect in deeper aquifer horizons.

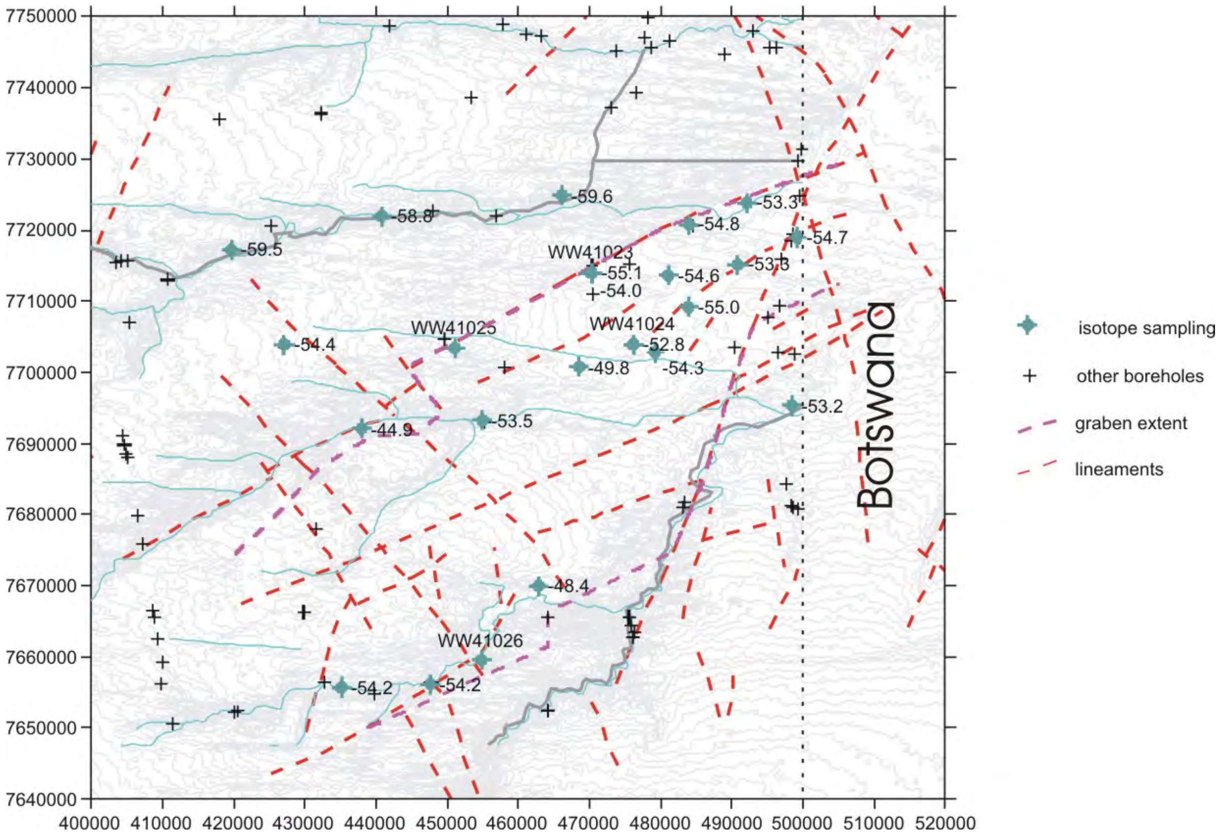


Figure 40: Spatial Distribution of Delta Deuterium Values (‰) in the Eiseb Graben Region

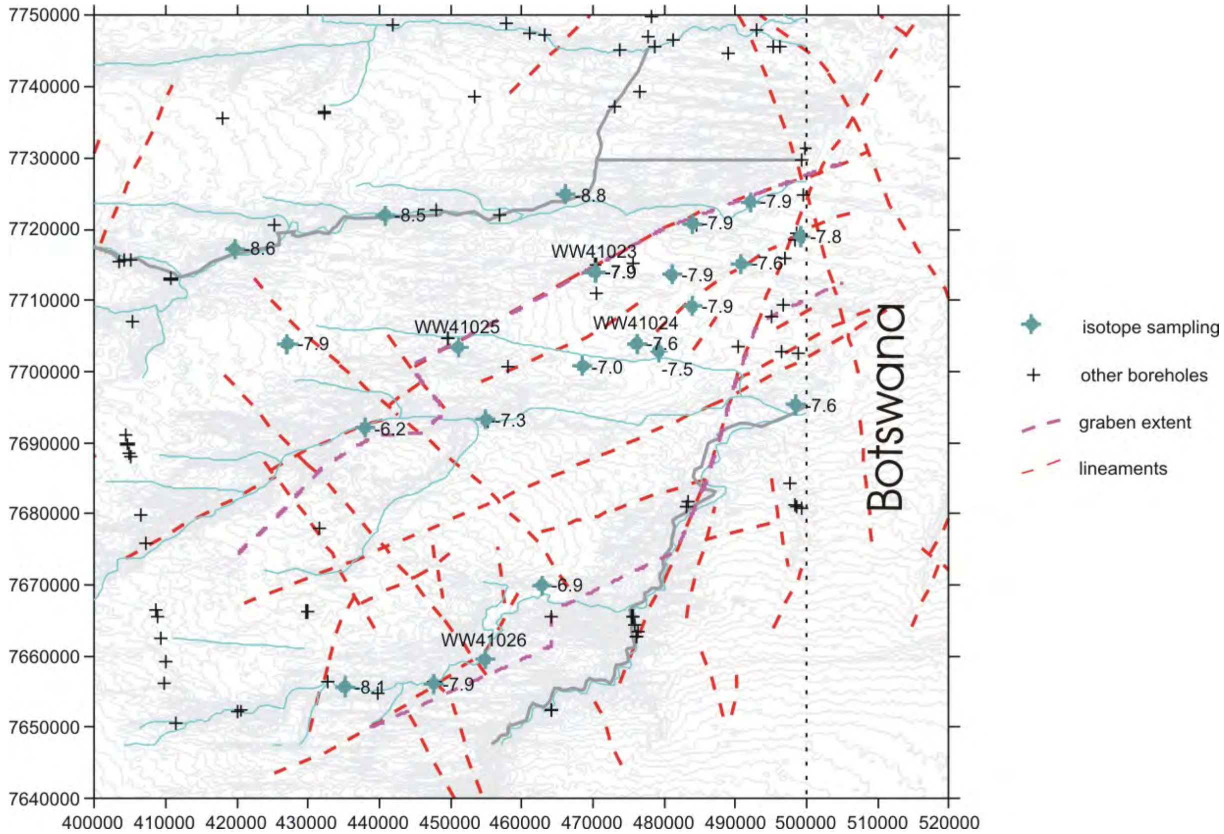


Figure 41: Spatial Distribution of Delta Oxygen-18 (‰) Values in the Eiseb Graben Region

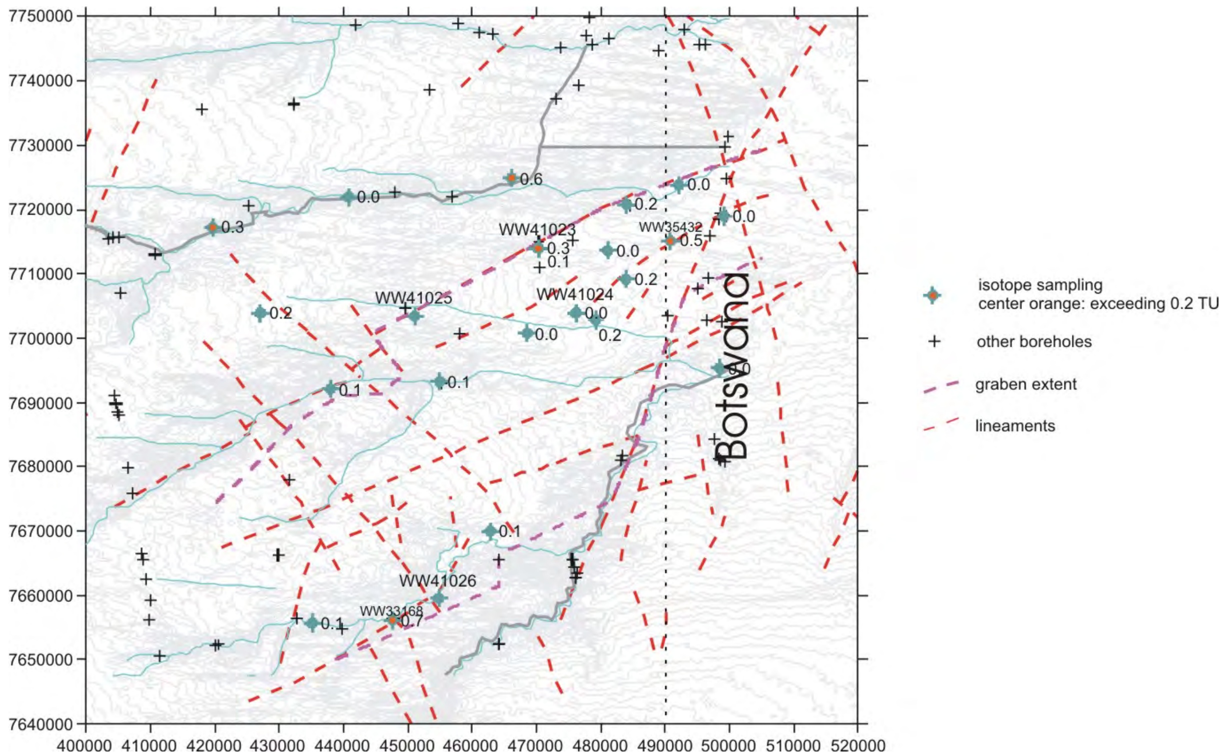


Figure 42: Spatial Distribution of Tritium Values (TU) in the Eiseb Graben Region

