SIBANYE - STILLWATER

UPDATED GEOHYDROLOGICAL IMPACT ASSESSMENT OF THE PROPOSED UNDERGROUND MINING EXTENSION AT KWEZI MINE, NORTHWEST PROVINCE

REVISION 1 REPORT

Report No.: MVB178/25/B047

January 2026

DOCUMENT APPROVAL RECORD

Report No.: MVB178/25/B047

ACTION	FUNCTION	NAME	DATE	SIGNATURE
Prepared	Geohydrologist	Dr. M van Biljon (PHD, Pr.Sci.Nat.)	15/07/2025	

RECORD OF REVISIONS AND ISSUES REGISTER

Date	Revision	Description	Issued to	Issue Format	No. Copies
15/07/2025	1	Revision 1 Report	Lukas Kekana Sibanye-Stillwater	Electronic	1
31/01/2026	1	Revision 2 Report	Lukas Kekana Sibanye-Stillwater	Electronic	1

Marius van Biljon (PhD, Pr. Sci. Nat.)
Geohydrologist

SIBANYE - STILLWATER

UPDATED GEOHYDROLOGICAL IMPACT ASSESSMENT OF THE PROPOSED UNDERGROUND MINING EXTENSION AT KWEZI MINE, NORTHWEST PROVINCE

REVISION 1 REPORT REPORT NO: MVB178/25/B047

CONTENTS PAGE

<u>Table of Figures</u>

<u>List of Tables</u>

MvB Consulting
32 La Paloma Estate
Falls Road, Homes Haven
Krugersdorp, 1759
Cell:+27 79 741 9595
E-mail: marius@mvbconsult.co.za

SIBANYE - STILLWATER

UPDATED GEOHYDROLOGICAL IMPACT ASSESSMENT OF THE PROPOSED UNDERGROUND MINING EXTENSION AT KWEZI MINE, NORTHWEST PROVINCE

REVISION 1 REPORT REPORT NO: MVB178/25/B047

1. INTRODUCTION AND TERMS OF REFERENCE

Sibanye Rustenburg Platinum Mines (Pty) Ltd (SRPM) is a subsidiary entity within the Sibanye Stillwater Limited group of companies. Kwezi Shaft is owned and operated by Sibanye Rustenburg Platinum Mines (Pty) Ltd. The Kwezi Shaft is mining the UG2 reserve as within the mining lease limits described under the mining right NW 30/5/1/2/2/80 MR. The shaft is considered to be on its production decline phase with the expected life of mine to be until 2025. There is an urgent need to find additional ounces of Platinum Group Metals (PGMs) in order for the Kwezi shaft to maintain a sustainable production profile (AvDE, 2024).

It is the intention of SRPM to expand the Mining Right Area through the incorporation of an area over a portion of remainder of portion 1 and portion 127 (now known as Rustenburg Ext 9) of the farm Rustenburg Town and Townlands 272 JQ (various erven) within Rustenburg, in the Northwest Province. The proposed expansion area lies at the border of the SRPM mining right and can be mined from the Kwezi Shaft (Figure 1.1).

In addition to the expansion of the Mining Right Area, SRPM intends to mine the UG2 Shallows Blocks (Blocks A and B). Timely addition of the UG2 Shallows blocks to the existing Kwezi production profile is required to optimise existing critical mass before decline in early 2025 (AvDE, 2024).

Alta van Dyk Environmental Consultants (Pty) Ltd (AvDE) initially appointed MVB Consulting (MVB) to undertake a hydrogeological assessment of the study area. An existing numerical groundwater model that was developed for the larger SRPM was used in this assessment. This model was, however, calibrated according to the mine monitoring data and very limited site-specific data was available. Due to the sensitivity of the project and the concerns from landowners, MVB was requested to update the model following the acquisition of more site-specific information. This data includes:

- Update of the hydrocensus.
- Test pumping of 28 boreholes.
- Sampling and analysis of 33 boreholes.

The results from the additional data collection are described in the report "*Geohydrological Impact Assessment of the Proposed Underground Mining Extension at Kwezi Mine, Northwest Province. Hydrocensus and Pump Test Assessment (MVB Consulting Report No.: MVB169/25/B047*".

The aim of the updated study was to develop a new numerical groundwater model for the study area, with specific attention to the proposed mining extension. The newly acquired test pumping results and aquifer parameters were incorporated into the model.

This report is an update of the report "*Geohydrological Impact Assessment of the Proposed Underground Mining Extension at Kwezi Mine, Northwest Province. (MVB Consulting Report No.: MVB159/24/B047*) and describes the following:

- Conceptual hydrogeological model.
- Aquifer classification and risk assessment.
- Numerical groundwater model development.
- Groundwater impact assessment.

This revision of the report includes the sampling of an additional four boreholes and the pump testing of three boreholes. Some additional sites, where no boreholes could be located. were also visited. The additional information includes:

- Sampled and tested boreholes:
    - KW1: North West Granite Slab Sales, 24 Mangaan Street.
    - KW3: SANY, 20A Mangaan Street.
    - CBH1: Coca Cola, 6 Brons Street.
- Sampled borehole:
    - KW2: Boeties Auto, 22 Mangaan Street.
- Sites visited (No boreholes):
    - P9: North West Granite Slab Sales, 24 Mangaan Street (Borehole covered and pump burned out).
    - P10: Anateng Construction, 20 Mangaan Street (Access denied).
    - P11: Sons & Joseph Motor Repairs (No borehole).
    - P12: Kamogelo, 18 Mangaan Street (No borehole).
    - P13: Board City (No borehole).

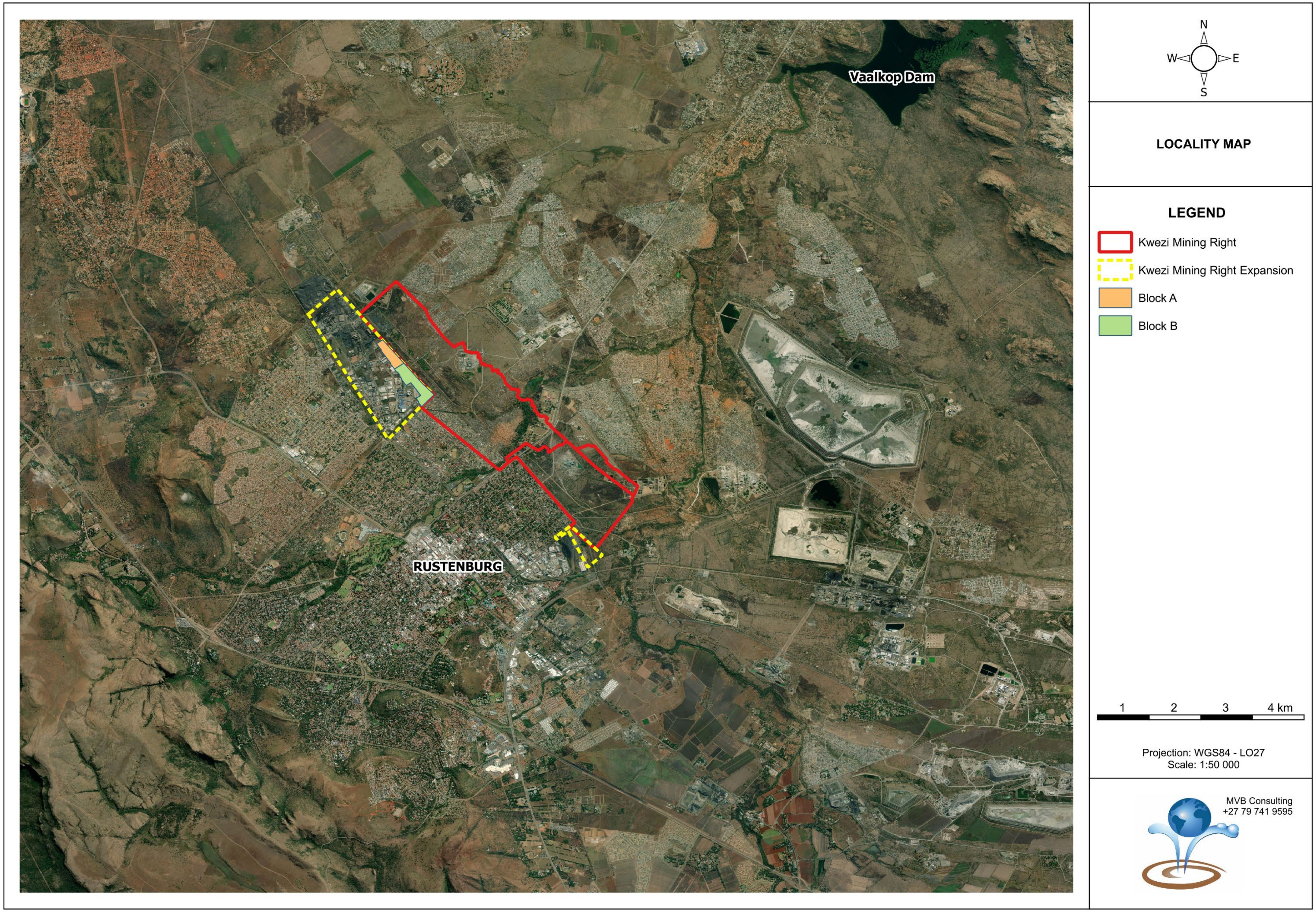


Figure 1.1: Locality of the study area

2. GEOGRAPHICAL SETTING

2.1 Topography and Drainage

The study area is situated in an area of gentle undulating plains, approximately 10 km northeast of the Magaliesberg Mountains. The regional drainage in the study area is from south to north. The Kwezi mining area is situated in quaternary catchments A22H (Hex), within the Crocodile West and Marico Water Management Area. The Hex River is the main regional arterial drainage for the greater Rustenburg area and traverses the mine property, flowing in a northerly direction (Figure 3.1).

Natural runoff generated on the majority of the mine's property drains into the Hex River upstream of Bospoort Dam via several small ephemeral streams. The streams closest to the study area include the Dorpspruit and Wildebeestfonteinspruit.

2.2 Climate and Rainfall

Rustenburg is situated in a sub-tropical region with reasonably high summer and winter daytime temperatures. Average temperatures range from 13 to 30°C in summer and approximately 2 to 24°C in winter. It is warm to hot with moist summers and cool, dry winters. The region is classed under the calm category as wind speeds are relatively low, frost is minimal during the winter seasons, the area is fog free and hailstorms are a rare occurrence (WAP, 2015).

The rainfall stations within close proximity to the general area are station 0511458_W, 0511642_W and 0511672_W. Monthly rainfall for these stations is presented in Table 2.1 The mean annual precipitation for these stations ranges from approximately 570 mm to 670 mm.

Table 2.1: Summary of monthly rainfall for closest rainfall stations to the Rustenburg Operations (WAP, 2015)

Month	0511458_W	0511642_W	0511672_W	Average
October	44	52	50	49
November	83	94	81	67
December	89	119	112	107
January	103	123	118	115
February	83	98	90	90
March	86	86	82	85
April	29	42	43	38
May	15	17	17	16
June	4	7	8	6
July	5	5	5	5
August	10	7	5	7
September	17	17	15	16
MAP (mm/a)	**567**	**667**	**627**	**620**

The evaporation in the region is estimated to be 1400 mm per year (Aurecon, 2013), which is more than double the annual precipitation. The effective recharge to the aquifers is estimated to be less than 3% of the MAP (Vegter et, al). The combined effects of the evaporation exceeding the precipitation, it is expected that groundwater recharge occurs in a pulse-like fashion during and after significant rainfall events (WAP, 2015).

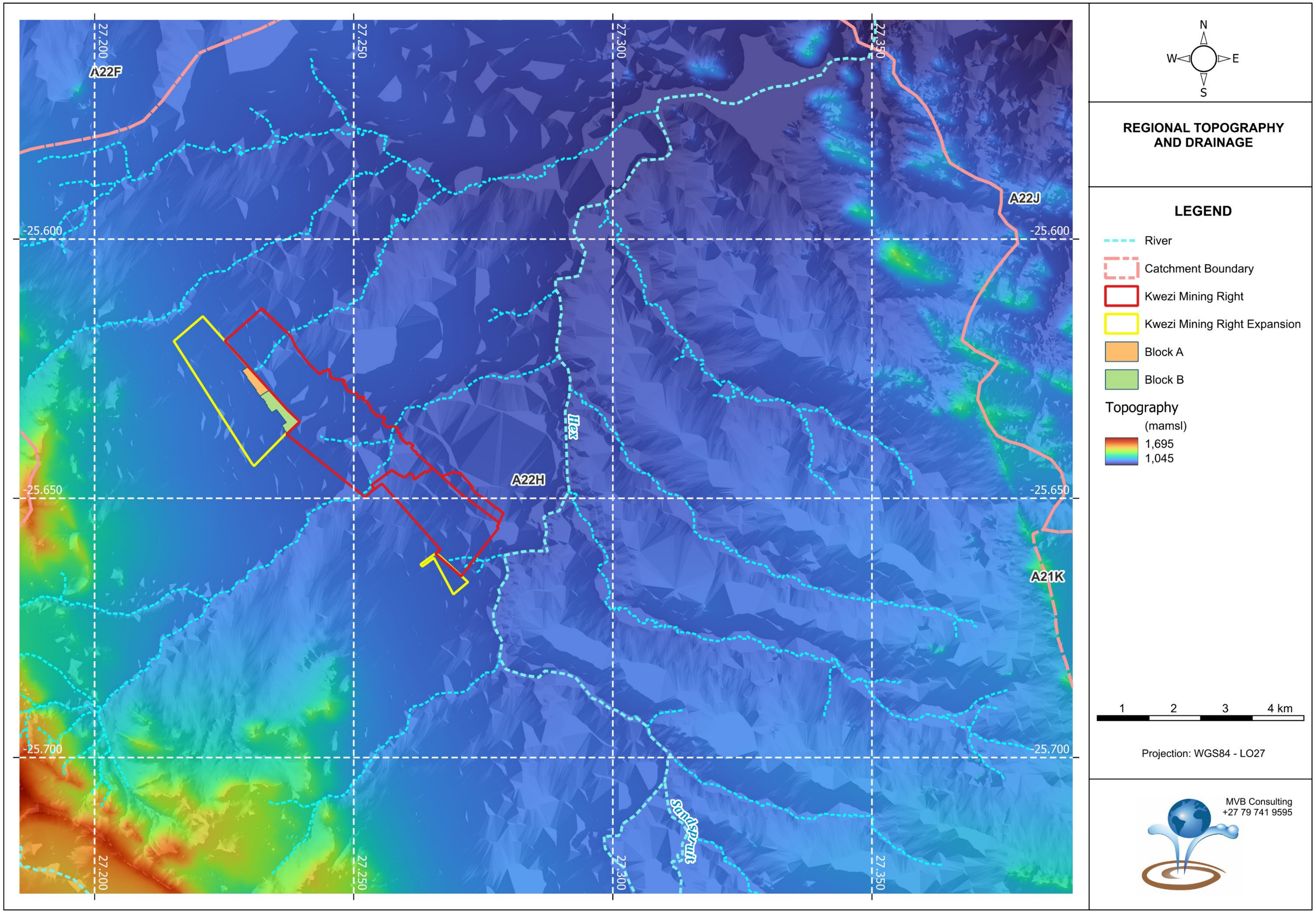


Figure 2.1: **Regional topography and drainage**

3. CONCEPTUAL GEOHYDROLOGICAL MODEL

The current understanding of the mine hydrogeology or the conceptual hydrogeological model was assessed based on the available mine data and previous investigations.

The following is a summary of the current understanding of the various components of the hydrogeological regime.

3.1 Description of the Regional and Mine Geology

The geology in the area is well understood due to the mining activities and has been described in detail by various authors. The following is a summary of the geological setting, mainly as described in the WAP report (WAP, 2015).

The geology of the region is dominated by the layered rocks of the Bushveld Igneous Complex (BIC) as shown in Figure 3.1. The BIC intruded concordantly into the volcano-sedimentary Pretoria Group strata of the Transvaal Supergroup about 2 060 million years ago. The Magaliesberg formation (upper Pretoria Group) is the floor to the BIC in the region.

The BIC extends approximately 350 km in an east-west direction and covers an area of approximately 66 000 km^2. The Rustenburg area overlies part of the ultramafic to mafic layered sequence – the so-called Rustenburg Layered Suite. The Rustenburg layered suite, consists stratigraphically of the following (Figure 3.2):

- Marginal Zone (norite).
- Lower Zone (norite).
- Critical Zone (pyroxenite, norite, anorthosite and chromitite). The Critical Zone also contains the Platinum Group Metal (PGM) bearing Merensky Reef and UG2 chromitite reefs which form the focus of the mining activities.
- Main Zone (gabbro-norite).
- Upper Zone (magnetite-gabbro).

The Critical Zone is subdivided into Lower, Middle and Upper Groups which contain thirteen major Chromitite seams (GSA, 2006). The lower group with seven seams (LG1-7), the middle group with five seams (MG1-5) and the Upper Group with three seams (UG1-3). Of particular importance is the UG2 chromitie layers within the upper Critical Zone, which is the target of the mining operations. The Critical Zone is overlain by the Main zone, a uniform sequence of cumulates consisting mostly of norite and gabbronorite. Overlaying the Main Zone is the Upper Zone, which consists of gabbro and anorthosite overlain by progressively more differentiated rock such as diorite.

In the study area the Merensky and UG2 reefs strike northwest by south-east and dip between approximately 10º and 14º to the northeast. Mining from the Merensky Reef started approximately 95 years ago from surface on sub-outcrop using on-reef declines. As mining depths increased, reef access was gained by progressively deeper vertical shafts. At present, the Merensky Reef has been mined along more than 28 km of strike and mining depths exceed 1 200 metres below surface (mbs). Opencast and underground mining of the UG2 Reef, situated 100-140 m below the Merensky Reef, started some 15 years ago. Access is mostly gained from vertical and decline shafts from the Merensky Reef operations.