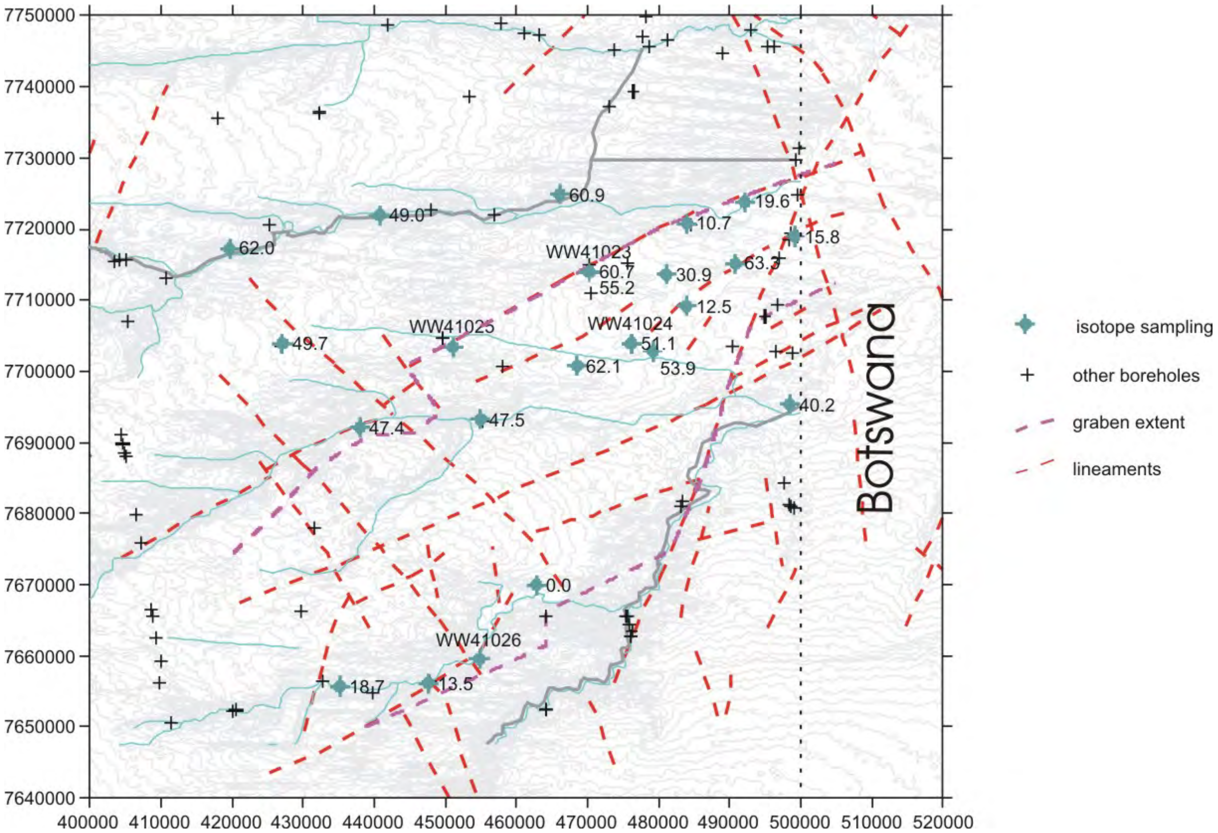


Figure 43: Spatial Distribution of Carbon-14 Values (pMC) in the Eiseb Graben Region

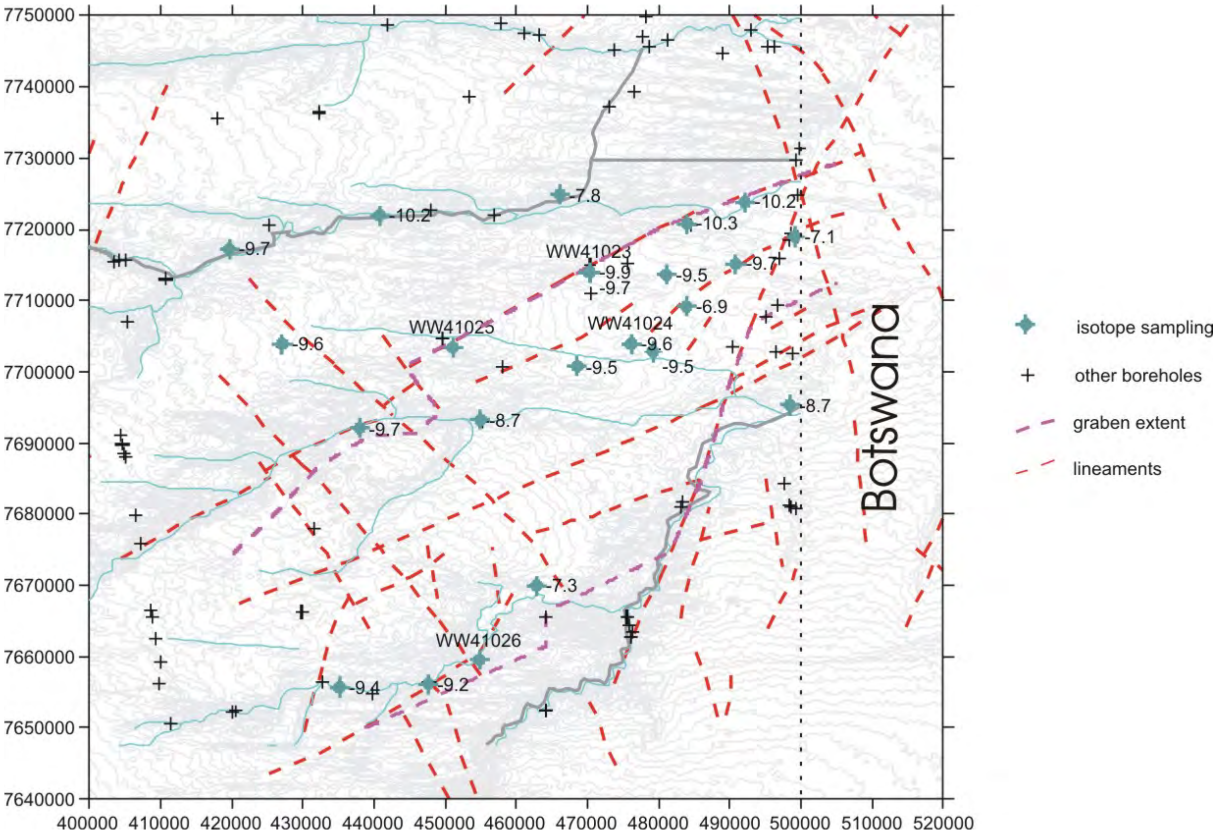


Figure 44: Spatial Distribution of Delta Carbon-13 Values (‰) in the Eiseb Graben Region

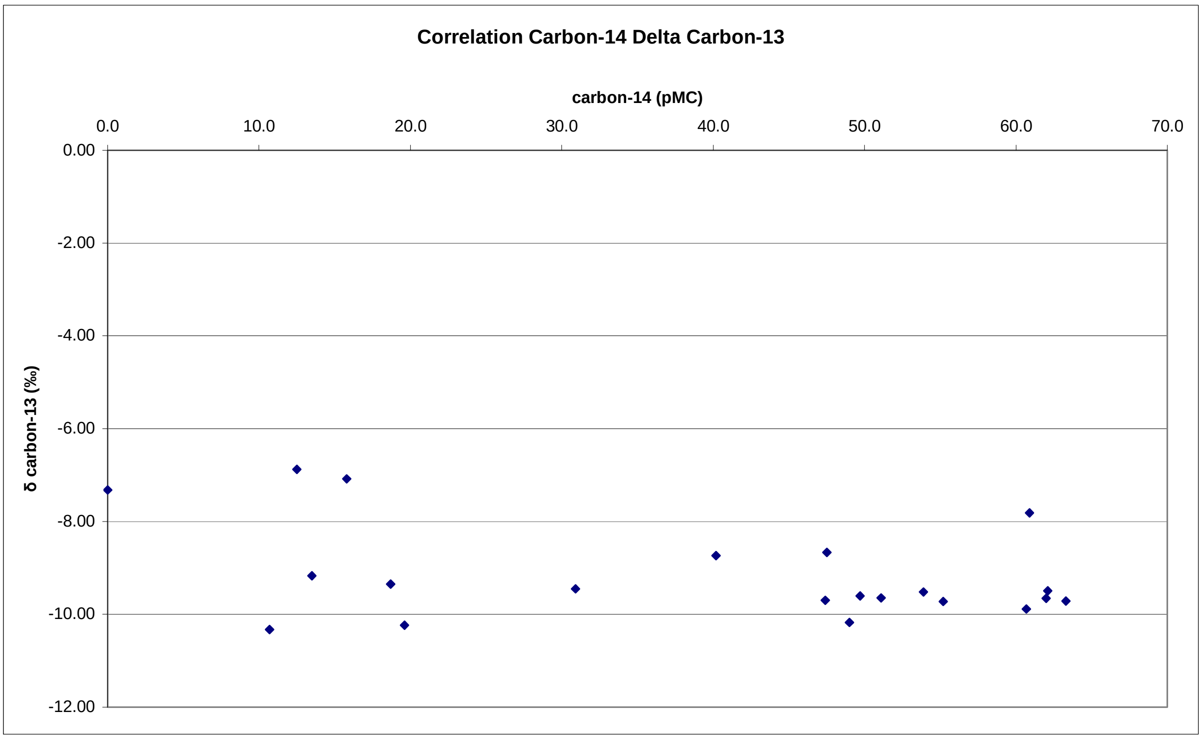


Figure 45: Correlation Carbon-14 – Delta Carbon-13

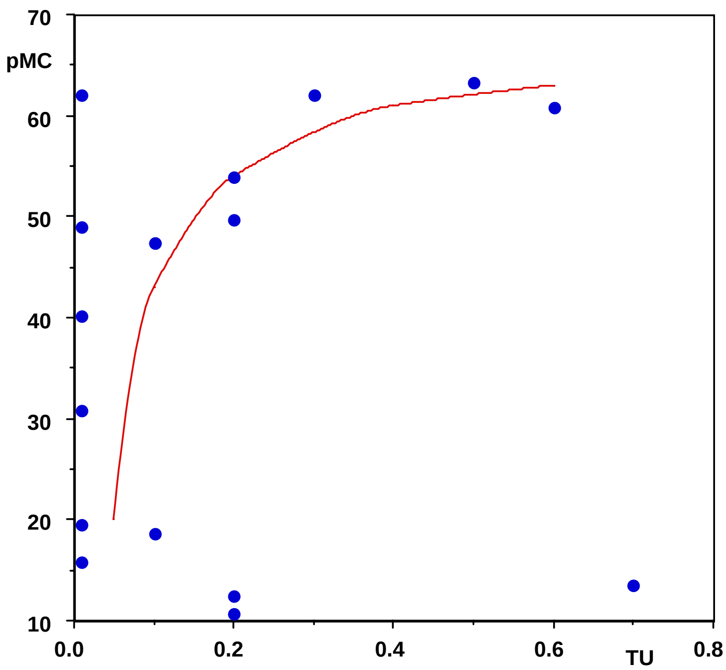


Figure 46: Correlation Tritium – Carbon-14

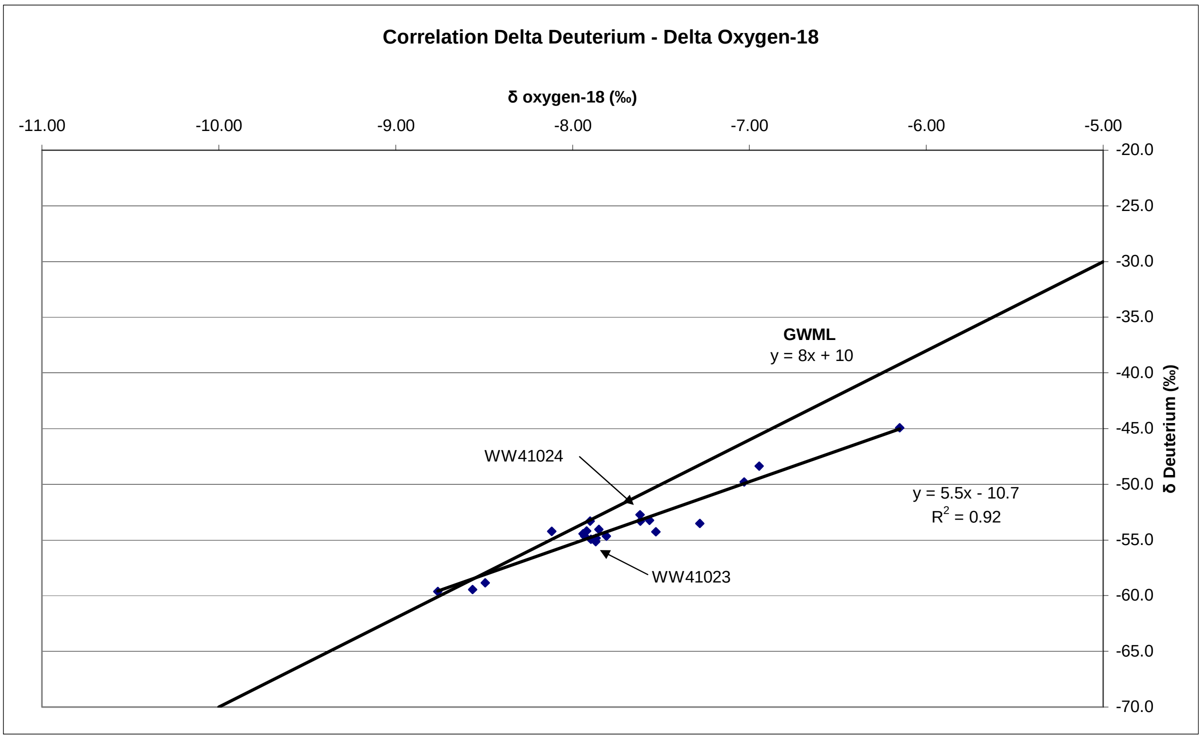


Figure 47: Correlation Delta Deuterium – Delta Oxygen-18

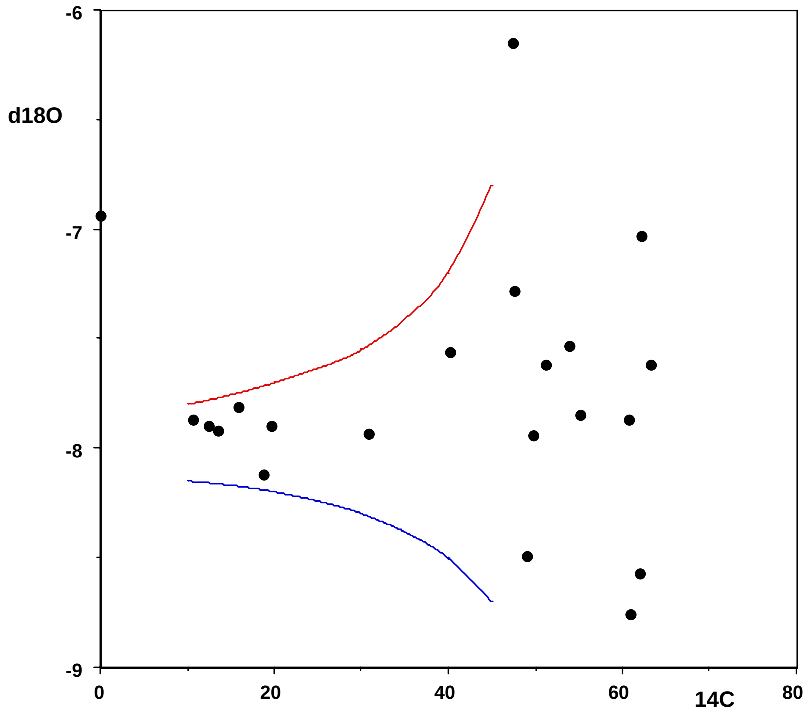


Figure 48: Correlation Carbon-14 (pMC) – Delta Oxygen-18 (‰)

4.5 Groundwater Monitoring

Presently there are no wells for monitoring of groundwater levels or groundwater quality in the area, with the exception of borehole no. 8857 on the Botswana side, near the border (UTM-E 500040, UTM-S 7723649; TD 179 m; Karoo sandstone aquifer). However, no meaningful monitoring data could be made available for this borehole. Before development of the newly detected groundwater resources it is strongly recommended to use the newly drilled boreholes WW41023 and WW41024 for monitoring purposes over a sufficiently long time period in order to provide data on the range of water level fluctuations and possible fluctuations in the chemical composition of the water. It is recommended to use data loggers for this purpose in order to save time and reduce costs. From the water level rise after rainfall and the time lag between rainfall events and peak water levels it may be possible to draw conclusions about the mechanism and amount of groundwater recharge.

4.6 Groundwater Exploitation Potential

In the absence of sufficient information on the correct geometry of the aquifer system, the horizontal and vertical distribution of hydraulic conductivities and the hydraulic gradient it is difficult to properly estimate the exploitation potential of the aquifer.

Figure 24 suggests that the graben at section 2 is around 26 km wide, with the area of the deep trench being around 9 km wide. At borehole WW41024 the saturated graben filling is only around 100 m thick, possibly thinning towards the southern graben margin. The maximum saturated thickness of the graben filling, which is possibly reached at its northern margin, exceeds 228 m.

Assuming an area along a vertical throughflow section of around 2.6E+6 m^2, a gradient of 0.75 ‰ and a hydraulic conductivity of on average 1 m/d one would arrive at a throughflow of around 0.7 MCM/a. Even though this estimation is based on conservative assumptions, this figure should presently only be considered as a very rough estimate.

5 Water Demand

The Water Supply and Sanitation Policy (WASP) was approved by the Government of Namibia in 1993 and is implemented by the Department of Rural Water Supply (DRWS) of the Department of Water Affairs. The WASP plan states that 80% of the rural population should have access to improved water supply by 2007. In 1997 the Namibian Cabinet issued the Community Based Management Strategy according to which responsibility for water points is to be handed over to communities in 2007.

The Rural Development Plan for the Omaheke Region envisions to “raise living standards and reduce poverty through the equitable, sustainable and decentralized provision of education, health, human resources development and the creation of economic opportunity for all, emphasizing the removal of gender discrimination and the development of marginalized groups, whilst improving infrastructure, preserving culture and heritage, reducing crime and ensuring peace, reconciliation and stability.”

The implementation of the WASP plan will mean that communities will have to bear considerable costs for operation and maintenance in the future and must technically be enabled to do so. In order to prepare the communities for this takeover process a ‘Rural Water Supply Development Plan for the Omaheke Region’ was prepared in 2002 by AFRICON. For the establishment of this plan 25% of the 481 water points were surveyed and at 10% of the water points water samples were taken and analyzed.

The main findings of this study were:

- The current water infrastructure at water points is in a poor condition;
- The average distance from water points to households is 507 m. The maximum distance is 2.5 km and thus within the acceptable limit of the Namibian guidelines;
- Sanitation systems are almost non-existent (only 4% have pit latrines and 96% no facility at all);
- Only 71% of the water points have elevated tanks for water storage for human consumption;
- Open storage tanks for livestock watering and irrigation exist at 92% of the water points with many of them leaking;
- Total rural water demand is expected to decrease due to declining population numbers (12,946 m^3/d in 2001).

The study suggested to rehabilitate the present water supply system and to improve the infrastructure at water points.

According to AFRICON there are currently no bulk water supply schemes in the Omaheke Region and there are presently no plans to construct any such schemes in the short or medium term. In the past years it was considered to supply the Omaheke Region by a pipeline connected to the Eastern National Water Carrier (Figure 49).