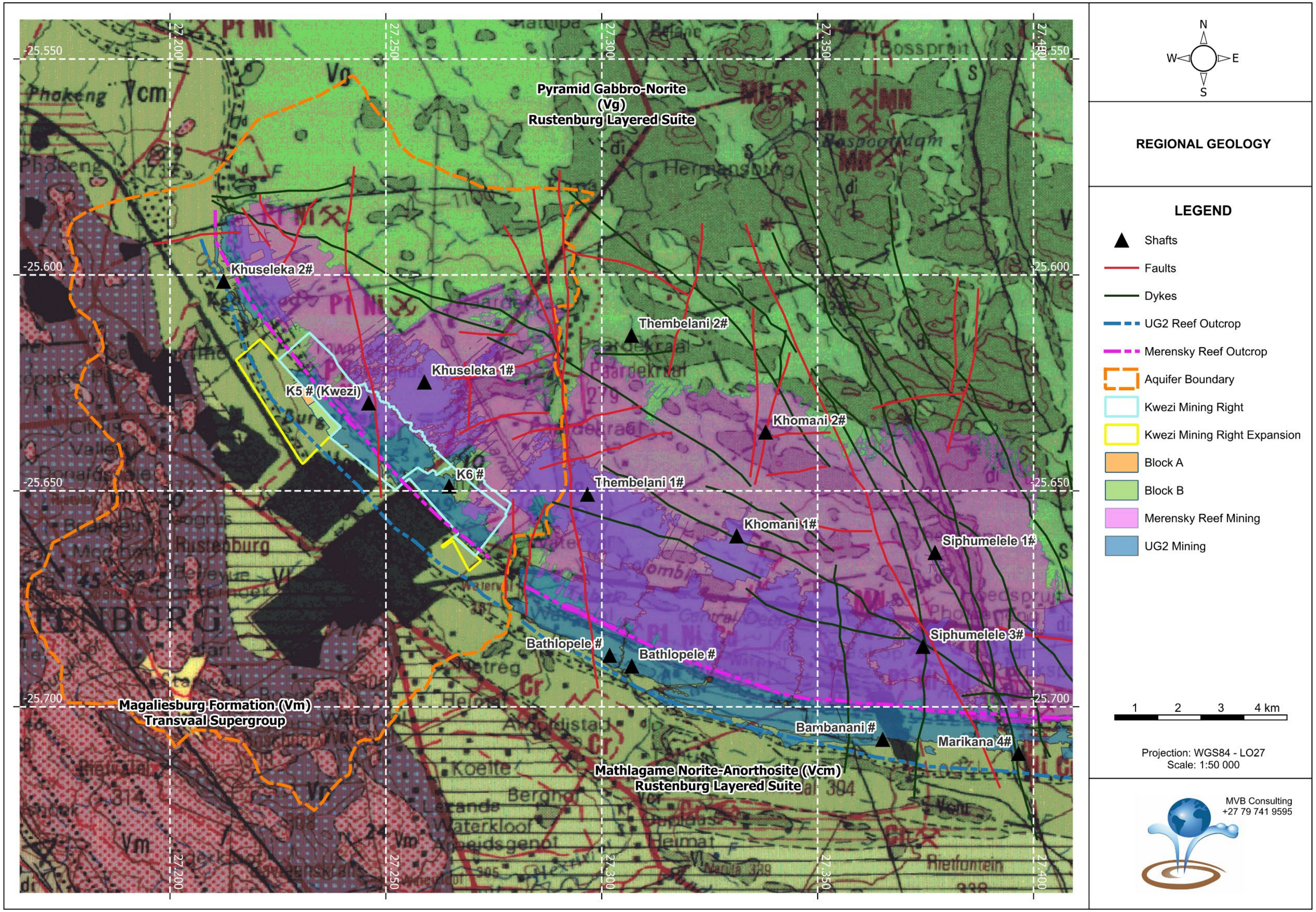


Figure 3.1: **Regional surface geology**

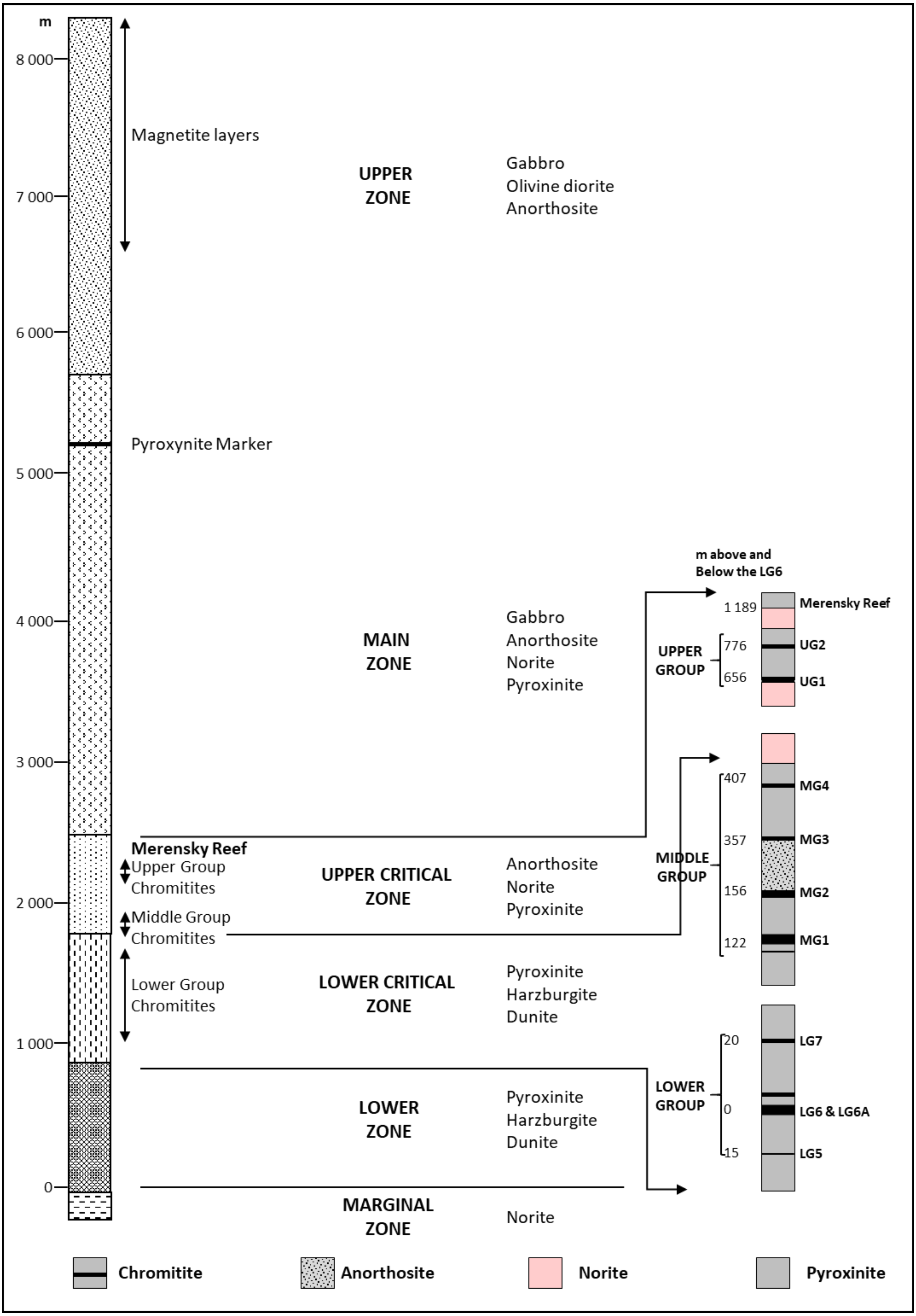


Figure 3.2: Generalised stratigraphic column of the Rustenburg Layered Suite of the Bushveld Complex (Viljoen & Schürmann, 1998)

3.2 Description of the Hydrogeology of the Region

3.2.1 Introduction

The hydrogeology of the study area was assessed based on available mine monitoring data and site-specific investigations. The hydrogeological setting and conceptual model of the study area is described according to the following criteria:

- Hydrocensus and borehole information.
- Aquifer type.
- Aquifer parameters.
- Groundwater gradients and flow.
- Hydrochemistry.

3.2.2 Updated Hydrocensus and Borehole Data

An initial hydrocensus was undertaken on the 3rd of October 2024 during which twenty-eight (28) properties were visited. Twenty-five (25) boreholes were identified during this census. During the public participation process several landowners indicated that their boreholes are not shown on the list. Many of the properties have been sub-divided and more than one borehole has been drilled by the business owners. A follow-up hydrocensus was therefore undertaken in December 2024 and January 2025. A further fourteen (14) boreholes were located (Figure 3.3).

Details of the property owners are presented in Table 3.1.

Additional information on landowners and photographs can be obtained from the Hydrocensus and Pump Test Assessment, MVB Consulting Report No.: MVB169/25/B047 (2025).

Figure 3.3: **Hydrocensus boreholes**

Table 3.1: Hydrocensus information – Summary

Borehole ID	Coordinates			Owner	Borehole Depth	Borehole Use and Abstraction		Hydrogeological information	
	Latitude	Longitude	Elevation			Primary Use	Abstraction Rate	Static Water Level	
			[mamsl]		[m]	[-]	[L/s]	[mbgl]	[mamsl]
BH1	-25.63950	27.22890	1149.91	Euro Steel	25	Industrial	0.40	14.51	1135.40
BH2	-25.63900	27.22790	1151.04	Twin Pack	60	Industrial	0.27	18.72	1132.32
BH3	-25.63810	27.22840	1151.23	Mattress & Lounge Corporation	45	Industrial	0.27	15.00	1136.23
BH4	-25.63490	27.22650	1155.00	Chemblocks	45	Industrial	1.11	17.50	1137.50
BH4A	-25.63229	27.22517	1149.63	Chemblocks (Gensec)	30	Commercial	1.38	10.84	1138.79
BH5	-25.63530	27.22650	1155.00	Allied Crane	70	Industrial	0.13	52.57	1102.43
BH6	-25.63200	27.23410	1144.52	Rustenburg Steel Construction	46	Industrial	0.27	13.23	1131.29
BH7	-25.63270	27.23410	1144.17	Flex Self Storage	65	Industrial	0.27	11.13	1133.04
BH8	-25.63470	27.23500	1142.11	Epol	25	Industrial	1.50	4.55	1137.56
BH9	-25.63400	27.23510	1142.25		25	Industrial	Unknown	10.00	1132.25
BH10	-25.63270	27.23590	1141.68	Mmutle Mining Projects	40	Industrial	0.27	19.56	1122.12
BH11	-25.63730	27.23620	1140.00	Khunene Technologies	80	Industrial	0.13	14.86	1125.14
BH12	-25.63720	27.23710	1138.73	Khunene Technologies	100	Not in use	Unknown	15.96	1122.77
BH13	-25.63160	27.23220	1147.14	Afri Readymix	60	Industrial	4.62	9.92	1137.22
BH14	-25.62910	27.22700	1153.09	Rustenburg Galvanisers	50	Industrial	Unknown	8.80	1144.29
BH15	-25.65650	27.25100	1142.53	Private Owner	50	Domestic	0.13	14.57	1127.96
BH16	-25.62900	27.23050	1149.01	Steel Services	120	Industrial	0.27	9.98	1139.03
BH17	-25.63340	27.23320	1145.00	Q4 Fuel	45	Industrial	Unknown	10.40	1134.60
BH18	-25.63850	27.23050	1147.68	Steel and Pipe	20	Domestic	0.13	3.83	1143.85
BH19	-25.63540	27.23120	1147.64	Bubbles Plastic	40	Domestic	1.38	9.72	1137.92
BH20	-25.62710	27.23130	1146.97	Glencore	30	Monitoring	No abstraction	8.05	1138.92

Borehole ID	Coordinates			Owner	Borehole Depth	Borehole Use and Abstraction		Hydrogeological information	
	Latitude	Longitude	Elevation			Primary Use	Abstraction Rate	Static Water Level	
			[mamsl]		[m]	[-]	[L/s]	[mbgl]	[mamsl]
BH21	-25.62680	27.23100	1147.01	Glencore	30	Monitoring	No abstraction	8.08	1138.93
BH22	-25.62770	27.23040	1148.15	Glencore	30	Monitoring	No abstraction	9.75	1138.40
BH23	-25.62760	27.23150	1147.07	Glencore	30	Monitoring	No abstraction	8.82	1138.25
BH24	-25.62970	27.23020	1149.60	SAB	70	Domestic	1.45	8.97	1140.63
BH25	-25.63930	27.23203	1142.52	Ruscon Investments	30	Commercial	1.38	2.95	1139.57
BH26	-25.63772	27.22785	1152.00	Rustenburg Engineering and Foundry	30	Production	2.00	6.40	1145.60
BH27	-25.63039	27.23268	1146.00	Northwest Recycling	31	Commercial	0.40	7.80	1138.20
BH28	-25.63027	27.23452	1144.00	Northwest Recycling	42	Monitoring	Unknown	7.05	1136.95
BH29	-25.63021	27.23444	1144.00	Northwest Recycling	45	Commercial/domestic	1.30	7.50	1136.50
BH30	-25.63501	27.23777	1140.95	Professional Clothing	75	Industrial/domestic	1.38	16.80	1124.20
BH31	-25.63505	27.23782	1138.43	Professional Clothing	45	Industrial/domestic	1.38	1.17	1136.83
BH32	-25.63477	27.23252	1147.97	RCL Foods (BH 1)	50	Not in use	Unknown	6.74	1141.26
BH33	-25.63472	27.23307	1144.33	RCL Foods (BH 2)	45	Irrigation	Unknown	5.88	1138.12
BH34	-25.63830	27.23317	1154.06	RCL Foods (BH 3)	35	Irrigation	Unknown	6.68	1147.32
BH35	-25.62852	27.22648	1140.96	VK Chrome Processing	40	Commercial	1.38	23.12	1117.84
BH35A	-25.62902	27.22510	1145.37	VK Chrome Processing	75	Commercial	1.66	10.23	1135.14
BH35B	-25.63211	27.22779	1143.55	VK Chrome Processing	50	Commercial	Unknown	7.30	1136.25
BH35C	-25.63149	27.22754	1142.92	VK Chrome Processing	45	Commercial	Unknown	7.54	1135.38
KW1	-25.63503	27.23836	1135.00	North West Granite Slab Sales	45	Industrial	1.11	4.3	1130.70
KW2	-25.63530	27.23802	1137.00	Boeties Auto	70	Industrial	0.03	28.64	1108.36
KW3	-25.63566	27.23761	1134.00	SANY	60	Industrial	0.17	3.51	1130.49
CBH1	-25.63418	27.23804	1139.00	Coca-Cola	35	Industrial	Unknown	7.44	1131.56

Borehole ID	Coordinates			Owner	Borehole Depth	Borehole Use and Abstraction		Hydrogeological information	
	Latitude	Longitude	Elevation			Primary Use	Abstraction Rate	Static Water Level	
			[mamsl]		[m]	[-]	[L/s]	[mbgl]	[mamsl]
Sites visited without boreholes									
P1	-25.6320	27.2352	1144.99	HMB Airconditioning	No borehole				
P2	-25.6383	27.2291	1149.16	S & S Engineering	No borehole				
P3	-25.6382	27.2288	1153.49	Blue Ribbon	No borehole				
P4	-25.6361	27.2271	1156.91	Aromax	No borehole				
P5	-25.6332	27.2396	1137.83	Madiba Supermarket	No borehole				
P6	-25.6372	27.2420	1138.18	Private	No borehole				
P7	-25.6394	27.2308	1143.83	Kolas Sports Bar	No borehole				
P8	-25.6446	27.2326	1149.68	Renata Tyres and Mags	No borehole				
P9	-25.63456	27.23857	1138.00	North West Granite Slab Sales	Borehole covered, pump burned out				
P10	-25.63568	27.23709	1134.00	Anateng Construction	Access denied				
P11	-25.63584	27.23672	1149.00	Son & Joseph Motor Repairs	No borehole				
P12	-25.63598	27.23665	1146.00	Kamogelo	No borehole				
P13	-25.63625	27.23641	1144.00	Board City	No borehole				

Note:

m = metres

mbgl = metres below ground level

mamsl = metres above mean sea level

L/s = liters per second

3.2.3 Aquifer Type

Previous studies and data related to the regional geology in the study area indicate that structural discontinuities such as dykes, fault planes and geological contact zones are the controlling agents for groundwater flow. The crystalline rocks of the BIC do not have primary porosity which would facilitate the flow of groundwater.

The following aquifers are present in the study area:

- ***Weathered Aquifer.*** The mafic intrusive norite that outcrops over most of the study area is characterized by weathering in the first few meters from surface. Norite is often associated with Nickel and Copper, which may give rise to higher naturally occurring concentrations in the groundwater.
- The weathering follows a broad pattern due to regional stresses and deformation with weathered basins mostly orientated in north-west by south-east trending valleys. This weathered overburden, which covers the project area, forms a shallow unconfined aquifer in the upper 10 to 50 m of the geological succession. The weathered overburden is treated as a single weathered aquifer unit and is described as a “highly weathered, yellowish white to yellowish brown norite. There are currently no aquifer parameter information available and literature-based values indicate that the unit generally has low to moderate transmissivity but high storativity.
- ***Primary Alluvial Aquifer.*** Along the course of the Hex River and other streams, the weathered aquifer has been partially or totally replaced by alluvial aquifers which were deposited by the river and retained hydraulic connectivity with it. The weathered aquifer is recharged by lateral inflow from the surface streams at saprolite-saprock interfaces.
- **Secondary Fractured Aquifer.** A deeper fractured semi-confined rock aquifer is formed by bedding planes, faults and joint planes of the unweathered norites, anorthosites and pyroxenites of the Rustenburg Layered Suite. In fractured rocks, the interconnected discontinuities are the main passage for groundwater flow. In the project area, regional fracture systems cause the upwelling of deeper groundwater which sustains the aquifer system. The crystalline unweathered and intact rocks are considered to have very low porosity and permeability. The hydraulic conductivity of these units is determined by fractures and mine openings.

An impermeable or semi-permeable interface between the upper weathered, and the deeper, fractured aquifer prevents vertical drainage of the shallow aquifer on a regional scale. Therefore, regionally, the groundwater flow in the shallow aquifer is driven by topographic gradients and local recharge. The vertical infiltration across the interface is governed by fractures, creating zones of permeability.

The soil cover consists mostly of a relatively thin (0-2m) layer of blackish clayey vertisol soil. The soil is a direct weathering product of the norite rocks in the area. In spite of the soil – locally referred to as ‘turf’ – has very high clay content, infiltration does occur through the soil horizon especially through cracks in the soil structure that form in the dry season. Deeper soil and colluvium cover (up to 6 m) is present near the Hex River and drainage lines of the shallow valleys draining the study area.

Reddish sandy loam soils occur in the direct vicinity of the intrusive felsic syenite dykes of Pilanesberg Complex origin. Better infiltration and slightly higher recharge can be expected in these areas.

A plan layout of the main geological features (dykes, faults etc.), specifically those affecting groundwater flow, is shown in Figure 3.1.

3.2.4 Aquifer Boundaries

Mine boundaries and aquifer boundaries seldom coincide. Criteria for selecting aquifer boundary conditions are primarily topography, hydrology and geology. The topography, geology, or both, may yield boundaries such as impermeable strata or potentiometric surface controlled by surface water, or recharge/discharge areas such as inflow boundaries along mountain ranges. The flow system allows the specification of boundaries in situations where natural boundaries are a great distance away.

Based on these conditions the aquifer boundaries for the study area were selected. The regional mining area can be divided into three (3) aquifers referred to as follows:

- SRPM Aquifer – western section of the mining area (including the Kwezi mining extension).
- Kroondal Aquifer – central section of the mining area.
- Marikana Aquifer – eastern section of the mining area.

There are additional internal flow boundaries within the delineated aquifer boundaries, and it is possible to further sub-divide the above compartments if required.

The Kwezi mining extension is in the SRPM Aquifer (see Figure 3.5).

3.2.5 Groundwater Gradients and Flow

The hydrocensus groundwater levels as well as the mine groundwater level monitoring was assessed used to develop a regional groundwater level map. The available groundwater levels are shown in Table 3.2.

Table 3.2: Groundwater levels

Borehole ID	Coordinates			Groundwater Level	
	Longitude	Latitude	Z	(mbgl)	(mamsl)
Hydrocensus Boreholes					
BH1	27.22890	-25.63950	1149.91	4.15	1145.76
BH2	27.22790	-25.63900	1151.04	18.72	1132.32
BH3	27.22840	-25.63810	1151.23	5.22	1146.01
BH4	27.22650	-25.63490	1155.00	8.10	1146.90
BH4A	27.22517	-25.63229	1149.63	10.84	1138.79
BH5	27.22650	-25.63530	1155.00	7.89	1147.11
BH6	27.23410	-25.63200	1144.52	8.80	1135.72
BH7	27.23410	-25.63270	1144.17	8.00	1136.17
BH8	27.23500	-25.63470	1142.11	4.55	1137.56
BH9	27.23510	-25.63400	1142.25	10.00	1132.25
BH10	27.23590	-25.63270	1141.68	19.56	1122.12
BH11	27.23620	-25.63730	1140.00	7.07	1132.93
BH12	27.23710	-25.63720	1138.73	7.86	1130.87
BH13	27.23220	-25.63160	1147.14	9.92	1137.22
BH14	27.22700	-25.62910	1153.09	7.95	1145.14
BH15	27.25100	-25.65650	1142.53	14.57	1127.96
BH16	27.23050	-25.62900	1149.01	8.96	1140.05
BH17	27.23320	-25.63340	1145.00	10.40	1134.60

Borehole ID	Coordinates			Groundwater Level	
	Longitude	Latitude	Z	(mbgl)	(mamsl)
BH18	27.23050	-25.63850	1147.68	3.83	1143.85
BH19	27.23120	-25.63540	1147.64	9.72	1137.92
BH20	27.23130	-25.62710	1146.97	7.26	1139.71
BH21	27.23100	-25.62680	1147.01	7.95	1139.06
BH22	27.23040	-25.62770	1148.15	7.32	1140.83
BH23	27.23150	-25.62760	1147.07	7.66	1139.41
BH24	27.23020	-25.62970	1149.60	8.97	1140.63
BH25	27.23203	-25.63930	1142.52	2.95	1139.57
BH26	27.22785	-25.63772	1152.00	6.40	1145.60
BH27	27.23268	-25.63039	1146.00	7.80	1138.20
BH28	27.23452	-25.63027	1144.00	7.05	1136.95
BH29	27.23444	-25.63021	1144.00	7.22	1136.78
BH30	27.23777	-25.63501	1140.95	16.80	1124.15
BH31	27.23782	-25.63505	1138.43	1.17	1137.26
BH32	27.23252	-25.63477	1147.97	6.74	1141.23
BH33	27.23307	-25.63472	1144.33	5.88	1138.45
BH34	27.23317	-25.63830	1154.06	6.68	1147.38
BH35	27.22648	-25.62852	1140.96	7.31	1133.65
BH35A	27.22510	-25.62902	1145.37	8.76	1136.61
BH35B	27.22779	-25.63211	1143.55	5.88	1137.67
BH35C	27.22754	-25.63149	1142.92	6.53	1136.39
Note: 18.72 mbgl – Pumping groundwater level					
Mine Monitoring Boreholes					
BF1	27.21623	-25.59890	1148.85	25.21	1123.64
BFU339	27.21174	-25.59450	1150.47	15.28	1135.19
BFU340	27.21134	-25.59460	1151.12	15.71	1135.41
EM05	27.30030	-25.66830	1121.34	6.52	1114.82
EM11	27.34801	-25.68470	1145.00	7.41	1137.59
EM16	27.32534	-25.66210	1131.76	0.81	1130.95
EM52	27.31981	-25.62810	1112.94	0.96	1111.98
EM53	27.31981	-25.62800	1112.96	1.21	1111.75
EM54	27.37459	-25.70190	1173.06	0.81	1172.25
EMHEX	27.28912	-25.60810	1090.43	4.94	1085.49
EMX	27.30853	-25.65620	1125.84	5.46	1120.38
GW01	27.28733	-25.68030	1135.24	51.91	1083.33
GW09	27.29222	-25.68310	1132.60	6.79	1125.81
GW14	27.29728	-25.68800	1130.49	8.25	1122.24
GW22	27.29500	-25.65430	1110.00	0.95	1109.05
GW25	27.37310	-25.68800	1170.24	1.16	1169.08
GW45	27.29972	-25.68870	1133.36	17.49	1115.87
KCBH01	27.36784	-25.70130	1172.06	6.38	1165.68
KCBH02	27.36835	-25.70140	1175.00	8.62	1166.38
KCBH03	27.36857	-25.70110	1175.00	6.81	1168.19
NB05	27.30166	-25.66890	1123.69	7.75	1115.94
NB07	27.32556	-25.66110	1131.58	1.46	1130.12
NB10	27.30272	-25.63730	1110.31	5.51	1104.80