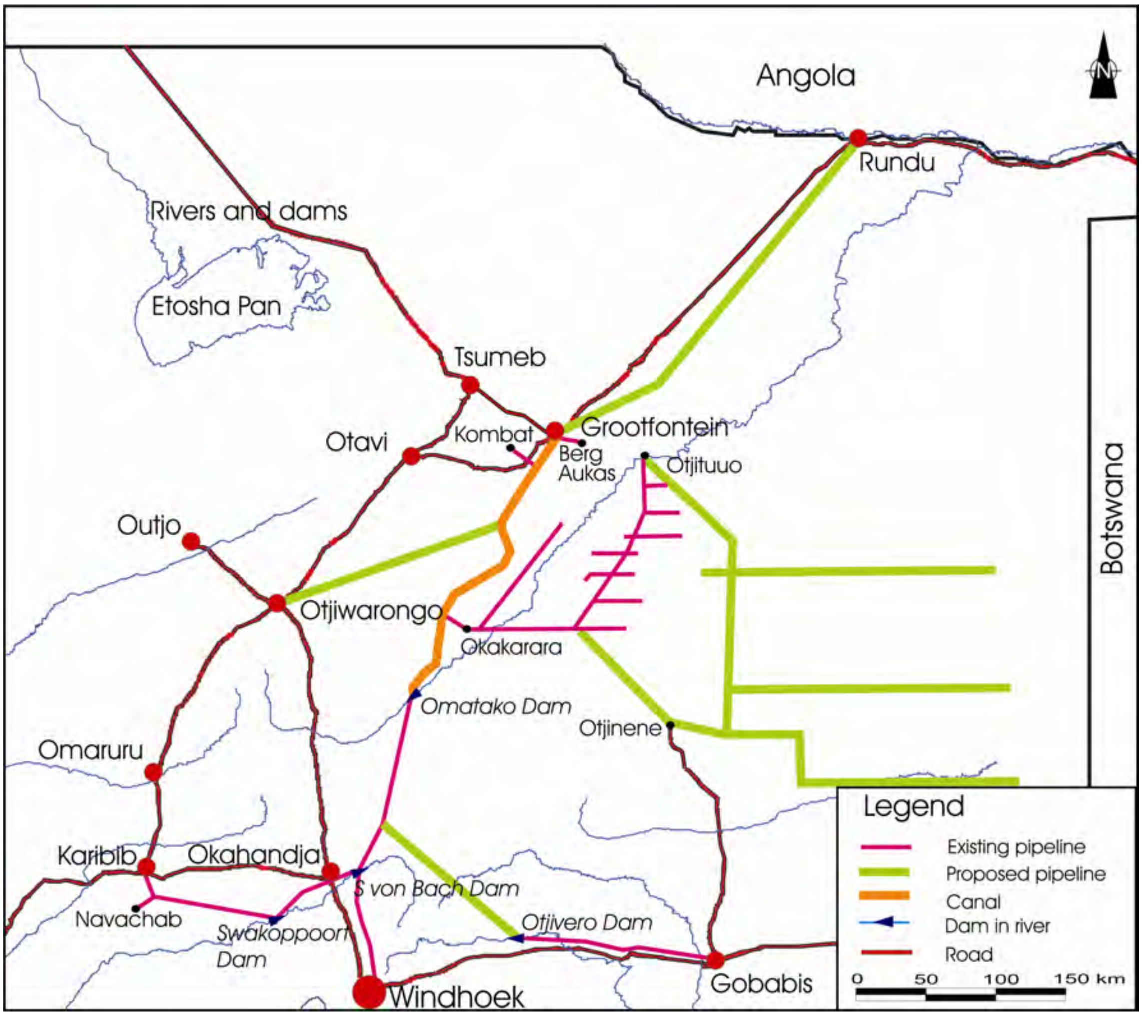


Figure 49: Water Supply Network in NE-Namibia

6 Recommendations and Conclusions

Within the framework of this investigation one borehole penetrated a high yielding rock unit at the northern margin of the central part of the Eiseb Graben. The yield encountered there is exceptionally high. However, the extent of this high yielding aquifer unit is still unknown. It could be limited to a rather small area, being deposited in the form of an alluvial fan, so that the long-term sustainable yield may be low or it could be part of an alluvial channel. Presently the latter hypothesis seems more likely. It is also still unknown whether the assumed alluvial channel extends further to the southwest. Isotope data indicate that water in the graben is partly young, so that it is assumed that there is some recent recharge to the Eiseb Graben.

In order to more precisely delineate the deep reaching trench at the northern margin of the Eiseb Graben and to improve the basis for decisions on further drilling sites it is recommended to carry out more TEM soundings. A total of 23 new TEM sites were proposed and measurements will be conducted during a later stage of this project phase, possibly in early 2005, on 4 lines (Figure 50). These additional measurements will decrease the spacing between lines to around 7 km and the spacing between measurement points to around 2.5 km. It is envisaged thereafter to drill two more deep boreholes (approximately 400 m deep) in the northeastern part of the Eiseb Graben with the aim to tap the aquifer in the assumed northern channel-like structure.

The boreholes drilled by INTERCONSULT in the lower part of the Eiseb Graben should be properly pump tested. The individual steps of step tests should last between 1 and 2 hours, depending on constant discharge tests should be performed over a pumping duration of at least 24 hours. It should also be envisaged to conduct a packer test in the open part of borehole WW41023 in order to more precisely locate the depths of the water strikes.

More hydrochemical and isotope analyses should be conducted in order to determine whether, to what extent and where from the Eiseb Graben Aquifer receives present-day recharge.

Before development of the Eiseb Graben Aquifer it is strongly recommended to monitor the water level and hydrochemical composition over an extended period of time (at least one year).

Based on the results of the proposed new investigations the long-term sustainable yield should be reevaluated.

The drilling concept of the present investigation proved to be suitable, i.e. the uppermost part of the borehole should be drilled with a large enough diameter (e.g. 311 mm) down to a depth where the Kalahari sediments become sufficiently consolidated. This section should be cased off with steel casing and drilling should then be continued using reverse circulation down to the final depth with a large enough drilling diameter (e.g. 250 mm). The lower section, if sufficiently consolidated, may be kept open while in the upper section plain/perforated uPVC casing should be installed.

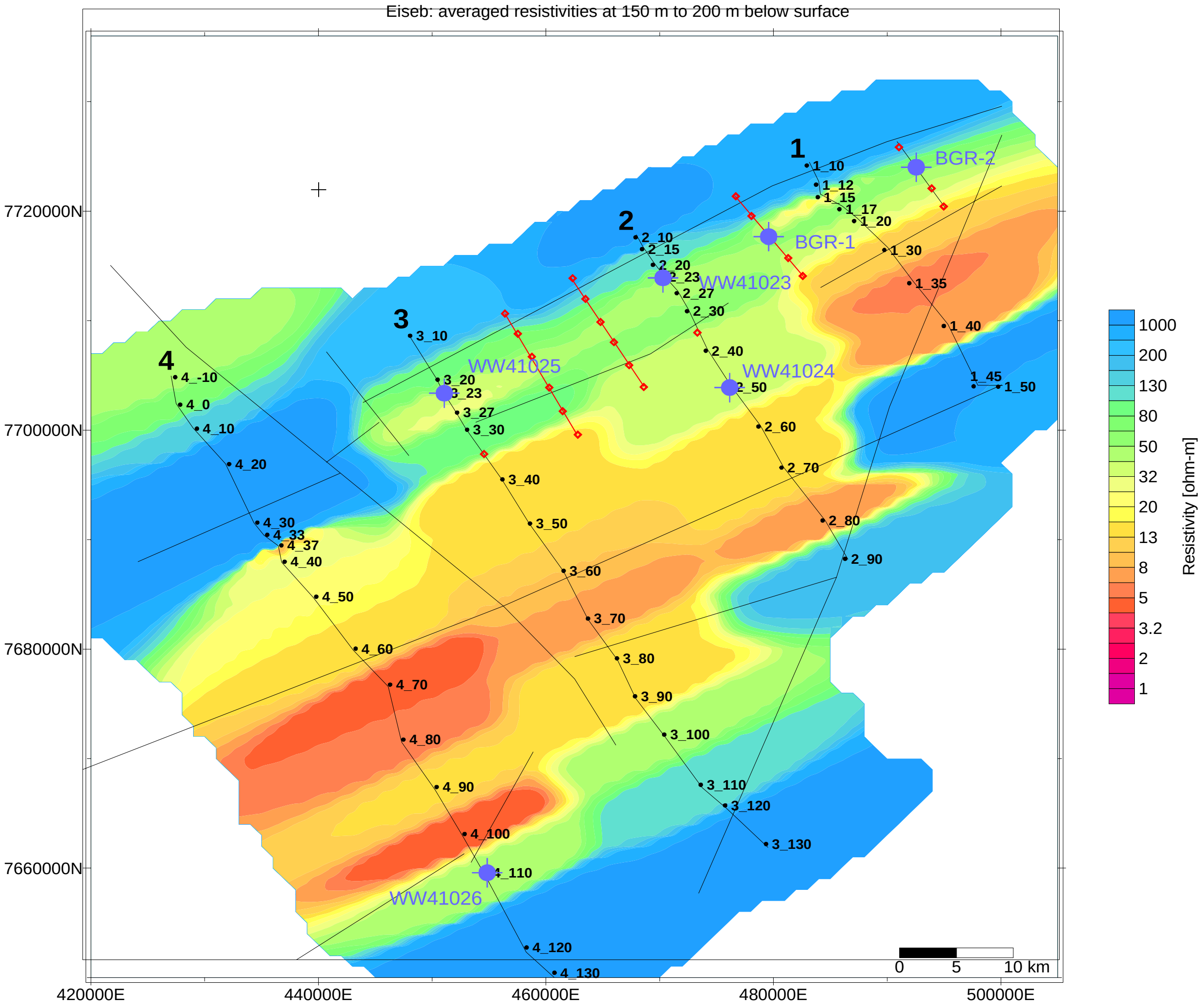


Figure 50: Locations of New Proposed TEM-Soundings and Boreholes in the Eiseb Graben

FEDERAL REPUBLIC OF GERMANY
Federal Institute for Geosciences and Natural Resources
BGR
Hannover

NAMIBIA
Department of Water Affairs
DWA
Windhoek

Windhoek, December 14, 2005

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Annex 1: Borehole Data

PK_ID	BHNO	Completion Report	Litholog	Geophysical Logging	LAT	LONG	UTM-E	UTM-S	DRILL DATE	BHNOTE	DEPTH	ELEVATION (SRTM)	DIAMETER	YIELD	LEVEL	STRIKE 1	STRIKE 2	STRIKE 3	DEEPEST STRIKE	MOST ACTUAL WATERLEVEL	DATE LEVEL	WATERLEVEL
					[dec deg]	[dec deg]	[m] zone 34S	[m] zone 34S			[m bgl]	[m asl]	[mm]	[m³/h]	[m bgl]	[m bgl]	[m bgl]	[m bgl]	[m bgl]	[m bgl]		[m asl]
14056	?	no	no		-20.99670	20.34330	431624.41	7678017.46		KARAPI borehole found by consultants in 1991		1167		0.2	0.00				0			
14078	?	no	no		-21.19300	20.13300	409886.89	7656188.08	1978		87.50	1244	150	1.1	0.00				61	35.00		
14076	?	no	no		-21.19300	20.49800	447769.97	7656351.71	1993		140.00	1138	204						136	119.96		
19959	?	no	no		-21.11000	20.65700	464252.06	7665581.01	1954		67.70	1133	150									
19282	?	no	no		-21.04800	19.83500	378838.13	7672038.60	1981		176.00		150						162			
14031	?	no	no		-20.76000	19.95830	391442.07	7704001.74		OTJINOKO					50.00					49.70	1991	
14025	?	no	no		-20.76330	19.95000	390580.44	7703630.93		OTJINOKO												
14068	?	no	no		-20.28500	20.88830	488207.84	7756909.21		DANEIB borehole found by consultants in 1991	90.00	1052		3	85.00					85.00	1991	967
14029	?	no	no		-20.30420	20.90330	489775.15	7754785.64		DANEIB borehole found by consultants	80.00	1027			30.00					29.70	1991	997
14028	?	no	no		-20.39170	20.75000	473786.53	7745086.49	1994		141.00	1057										
14067	?	no	no		-20.63320	20.98523	498331.26	7718382.65				1029										
14038	?	no	no		-20.97000	20.98830	498653.76	7681112.25	1975	EPUKIRO OM.	120.00	1070		2							?	
44416	WW10157	yes	yes		-20.26460	20.85450	484676.97	7759163.81	1970		115.00	1062		10	27.00							1035
53989	WW10158	yes	yes		-20.25630	20.83290	482420.60	7760080.10	1970		139.00	1069	150	1	23.00	23						1046
14070	WW10263	yes	yes		-20.27180	20.81610	480668.18	7758363.10	1970	GAM KALAHARI G 23696	137.00	1055		1.5	10.00					9.45	1970	1045
14045	WW10413	yes	yes		-20.84170	20.98500	498309.44	7695310.13	1970	Epukiro Boarder Post	101.50	1035	150	0								
18545	WW10414	yes	yes		-21.10920	20.12250	408745.81	7665456.62	1970	161.5M KALDAMARA G 21976	167.90	1215	130	1.4	147.00	164			164.3	146.90	1970	1068
18546	WW16011	no	no		-21.24330	20.14800	411473.74	7650629.58	1972	-78M KAL. GRANITE G 25555	163.00	1236	150	0.1								
18547	WW16014	no	no		-21.01530	20.10740	407119.47	7675840.16	1972	-57M KAL. KARROO G 25556	129.00	1157		0.1	120.00					120.00	1991	1037
14081	WW16015	no	no		-20.87700	20.08300	404496.31	7691131.86	1972		235.50	1217	150	2.4	145.00	164	195		195	145.00	1972	1072
14043	WW16073	no	no		-20.97960	20.10080	406411.39	7679787.34	1972	G 25562	158.50	1219	150		6.00	6			6	6.00		1213
14042	WW16074	no	no		-20.73440	20.09300	405447.69	7706919.43	1972	-27M KAL. DAMARA G 25558	157.00	1204	150								1972	
14071	WW16079	no	no		-20.41170	19.80990	375712.35	7742443.44	1972	-42M KAL. DAMARA G 25559	212.00		150	0.7	112.00	146	201		201	112.00	1972	
14083	WW16653	yes	yes		-20.77390	20.96800	496539.49	7702812.65	1973	ROOIBOKLAG-87M KAL. TSUMIS	199.00	1044	150	2.4	151.00	173			173	150.80	1973	893
	WW16666	yes	yes		-20.77690	20.99000	498829.13	7702480.97	1973	ROOIBOKLAG	78.00	1045	150								1973	
14077	WW16785	yes	yes		-20.57510	20.99590	499442.58	7724811.94	1973	ROOILYN	146.60	1019	150	1.4	110.00	127			127	110.00	1973	909
14041	WW21242	yes	yes		-20.73010	20.95290	494966.57	7707659.16	1975	ROOILYN	147.00		130	2	128.00	138			137.5	128.40	1975	
	WW21290	yes	yes		-20.52980	20.99350	499192.28	7729824.70	1975	ROOILYN KALAHARI	129.00	1027		4.8	43.00	51			51	43.00	1975	984
14030	WW21372	yes	yes		-21.25440	20.03320	399569.81	7649332.55	1975	-90M KAL. DAMARA G 29059	201.00	1288									1975	
14066	WW23304	yes	yes		-21.20580	19.83540	379007.66	7654573.34	1978	HAASVLAKTESAND 0-70 KALKRETE WH.GRANITE	186.70		150								1978	
14039	WW25240	yes	yes		-20.62840	19.98880	394526.14	7718586.35	1981	35M LIME SCHIST	212.00			3.2	110.00	194			194	110.00	1991	
44417	WW25241	yes	yes		-20.64250	19.84750	379815.59	7716927.88	1981		132.00		150	18	78.00	110			110	78.00	1981	
14040	WW25242	yes	yes		-20.65810	20.07410	403431.77	7715352.40	1981	HEREROLAND12M LIME 21M SANDSTSCHIST	240.00	1144	150								1981	
14044	WW25243	yes	yes		-20.62810	19.87230	382388.17	7718539.72	1981	1M SAND 11M LIME SCHIST	185.00		150								1981	
14069	WW25244	yes	yes		-20.63200	19.86840	381984.84	7718105.27	1981		176.00		150								1981	
14073	WW25251	yes	yes		-20.65570	20.08070	404117.74	7715621.91	1981	HEREROLAND-9M SAND 18M LIME SCHIST	200.00	1153	150								1981	
14074	WW25255	yes	yes		-20.91480	19.82700	377898.83	7686775.09	1981	OTJINOKO 86M MARBLE SCHIST	200.00		150			87			87	155.00	1991	
14072	WW25256	yes	yes		-20.88890	19.88440	383848.07	7689684.20	1981	OTJINOKO 39M KAL. SCHIST	201.00		150								1981	
18548	WW25257	yes	yes		-20.83800	19.87240	382560.46	7695308.97	1981	OTJINOKO 15M CALCR SCHIST	201.00		150							79.00	1991	
18550	WW25258	yes	yes		-20.83540	19.93230	388790.78	7695639.20	1981	OTJINOKO	201.00		150								1981	
18549	WW25259	yes	yes		-20.79190	19.95260	390871.61	7700467.41	1981	OTJINOKO	201.00		150							60.30	1991	
8841	WW25442	yes	yes		-20.62850	19.87980	383169.88	7718500.85	1981	-9M SAND SANDSTONE	190.00			3	64.00	82			82	64.00	1981	
14060	WW25448	yes	yes		-20.63680	20.03080	398907.43	7717683.36	1981	EISEB -45 m KAL.SCHIST	195.00	1147	160								1981	
8842	WW25462	yes	yes		-20.91410	19.82640	377835.87	7686852.11	1981	OTJINOKO RREC Y 1.1 108M MARBL	207.00		150	1.6	83.00	97			97	82.70	1981	
14061	WW25463	no	no		-20.91430	19.82720	377919.23	7686830.59	1981	OTJINOKO RREC Y 4 AVAIL.	115.00		150	6.1	79.00	92			92	78.70	1981	
8843	WW25466	yes	yes		-20.84380	19.95340	390992.17	7694723.94	1981	OTJINOKO REC Y 1.3 42M KAL. SCHIST	201.00		150	2.1	127.00	162			162	127.40	1981	
14062	WW25467	yes	yes		-20.71870	20.02440	398295.19	7708615.42	1981	OTJINOKO REC Y 2 24M KAL. SCHIST	151.00	1145	150	3.1	61.00	67			67	61.30	1981	1084
14063	WW25755	yes	yes		-20.90160	20.08750	404979.83	7688411.99	1981	ROOILYN	212.00	1219	150		165.00	164			164	165.00	1981	1054
14064	WW25756	yes	yes		-20.90430	20.08810	405043.92	7688113.53	1981	ROOILYN 105M KAL. DAMARA	231.00	1219	150	0.2	147.00	159			159	147.00	1981	1072
19284	WW25757	yes	yes		-20.88910	20.08530	404743.16	7689794.09	1981	ROOILYN 102M KAL. GNEISS	252.00	1219	150		145.00	171			171	145.30	1981	1074
19287	WW25759	yes	yes		-21.10010	20.12210	408698.71	7666463.52	1981	60M KAL.SDKAROO	243.00	1218	150								1981	
19285	WW25760	yes	yes		-21.16550	20.13410	409984.44	7659232.26	1981	-96M KAL. KAROO	162.00	1234	318	1.5					144	133.60	1981	
19283	WW25761	yes	yes		-21.13660	20.12870	409406.31	7662427.68	1981	Elandslaagte (-81m Kal.,Karoo)	231.00	1216	150								1981	
48968	WW27010	yes	yes		-20.27490	20.85440	484667.53	7758024.06	1983	DANEIB	120.00	1034		0.6	11.00	27			27	10.62	1983	1023
19288	WW27011	no	no		-20.27480	20.88490	487852.08	7758037.64	1983	DANEIB		1059										
14065	WW27012	yes	yes		-20.33600	20.93360	492939.64	7751268.39	1983	DANEIB	200.30	1016	150	4.9	43.00	160			160	42.60	1983	973
7656	WW27013	yes	yes		-20.31260	20.80270	479274.43	7753846.79	1983	DANEIB	203.80	1078		0.1	143.00	161			161	143.40	1983	935
14079	WW27014	yes	yes		-20.38720	20.79670	478658.29	7745591.15	1983	DANEIB	102.50	1044		0.9	53.00	70			70	53.18	1983	991
19286	WW29348	yes	yes		-21.15110	19.98930	394942.14	7660737.13	1987	S/LIMST 30CLAY 50 Q/SCH/PEG	201.00		160		133.00					133.00	1987	
19975	WW29349	yes	yes		-21.18680	19.80560	375898.84	7656653.29	1987	CLAY 48 Q/SCH/PEG.200	222.00		160									
19977	WW29359	yes	yes		-21.15080	19.99070	395087.29	7660771.26	1987	S/LIMST 35CLAY 51 Q/SCH/PEG.	201.00		160		133.00					133.00	1987	
19976	WW30491	yes	yes		-21.17850	19.93690	389522.01	7657668.99	1988	LIMST/S 30SCH/Q.SCH163QUARTZ P	201.00		160		133.00					133.00	1988	
38689	WW30492	yes	yes		-21.18680	19.80710	376054.55	7656654.46	1987	LIMST 20 CLAY 50 GRAN/SCH.	110.00		160									
19289	WW30493	yes	yes		-21.18690	19.80400	375732.83	7656640.97	1987	S/CLAY 49 LIMST 66 GRAN.120	120.00		160									
51177	WW30497	yes	yes		-21.22840	20.65480	464052.12	7652477.59	1988	0 SAND KALKREET KWARTSIET	102.00	1125	160	0								
	WW30498	yes	yes		-21.10950	20.76540	475508.50	7665656.78	1988	0 0	68.00	1079	152	50					44	88.00	1988	
51178	WW30506	yes	yes		-21.22890	20.65580	464156.00	7652422.48	1988	0 SAND KWARTSIET	99.00	1130	160									
51179	WW30507	yes	yes		-21.22930	20.65640	464218.35	7652378.35	1988	HEREROLAND EAST	120.00	1134	150	1.8	12.00	57			57	12.00	1988	1122
51180	WW30520	no	no		-21.14970	19.99130	395148.81	7660893.40	1987	KALAHARILAE	215.00		150									
51138	WW33157	no	no		-21.13529	20.77057	476049.49	7662803.51	1993	HHO 1993/LUXDEV Rehab	20.00	1084	165	14.5	4.00	11			10.5	4.48		1080
51181	WW33158	no	no		-21.13531	20.77074	476067.14	7662801.32	1993	HHO 1993/LUXDEV Rehab	122.00	1084	204	6.5	4.00	15			14.8	4.43		1080
51139	WW33159	no	no		-21.12890	20.77230	476228.09	7663510.92	1993	HHO 1993	68.00	1086	204	4	7.00	12	22	33				1079
54583	WW33160	no	no		-21.12001	20.76922	475906.87	7664494.27	1993	HHO 1993/LUXDEV Rehab	160.00	1087	165	4.7	12.00	14	18	149	18	11.80		1075
54547	WW33161	no	no		-21.11021	20.76696	475670.61	7665578.45	1993	HHO 1993/LUXDEV Rehab	99.00	1075	204	1.8	15.00	19	28		28	14.58		1060
	WW33167	no	no	yes	-21.19340	20.49800	447770.11	7656307.44	1993	HHO 1993	250.00	1140	165	1	120.00	136			130	120.24		1020
54543	WW33168	no	no		-21.19350	20.49810	447780.52	7656296.41	1993	HHO 1993	250.00	1138	165	1	120.00	130			130	120.24		1018
8474	WW34092	no	yes		-20.47675	20.21557	418070.94	7735499.15	1993	Drought relief 1993	252.00	1179	165	0								
8650	WW34093	no	no	yes	-21.20740	20.42030	439711.55	7654730.54	1993	Elandslaagte	210.00	1145	210									