Borehole ID	Coordinates			Groundwater Level	
	Longitude	Latitude	Z	(mbgl)	(mamsl)
NB12	27.36774	-25.69700	1164.76	18.98	1145.78
NB12A	27.36766	-25.69910	1170.00	29.23	1140.77
NB14	27.37074	-25.70130	1171.34	7.85	1163.49
NB25	27.33732	-25.63470	1120.83	1.35	1119.48
NB27	27.34219	-25.63620	1125.47	3.68	1121.79
NB29	27.36938	-25.69060	1163.46	7.21	1156.25
NB35	27.30049	-25.68980	1132.11	9.74	1122.37
NB36	27.30220	-25.69080	1130.96	7.81	1123.15
NB47	27.33152	-25.66670	1139.25	2.80	1136.45
NB51	27.33618	-25.68130	1140.18	9.29	1130.89
NB56	27.35093	-25.68080	1155.66	1.67	1153.99
NBH04	27.30652	-25.61300	1096.34	1.16	1095.18
NBH06	27.30249	-25.66300	1123.57	10.69	1112.88
PD04	27.29440	-25.62110	1102.67	8.86	1093.81
WAPBH09A	27.31116	-25.65330	1120.26	1.49	1118.77
WAPBH09C	27.31125	-25.65320	1120.14	1.31	1118.83
WAPBH12	27.38207	-25.70260	1183.96	11.56	1172.40
WV BH01	27.27709	-25.67700	1126.17	6.26	1119.91
WV BH04	27.27930	-25.67780	1125.02	6.28	1118.74
WV BH05	27.27908	-25.67960	1125.00	5.37	1119.63
WV BH06	27.28418	-25.68240	1130.00	10.10	1119.90

Please note that the above groundwater levels in some of the hydrocensus boreholes may differ from Table 3.1 as the hydrocensus measurements may have been a pumping water level. The groundwater levels in the above table were measured just before the pumping tests and believed to be the Rest Water Level (RWL).

Typically, a linear relationship exists between the depth to groundwater and the topography since groundwater normally drains under gravity towards streams and rivers. This relationship is known as the Bayesian Correlation and to prove that it exists in the study area the hydrocensus and monitoring borehole water levels and collar elevation was plotted (Figure 3.4). The four graphs in this figure illustrates the following correlations:

- Top Left Graph: Correlation in all the hydrocensus boreholes (58%),
- Top Right Graph: Correlation in the hydrocensus boreholes, with the pumping water levels removed. The correlation improves to 78%.
- Bottom Left Graph: Correlation in the mine monitoring boreholes (93%).
- Bottom Right Graph: Correlation in all available boreholes, excluding pumping boreholes. The regional correlation is 93%, indicating that the groundwater flow mimics the topography.

The hydrocensus and monitoring borehole data, as well as the topography was used to interpolate a regional groundwater gradient map (Figure 3.5).

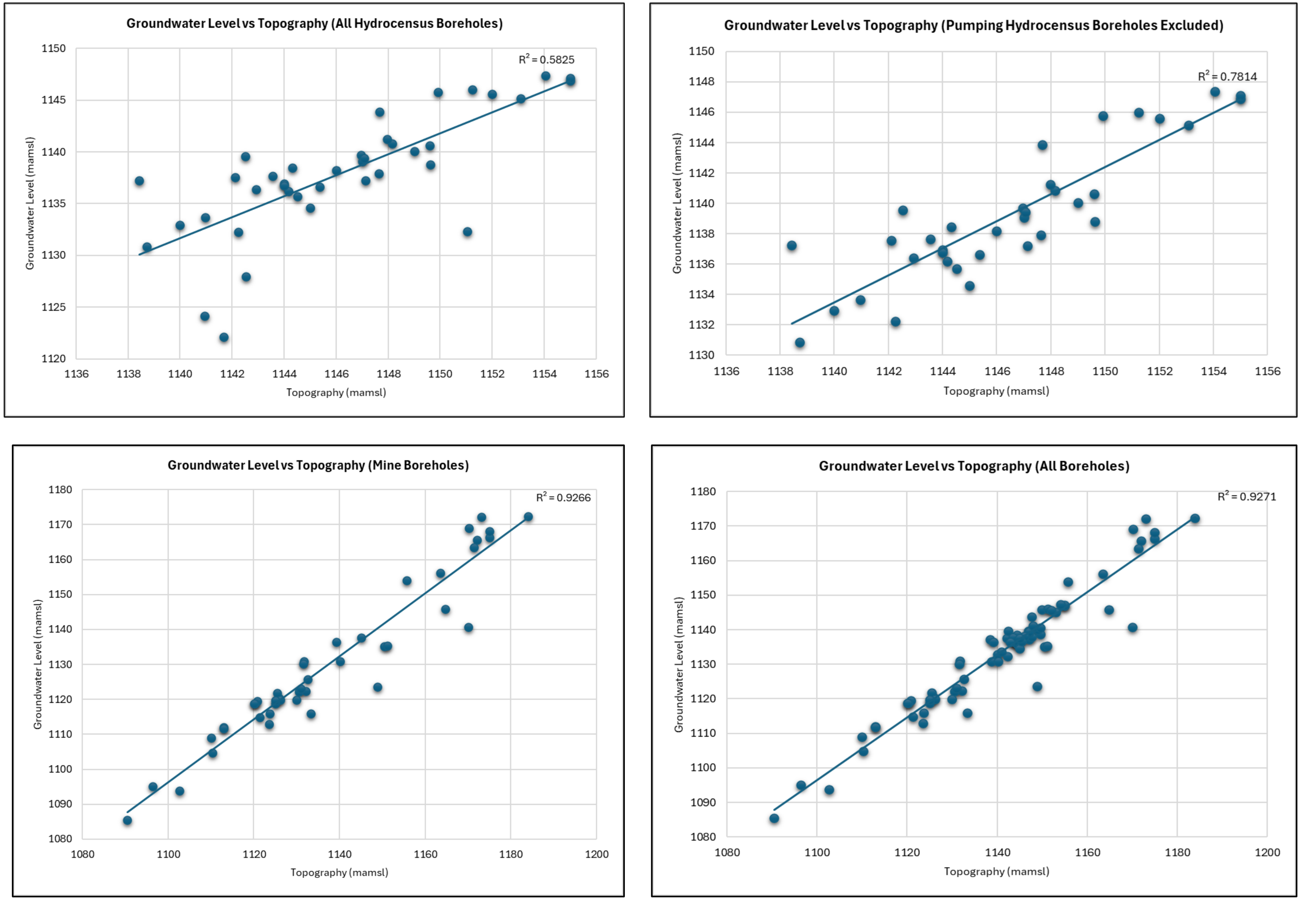


Figure 3.4: Relationship between topography and groundwater table

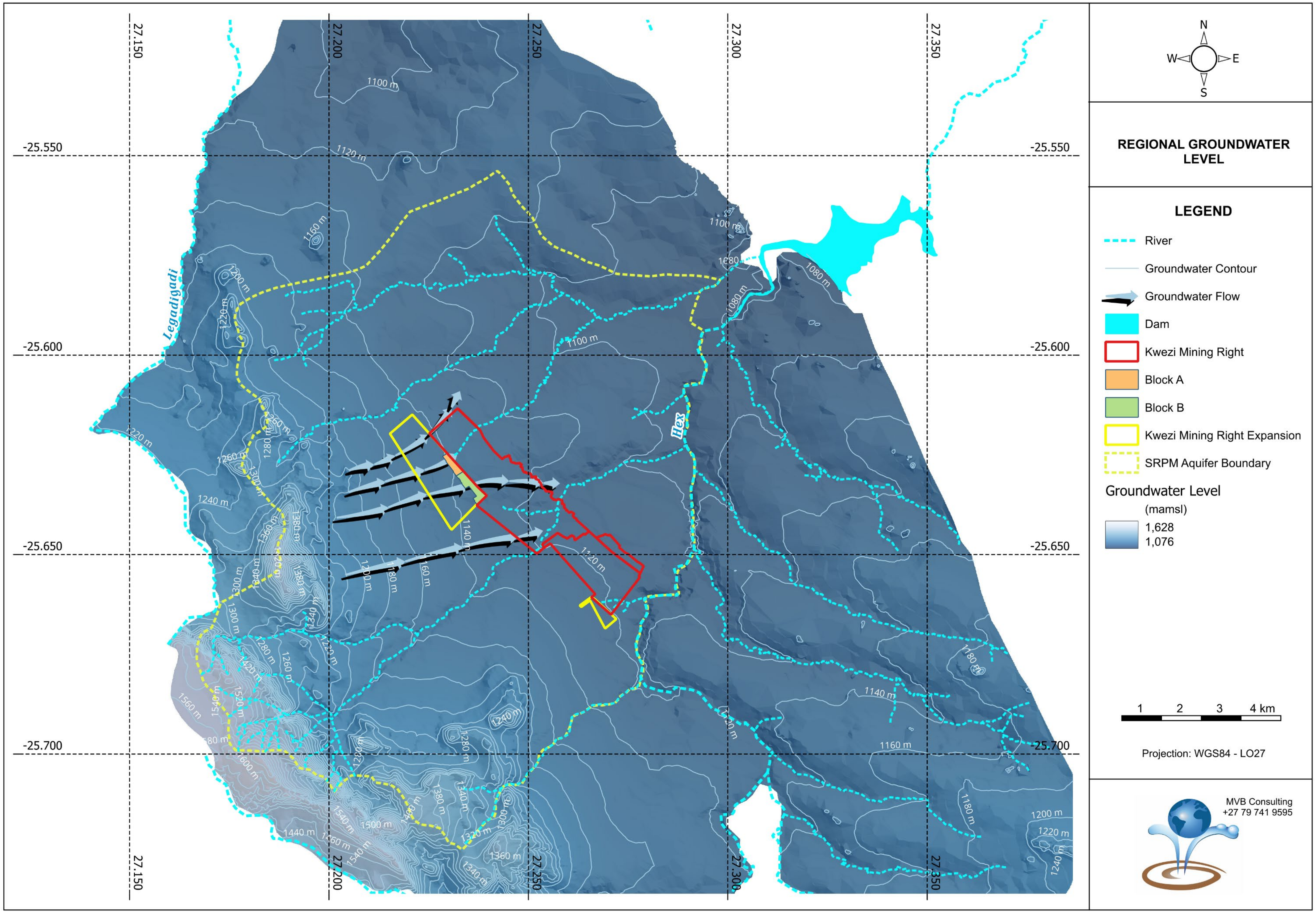


Figure 3.5: Regional groundwater gradients and flow

3.2.6 Aquifer Parameters

Aquifer parameters are obtained from the test pumping of boreholes. Important parameters that can be obtained from borehole or test pumping include Hydraulic Conductivity (K), Transmissivity (T) and Storativity (S). These parameters are defined as follows (Krusemann and De Ridder, 1991):

- Hydraulic Conductivity (K): This is the volume of water that will move through a porous medium in unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow. It is normally expressed in metres per day (m/day).
- Transmissivity (T): This is the rate of flow under a unit hydraulic gradient through a cross-section of unit width over the full, saturated thickness of the aquifer. Transmissivity is the product of the average hydraulic conductivity and the saturated thickness of the aquifer. Transmissivity is expressed in metres squared per day (m^2/day).
- Storativity (S): The storativity of a saturated confined aquifer is the volume of water released from storage per unit surface area of the aquifer per unit decline in the component of hydraulic head normal to that surface. Storativity is a dimensionless quantity.

3.2.6.1. Regional Parameter Estimation

The WAP report (2015) states that several pumping tests have been conducted, although the test results are not available. Aquifer parameters typical of the region that was obtained from literature are summarised in Table 4.3 below. These values were used during the initial modelling.

Table 3.3: Summarised regional aquifer parameters

Borehole	Hydraulic Conductivity (m/day)	Transmissivity (m^2/day)	Storativity (m^2/day)	Source
Weathered BIC	0.23 - 73	6 – 1 825	0.008 – 0.35	SRK (2000)
	0.3 – 3	13 – 157		CRM (2006)
	5 - 93	73 - 535	0.001 – 0.1	WGS (2007)
	1.3		3	Delta h (2012)
Fractures BIC	0.89 - 29	22 - 725	0.00002-0.02	SRK (2000)
	0.03			Delta h (2012)
Transvaal Group	0.028			Delta h (2012)
Faults	0.2			Delta h (2012)

3.2.6.2. Site-Specific Parameter Estimation

Site-specific aquifer parameters were calculated after the pump testing of twenty-five (25) of the hydrocensus boreholes. The pump test information is shown in Table 3.4. Not all the boreholes could be tested as some of the landowners refused entry to the pump testing contractors. The following boreholes were pump tested.

Table 3.4: Pump tested boreholes

Borehole ID	Owner	Pump Tested	Borehole Sampled	Comment
BH1	Euro Steel	Yes	Yes	Tested
BH2	Twin Pack	No	No	Could not obtain permission to test
BH3	Mattress & Lounge Corporation	Yes	Yes	Tested
BH4	Chemblocks	Yes	Yes	Tested
BH4A	Chemblocks (Gensec)	Yes	Yes	Tested
BH5	Allied Crane	Yes	Yes	Tested
BH6	Rustenburg Steel Construction	Yes	Yes	Tested
BH7	Flex Self Storage	Yes	Yes	Tested
BH8	Epol	No	No	Boreholes were previously tested and sampled by private consultant. Reports were made available
BH9		No	No	
BH10	Mmutle Mining Projects	No	No	Could not obtain permission to test
BH11	Khunene Technologies	Yes	Yes	Tested
BH12	Khunene Technologies	Yes	Yes	Tested
BH13	Afri Readymix	Yes	Yes	Tested
BH14	Rustenburg Galvanisers	Yes	Yes	Tested
BH15	Private Owner	No	No	Borehole located several km outside potential impacted area
BH16	Steel Services	Yes	Yes	Tested
BH17	Q4 Fuel Marolien	Yes	Yes	Tested
BH18	Steel and Pipe	No	No	Could not obtain permission to test
BH19	Bubbles Plastic	Yes	Yes	Tested
BH20	Glencore	Yes	Yes	Tested
BH21	Glencore	Yes	Yes	Tested
BH22	Glencore	Yes	Yes	Tested
BH23	Glencore	Yes	Yes	Tested
BH24	SAB	Yes	Yes	Tested
BH25	Ruscon Investments	No	No	Could not obtain permission to test
BH26	Rustenburg Engineering and Foundry	No	No	Could not obtain permission to test
BH27	Northwest Recycling	Yes	No	Borehole pumped dry in 5 minutes. No data obtained
BH28	Northwest Recycling	No	No	Borehole only used for monitoring, 2m from pumping borehole
BH29	Northwest Recycling	Yes	Yes	Tested
BH30	Professional Clothing	No	Yes	

<table>
<tr><th>Borehole ID</th><th>Owner</th><th>Pump Tested</th><th>Borehole Sampled</th><th>Comment</th></tr>
<tr><td>BH31</td><td>Professional Clothing</td><td>No</td><td>Yes</td><td>Owner allowed the sampling, but not the testing of the boreholes</td></tr>
<tr><td>BH32</td><td>RCL Foods (BH 1)</td><td>No</td><td>Yes</td><td rowspan="3">Owner allowed the sampling, but not the testing of the boreholes</td></tr>
<tr><td>BH33</td><td>RCL Foods (BH 2)</td><td>No</td><td>Yes</td></tr>
<tr><td>BH34</td><td>RCL Foods (BH 3)</td><td>No</td><td>Yes</td></tr>
<tr><td>BH35</td><td>VK Chrome Processing</td><td>Yes</td><td>Yes</td><td>Tested</td></tr>
<tr><td>BH35A</td><td>VK Chrome Processing</td><td>Yes</td><td>Yes</td><td>Tested</td></tr>
<tr><td>BH35B</td><td>VK Chrome Processing</td><td>Yes</td><td>Yes</td><td>Tested</td></tr>
<tr><td>BH35C</td><td>VK Chrome Processing</td><td>Yes</td><td>Yes</td><td>Tested</td></tr>
<tr><td>KW1</td><td>Tombstones</td><td>Yes</td><td>Yes</td><td>Tested</td></tr>
<tr><td>KW2</td><td>Boeties Auto</td><td>No</td><td>Yes</td><td>Owner allowed the sampling, but not the testing of the borehole</td></tr>
<tr><td>KW3</td><td>SANY</td><td>Yes</td><td>Yes</td><td>Tested</td></tr>
<tr><td>CBH1</td><td>Coca-Cola</td><td>Yes</td><td>Yes</td><td>Tested</td></tr>
</table>

To limit the disturbance to the landowners and to reduce the risk of damaging their infrastructure during the pump testing, the pumps installed in the boreholes were used for testing the boreholes. As a result, not all the tests were able to stress the aquifer/borehole enough to drop the water level down to the pump inlet within the pumped time of the Constant Discharge Test (CDT). The boreholes could not be pumped for longer than 12 hours due to landowners not allowing working at night. The data can nevertheless be used for comparative purposes should a claim arises in future.

A summary of the pump testing is presented in Table 3.5. The transmissivity values in the tested boreholes varies between 0.99 m^2/day – 70.1 m^2/day.

The detailed pump test interpretation and borehole yield calculations can be obtained from the pump testing report, Hydrocensus and Pump Test Assessment, MVB Consulting Report No.: MVB169/25/B047 (2025).