PK_ID	BHNO	Completion Report	Litholog	Geophysical Logging	LAT	LONG	UTM-E	UTM-S	DRILL DATE	BHNOTE	DEPTH	ELEVATION (SRTM)	DIAMETER	YIELD	LEVEL	STRIKE 1	STRIKE 2	STRIKE 3	DEEPEST STRIKE	MOST ACTUAL WATERLEVEL	DATE LEVEL	WATERLEVEL
8477	WW34097	yes	yes		-20.45770	19.88270	383342.66	7737405.89	1993	Eisb Omuramba	222.00		165									
8846	WW34098	yes	yes		-20.91050	19.80850	375971.42	7687236.84	1993	Ombaue	190.00		165	7								
14082	WW34363	no	no		-20.62863	20.99620	499473.99	7718888.42	1975	BUFFELSVLEI borehole found by LHC		1026	200	1.2								
48957	WW34451	no	no		-20.29170	20.89530	488939.14	7756168.31	1994	GAM 1994	110.00			2.5	26.00	103			103	26.49		
48958	WW34452	no	no		-20.36670	20.93420	493003.62	7747871.32	1994	GAM 1994	140.00	1014										
48959	WW34453	no	no		-20.37900	20.82120	481213.55	7746501.50	1994	GAM 1994	150.00	1040		0.1								
48960	WW34454	no	no		-20.27280	20.87480	486797.35	7758258.18	1994	GAM 1994	140.00			2.5	31.00	55			55	30.50		
48961	WW34456	no	no		-20.37350	20.78780	477727.74	7747105.96	1994	GAM 1994	65.00	1068										
52364	WW34457	no	no		-20.38770	20.96570	496291.13	7745548.56	1994	GAM 1994	113.00	1033		1.1	72.00	95			95	72.27		961
52365	WW34461	no	no		-20.39550	20.89600	489019.47	7744682.39	1994	GAM 1994	150.00	1048		0.1								
52366	WW34466	no	no		-20.31670	20.83100	482229.03	7753396.39	1994	GAM 1994	160.00											
48895	WW34848	no	no		-20.28830	20.46260	443763.35	7756456.75	1994	GAM 1994	202.00				80.00					80.00		
52298	WW34854	no	no		-20.28530	20.46320	443824.92	7756788.93	1994	GAM 1994	202.00				75.00	173			173	75.00		
48965	WW34859	no	no		-20.26950	20.99570	499420.86	7758628.28	1994	GAM 1994 - Rehab Reimann	150.00			2	103.00	132			132	103.30		
48936	WW34862	no	no		-20.30470	20.54070	451922.46	7754666.58	1994	GAM 1994	200.00					147			147			
48937	WW34865	no	no		-20.29250	20.56970	454946.37	7756024.74	1994	GAM 1994	250.00					90			90			
48938	WW34876	no	no		-20.28990	20.52370	450143.04	7756299.27	1994	GAM 1994	363.00					63			63			
52395	WW34878	no	no		-20.35590	20.59770	457886.73	7749016.49	1994	GAM 1994	185.00	1092		1.7		81			156	156.00		
52342	WW34879	no	no		-20.36880	20.62810	461062.46	7747596.48	1994	GAM 1994	206.00	1072			181.00					181.00		891
48941	WW34880	no	no		-20.37070	20.64970	463316.87	7747391.17	1994	GAM 1994	156.00	1074		0.4	91.00					90.90		983
52299	WW35037	no	no		-20.46920	20.35220	432315.67	7736396.94	1994	GAM 1994	201.00	1158										
48966	WW35038	no	no		-20.34870	20.79290	478256.45	7749850.89	1994	GAM 1994	251.00	1077		0.4	102.00	229			229	101.70		975
48967	WW35039	no	no		-20.44380	20.77550	476454.92	7739325.14	1994	GAM 1994	206.00	1079		0.3	102.00	126			126	101.80		977
48898	WW35040	no	no		-20.46930	20.35260	432357.43	7736386.04	1994	GAM 1994	205.00	1158										
52344	WW35041	no	no		-20.46340	20.74220	472985.18	7737151.16	1994	GAM 1994	201.00	1088		0.7	94.00	112			112	93.60		994
48943	WW35042	no	no		-20.44900	20.55500	453458.48	7738702.78	1994	GAM 1994	216.00	1134		0.2								
48899	WW35043	no	no		-20.34210	20.46060	443574.00	7750502.67	1994	GAM 1994	201.00			0.3								
48900	WW35044	no	no		-20.35800	20.44390	441836.96	7748737.41	1994	GAM 1994	111.00	1105		1.5	80.00	99			98.5	79.60		1025
52296	WW35045	yes	yes		-20.30590	20.11030	406990.65	7754350.21	1994	GAM 1994	116.00			1.2	85.00	98			98	85.00		
9536	WW35099	no	no		-20.65560	20.97160	496911.86	7715903.71	1995	Okaokonguinja		1035										
9537	WW35120	no	no		-20.96940	20.98610	498425.09	7681178.63	1995	Otjozondera	200.00	1070										
9525	WW35176	yes	yes		-20.97270	20.99330	499173.47	7680813.49	1995	Otozondera	300.00	1070	165									
9526	WW35177	yes	yes	yes	-20.62350	20.98830	498650.98	7719456.06	1995	Okaokonguinja	242.00	1030	205									
9396	WW35418	yes	yes		-20.73430	20.00190	395963.07	7706874.66	1996	Outjiro ,Epukiro	187.00		152		150.00	73			73	150.00	1996	
48986	WW35431	yes	yes		-20.62633	20.99283	499122.91	7719142.93	1996	EISEB 1/1996	155.00	1027		2.4	131.00	144			144	130.80		896
48987	WW35432	yes	yes		-20.66283	20.91283	490791.14	7715101.47	1996	EISEB 2/1996	161.00	1043		3.1	132.00	144			144	132.00		911
48988	WW35433	yes	yes		-20.71650	20.84667	483906.22	7709157.29	1996	EISEB 3/1996	185.00	1050		3.5	140.00	153			153	140.00		910
49000	WW35434	yes	yes		-20.77383	20.80117	479176.87	7702807.99	1996	EISEB 4/1996	186.00	1065		3.5	146.00	164			164	146.00		919
48992	WW35435	yes	yes		-20.79200	20.69900	468547.35	7700780.82	1996	EISEB 5/1996	185.00	1080		1.7	156.00	156			156	156.00		924
52402	WW35436	no	yes	yes	-20.79317	20.59717	457950.98	7700628.24	1996	EISEB 6/1996	209.00	1100	156	1.5	140.00	147			147	140.00		960
48989	WW35437	yes	yes	yes	-20.71430	20.97020	496767.24	7709408.01	1996	EISEB 7/1996	203.00	1033	205	0.5	165.00	170			170	165.00		868
49001	WW35438	yes	yes	yes	-20.76730	20.90900	490398.74	7703540.67	1996	EISEB 8/1996	185.00	1050	204	2	165.00	170			170	165.00		885
52391	WW35439	yes	yes		-20.58430	20.92570	492127.57	7723792.13	1996	EISEB 9/1996	157.00	1026	204	3.5	124.00	128			128	124.00		902
	WW35440	yes	yes		-20.61417	20.85217	484468.53	7720481.55		EISEB 10/1996	151.00	1038		3								
4033	WW36855	yes	yes		-21.10230	20.32550	429823.95	7666323.08	1997	ELANDSLAAGTE	246.00	1188	150		134.00	144			144	133.60	1997	1054
	WW37022	yes	yes		-20.75680	20.51630	449523.38	7704629.94	1998	Eiseb	222.00	1121	254	0.2								
	WW39907	yes	yes		-20.67606	20.81942	481064.15	7713629.43		Annual Drilling 2000/2001	165.00	1058		2								
	WW40391	yes	yes		-20.94088	20.97796	497578.59	7684334.63		DWA-rig	282.00	1062	168	0								
	WW40392	yes	yes	yes	-20.70000	20.71850	470558.84	7710965.27		DWA-rig	204.00	1071	168	3								
	WW40393	yes	yes	yes	-20.51667	21.00000	499869.84	7731277.64		DWA-rig	120.00	1036	168	0.5								
	WW40573	yes	no		-20.38630	20.95667	495348.93	7745703.26		Rehab Reimann	103.00			1.6								
	WW30501				-21.19202	20.35253	432671.56	7656405.41				1154										
	WW36631			yes	-21.22836	20.23532	420525.73	7652329.36				1208										
	WW36633			yes	-20.76587	20.29997	427010.06	7703543.76			182.00	1173		0.1	140.80							1032.2
	WW37021			yes	-21.22868	20.23193	420174.14	7652292.24				1208		unknown	173.57							1034.43
	WW37022			yes	-20.75699	20.51632	449525.52	7704608.92			222.00	1122		0.2								
	WW37023				-20.65617	20.09102	405193.00	7715575.95						unknown	bh collapsed							
	Rooiboklaagte Omuramba			yes	-20.86250	20.57106	455254.33	7692948.97				1065		1								
	Rooiboklaagte Omuramba - Otjovakuru No.1				-20.85994	20.56837	454973.77	7693231.52			153.00	1065		2	113.00							952
	Rooiboklaagte Omuramba - Otjovakuru No.2				-20.86975	20.40510	437994.83	7692091.72			125.00	1083		1								
	Rooiboklaagte Omuramba - Otjovakuru No.2			yes	-20.86877	20.40551	438037.08	7692200.33			138.00	1084		2	116.00							968
	Ourundu Ozondjima			yes	-20.97043	20.83867	483101.47	7681056.26				1065		None								
	Ovie				-20.57427	20.67622	466128.72	7724870.28			120.00	1045		1								
	Otjondorona				-20.59939	20.58696	456833.87	7722069.49				1059		1								
	Tjoruharvi				-20.59391	20.50214	447994.19	7722651.19				1083		1								
	Otjoahe				-20.60011	20.43261	440751.57	7721941.40				1096		1								
					-20.64220	20.23014	419676.75	7717196.85			136.00			1								
	Okamukoto				-20.61097	20.28385	425256.51	7720678.49			82.00	1106		1								
					-20.67989	20.14364	410687.93	7712980.69						1.5								
	Ojovazandu				-20.76238	20.30092	427107.27	7703930.41			182.00	1173		1								
	Embonde (South)				-21.19847	20.37641	435152.85	7655701.53				1148		1.5								
	Otjora				-21.07035	20.64349	462839.32	7669965.82				1090		unknown								
	Ourundu Ozondjima				-20.96430	20.84111	483354.40	7681734.88				1064		n/a								
	Embonde			yes	-20.66096	20.76682	475583.94	7715293.41				1060		n/a								
	Embonde			yes	-20.66474	20.71656	470350.02	7714866.78				1069		n/a								

Annex 2: Hydrochemical Data

Part 1: Contents in mg/l (only samples with < 10% analytical error)
General Data

PK_ID	BHNO	NAME	LAT	LONG	UTM-E	UTM-S	Date_sampling	pH	EC	TDS
14056	?	KARAPI borehole found by consultants in 1991	-20.99670	20.34330	431624.41	7678017.46		0.0	0.0	0.0
14083	WW16653	ROOIBOKLAG-87M KAL. TSUMIS	-20.77390	20.96800	496539.49	7702812.65				
-	WW16666	ROOIBOKLAG	-20.77690	20.99000	498829.13	7702480.97				
44417	WW25241	WW25241	-20.64250	19.84750	379815.59	7716927.88				
8841	WW25442	WW25442	-20.62850	19.87980	383169.88	7718500.85				
8842	WW25462	OTJINOKO	-20.91410	19.82640	377835.87	7686852.11				
8843	WW25466	OTJINOKO	-20.84380	19.95340	390992.17	7694723.94				
	WW 10413	Agarop Pos	-20.84159	20.98632	498446.75	7695322.31	08/2004	7.4	373.0	2968.8
	WW 41024	BE-2	-20.76365	20.77197	476136.00	7703930.00	08/2004	7.5	140.8	1015.8
	WW 41023	BE-1 A (after CD test)	-20.67284	20.71558	470250.00	7713970.00	28/08/2004	8.0	48.3	229.7
	WW 41023	BE-1 B (after step test)	-20.67284	20.71558	470250.00	7713970.00	24/08/2004	7.9	45.4	341.3
	-	Embonde south	-21.19847	20.37641	435152.85	7655701.53	08/2004	8.0	45.5	282.8
	-	Otjiparu	-20.64220	20.23014	419676.75	7717196.85	08/2004	7.4	133.0	837.6
	WW 33168	Otjitazu	-21.19489	20.49659	447780.52	7656296.41	08/2004	8.5	61.0	400.4
	-	Otjoahe	-20.60011	20.43261	440751.57	7721941.40	08/2004	7.4	86.7	554.2
	-	Otjora	-21.07035	20.64349	462839.32	7669965.82	08/2004	8.0	37.9	264.9
	-	Otjovakura 1	-20.85994	20.56837	454973.77	7693231.52	08/2004	7.5	198.3	1386.6
	-	Otjovakuru 2	-20.86975	20.40510	437994.83	7692091.72	08/2004	8.1	45.7	303.0
	-	Otjovazandu	-20.76238	20.30092	427107.27	7703930.41	08/2004	7.8	226.9	1827.0
	-	Ovie	-20.57427	20.67622	466128.72	7724870.28	08/2004	7.3	130.3	912.4
	WW 35431	Pos 1	-20.62806	20.99292	499122.91	7719142.93	08/2004	7.8	117.7	800.5
	WW 35440	Pos 10	-20.61157	20.84741	484468.53	7720481.55	08/2004	7.4	147.2	1052.9
	WW 39907	Pos 11	-20.67613	20.81942	481064.15	7713629.43	08/2004	7.9	41.9	245.6
	WW 35432	Pos 2	-20.66277	20.91318	490791.14	7715101.47	08/2004	7.5	103.1	742.8
	WW 35433	Pos 3	-20.71652	20.84666	483906.22	7709157.29	08/2004	8.0	99.9	666.1
	WW 35434	Pos 4	-20.77389	20.80109	479176.87	7702807.99	08/2004	7.7	74.3	478.1
	WW 35435	Pos 5	-20.79203	20.69919	468547.35	7700780.82	08/2004	7.6	99.6	658.7
	WW 35439	Pos 9	-20.58423	20.92551	492127.57	7723792.13	08/2004	7.4	122.0	805.3

Contents in mg/l

BHNO	NAME	Na	K	Ca	Mg	Fe	Mn	Cl	SO4	HCO3	NO3	NO3-N	NO2_N
?	KARAPI borehole found by consultants in 1991	620.0	19.0	190.0	12.0	0.0	0.0	150.0	1500.0	3.0	17.7	4.0	0.0
WW16653	ROOIBOKLAG-87M KAL. TSUMIS	450.0	19.0	75.0	100.0			165.0	1450.0	5.6	15.5	3.5	
WW16666	ROOIBOKLAG	695.0	30.0	75.0	105.0			70.0	2100.0	6.3	2.2	0.5	
WW25241	WW25241	320.0	13.0	190.0	60.0			290.0	1210.0	3.8	4.4	1.0	
WW25442	WW25442	450.0	14.0	130.0	35.0			300.0	1200.0	4.9	15.5	3.5	
WW25462	OTJINOKO	78.0	11.0	65.0	45.0			40.0	360.0	7.1	8.9	2.0	
WW25466	OTJINOKO	122.0	12.0	84.0	39.0			35.0	530.0	5.7	2.2	0.5	
WW 10413	Agarop Pos	476.0	18.0	269.0	95.0	0.1		181.0	1516.0	262.1	28.5	6.4	0.0
WW 41024	BE-2	133.0	8.8	94.0	49.0	0.0		45.0	348.0	292.6	68.0	15.3	0.2
WW 41023	BE-1 A (after CD test)	21.0	4.9	44.0	21.0	0.0		12.0	4.4	243.8	17.4	3.9	0.7
WW 41023	BE-1 B (after step test)	19.0	4.1	42.0	19.0	0.0		11.0	3.0	221.9	26.3	5.9	0.1
-	Embonde south	77.0	5.6	20.0	5.6	0.1		14.0	38.0	197.5	7.8	1.8	0.0
-	Otjiparu	101.0	6.9	101.0	61.0	0.1		107.0	202.0	343.8	20.1	4.5	0.0
WW 33168	Otjitazu	126.0	21.0	4.0	2.8	0.1		10.0	10.0	319.4	17.7	4.0	0.1
-	Otjoahe	43.0	8.1	82.0	44.0	0.1		20.0	14.0	460.8	50.8	11.5	0.1
-	Otjora	63.0	6.6	14.0	6.2	0.1		10.0	12.0	186.5	6.9	1.6	0.0
-	Otjovakura 1	289.0	16.0	89.0	44.0	0.0	0.0	51.0	670.0	365.7	19.2	4.3	0.3
-	Otjovakuru 2	65.0	5.9	20.0	9.5	0.0	0.0	11.0	14.0	225.5	12.8	2.9	0.0
-	Otjovazandu	173.0	15.0	234.0	104.0	0.3	0.0	72.0	1080.0	256.0	6.0	1.4	
-	Ovie	101.0	7.1	102.0	36.0			86.0	175.0	355.9	75.3	17.0	0.1
WW 35431	Pos 1	148.0	7.7	74.0	24.0			38.0	375.0	204.8	9.4	2.1	0.0
WW 35440	Pos 10	99.0	8.6	141.0	60.0	0.2	0.0	60.0	422.0	292.6	18.0	4.1	0.0
WW 39907	Pos 11	51.0	3.8	24.0	9.8	0.0		11.0	25.0	182.9	12.6	2.9	0.1
WW 35432	Pos 2	114.0	8.9	64.0	31.0	0.0		21.0	210.0	355.9	6.5	1.5	0.1
WW 35433	Pos 3	188.0	5.1	15.0	6.6	0.1		23.0	230.0	243.8	11.2	2.5	0.0
WW 35434	Pos 4	79.0	6.6	45.0	19.0	0.0		32.0	13.0	316.9	72.2	16.3	0.1
WW 35435	Pos 5	107.0	6.9	60.0	32.0	0.1	0.0	30.0	170.0	326.7	34.6	7.8	0.0
WW 35439	Pos 9	118.0	7.4	100.0	39.0	0.0		55.0	330.0	262.1	8.8	2.0	