Table 3.5: Summary of pump test results

Borehole	BH1	BH3	BH4	BH4A	BH5	BH6	BH7	BH11
Owner	Euro Steel	Mattress & Lounge Corporation	Chemblocks	Chemblocks (Gensec)	Allied Crane	Rustenburg Steel Construction	Flex Self Storage	Khunene Technologies
Borehole Information								
Latitude	27.2289	27.2284	27.2265	27.22517	27.2265	27.2341	27.2341	27.2362
Longitude	-25.6395	-25.6381	-25.6349	-25.6323	-25.6353	-25.632	-25.6327	-25.6373
Depth (m)	25	45	45	30	75	45	70	80
Water Level (m below surface)	4.15	5.22	8.10	13.44	7.89	8.80	8.00	7.07
Pump Depth (m below surface)	18	37	40	26	70	43	68	80
Available Drawdown (m)	13.85	31.78	31.90	12.56	62.11	34.20	60.00	72.93
Pump Test Information								
Constant Rate Test								
Abstraction Rate (lit/sec)	0.82	0.96	1.38	2.28	1.07	1.15	1.14	3.72
Test Duration (minutes)	720	720	720	380	720	720	720	720
Recovery Test								
Test Duration (minutes)	720	10	700	720	710	50	600	720
Percentage Recovery (%)	98	100	98	96	92	99	86	99
Pump Test Results								
Transmissivity (m^2/day)								
Constant Rate Test	8.09×10^{1}	3.24×10^{1}	3.73×10^{0}	2.58×10^{1}	8.84×10^{0}	1.93×10^{0}	8.54×10^{-1}	1.92×10^{0}
			1.87×10^{1}	3.51×10^{0}		3.51×10^{1}	1.08×10^{1}	2.60×10^{1}
Recovery Test	5.95×10^{1}	3.01×10^{0}	1.52×10^{1}	2.03×10^{1}	4.70×10^{0}	3.01×10^{1}	8.55×10^{0}	1.30×10^{1}
Average	**7.02×10^{1}**	**1.77×10^{1}**	**1.25×10^{1}**	**1.65×10^{1}**	**6.77×10^{0}**	**2.24×10^{1}**	**6.74×10^{0}**	**1.36×10^{1}**
Hydraulic Conductivity m/day)								
Constant Rate Test	6.08×10^{0}	1.02×10^{0}	1.17×10^{-1}	1.99×10^{0}	1.42×10^{-1}	5.65×10^{-2}	1.42×10^{-2}	2.64×10^{-2}
			5.86×10^{-1}	2.70×10^{-1}		1.03×10^{0}	1.80×10^{-1}	3.57×10^{-1}
Recovery Test	4.48×10^{0}	9.46×10^{-2}	4.74×10^{-1}	1.56×10^{0}	7.57×10^{-2}	8.79×10^{-1}	1.42×10^{-1}	1.78×10^{-1}
Average	**5.28×10^{0}**	**5.57×10^{-1}**	**3.92×10^{-1}**	**1.27×10^{0}**	**1.09×10^{-1}**	**6.55×10^{-1}**	**1.12×10^{-1}**	**1.87×10^{-1}**

Borehole	BH12	BH13	BH14	BH16	BH17	BH19	BH20	BH21
Owner	Khunene Technologies	Afri Ready Mix	Rustenburg Galvanisers	Steel Services	Q4 Fuel	Bubbles Plastic	Glencore	Glencore
Borehole Information								
Latitude	27.2371	27.2322	27.227	27.2305	27.2332	27.2312	27.2313	27.231
Longitude	-25.6372	-25.6316	-25.6291	-25.629	-25.6334	-25.6354	-25.6271	-25.6268
Depth (m)	100	45	50	120	45	30	32	30
Water Level (m below surface)	7.86	10.78	7.95	8.96	10.55	9.72	7.26	7.95
Pump Depth (m below surface)	40	43	48	100	40	28	30	30
Available Drawdown (m)	32.14	32.22	40.05	91.04	29.45	18.28	22.74	22.05
Pump Test Information								
Constant Rate Test								
Abstraction Rate (lit/sec)	1.82	2.27	1.07	0.85	1.01	1.06	1.02	0.8
Test Duration (minutes)	720	720	720	700	720	720	720	45
Recovery Test								
Test Duration (minutes)	720	700	7	1420	720	7	720	720
Percentage Recovery (%)	99	100	100	100	97	100	99	37
Pump Test Results								
Transmissivity (m^2/day)								
Constant Rate Test	8.58×10^{1}	2.43×10^{2} 1.82×10^{1}	2.47×10^{1}	9.41×10^{1}	3.31×10^{1}	1.47×10^{1}	6.55×10^{1}	3.94×10^{-1} 2.15×10^{1}
Recovery Test	6.62×10^{1}	4.61×10^{1}	5.38×10^{0}	6.41×10^{1}	4.65×10^{1}	1.98×10^{1}	6.10×10^{1}	1.59×10^{-1}
Average	**7.60×10^{1}**	**1.02×10^{2}**	**1.50×10^{1}**	**7.91×10^{1}**	**3.98×10^{1}**	**1.72×10^{1}**	**6.32×10^{1}**	**7.35×10^{0}**
Hydraulic Conductivity (m/day)								
Constant Rate Test	2.64×10^{-2} 3.57×10^{-1}	2.67×10^{0}	7.55×10^{0} 5.64×10^{-1}	6.16×10^{-1}	1.03×10^{0}	1.12×10^{0}	8.03×10^{-1}	2.88×10^{0}
Recovery Test	1.78×10^{-1}	2.06×10^{0}	1.43×10^{0}	1.34×10^{-1}	7.04×10^{-1}	1.58×10^{0}	1.08×10^{0}	2.68×10^{0}
Average	**1.87×10^{-1}**	**2.36×10^{0}**	**3.18×10^{0}**	**3.75×10^{-1}**	**8.67×10^{-1}**	**1.35×10^{0}**	**9.42×10^{-1}**	**2.78×10^{0}**

<table>
<tr><th>Borehole</th><th>BH22</th><th>BH23</th><th>BH24</th><th>BH29</th><th>BH35</th><th>BH35A</th><th>BH35B</th><th>BH35C</th></tr>
<tr><th>Owner</th><th>Glencore</th><th>Glencore</th><th>SA Breweries</th><th>Northwest Recycling</th><th>VK Chrome Processing</th><th>VK Chrome Processing</th><th>VK Chrome Processing</th><th>VK Chrome Processing</th></tr>
<tr><td colspan="9">Borehole Information</td></tr>
<tr><td>Latitude</td><td>27.2304</td><td>27.2315</td><td>27.2302</td><td>27.23444</td><td>27.22648</td><td>27.2251</td><td>27.22779</td><td>27.22754</td></tr>
<tr><td>Longitude</td><td>-25.6277</td><td>-25.6276</td><td>-25.6297</td><td>-25.6302</td><td>-25.6285</td><td>-25.629</td><td>-25.6321</td><td>-25.6315</td></tr>
<tr><td>Depth (m)</td><td>30</td><td>30</td><td>70</td><td>45</td><td>40</td><td>75</td><td>50</td><td>40</td></tr>
<tr><td>Water Level (m below surface)</td><td>7.32</td><td>7.66</td><td>8.97</td><td>7.22</td><td>7.31</td><td>8.76</td><td>5.88</td><td>6.53</td></tr>
<tr><td>Pump Depth (m below surface)</td><td>29</td><td>29</td><td>58</td><td>43</td><td>39</td><td>74</td><td>48</td><td>37</td></tr>
<tr><td>Available Drawdown (m)</td><td>21.68</td><td>21.34</td><td>49.03</td><td>35.78</td><td>31.69</td><td>65.24</td><td>42.12</td><td>30.47</td></tr>
<tr><td colspan="9">Pump Test Information</td></tr>
<tr><td colspan="9">Constant Rate Test</td></tr>
<tr><td>Abstraction Rate (lit/sec)</td><td>1.56</td><td>0.76</td><td>1.45</td><td>1.34</td><td>1.6</td><td>1.6</td><td>1.1</td><td>1.3</td></tr>
<tr><td>Test Duration (minutes)</td><td>720</td><td>6</td><td>720</td><td>480</td><td>720</td><td>720</td><td>720</td><td>85</td></tr>
<tr><td colspan="9">Recovery Test</td></tr>
<tr><td>Test Duration (minutes)</td><td>720</td><td>720</td><td>700</td><td>400</td><td>700</td><td>700</td><td>720</td><td>60</td></tr>
<tr><td>Percentage Recovery (%)</td><td>98</td><td>26</td><td>99</td><td>100</td><td>99</td><td>99</td><td>95</td><td>100</td></tr>
<tr><td colspan="9">Pump Test Results</td></tr>
<tr><td colspan="9">Transmissivity (m^2/day)</td></tr>
<tr><td rowspan="3">Constant Rate Test</td><td>5.06×10^{0}</td><td rowspan="3">3.92×10^{-1}</td><td rowspan="3">2.98×10^{1}</td><td>8.84×10^{0}</td><td>1.34×10^{0}</td><td rowspan="3">3.75×10^{1}</td><td>2.34×10^{0}</td><td>2.21×10^{0}</td></tr>
<tr><td>2.19×10^{1}</td><td>1.82×10^{0}</td><td rowspan="2">6.25×10^{1}</td><td rowspan="2">1.45×10^{1}</td><td>6.88×10^{-1}</td></tr>
<tr><td>1.09×10^{0}</td><td>2.00×10^{1}</td><td>4.75×10^{0}</td></tr>
<tr><td>Recovery Test</td><td>2.26×10^{1}</td><td>1.60×10^{1}</td><td>6.91×10^{1}</td><td>2.26×10^{1}</td><td>3.26×10^{1}</td><td>3.26×10^{1}</td><td>4.61×10^{1}</td><td>9.95×10^{0}</td></tr>
<tr><td>Average</td><td>1.27×10^{1}</td><td>9.96×10^{-1}</td><td>4.95×10^{1}</td><td>1.33×10^{1}</td><td>3.22×10^{1}</td><td>3.51×10^{1}</td><td>2.09×10^{1}</td><td>9.37×10^{0}</td></tr>
<tr><td colspan="9">Hydraulic Conductivity (m/day)</td></tr>
<tr><td rowspan="3">Constant Rate Test</td><td>2.33×10^{-1}</td><td rowspan="3">1.84×10^{-2}</td><td rowspan="3">6.08×10^{-1}</td><td>2.49×10^{-1}</td><td>4.22×10^{-2}</td><td rowspan="3">5.75×10^{-1}</td><td>5.56×10^{-2}</td><td>7.27×10^{-2}</td></tr>
<tr><td>1.01×10^{0}</td><td>5.15×10^{-2}</td><td rowspan="2">1.97×10^{0}</td><td rowspan="2">3.45×10^{-1}</td><td>2.26×10^{-2}</td></tr>
<tr><td>5.04×10^{-2}</td><td>5.65×10^{-1}</td><td>1.56×10^{-1}</td></tr>
<tr><td>Recovery Test</td><td>1.04×10^{0}</td><td>7.49×10^{-1}</td><td>1.41×10^{0}</td><td>6.39×10^{-1}</td><td>4.99×10^{-1}</td><td>4.99×10^{-1}</td><td>1.09×10^{0}</td><td>3.26×10^{-1}</td></tr>
<tr><td>Average</td><td>5.83×10^{-1}</td><td>3.84×10^{-1}</td><td>1.01×10^{0}</td><td>3.76×10^{-1}</td><td>6.87×10^{-1}</td><td>5.37×10^{-1}</td><td>4.97×10^{-1}</td><td>1.44×10^{-1}</td></tr>
</table>

Borehole	KW1	KW3	CBH1
Owner	NW Granite	Sany	Coca-Cola
Borehole Information			
Latitude	27.23836	27.23761	27.23804
Longitude	-25.63503	-25.63566	-25.63418
Depth (m)	45	60	35
Water Level (m below surface)	4.30	3.51	7.44
Pump Depth (m below surface)	25	20	30
Available Drawdown (m)	21.59	16.31	22.56
Pump Test Information			
Constant Rate Test			
Abstraction Rate (lit/sec)	0.23	0.46	1.10
Test Duration (minutes)	500	70	300
Recovery Test			
Test Duration (minutes)	90	60	70
Percentage Recovery (%)	71	97	99
Pump Test Results			
Transmissivity (m^2/day)			
Constant Rate Test	1.52×10^{0}	1.97×10^{0}	1.44×10^{2}
	1.44×10^{0}	4.22×10^{-1}	
Recovery Test	2.49×10^{0}	4.86×10^{-1}	2.97×10^{1}
Average	**6.14×10^{0}**	**9.59×10^{-1}**	**8.69×10^{1}**
Hydraulic Conductivity (m/day)			
Constant Rate Test	7.25×10^{-2}	1.23×10^{-1}	6.55×10^{0}
	6.88×10^{-1}	2.64×10^{-2}	
Recovery Test	1.19×10^{-1}	3.04×10^{-2}	1.35×10^{0}
Average	**2.93×10^{-1}**	**5.99×10^{-2}**	**3.95×10^{0}**

3.2.7 Groundwater Quality Assessment

3.2.7.1. Mine Monitoring Boreholes

The latest groundwater quality in the closest monitoring boreholes is summarised in Table 3.6. The groundwater quality is compared against the Water Use License (WUL) specified limits and in the absence of WUL limits the quality is compared against the DWAF Livestock Watering Guidelines (1996).

The localities of the Kwezi mine monitoring and hydrocensus boreholes are shown on Figure 3.6.

Kwezi (K5) Shaft Monitoring. There are three boreholes (ATG01, ATG05 and NBH02) monitoring the area down-gradient from the Kwezi (K5) Shaft.

- Borehole NBH02 is clean and none of the parameters exceed the WUL limits.
- Borehole ATG01 is located directly downgradient from K5 Shaft: This borehole shows quite deep groundwater levels as compared to ATG05 and NBH02. Groundwater may be flowing into the underground workings at this point. None of the parameters exceed the guideline limits.
- Borehole ATG05 is located downstream of the shaft coffer dam. It shows good quality and none of the parameters exceed the guideline limits.

K6 Shaft Monitoring. There are four boreholes (AK6 G01, AK6 G05, AK6 G07 and AK6 G09) monitoring the area up- and down-gradient from the Kwezi (K6) Shaft.

- The water quality in all four boreholes is good and none of the parameters exceed the guideline limits.

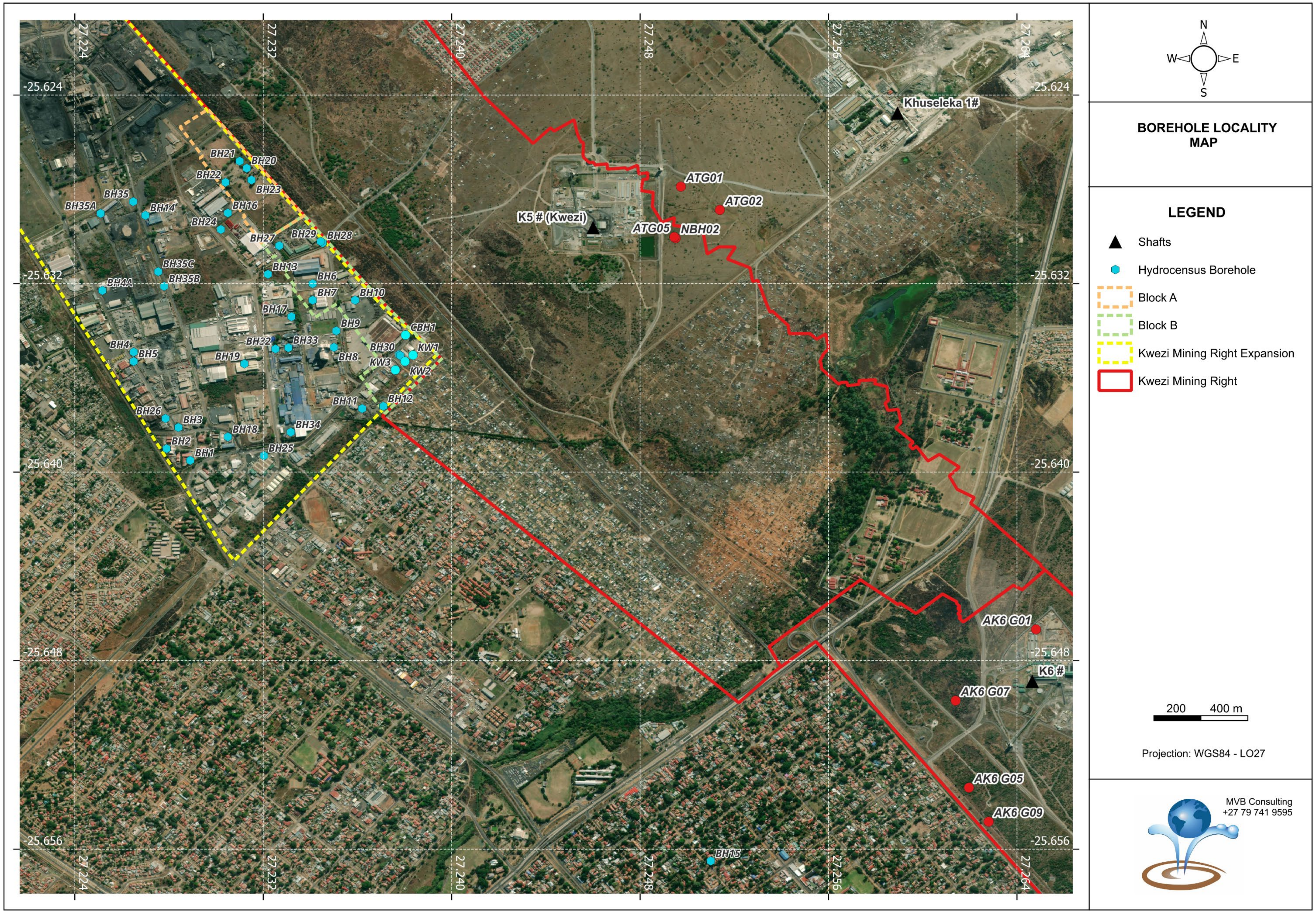


Figure 3.6: **Monitoring and hydrocensus borehole locality**

Table 3.6: Groundwater chemistry in the Kwezi monitoring boreholes

BH ID	pH	EC	TDS	Alk.	Cl	SO_4	NO_3-N	NH_4-N	PO_4-P	F	Ca	Mg	Na	K	Al	Fe	Mn	Cr	Cr^{6+}
	pH Units	mS/m	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ	mg/ℓ
RPM WUL 2018	6-9.5	<150	-	-	<200	<200	<10	-	-	<1	<150	<100	<200	-	-	-	-	-	-
DWS Livestock 1996	-	-	<1000	-	<1500	<1000	<100	-	-	<2	<1000	<500	<2000	-	<5	<10	<10	<1	<1
Kwezi (K5) Shaft)																			
NBH02	8.07	58	392	208	39	45	5.91	1.00	0.04	0.28	37	30.60	36.50	0.85	0.002	0.004	0.001	0.003	0.002
ATG05	7.93	55.8	393	181	36	44	7.42	0.746	0.007	0.23	38.1	32.9	42.3	0.699	0.002	0.004	0.002	0.003	0.002
ATG01	7.25	104	677	506	49	0	0.049	6.78	0.003	0.243	92.3	23.1	102	41.1	0.002	0.004	0.519	0.003	0.002
Kwezi (K6) Shaft																			
AK6 G01	7.80	58	367	276	13	28	0.71	10.80	0.029	0.072	70.6	19.8	21	6.96	0.002	0.004	0.346	0.003	0.002
AK6 G05	7.12	126	721	587	98	0	0.222	35.7	0.005	0.205	68.9	77.6	21.9	6.75	0.002	0.0421	0.411	0.003	0.002
AK6 G07	6.96	87	568	397	60	13	0.08	7.04	0.005	0.202	95.7	56	18.9	4.26	0.002	0.004	0.497	0.003	0.002
AK6 G09	7.30	142	883	638	98	33	0.122	23.9	1.41	0.22	121	96.6	31.7	5.48	0.002	0.004	0.693	0.003	0.002

3.2.7.2. Hydrocensus Boreholes

All the pumped boreholes were sampled, as well as two non-tested boreholes at Professional Clothing (Mr Karani) and three boreholes at RCL Foods (Rainbow Chickens). The samples were submitted to Waterlab (Pty) Ltd, a SANAS accredited laboratory in Pretoria.

The groundwater quality is compared against the SANS 241 (2015) Drinking Water Limits. The SANS 241 Drinking Water Specification is the definitive reference on acceptable limits for drinking water quality parameters (for a lifetime consumption) in South Africa and provides guideline levels for a range of water quality characteristics.

Concentrations that exceed the SANS 241 limits are highlighted in **red**.

The laboratory certificates can be obtained from the pump testing report, Hydrocensus and Pump Test Assessment, MVB Consulting Report No.: MVB169/25/B047 (2025).

With reference to Table 3.7 below the following observations are made:

- The groundwater quality is generally good and very few parameters exceed the guideline limits.
- The major cations and anions the exceed the limits include the following:
    - EC & TDS (Boreholes BH1, BH5, BH11, BH16 and BH22).
    - Chloride (Borehole BH16).
    - Nitrate (Boreholes BH1, BH3, BH4A, BH9, BH30 and BH35).
- Heavy metal concentrations that exceed the limits include the following:
    - Aluminium (Boreholes BH11, Bh21, BH23, BH31, BH33 and BH35C).
    - Barium (Boreholes BH20 and BH22).
    - Total Chromium (Boreholes BH3, BH19, BH29 and BH32).
    - Iron (Boreholes BH16, BH21 and BH29).
    - Lead (Borehole BH21).
    - Manganese (Boreholes BH20 and BH22).
- The above exceedances are not related to the mining activities. There is no clear trend as to where other potential sources are situated, as illustrated in Figure 3.7. The distribution of the TDS concentrations in the hydrocensus boreholes is shown in this figure. TDS provides an overall indication of the health of the aquifer and five boreholes exceed the SANS 241 limits (1 220 mg/L). These boreholes are, however, not confined to a single area, which indicate more than one smaller potential source.

Table 3.7: Groundwater chemistry in the hydrocensus boreholes

Parameter (mg/L unless stated otherwise)	SANS 241	KBH10 (BH1)	KBH12 (BH3)	KBH7 (BH4)	KBH8 (BH4A)	KBH5 (BH5)	KBH1 (BH6)	KBH2 (BH7)	EPOL1 (BH8)	EPOL2 (BH9)	KBH21 (BH11)	KBH22 (BH12)
pH - Value @ 25 ºC	≥ 5 to ≤ 9.7	7.3	7.3	7.4	7.2	7.2	7.3	7.5	7.1	7.1	7.4	7.2
Electrical Conductivity in mS/m @ 25°C	≤ 170	188	170	160	139	196	122	123	95	132	168	146
Total Dissolved Solids @ 180°C	≤ 1 200	1 272	1 144	1164	954	1 244	802	804	708	1 040	1 322	1 016
Total Alkalinity as $CaCO_3$	-	540	480	344	344	572	360	348	-	-	348	380
Chloride as Cl	≤ 300	159	158	146	89	198	108	106	65	110	167	136
Sulphate as SO_4	≤ 500	171	155	159	157	215	124	148	88	148	176	156
Fluoride as F	≤ 1.5	<0.2	<0.2	<0.2	<0.2	<0.2	0.2	<0.2	0.2	0.1	<0.2	<0.2
Nitrate as N	≤ 11	25	12	13	23	6.2	6.3	4.8	7.3	16.9	3.7	2.6
Ortho Phosphate as P	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	-	-	0.1	<0.1
Free and Saline Ammonia as N	≤ 1.5	0.1	0.1	0.1	<0.1	<0.1	<0.1	<0.1	0.2	0.1	0.2	0.3
Sodium as Na	≤ 200	40	72	38	37	51	27	24	15.3	19.6	46	66
Potassium as K	-	<0.5	<0.5	1.5	0.9	1.5	2.2	2.6	0.7	1.1	1.9	1.7
Calcium as Ca	-	105	109	99	95	107	58	63	38	49.9	100	91
Magnesium as Mg	-	182	128	144	117	185	107	115	79	81	129	106
Aluminium as Al	≤ 0.3	<0.100	<0.100	0.119	0.106	0.146	<0.100	<0.100	-	-	0.314	<0.100
Arsenic as As	≤ 0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.002	-	-	<0.001	<0.001
Barium as Ba	≤ 0.7	0.12	0.118	0.105	0.068	0.126	0.033	<0.025	-	-	0.065	0.053
Boron as B	≤ 2.4	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	-	-	<0.025	<0.025
Total Chromium as Cr	≤ 0.05	<0.025	0.067	<0.025	<0.025	<0.025	0.026	<0.025	-	-	0.038	<0.025
Cobalt as Co	-	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	-	-	<0.025	<0.025
Copper as Cu	≤ 2	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	-	-	<0.010	<0.010
Iron as Fe	≤ 2	0.051	<0.025	0.037	<0.025	0.192	<0.025	<0.025	-	-	0.032	<0.025
Lead as Pb	≤ 0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	-	<0.001	<0.001
Manganese as Mn	≤ 0.4	<0.025	<0.025	<0.025	<0.025	0.31	<0.025	<0.025	-	-	<0.025	<0.025
Mercury as Hg	≤ 0.006	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-	-	<0.001	<0.001
Nickel as Ni	≤ 0.07	<0.025	<0.025	<0.025	<0.025	0.03	<0.025	0.025	-	-	<0.025	<0.025
Selenium as Se	≤ 0.04	<0.001	<0.001	<0.001	0.003	<0.001	<0.001	0.001	-	-	<0.001	0.001
Strontium as Sr	-	0.568	0.593	0.568	0.432	0.462	0.262	0.169	-	-	0.444	0.428
Uranium as U	≤ 0.03	0.012	0.009	0.004	0.005	-	-	-	-	-	0.004	0.003
Zinc as Zn	≤ 5	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	-	-	<0.025	<0.025

Parameter (mg/L unless stated otherwise)	SANS 241	KBH3 (BH13)	KBH4 (BH14)	KBH11 (BH16)	KBH9 (BH17)	KBH13 (BH19)	KBH20 (BH20)	KBH23 (BH21)	KBH24 (BH22)	KBH25 (BH23)	KBH6 (BH24)	KBH15 (BH29)
pH - Value @ 25 ºC	≥ 5 to ≤ 9.7	7.3	7.2	7.3	7.3	7.4	7.4	7.2	7.3	8.1	7.3	7.3
Electrical Conductivity in mS/m @ 25°C	≤ 170	117	112	197	108	129	159	123	172	120	119	114
Total Dissolved Solids @ 180°C	≤ 1 200	772	744	1 314	696	878	1 104	848	1 264	700	722	708
Total Alkalinity as $CaCO_3$	-	388	360	344	336	356	316	304	360	156	380	356
Chloride as Cl	≤ 300	80	73	318	62	101	213	137	171	193	102	87
Sulphate as SO_4	≤ 500	129	129	114	119	167	121	92	225	98	105	116
Fluoride as F	≤ 1.5	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrate as N	≤ 11	4.7	6.4	11	4.8	4.9	2.1	1.8	1.4	1.3	6	3.6
Ortho Phosphate as P	-	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Free and Saline Ammonia as N	≤ 1.5	<0.1	<0.1	0.1	<0.1	0.1	0.2	0.2	0.2	0.5	<0.1	0.1
Sodium as Na	≤ 200	25	25	30	27	41	45	34	54	42	21	42
Potassium as K	-	0.8	0.8	<0.5	0.9	<0.5	1.5	1.4	1.6	1.6	0.6	<0.5
Calcium as Ca	-	62	62	96	66	88	107	64	124	39	57	75
Magnesium as Mg	-	99	104	184	95	106	122	102	127	97	115	85
Aluminium as Al	≤ 0.3	<0.100	<0.100	<0.100	<0.100	<0.100	0.121	2.32	0.109	0.378	<0.100	<0.100
Arsenic as As	≤ 0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Barium as Ba	≤ 0.7	0.049	0.063	0.082	0.04	0.057	0.079	0.034	0.078	<0.025	0.053	0.054
Boron as B	≤ 2.4	<0.025	<0.025	0.061	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	0.116
Total Chromium as Cr	≤ 0.05	<0.025	<0.025	<0.025	<0.025	0.076	<0.025	<0.025	<0.025	<0.025	<0.025	0.123
Cobalt as Co	-	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Copper as Cu	≤ 2	<0.010	<0.010	0.028	<0.010	<0.010	0.062	<0.010	<0.010	<0.010	<0.010	<0.010
Iron as Fe	≤ 2	0.072	<0.025	0.21	<0.025	<0.025	0.265	8.7	0.254	0.628	<0.025	15
Lead as Pb	≤ 0.01	0.005	<0.001	0.001	<0.001	<0.001	0.002	0.076	<0.001	0.002	<0.001	<0.001
Manganese as Mn	≤ 0.4	<0.025	<0.025	<0.025	<0.025	<0.025	1.15	0.141	0.798	0.033	<0.025	0.167
Mercury as Hg	≤ 0.006	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel as Ni	≤ 0.07	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Selenium as Se	≤ 0.04	<0.001	0.001	0.001	<0.001	0.004	0.001	<0.001	0.002	0.001	<0.001	<0.001
Strontium as Sr	-	0.276	0.29	0.462	0.267	0.407	0.487	0.292	0.539	0.063	0.278	0.395
Uranium as U	≤ 0.03	-	-	0.002	0.002	0.002	0.004	0.003	0.005	0.001		0.003
Zinc as Zn	≤ 5	<0.025	<0.025	0.052	<0.025	0.027	0.069	<0.025	<0.025	<0.025	<0.025	0.044

Parameter (mg/L unless stated otherwise)	SANS 241	KBH26 (BH30)	KBH27 (BH31)	KBH28 (BH32)	KBH29 (BH33)	KBH30 (BH34)	KBH16 (BH35)	KBH17 (BH35A)	KBH18 (BH35B)	KBH19 (BH35C)
pH - Value @ 25 ºC	≥ 5 to ≤ 9.7	7.7	7.7	7.4	7.3	7.4	7.3	7.4	7.5	7.8
Electrical Conductivity in mS/m @ 25°C	≤ 170	99.2	36.3	112	131	158	120	130	52.3	102
Total Dissolved Solids @ 180°C	≤ 1 200	682	240	728	842	1002	762	974	412	736
Total Alkalinity as $CaCO_3$	-	280	100	212	292	456	332	360	224	304
Chloride as Cl	≤ 300	26	16	92	96	103	82	95	10	15
Sulphate as SO_4	≤ 500	132	42	147	116	142	131	134	49	92
Fluoride as F	≤ 1.5	0.4	0.3	0.3	0.2	0.2	<0.2	<0.2	<0.2	<0.2
Nitrate as N	≤ 11	16	<0.1	3.2	4.6	4.4	16	3.9	1	11
Ortho Phosphate as P	-	<0.1	0.1	0.1	0.3	<0.1	<0.1	<0.1	<0.1	<0.1
Free and Saline Ammonia as N	≤ 1.5	0.2	0.3	<0.1	<0.1	<0.1	0.1	0.2	0.2	0.2
Sodium as Na	≤ 200	57	18	36	125	86	28	37	25	29
Potassium as K	-	5.3	1.9	0.9	2.6	<0.5	<0.5	0.9	0.8	0.8
Calcium as Ca	-	82	30	58	73	84	65	66	37	67
Magnesium as Mg	-	45	15	90	53	117	107	119	48	91
Aluminium as Al	≤ 0.3	0.259	0.756	0.154	0.327	0.109	<0.100	0.106	<0.100	0.986
Arsenic as As	≤ 0.01	<0.001	<0.001	0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Barium as Ba	≤ 0.7	0.06	0.038	0.04	0.1	0.098	0.069	0.084	0.027	0.042
Boron as B	≤ 2.4	0.14	0.034	0.039	0.061	<0.025	<0.025	<0.025	<0.025	<0.025
Total Chromium as Cr	≤ 0.05	<0.025	<0.025	0.068	<0.025	0.24	0.042	<0.025	<0.025	0.048
Cobalt as Co	-	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Copper as Cu	≤ 2	0.022	0.035	0.02	0.022	0.017	<0.010	<0.010	<0.010	0.057
Iron as Fe	≤ 2	0.161	1.5	0.086	0.364	<0.025	<0.025	0.078	0.182	1.9
Lead as Pb	≤ 0.01	0.002	0.004	0.001	0.004	0.001	<0.001	<0.001	<0.001	0.003
Manganese as Mn	≤ 0.4	0.236	0.285	0.033	0.059	<0.025	<0.025	<0.025	0.092	0.063
Mercury as Hg	≤ 0.006	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Nickel as Ni	≤ 0.07	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025	<0.025
Selenium as Se	≤ 0.04	0.003	0.001	0.003	0.002	0.002	<0.001	0.001	0.001	0.001
Strontium as Sr	-	0.423	0.086	0.264	0.395	0.485	0.32	0.355	0.173	0.285
Uranium as U	≤ 0.03	0.003	<0.001	<0.001	0.002	0.005	0.003	0.004	<0.001	0.002
Zinc as Zn	≤ 5	<0.025	0.277	0.04	0.089	<0.025	0.09	<0.025	0.151	0.033

Parameter (mg/L unless stated otherwise)	SANS 241	KW1	KW2	KW3	CBH1
pH - Value @ 25 ºC	≥ 5 to ≤ 9.7	7.3	7.8	7.9	7.3
Electrical Conductivity in mS/m @ 25°C	≤ 170	161	133	104	124
Total Dissolved Solids @ 180°C	≤ 1 200	1020	852	640	848
Total Alkalinity as $CaCO_3$	-	520	496	428	392
Chloride as Cl	≤ 300	239	138	90	130
Sulphate as SO_4	≤ 500	246	212	112	122
Fluoride as F	≤ 1.5	<0.2	<0.2	<0.2	0.2
Nitrate as N	≤ 11	3.1	0.8	1.2	12
Ortho Phosphate as P	-	<0.1	<0.1	<0.1	<0.1
Free and Saline Ammonia as N	≤ 1.5	0.1	0.3	0.5	<0.1
Sodium as Na	≤ 200	69	75	70	58
Potassium as K	-	2.3	2	<0.5	0.7
Calcium as Ca	-	158	132	81	85
Magnesium as Mg	-	99	69	61	101
Aluminium as Al	≤ 0.3	3.88	<0.100	<0.100	<0.100
Arsenic as As	≤ 0.01	<0.001	<0.001	<0.001	<0.001
Barium as Ba	≤ 0.7	0.100	0.133	0.074	0.064
Boron as B	≤ 2.4	0.104	0.079	0.049	0.049
Total Chromium as Cr	≤ 0.05	<0.025	<0.025	<0.025	<0.025
Cobalt as Co	-	<0.025	<0.025	<0.025	<0.025
Copper as Cu	≤ 2	<0.010	<0.010	0.123	<0.010
Iron as Fe	≤ 2	0.983	<0.025	0.101	<0.025
Lead as Pb	≤ 0.01	0.003	0.001	0.001	<0.001
Manganese as Mn	≤ 0.4	0.223	0.573	0.469	<0.025
Mercury as Hg	≤ 0.006	<0.001	<0.001	<0.001	<0.001
Nickel as Ni	≤ 0.07	<0.025	<0.025	<0.025	<0.025
Selenium as Se	≤ 0.04	<0.001	<0.001	0.001	0.001
Strontium as Sr	-	0.76	0.668	0.377	0.392
Uranium as U	≤ 0.03	0.005	0.003	0.003	0.004
Zinc as Zn	≤ 5	0.045	<0.025	<0.025	<0.025

Figure 3.7: **Distribution of the TDS concentrations in the hydrocensus boreholes**

The chemical character of the water at the sampling points is best described with the aid of the Piper diagram. The Piper diagram is one of the most commonly used techniques to interpret groundwater chemistry data.

This method proposed the plotting of cations and anions on adjacent trilinear fields with these points then being extrapolated to a central diamond field. Here the chemical character of water, in relation to its environment, could be observed and changes in the quality interpreted. The cation and anion plotting points are derived by computing the percentage equivalents for the main diagnostic cations of Ca, Mg and Na, and anions Cl, SO_4 and HCO_3.

Different waters from different environments always plot in diagnostic areas. The upper half of the diamond normally contains water of static and disordinate regimes, while the middle area normally indicates an area of dissolution and mixing. The lower triangle of this diamond shape indicates an area of dynamic and co-ordinated regimes. Sodium chloride brines normally plot on the right-hand corner of the diamond shape while recently recharge water plots on the left-hand corner of the diamond plot. The top corner normally indicates water contaminated with gypsum (mine impact). In general, the top half of the diamond contains static waters and other unusual waters high in Mg/Ca Cl_2 and Ca/Mg SO_4. The lower half contains those waters normally found in a dynamic basin environment. The values for mixtures of any two waters in any proportion plot along a line joining their respective points in each of these diagrams. Water therefore being invaded by an industrial effluent will plot a vector towards the analysis of the invading fluid.

The Piper diagram for the Kwezi groundwater monitoring boreholes is shown as Figure 3.8.

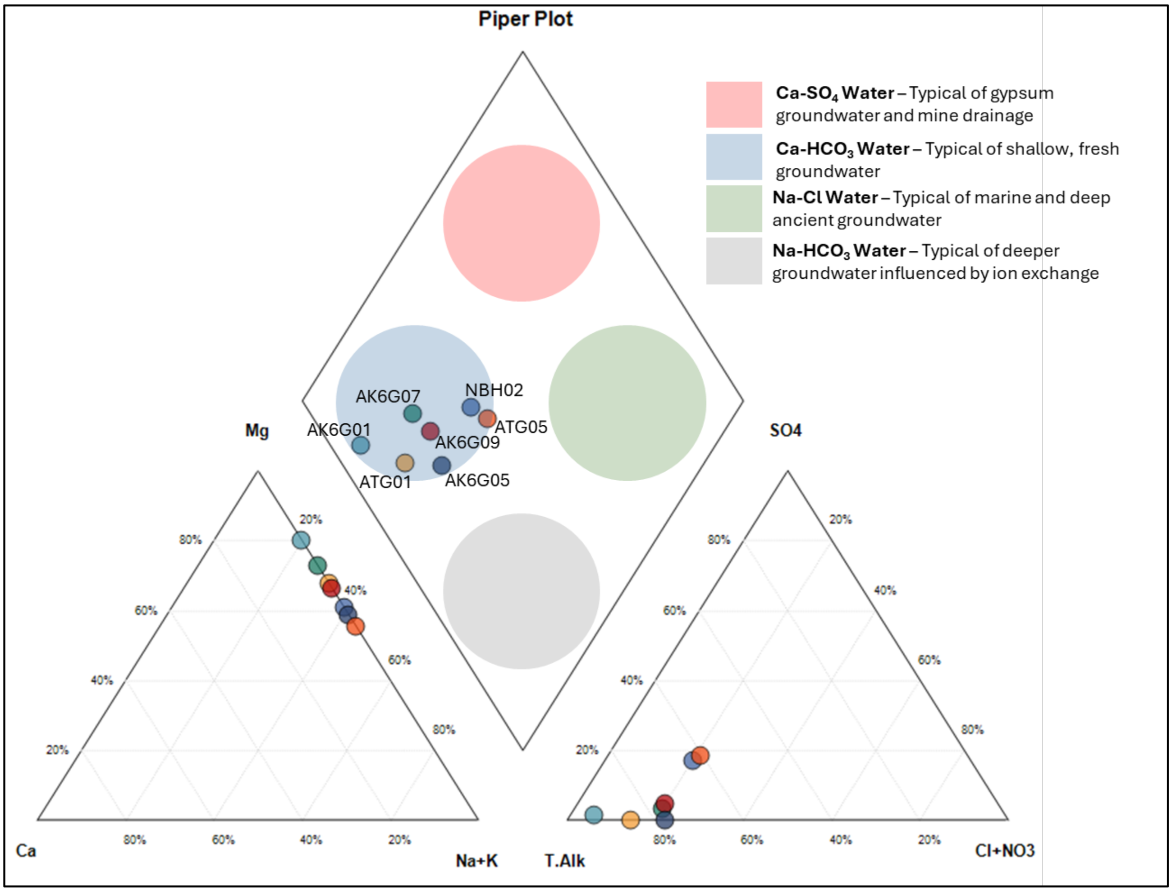


Figure 3.8: Piper diagram for the Kwezi mine monitoring boreholes

The mine monitoring boreholes are characterised as Ca-HCO_3 (fresh groundwater) type water. The hydrocensus boreholes are moving towards the Ca-SO_4 type water, which is indicative of impacted water.

The Piper diagram for the hydrocensus boreholes is shown as Figure 3.9.

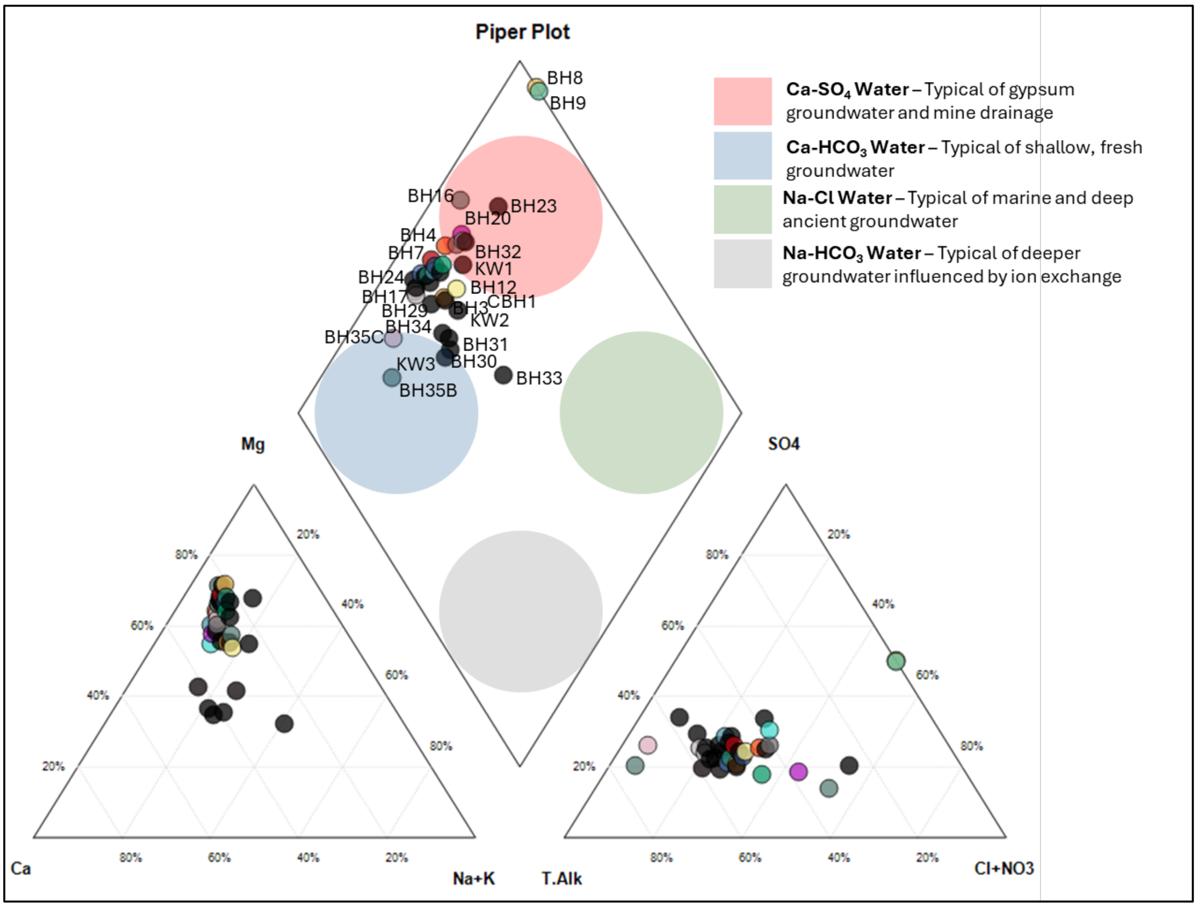


Figure 3.9: Piper diagram for the hydrocensus groundwater samples

Most of the hydrocensus groundwater is characterised as Ca-HCO_3 (fresh groundwater) type water, but there are several boreholes moving towards the Ca-SO_4 (contaminated groundwater) type water. This is indicative of the presence of contaminant sources within the industrial area. Boreholes BH8 and BH9 (Epol) is characterised as Ca-SO_4 (contaminated groundwater) type water. These boreholes were not sampled during the hydrocensus, but during a previous hydrogeological study.