Part 2: Contents in meq/l (only samples with < 10% analytical error)

PK_ID	BHNO	BHNOTE	Na_meq-l	K_meq-l	Ca_meq-l	Mg_meq-l	Fe_meq-l	Mn_meq-l	Cl_meq-l	SO4_meq-l	HCO3_meq-l	NO3_meq-l	NO2_meq-l
14056	?	KARAPI borehole found by consultants in 1991	26.97	0.49	9.48	0.99			4.23	31.23	0.05	0.29	
14083	WW16653	ROOIBOKLAG-87M KAL. TSUMIS	19.57	0.49	3.74	8.23			4.65	30.19	0.09	0.25	
-	WW16666	ROOIBOKLAG	30.23	0.77	3.74	8.64			1.97	43.72	0.10	0.04	
44417	WW25241		13.92	0.33	9.48	4.94			8.18	25.19	0.06	0.07	
8841	WW25442		19.57	0.36	6.49	2.88			8.46	24.98	0.08	0.25	
8842	WW25462	OTJINOKO	3.39	0.28	3.24	3.70			1.13	7.50	0.12	0.14	
8843	WW25466	OTJINOKO	5.31	0.31	4.19	3.21			0.99	11.03	0.09	0.04	
	WW 10413	Agarop Pos	20.70	0.46	13.42	7.82	0.00	0.00	5.11	31.56	4.30	0.46	0.00
	WW 41024	BE-2	5.79	0.23	4.69	4.03	0.00	0.00	1.27	7.25	4.79	1.10	0.00
	WW 41023	BE-1 A	0.91	0.13	2.20	1.73	0.00	0.00	0.34	0.09	4.00	0.28	0.01
	WW 41023	BE-1 B	0.83	0.10	2.10	1.56	0.00	0.00	0.31	0.06	3.64	0.42	0.00
	-	Embonde south	3.35	0.14	1.00	0.46	0.00	0.00	0.39	0.79	3.24	0.13	0.00
	-	Otjiparu	4.39	0.18	5.04	5.02	0.00	0.00	3.02	4.21	5.63	0.32	0.00
	WW 33168	Otjitazu	5.48	0.54	0.20	0.23	0.00	0.00	0.28	0.21	5.23	0.29	0.00
	-	Otjoahe	1.87	0.21	4.09	3.62	0.00	0.00	0.56	0.29	7.55	0.82	0.00
	-	Otjora	2.74	0.17	0.70	0.51	0.00	0.00	0.28	0.25	3.06	0.11	0.00
	-	Otjovakura 1	12.57	0.41	4.44	3.62	0.00	0.00	1.44	13.95	5.99	0.31	0.01
	-	Otjovakuru 2	2.83	0.15	1.00	0.78	0.00	0.00	0.31	0.29	3.70	0.21	0.00
	-	Otjovazandu	7.53	0.38	11.68	8.56	0.01	0.00	2.03	22.49	4.20	0.10	0.00
	-	Ovie	4.39	0.18	5.09	2.96	0.00	0.00	2.43	3.64	5.83	1.21	0.00
	WW 35431	Pos 1	6.44	0.20	3.69	1.97	0.00	0.00	1.07	7.81	3.36	0.15	0.00
	WW 35440	Pos 10	4.31	0.22	7.04	4.94	0.01	0.00	1.69	8.79	4.79	0.29	0.00
	WW 39907	Pos 11	2.22	0.10	1.20	0.81	0.00	0.00	0.31	0.52	3.00	0.20	0.00
	WW 35432	Pos 2	4.96	0.23	3.19	2.55	0.00	0.00	0.59	4.37	5.83	0.11	0.00
	WW 35433	Pos 3	8.18	0.13	0.75	0.54	0.00	0.00	0.65	4.79	4.00	0.18	0.00
	WW 35434	Pos 4	3.44	0.17	2.25	1.56	0.00	0.00	0.90	0.27	5.19	1.16	0.00
	WW 35435	Pos 5	4.65	0.18	2.99	2.63	0.00	0.00	0.85	3.54	5.35	0.56	0.00
	WW 35439	Pos 9	5.13	0.19	4.99	3.21	0.00	0.00	1.55	6.87	4.30	0.14	0.00

Part 2: Contents in meq% (only samples with < 10% analytical error)

PK_ID	BHNO	BHNOTE	Na_meq%	K_meq%	Ca_meq%	Mg_meq%	Fe_meq%	Mn_meq%	Cl_meq%	SO4_meq%	HCO3_meq%	NO3_meq%
14056	?	KARAPI borehole found by consultants in 1991	71.11	1.28	25.00	2.60	0.00	0.00	11.82	87.24	0.14	0.80
14083	WW16653	ROOIBOKLAG-87M KAL. TSUMIS	61.11	1.52	11.68	25.69	0.00	0.00	13.23	85.80	0.26	0.71
-	WW16666	ROOIBOKLAG	69.69	1.77	8.63	19.92	0.00	0.00	4.31	95.39	0.23	0.08
44417	WW25241		48.55	1.16	33.07	17.22	0.00	0.00	24.39	75.13	0.18	0.21
8841	WW25442		66.81	1.22	22.14	9.83	0.00	0.00	25.04	73.92	0.24	0.74
8842	WW25462	OTJINOKO	31.95	2.65	30.54	34.87	0.00	0.00	12.64	83.99	1.30	1.60
8843	WW25466	OTJINOKO	40.77	2.36	32.21	24.66	0.00	0.00	8.11	90.69	0.77	0.29
	WW 10413	Agarop Pos	48.82	1.09	31.65	18.43	0.00	0.00	12.32	76.16	10.36	1.11
	WW 41024	BE-2	39.27	1.53	31.84	27.37	0.00	0.00	8.80	50.23	33.24	7.60
	WW 41023	BE-1 A	18.40	2.52	44.24	34.81	0.02	0.00	7.16	1.94	84.54	5.95
	WW 41023	BE-1 B	18.00	2.28	45.64	34.05	0.03	0.00	6.98	1.40	81.78	9.56
	-	Embonde south	67.62	2.89	20.15	9.30	0.04	0.00	8.65	17.33	70.90	2.75
	-	Otjiparu	30.03	1.21	34.45	34.31	0.01	0.00	22.89	31.89	42.72	2.46
	WW 33168	Otjitazu	84.95	8.33	3.09	3.57	0.06	0.00	4.66	3.44	86.38	4.72
	-	Otjoahe	19.10	2.12	41.78	36.97	0.04	0.00	6.11	3.16	81.78	8.88
	-	Otjora	66.49	4.10	16.95	12.38	0.09	0.00	7.59	6.72	82.26	2.99
	-	Otjovakura 1	59.73	1.94	21.10	17.20	0.01	0.01	6.63	64.26	27.61	1.43
	-	Otjovakuru 2	59.41	3.17	20.97	16.43	0.01	0.01	6.85	6.43	81.57	4.55
	-	Otjovazandu	26.73	1.36	41.47	30.40	0.04	0.01	7.05	78.04	14.56	0.34
	-	Ovie	34.79	1.44	40.31	23.46	0.00	0.00	18.48	27.75	44.43	9.25
	WW 35431	Pos 1	52.33	1.60	30.02	16.05	0.00	0.00	8.65	63.00	27.08	1.23
	WW 35440	Pos 10	26.09	1.33	42.63	29.91	0.04	0.00	10.87	56.43	30.80	1.86
	WW 39907	Pos 11	51.35	2.25	27.72	18.67	0.01	0.00	7.67	12.87	74.12	5.04
	WW 35432	Pos 2	45.36	2.08	29.21	23.33	0.01	0.00	5.43	40.06	53.44	0.96
	WW 35433	Pos 3	85.17	1.36	7.80	5.66	0.02	0.00	6.73	49.65	41.43	1.87
	WW 35434	Pos 4	46.34	2.28	30.29	21.09	0.01	0.00	11.96	3.59	68.85	15.44
	WW 35435	Pos 5	44.49	1.69	28.62	25.17	0.02	0.01	8.21	34.33	51.94	5.41
	WW 35439	Pos 9	37.96	1.40	36.90	23.73	0.01	0.00	12.06	53.39	33.38	1.10