3.2.8 Aquifer Classification and Vulnerability

An aquifer classification system provides a framework and objective basis for identifying and setting appropriate levels of groundwater resource protection. This would facilitate the adoption of a policy of differentiated groundwater protection.

Other uses could include:

- Defining levels of investigation required for decision making.
- Setting of monitoring requirements; and
- Allocation of manpower resources for contamination control functions.

The aquifer classification system used to classify the aquifers is the proposed National Aquifer Classification System of Parsons (1995). This system has a certain amount of flexibility and can be linked to second classifications such as a vulnerability or usage classification. Parsons suggests that aquifer classification forms a very useful planning tool that can be used to guide the management of groundwater issues. He also suggests that some level of flexibility should be incorporated when using such a classification system.

The South African Aquifer System Management Classification is presented by five major classes:

- o Sole Source Aquifer System.
- o Major Aquifer System.
- o Minor Aquifer System.
- o Non-Aquifer System; and
- o Special Aquifer System.

The following definitions apply to the aquifer classification system:

- Sole source aquifer system: "An aquifer that is used to supply 50% or more of domestic water for a given area, and for which there are no reasonable alternative sources should the aquifer become depleted or impacted upon. Aquifer yields and natural water quality are immaterial."
- Major aquifer system: "Highly permeable formations, usually with a known or probable presence of significant fracturing. They may be highly productive and able to support large abstractions for public supply and other purposes. Water quality is generally very good".
- Minor aquifer system: "These can be fractured or potentially fractured rocks that do not have a high primary permeability, or other formations of variable permeability. Aquifer extent may be limited and water quality variable. Although this aquifer seldom produces large quantities of water, they are both important for local supplies and in supplying base flow for rivers".
- Non-aquifer system: "These are formations with negligible permeability that are generally regarded as not containing groundwater in exploitable quantities. Water quality may also be such that it renders the aquifer unusable. However, groundwater flow through such rocks does occur, although imperceptible, and needs to be considered when assessing risk associated with persistent pollutants".
- Special aquifer system: "An aquifer designated as such by the Minister of Water Affairs, after due process".

A second variable classification is needed for sound decision making, as the ability of an aquifer to yield water to a particular user is not adequately stated. In this case it was decided to use the vulnerability of the aquifer to contamination as a second parameter (Table 3.8). A weighting and rating approach is then used to decide on the appropriate level of groundwater protection (Table 3.9).

Table 3.8: Ratings for the aquifer quality management classification system

Class	Points	Class	Points
Sole Source Aquifer System	6	**High**	3
Major Aquifer System	4	**Medium**	2
Minor Aquifer System	2	**Low**	1
Non-Aquifer System	0		
Special Aquifer System	0-6		

Table 3.9: Appropriate level of groundwater protection required

GQM Index	Level of Protection
<1	Limited Protection
1 – 3	Low Level Protection
3 – 6	Medium Level Protection
6 – 10	High Level Protection
>10	Strictly Non-degradation

After rating the aquifer system management and the aquifer vulnerability, the points are multiplied to obtain a Groundwater Quality Management (GQM) index.

Based on the above, the aquifers in the study area are classified as follows:

Description	Aquifer	Vulnerability	Rating	Protection
Weathered Aquifer	Minor (2)	1	2	Low
Fractured Aquifer	Minor (2)	1	2	Low

4. DESCRIPTION OF THE UNDERGROUND MINING ENVIRONMENT

4.1 Mining Extent

The extent of the underground mining on the Merensky and UG2 reefs is shown in Figure 4.2 and the 3-dimensional representation of the mined-out area is shown in Figure 4.1.

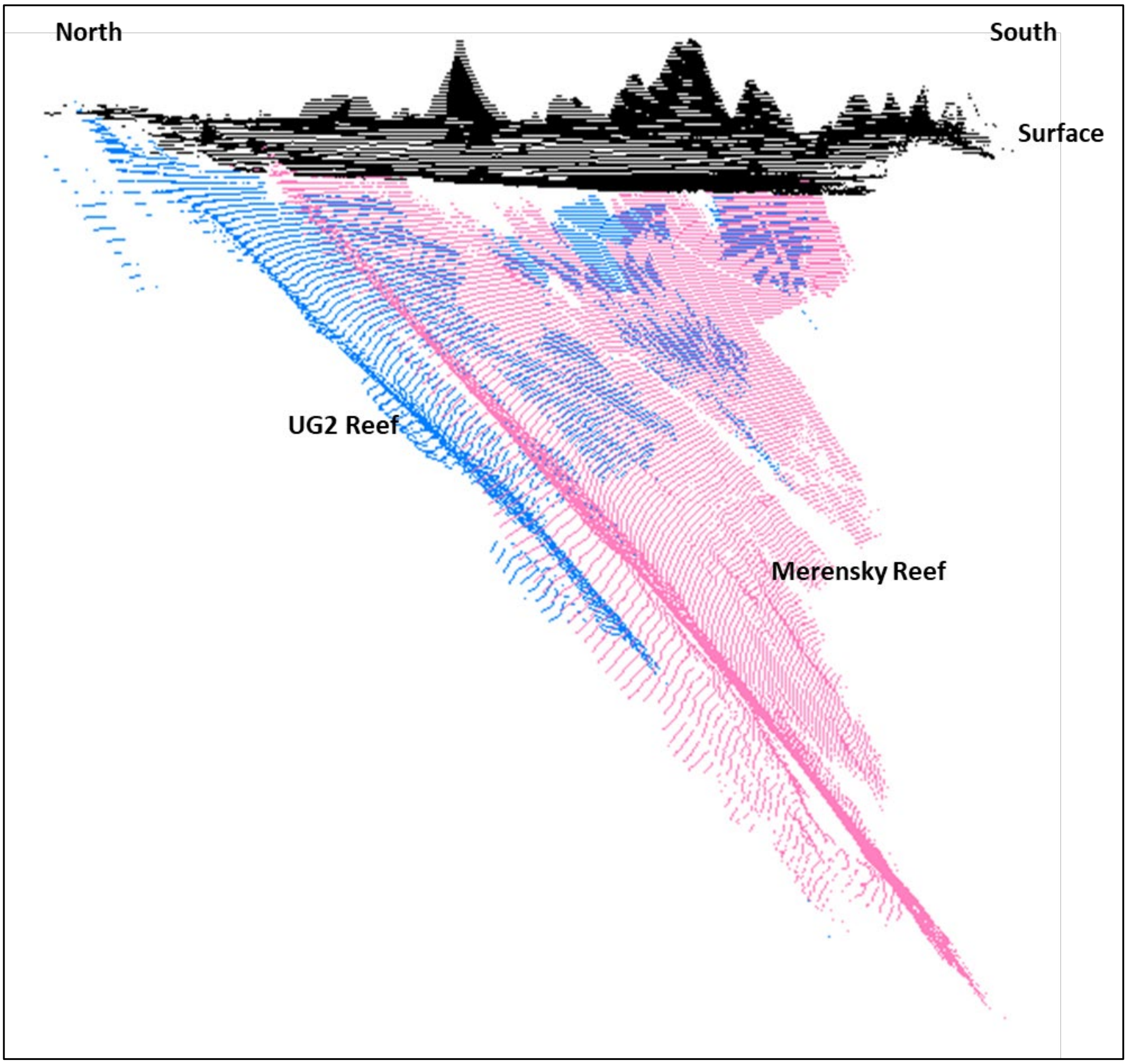


Figure 4.1: 3-Dimensional mined-out model

The elevations of the mining horizons are summarised in Table 4.1. The elevations are shown in metres above/below mean sea level.

Table 4.1: Mining elevations

Reef	Mining Elevation
Merensky Reef	1 160 mamsl to -180 mbmsl
UG2 Reef	1 210 mamsl to 170 mamsl

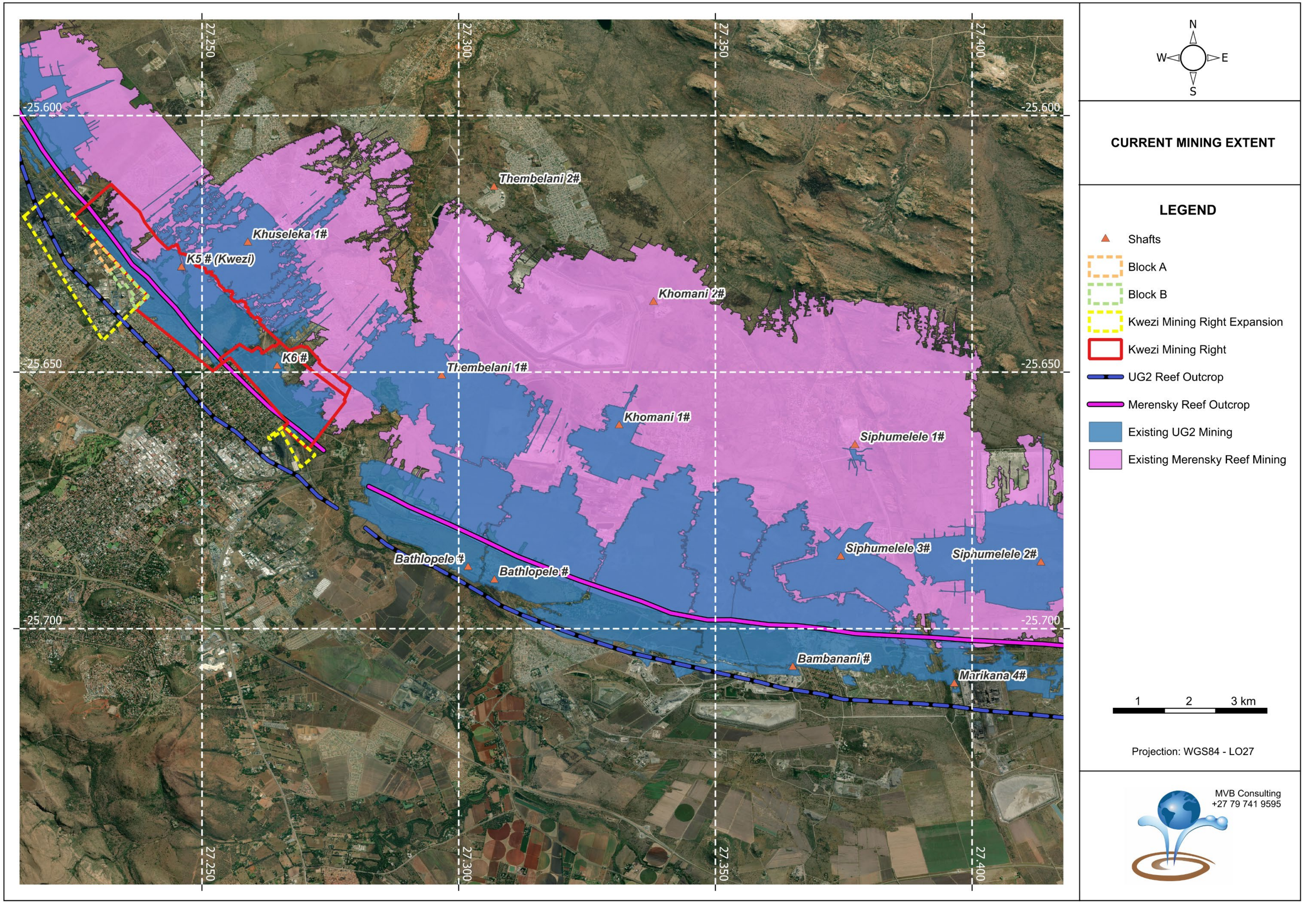


Figure 4.2: **Underground mining extent**

4.2 Groundwater Inflow and Current Abstraction Volumes

The water that currently flows into the Rustenburg Platinum Mines primarily emanate from the overlying aquifer.

The volume of water pumped from the mine reflects the groundwater inflow volume into the mine. The daily pumping volumes were supplied by the mine and is summarised in Table 4.2.

Table 4.2: Groundwater inflow into the shafts in the SRPM aquifer

Shaft	Average Groundwater Inflow (ML/day)
Kwezi (K5) Shaft	0.98
Kwezi (K6) Shaft	0.74
Khuseleka 1	0.58
Khuseleka 2	1.50
Total Inflow (ML/day)	**3.79**

Note: ML/day = Megalitres per day

4.3 Geochemistry and Mine Water Quality

4.3.1 Waste Classification

Kwezi do not propose to bring the waste material to surface, but leave it underground.

SRK Consulting (South Africa) (Pty) Ltd was requested by Sibanye to conduct a geochemical and waste classification assessment of the Mine Residue Deposits (MRDs) generated by mining operations, including the waste rock material. The following is a summary from the SRK report (Nxumalo, Sahadeo and Reddy, 2023).

The mineralogy of the Kwezi Waste Rock Dump (WRD) indicates that plagioclase is a predominant mineral and enstatite occur as an abundant mineral. Chromite and quartz occur in minor amounts and the remaining minerals, namely, talc, chlorite, biotite, actinolite, augite, and montmorillonite all occur in trace amounts.

The waste rock samples are characterised predominantly by enstatite and plagioclase. The other aluminosilicate minerals that are in the samples are talc, actinolite, augite, and montmorillonite. These aluminosilicate minerals can react with and consume acidity, thus contributing to the overall neutralisation potential of the samples. Based on the laboratory results, no acid-producing minerals were detected by XRD.

The mineralogy of the waste rock samples is shown in Table 4.3.

Table 4.3: Mineralogical composition of the waste rock samples

Weathering Rate / Solubility		Mine Residue Deposits/ Sample Points		KWEZI WRD
		Minerals %	Molecular Formula	Waste Rock
Acid Neutralising Minerals	Intermediate	Talc	Mg3Si4O10(OH)2	1
		Chlorite	(Mg,Fe)5Al(AlSi3O10)(OH)8	1.4
		Biotite	K(Mg,Fe)3((OH)2AlSi3O10)	0
		Enstatite	MgSiO3	33.5
		Actinolite	$Ca_2(Mg,Fe)5Si_8O_{22}(OH)$	1.1
		Augite	Ca(Mg,Fe)Si2O6	2.8
		Lizardite	$Mg_3(OH)_4$	0
		Diopside	$MgCaSi_2O_6$	0
	Slow	Chromite	(Fe,Mg)Cr2O4	4.2
		Plagioclase	(Na,Ca)(Al,Si)4O8	51
		Anthophyllite	(Mg,Fe)7Si8O22(OH)2	0
	Very Slow	Smectite	CaMg2AlSi4(OH)2.(H2O)	-
		Montmorillonite	Al2H2O12Si4	1.5
	Inert	Quartz	SiO2	3.6
	Total wt%			100.1
	Key:			
	Predominant	>50%		
	Abundant	20-50%		
	Less abundant	10-20%		
	Minor	3-10%		
	Trace	<3%		

The exceedance of the different threshold values determines the level of risk associated with the disposal of the waste to the landfill. The waste assessed in terms of the N&S for Assessment of Waste for Landfill Disposal set in terms of Section 7(1) of the Act must then be disposed of at a licensed Landfill as indicated in Table 4.4.

Based on the TC and LC limits of the elements and chemical substances in the samples exceeding the corresponding TCT and LCT limits respectively, the study identified exceedances as detailed in Table 4.5 and Table 4.6.

Highlighted in the colour of the respective threshold category are the concentrations of constituents above the threshold. For instance, TC above TCT0 is highlighted in green in the tables.

Table 4.4: Criteria, waste type, and landfill disposal requirements

Criteria	Waste Type	Landfill Disposal Requirement
LC > LCT3 or TC > TCT2	Type 0	No disposal - treatment, and re-assessment required in terms of the Norms and Standards for Assessment of Waste for Landfill Disposal.
LCT2 < LC ≤ LCT3 or TCT1 < TC ≤ TCT2	Type 1	Class A
LCT1 < LC ≤ LCT2 and TC ≤ TCT1	Type 2	Class B
LCT0 < LC ≤ LCT1 and TC ≤ TCT1	Type 3	Class C
LC ≤ LCT0 and TC ≤ TCT0	Type 4	Class D
TC > TCT2 and LC < LCT3	Type 1	Class A
LC < LCT0, irrespective of TC	Type 3	Class C

Table 4.5: Leachable concentrations relative to the threshold values for metal ions and inorganic anions

Elements & Chemical Substances in Waste	Leachable Concentrations Threshold (LCT) Limits (mg/l)				
	LCT0	LCT1	LCT2	LCT3	KWEZI WRD
Metal Ions					
As, Arsenic	0.01	0.5	1	4	<0.003
B, Boron	0.5	25	50	200	0.019
Ba, Barium	0.7	35	70	280	0.429
Cd, Cadmium	0.003	0.15	0.3	1.2	0.001
Co, Cobalt	0.5	25	50	200	0.006
CrT, Chromium Total	0.1	5	10	40	0.002
Cu, Copper	2	100	200	800	0.013
Hg, Mercury	0.006	0.03	0.6	2.4	<0.001
Mn, Manganese	0.5	25	50	200	0.696
Mo, Molybdenum	0.07	3.5	7	28	<0.001
Ni, Nickel	0.07	3.5	7	28	0.063
Pb, Lead	0.01	0.5	1	4	<0.001
Sb, Antimony	0.02	1	2	8	<0.002
Se, Selenium	0.01	0.5	1	4	<0.001
V, Vanadium	0.2	10	20	80	0.036
Zn, Zinc	5	250	500	2 000	0.093
Inorganic Anions					
TDS	1000	12 500	25 000	100 000	20.5
Chloride	300	15 000	30 000	120 000	<2.0
Sulphate, SO4	250	12 500	25 000	100 000	<4.0
NO3 as N, Nitrite- N	11	550	1100	4 400	<0.1
Fluoride	1.5	75	150	600	<0.1

Table 4.6: Total concentrations relative to threshold values for metal ions

Elements & Chemical Substances in Waste	Total Concentrations Threshold (TCT) Limits (mg/kg)			
	TCT0	TCT1	TCT2	KWEZI WRD
As, Arsenic	5.8	500	2000	<2
B, Boron	150	15 000	60 000	19.09
Ba, Barium	62.5	6 250	25 000	47.56
Cd, Cadmium	7.5	260	1040	<0.1
Co, Cobalt	50	5 000	20 000	12.57
CrT, Chromium Total	46 000	800 000	N/A	117
Cu, Copper	16	19 500	78 000	1191
Hg, Mercury	0.93	160	640	<0.1
Mn, Manganese	1 000	25 000	100 000	230
Mo, Molybdenum	40	1 000	4 000	<0.1
Ni, Nickel	91	10 600	42 400	111
Pb, Lead	20	1 900	7 600	1.28
Sb, Antimony	10	75	300	<1
Se, Selenium	10	50	200	<3
V, Vanadium	150	2 680	10720	19.27
Zn, Zinc	240	160 000	640 000	39.86

The Leachable Concentrations in the Kwezi waste rock shows that the only metal that exceed the LCT0 threshold is manganese. It should be noted that Kwezi WRD was leached using acetic acid instead of distilled water.

The Total Concentrations in the Kwezi waste rock shows that the only metals that exceed the TCT0 threshold are copper and nickel.

The Kwezi waste rock samples are classified as Type 3 waste which corresponds to a Class C disposal facility.

4.3.2 Geochemical Assessment of the Mine Water Quality

Geochemical modelling was undertaken to assess if the water quality will deteriorate and determine potential water quality that may decant in future. The modelling was undertaken by Dr. Robert Hansen from Geochemical Dynamic Systems (GeoDyn).

The geochemical risk assessment (GeoDyn, 2021) indicated that the mineral waste is unlikely to leach metal and metalloid contaminants into the groundwater in a post-closure scenario. Sulphate and nitrogen compounds were identified as potential leachates, however, the concentrations were shown to be unlikely to exceed regulatory guideline values, including the SANS 241 drinking water standards. However, some observations of sulphate and nitrogen species in downgradient groundwater monitoring boreholes are exceeded in the operational phase. Therefore, sulphur and nitrogen as well as pH, were the focus of the analyses of the assessment of historic groundwater monitoring data. Chloride is also a chemical of concern as concentrations are elevated in some of the water samples. Chloride may, however, originate from a variety of non-mining related sources, whereas sulphate is more specific to mining.

The objective of the geochemical assessment was to determine the long-term post-closure water quality in the underground mine workings. Geochemical modelling was conducted, using the modelling software PHREEQC, to determine the long-term geochemical behaviour of the mineral in the rock.

The simulation time for the geochemical models is 100 years post-closure. The model result is shown in Table 5.7.

Table 4.7: Post-closure water quality geochemical modelling result (GeoDyn, 2021)

Parameter	RPM WUL 2018	Drinking Water	Underground Mine Void
pH	**6-9.5**	**≥5 to ≤9.7**	7.8
Total Dissolved Solids		**≤1 200**	740
Calcium	**<150**		241
Sodium			52
Potassium			5
Magnesium			38
Bicarbonate			26
Sulphate	**<200**	**≤500**	378
Chloride	**<200**	**≤300**	41
Nitrate	**<10**	**≤11**	0.2
Ammonium		**≤1.5**	<0.001
Aluminium		**≤0.3**	<0.001
Iron		**≤2**	<0.001
Manganese		**≤0.4**	<0.001
Nickel		**≤0.07**	0.001
Molybdenum			0.001

With reference to Table 4.7, the modelling results are as follows:

- The model results for the underground mine voids, indicates that the risk of the development of AMD (Acid Mine Drainage) conditions is negligible. The post-closure underground mine void geochemical system has acid neutralisation capacity, which is far more than the acid production capacity.

  The model sulphate concentration is below regulatory guideline values, i.e SANS 241 and R635 LCT0. This is due to the lower oxygen concentration in the underground mine voids. The TDS is significantly lower due to lower oxygen concentration in the underground mine voids.

  Model nitrate and ammonia concentrations are shown to be low in the 100-year post-closure scenario. This is due to denitrification process related to microbial organisms present in the groundwater system.

  Model metal and metalloid concentrations in the post-closure are very low. This is due to the relatively low sulphide mineral contents, the relatively low oxygen concentrations in the underground mine voids as well as the ability of the geochemical system to adsorb metals and metalloids, thereby removing them from the mine void water.

4.4 Potential for Mine Water Decant

An updated review of the groundwater levels in the hydrocensus and mine monitoring boreholes have shown that the groundwater mimics the topography. There are a few boreholes that shows a slightly depressed elevations due to groundwater seeping into the underground workings.

These small dewatering cones will recover post-closure, once the mine void is rewatered. The groundwater table overlying the mine will be the base elevation that will control the potential for mine water decant.

At the reef outcrop positions, where the mine workings are at or closest to the surface the static groundwater level is expected to be on average 9 – 11m below the natural ground level. Decant is therefore not expected to occur along the reef outcrop.

Once the mine workings are completely re-watered the ingress water will push-up into the shafts and some of the shafts may become free-flowing, dependent on its collar elevation in relation to the elevation of the hydraulic gradient. The shaft collars were re-evaluated based on closer spaced topographical contours and the regional groundwater level was refined with the additional groundwater level information from the hydrocensus boreholes. Based on these assessments Table 4.8 was updated.

Table 4.8: Shaft collar elevations compared to static groundwater level

Shaft	Collar Elevation (mamsl)	Groundwater Elevation (mamsl)	Difference (m)
Khuseleka 2#	1 156.01	1 137.55	18.46
Khuseleka 1#	1 127.45	1120.13	7.32
Thembelani 1#	1 115.37	1 112.41	2.96
Thembelani 2#	1 098.36	1 096.34	2.02
Bathlopele #	1 137.46	1 128.81	8.65
Bathlopele #	1 137.68	1 125.47	12.21
Khomanani 1#	1 140.00	1 135.80	4.20
Khomanani 2#	1 124.20	1 121.46	2.74
Siphumelele 3#	1 175.35	1 171.20	4.15

All the shaft collars are above the expected static groundwater elevation. Thembelani 2 Shaft was previously considered a potential decant point, but the current study shows that the groundwater level will stabilise ±2m below the shaft collar. The current groundwater level in borehole NBH04, which is approximately 100m down-gradient from this shaft, is 1 095.14 mamsl (1.16 mbgl). This is confirmation that the above table is accurate. This and the fact that the shafts will be plugged during rehabilitation significantly reduces the risk of mine water decant.

Any dewatering cone that may develop in the Kwezi extension area is expected to fully recover after mining ceases.

5. NUMERICAL GROUNDWATER MODELLING

5.1 Introduction

An existing numerical groundwater model that was developed for the larger SRPM was used during the previous assessment. This model was, however, calibrated according to the mine monitoring data and very limited site-specific data was available. Due to the sensitivity of the project and the concerns from landowners, MVB updated the model following the acquisition of more site-specific information. This data includes:

- Update of the hydrocensus.
- Test pumping of 25 boreholes.
- Sampling and analysis of 29 boreholes.

The section below discusses the construction and parameters of the new groundwater model.

A numerical groundwater model is a useful tool to assess the current and potential future impacts from the project on the groundwater regime. In this instance the potential impacts are:

- Estimated groundwater inflow volumes into the underground workings.
- Impact on the groundwater levels during the operational and post-closure phase of the mine.
- Potential contaminant migration from the mine workings.

The basic steps involved in modelling can be summarized as:

- *Collecting and interpreting field data*: Field data are essential to understand the natural system and to specify the groundwater problem investigated. The numerical model develops into a site-specific groundwater model when real field parameters are assigned. The quality of the simulations depends largely on the quality of the data input.
- *Calibration & validation*: Model calibration and validation are required to overcome the lack of input data, but they also accommodate the simplification of the natural system in the model. In model calibration simulated values like potentiometric surface or concentrations are compared with field measurements. The model input data are altered within ranges until the simulated and observed values are fitted within a chosen tolerance. Input data and comparison of simulated and measured values can be altered either manually or automatically.
- *Model validation*: Model validation is required to demonstrate that the model can be reliably used to make predictions. A common practice in validation is the comparison of the model with a data set not used in model calibration. Calibration and validation are accomplished if all known and available groundwater scenarios are reproduced by the model without varying the material properties or aquifer characteristics supplied to the model.
- *Modelling scenarios*: Alternative scenarios for a given area may be assessed efficiently. When applying numerical models in a predictive sense limit exist in model application. Predictions of a relative nature are often more useful than those of an absolute nature

5.2 Assumptions and Limitations

The following conditions typically need to be described in a model:

- Geological and geohydrological features.

- Boundary conditions of the study area (based on the geology and geohydrology).
- Initial groundwater levels of the study area.
- The processes governing groundwater flow.
- Assumptions for the selection of the most appropriate numerical code.

Field data is essential in solving the conditions listed above and developing the numerical model into a site-specific groundwater model. Specific assumptions related to the available field data include:

- The top of the aquifer is represented by the generated groundwater heads.
- The available geological / geohydrological information was used to describe the different aquifers. The available information on the geology and field tests is considered as correct.
- Many aquifer parameters have not been determined in the field and therefore had to be estimated.

To develop a model of an aquifer system certain assumptions must be made. The following assumptions were made:

- The system is initially in equilibrium and therefore in steady state even though natural conditions have been disturbed.
- No abstraction boreholes were included in the initial model.
- The boundary conditions assigned to the model are considered correct.
- The impacts of other activities (e.g. agriculture) have not been considered.

It is important to note that a numerical groundwater model is a representation of the real system. It is therefore at most an approximation and the level of accuracy depends on the quality of the data that is available. This implies that there are always errors associated with groundwater models due to uncertainty in the data and the capability of numerical methods to describe natural physical processes.

5.3 Model Set-up

To investigate the behaviour of aquifer systems in time and space it is necessary to employ a mathematical model. FEFLOW a modular three-dimensional finite element groundwater flow model was the software used during this investigation. It is an internationally accepted modelling package which calculates the solution of the groundwater flow equation using the finite element approach.

The modelling area was selected based on a combination of topographical and drainage control and covers an area of approximately 430 km^2. The model network extends over a larger area than the area under investigation to ensure that the model boundaries will not affect simulation results.

The model consists of four layers:

- Layer 1: 30m Weathered formations.
- Layer 2: 100m Fractured formations, including underground mining.
- Layer 3: 200m Fractured formations, including underground mining.
- Layer 4: 200m Fractured formations, including underground mining.

Once the network has been set up all initial and boundary conditions sources sinks, and aquifer parameters are entered.

The model domain in relation to the proposed mining extension is shown in Figure 5.1.

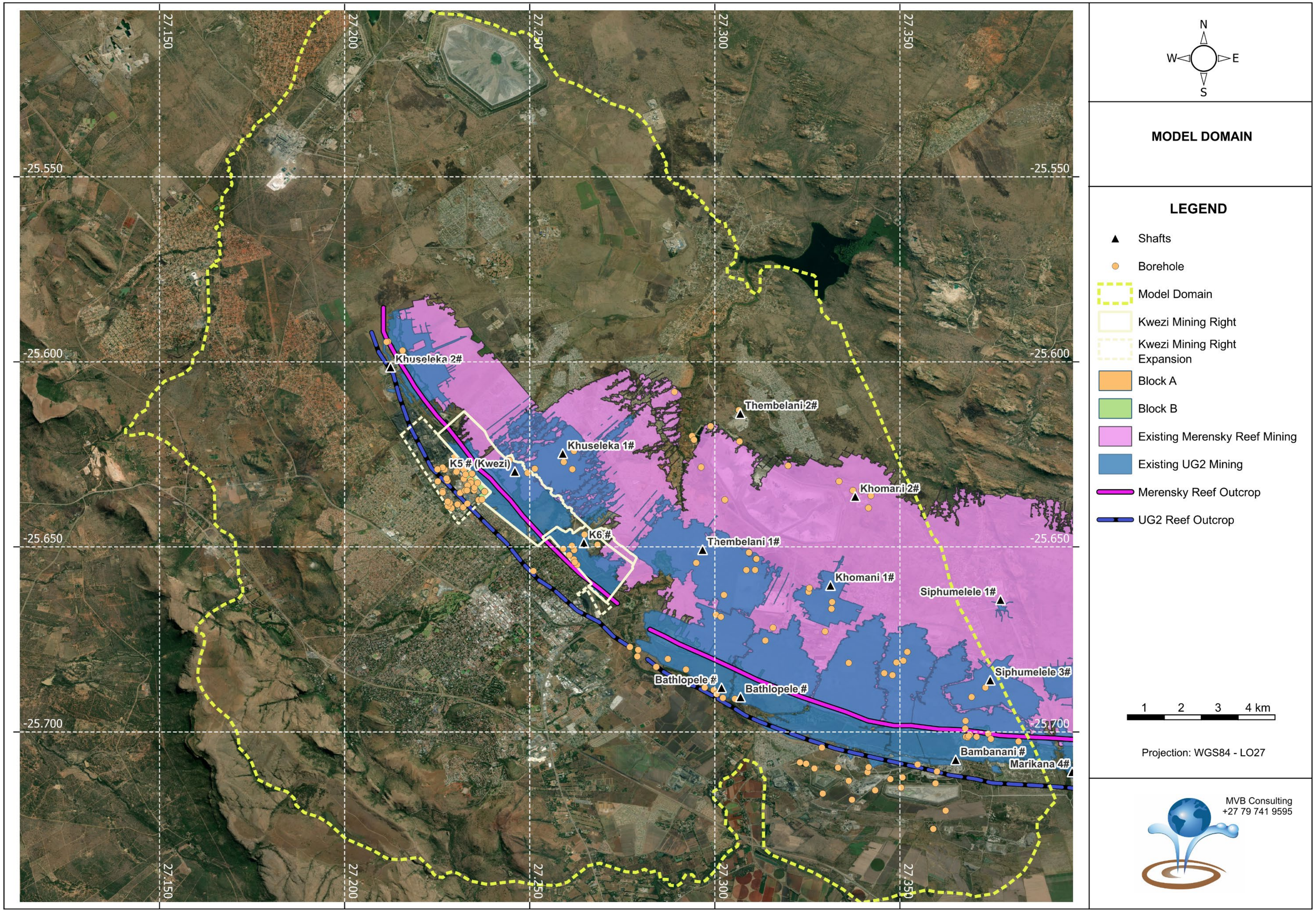


Figure 5.1: **Model domain**

5.4 Model Boundary Conditions

One of the first and most demanding tasks in groundwater modelling is that of identifying the model area and its boundaries. Consequently, a model boundary is the interface between the model area and the surrounding environment. Conditions on the boundaries however must be specified. Boundaries occur at the edges of the model area and at locations in the model area where external influences are represented such as rivers boreholes and leaky impoundments.

Criteria for selecting hydraulic boundary conditions are primarily topography, hydrology and geology. The topography geology or both may yield boundaries such as impermeable strata or potentiometric surface controlled by surface water or recharge/discharge areas such as inflow boundaries along mountain ranges. The flow system allows the specification of boundaries in situations where natural boundaries are a great distance away.

Boundary conditions must be specified for the entire boundary and may vary with time. At a given boundary section just one type of boundary condition can be assigned. As a simple example it is not possible to specify groundwater flux and groundwater head at an identical boundary section. Boundaries in groundwater models can be specified as:

- Dirichlet (also known as constant head or constant concentration) boundary conditions.
- Neuman (or specified flux) boundary conditions.
- Cauchy (or a combination of Dirichlet and Neuman) boundary conditions.

The tributaries were set as constant head boundaries that were limited by a maximum hydraulic head set as a constraint. This is commonly used where small streams or non-perennial drainages occur within a model domain. Natural groundwater divides were set as no-flow boundaries.

5.5 Initial Conditions

Initial conditions are vital for modelling flow problems. Initial conditions must be specified for the entire area. Generally, the initial water level/head distribution acts as the starting distribution for the numerical calculation. The water levels shown in Figure 3.5 were used as the starting groundwater table.

5.6 Sources and Sinks

Sources and sinks can be defined as recharge and abstraction sources in the aquifer. Sources can be precipitation and inflow from surface water and recharging boreholes. Sinks can be abstraction boreholes springs evapotranspiration and outflow to surface water. Initially only recharge due to precipitation was included in the model. The average mean annual precipitation (MAP) is approximately 620 mm/a. The effective recharge for the different zones is shown in Figure 5.2.

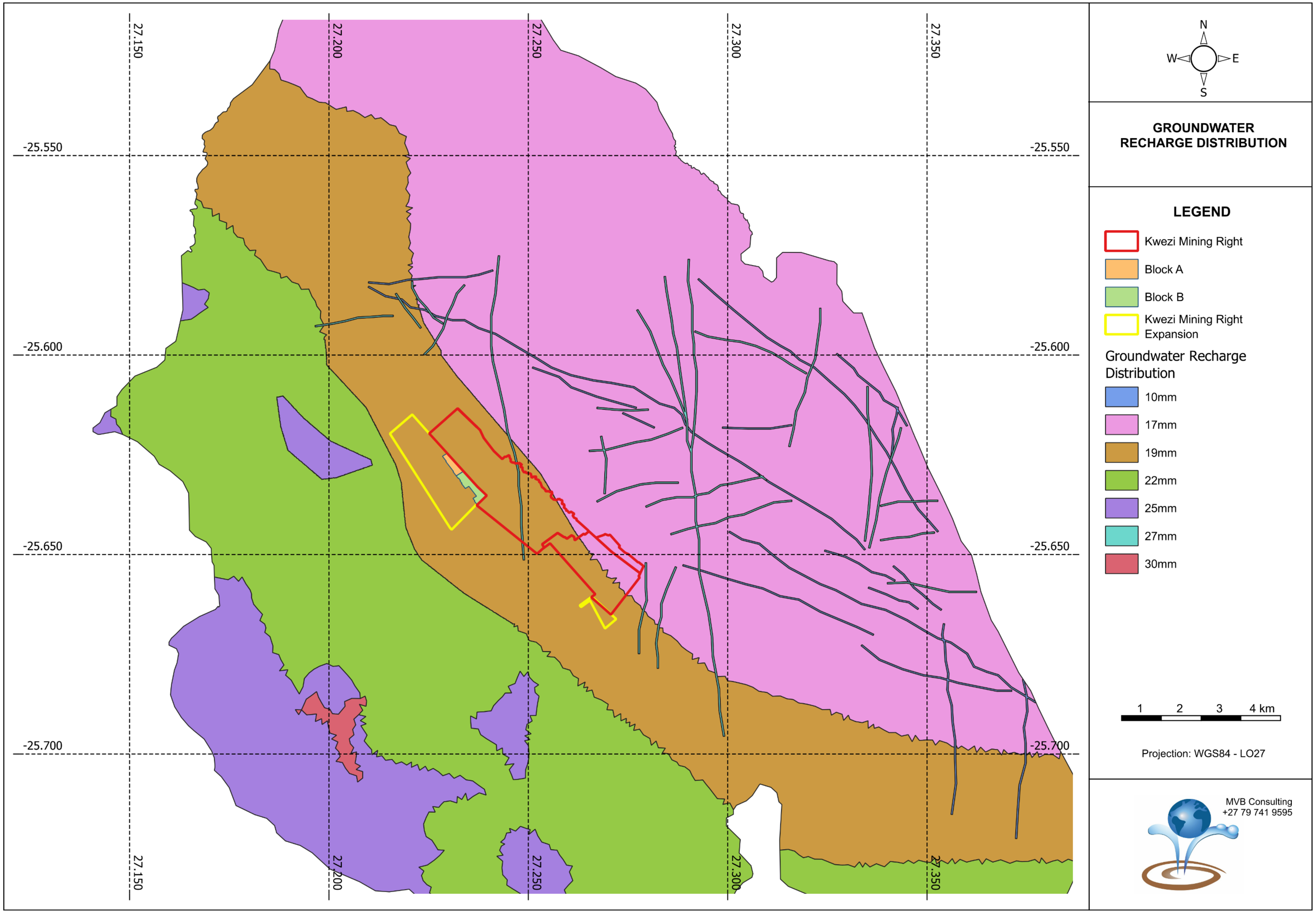


Figure 5.2: Groundwater recharge distribution

5.7 Aquifer Parameters

The aquifer parameters discussed in Section 4.2.6 were initially used in the numerical model. The model is calibrated using the groundwater level elevations which are a function of the product of the saturated aquifer thickness the hydraulic conductivity and effective aquifer recharge. Should the average aquifer thickness therefore be under/overestimated this can be compensated for by adjustment of the hydraulic conductivity values during model calibration.

The simulated groundwater level distribution is compared to the measured head distribution and the hydraulic conductivity or recharge values can be altered until an acceptable correlation between measured and simulated heads is obtained. The calibration process was done by adjusting the model parameters for hydraulic conductivity (K) and recharge within a narrow range compatible with the historic data and geohydrological situation.

The calibrated aquifer parameters are shown in Table 5.1 and on Figure 5.3.

Table 5.1: Calibrated aquifer parameters

Model Layer	Hydrostratigraphic unit	Layer thickness (m)	Hydraulic Conductivity (K)		Recharge (Re)	Specific storage (Sc)
			Kx,y 1:1 (m/d)	Kz 1:10 (m/d)	In/Outflow on top/bottom (mm/a)	Sc (1/m)
Layer 01	Alluvial deposits	30.00	1.00E+00	1.00E+00	30.0	5.00E-02
	Pyramid Gabbro-Norite		5.00E-01	5.00E-02	17.0	9.50E-03
	Schilpadnest Subsuite		4.00E-01	4.00E-02	18.6	7.50E-03
	Vlakfontein Sbsuite & Kolobeng Norite		2.00E-01	2.00E-02	22.0	5.00E-03
	Magaliesberg Fm, Pretoria Grp		1.00E-01	1.00E-02	25.0	1.00E-03
	Fault zones		7.50E-01	7.50E-02	27.5	1.00E-02
	Dykes		1.00E-01	1.00E-02	10.0	5.00E-04
Layer 02	Pyramid Gabbro-Norite	100.00	2.50E-01	2.50E-02		4.75E-03
	Schilpadnest Sbsuite		2.00E-01	2.00E-02		3.75E-03
	Vlakfontein Sbsuite & Kolobeng Norite		1.00E-01	1.00E-02		2.50E-03
	Magaliesberg Fm, Pretoria Grp		5.00E-02	5.00E-03		5.00E-04
	Fault zones		3.75E-01	3.75E-02		5.00E-03
	Dykes		5.00E-02	5.00E-03		2.50E-04
Layer 03	Pyramid Gabbro-Norite	200.00	1.25E-01	1.25E-02		2.38E-03
	Schilpadnest Sbsuite		1.00E-01	1.00E-02		1.88E-03
	Vlakfontein Sbsuite & Kolobeng Norite		5.00E-02	5.00E-03		1.25E-03
	Magaliesberg Fm, Pretoria Grp		2.50E-02	2.50E-03		2.50E-04
	Fault zones		1.88E-01	1.88E-02		2.50E-03
	Dykes		2.50E-02	2.50E-03		1.25E-04
Layer 04	Pyramid Gabbro-Norite	200.00	6.25E-02	6.25E-03		1.19E-03
	Schilpadnest Sbsuite		5.00E-02	5.00E-03		9.38E-04
	Vlakfontein Sbsuite & Kolobeng Norite		2.50E-02	2.50E-03		6.25E-04
	Magaliesberg Fm, Pretoria Grp		1.25E-02	1.25E-03		1.25E-04
	Fault zones		9.38E-02	9.38E-03		1.25E-03
	Dykes		1.25E-02	1.25E-03		6.25E-05

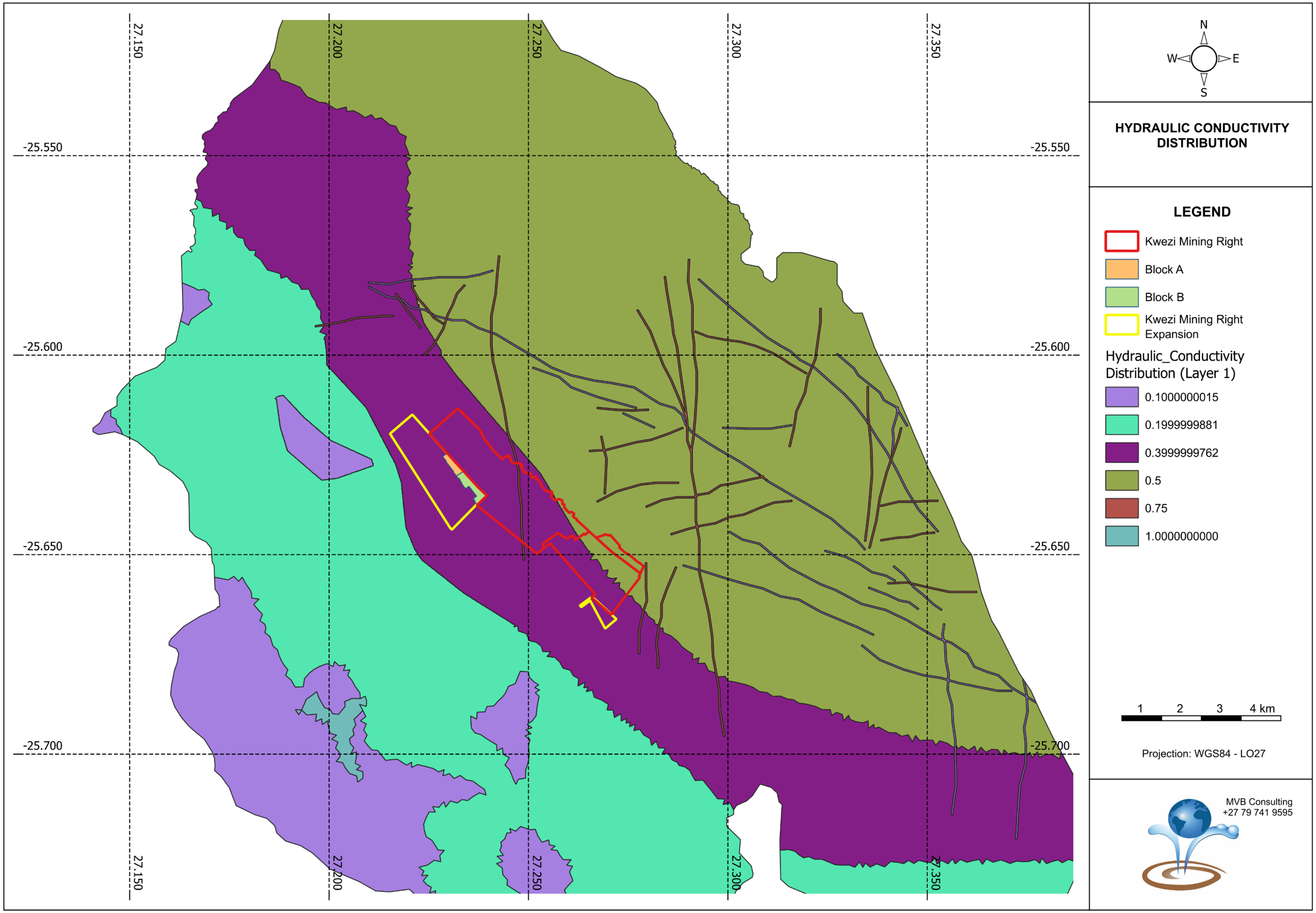


Figure 5.3: Aquifer parameter distribution

5.8 Calibration of the Model

A groundwater flow model for the study area was constructed to simulate disturbed groundwater flow conditions. The calibrated conditions serve as starting heads for the transient simulations of groundwater flow.

The simulation model (FEFLOW) used in this modelling study is based on three-dimensional groundwater flow and may be described by the following equation:

$$\frac{\partial}{\partial x}(K_x\frac{\partial h}{\partial x})+\frac{\partial}{\partial y}(K_y\frac{\partial h}{\partial y})+\frac{\partial}{\partial z}(K_z\frac{\partial h}{\partial z})\pm W=S\frac{\partial h}{\partial t} \qquad (1)$$

Where:

h	= hydraulic head [L].
K_x K_y K_z	= Hydraulic Conductivity [L/T].
S	= storage coefficient.
t	= time [T].
W	= source (recharge) or sink (pumping) per unit area [L/T].
x y z	= spatial co-ordinates [L].

For steady state conditions the groundwater flow Equation (1) reduces to the following equation:

$$\frac{\partial}{\partial x}(K_x\frac{\partial h}{\partial x})+\frac{\partial}{\partial y}(K_y\frac{\partial h}{\partial y})+\frac{\partial}{\partial z}(K_z\frac{\partial h}{\partial z})\pm W=0 \qquad (2)$$

The head distribution is dependent upon the recharge hydraulic conductivity sources sinks and boundary conditions specified. For a given recharge component and set of boundary conditions the head distribution across the aquifer can be obtained for a specific hydraulic conductivity value. The simulated head distribution can then be compared to the measured head distribution and the hydraulic conductivity or recharge values can be altered until an acceptable correspondence between measured and simulated heads is obtained.

The calibration process was done by changing the model parameters for hydraulic conductivity and recharge. Hydro-census boreholes were used to calibrate groundwater flow model with these boreholes providing the only available data. The calibration objective was reached when an acceptable correlation was obtained between the observed and simulated piezometric heads (Table 5.2 and Figure 6.2).

Table 5.2: Flow calibration results

Calibration BH	Topographical Elevation (mamsl)	Water Level (mbgl)	Measured head elevation (mamsl)	Simulated head elevation (mamsl)	Mean Error (m)	Mean Absolute Error (m)	Root Mean Square Error (m)
BH1	1149.51	14.51	1135.00	1143.33	-8.33	8.33	69.39
BH3	1151.22	15.00	1136.22	1143.05	-6.83	6.83	46.65
BH4	1155.09	17.50	1137.59	1142.85	-5.26	5.26	27.66
BH4A	1157.69	10.84	1146.85	1142.52	4.33	4.33	18.77
BH6	1144.57	13.23	1131.34	1136.78	-5.44	5.44	29.64
BH7	1144.22	11.13	1133.09	1137.07	-3.98	3.98	15.82
BH8	1142.16	4.55	1137.61	1137.27	0.34	0.34	0.11
BH9	1142.29	10.00	1132.29	1136.92	-4.63	4.63	21.46
BH13	1147.06	9.92	1137.14	1137.87	-0.73	0.73	0.53
BH14	1153.03	8.80	1144.23	1140.03	4.20	4.20	17.62
BH15	1142.26	14.57	1127.69	1135.14	-7.45	7.45	55.52
BH16	1148.89	9.98	1138.91	1137.87	1.04	1.04	1.08
BH17	1145.08	10.40	1134.68	1137.95	-3.27	3.27	10.71
BH18	1147.89	3.83	1144.06	1141.87	2.19	2.19	4.80
BH19	1147.61	9.72	1137.89	1140.10	-2.21	2.21	4.90
BH20	1146.93	8.05	1138.88	1136.59	2.29	2.29	5.25
BH21	1146.94	8.08	1138.86	1136.65	2.21	2.21	4.87
BH22	1148.37	9.75	1138.62	1137.39	1.23	1.23	1.50
BH23	1147.06	8.82	1138.24	1136.67	1.57	1.57	2.47
BH24	1149.45	8.97	1140.48	1138.35	2.13	2.13	4.55
BH25	1145.41	2.95	1142.46	1141.18	1.29	1.29	1.65
BH26	1152.16	6.40	1145.76	1143.24	2.52	2.52	6.36
BH27	1146.64	7.80	1138.84	1137.06	1.78	1.78	3.18
BH28	1144.60	7.05	1137.55	1135.80	1.75	1.75	3.05
BH29	1144.71	7.50	1137.21	1135.83	1.38	1.38	1.90
BH31	1137.90	1.17	1136.73	1135.46	1.27	1.27	1.62
BH32	1145.51	6.74	1138.77	1138.97	-0.20	0.20	0.04
BH33	1144.70	5.88	1138.82	1138.58	0.24	0.24	0.06
BH34	1143.99	6.68	1137.31	1139.99	-2.68	2.68	7.16
BH35A	1155.53	10.23	1145.30	1141.10	4.20	4.20	17.64
BH35B	1153.26	7.30	1145.96	1140.86	5.11	5.11	26.06
BH35C	1153.27	7.54	1145.73	1140.74	4.99	4.99	24.93
AQG11	1148.15	1.81	1146.34	1137.39	8.95	8.95	80.03
BF1	1148.60	16.23	1132.37	1141.10	-8.73	8.73	76.21
BFU339	1150.76	15.23	1135.53	1140.86	-5.33	5.33	28.36
BFU340	1151.09	15.63	1135.46	1140.74	-5.28	5.28	27.85
EM05	1121.21	8.70	1112.51	1121.29	-8.78	8.78	77.02
EM11	1144.92	10.01	1134.91	1125.17	9.74	9.74	94.93
EM16	1131.90	2.21	1129.69	1126.71	2.98	2.98	8.86
EM24	1116.09	0.18	1115.91	1126.59	-10.68	10.68	114.08
EMX	1129.26	7.26	1122.00	1126.83	-4.83	4.83	23.34
NB12A	1170.00	18.13	1151.87	1152.08	-0.21	0.21	0.04
NB25	1120.65	2.30	1118.35	1124.08	-5.73	5.73	32.81
NB26	1122.54	2.62	1119.92	1123.10	-3.18	3.18	10.11

Calibration BH	Topographical Elevation (mamsl)	Water Level (mbgl)	Measured head elevation (mamsl)	Simulated head elevation (mamsl)	Mean Error (m)	Mean Absolute Error (m)	Root Mean Square Error (m)
NB27	1125.32	5.04	1120.28	1127.48	-7.20	7.20	51.85
NB31	1135.23	5.28	1129.95	1134.12	-4.17	4.17	17.37
NB56	1155.65	1.32	1154.33	1152.32	2.01	2.01	4.03
NBH01	1147.10	25.94	1121.16	1127.22	-6.06	6.06	36.76
NBH02	1128.45	7.23	1121.22	1128.48	-7.26	7.26	52.74
NBH05	1103.73	4.43	1099.30	1111.29	-11.99	11.99	143.76
WAPBH09C	1120.29	1.81	1118.48	1127.34	-8.86	8.86	78.55
WVBH04	1125.33	6.96	1118.37	1117.07	1.30	1.30	1.70
Average	**1142.72**	**8.52**	**1134.19**	**1135.70**	**-1.51**	**4.24**	**26.87**
Minimum	**1103.73**	**0.18**	**1099.30**	**1111.29**	**-11.99**	**0.20**	**0.04**
Maximum	**1170.00**	**25.94**	**1154.33**	**1152.32**	**9.74**	**11.99**	**143.76**
Correlation			**0.90**				
∑					**-78.27**	**220.33**	**1397.37**
1/n					**-1.51**	**4.24**	**26.87**
Root Mean Square Deviation (RMSD)					**1.23**	**2.06**	**5.18**
Normalised Root Mean Square Deviation (NRMSD) (% of water level range)							**9.42**

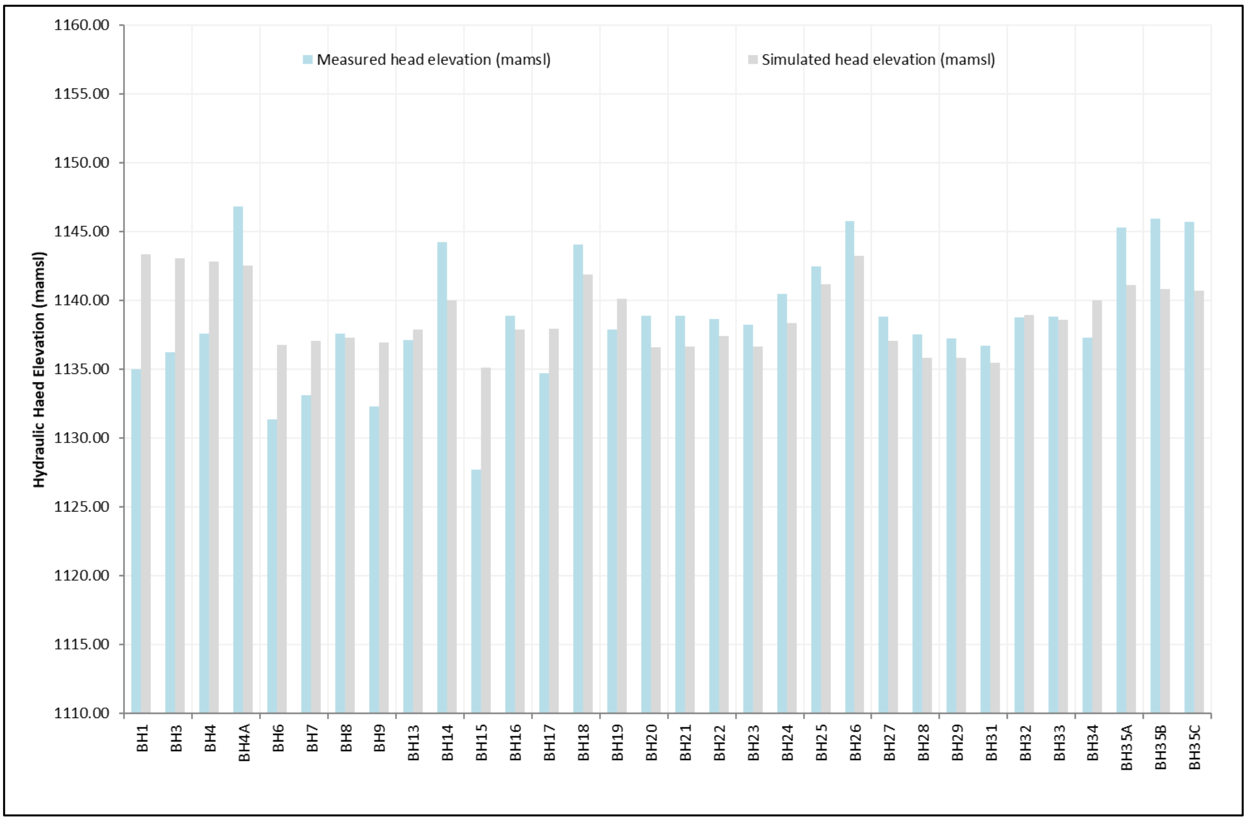


Figure 5.4: Correlation between simulated and observed groundwater levels

6. GEOHYDROLOGICAL IMPACTS

The primary risk that the proposed mining extension poses is the risk of dewatering and disruption of private groundwater supply. The hydrocensus identified thirty-nine (39) private boreholes in the industrial area overlying the proposed mining extension.

The numerical model was used to simulate the following:

- Expected groundwater inflow volume into the mining extension.
- The expected groundwater level drawdown as a result of the groundwater inflow.
- The groundwater level recovery post-closure.

6.1 Groundwater Inflow

The modelled groundwater inflow volumes are presented in Figure 6.1and Figure 6.2 for Block A and Block B respectively.

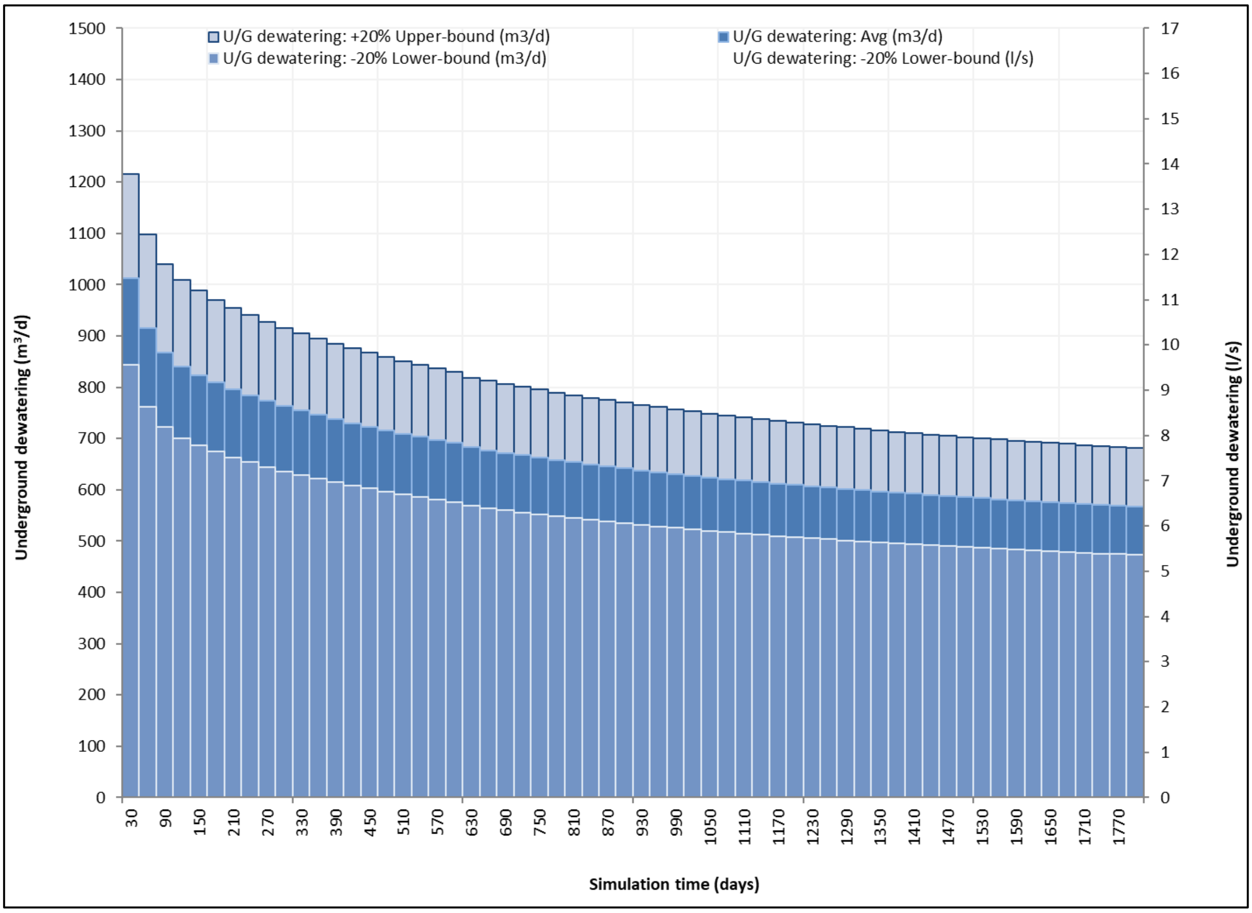


Figure 6.1: Estimated groundwater inflow volume – Block A

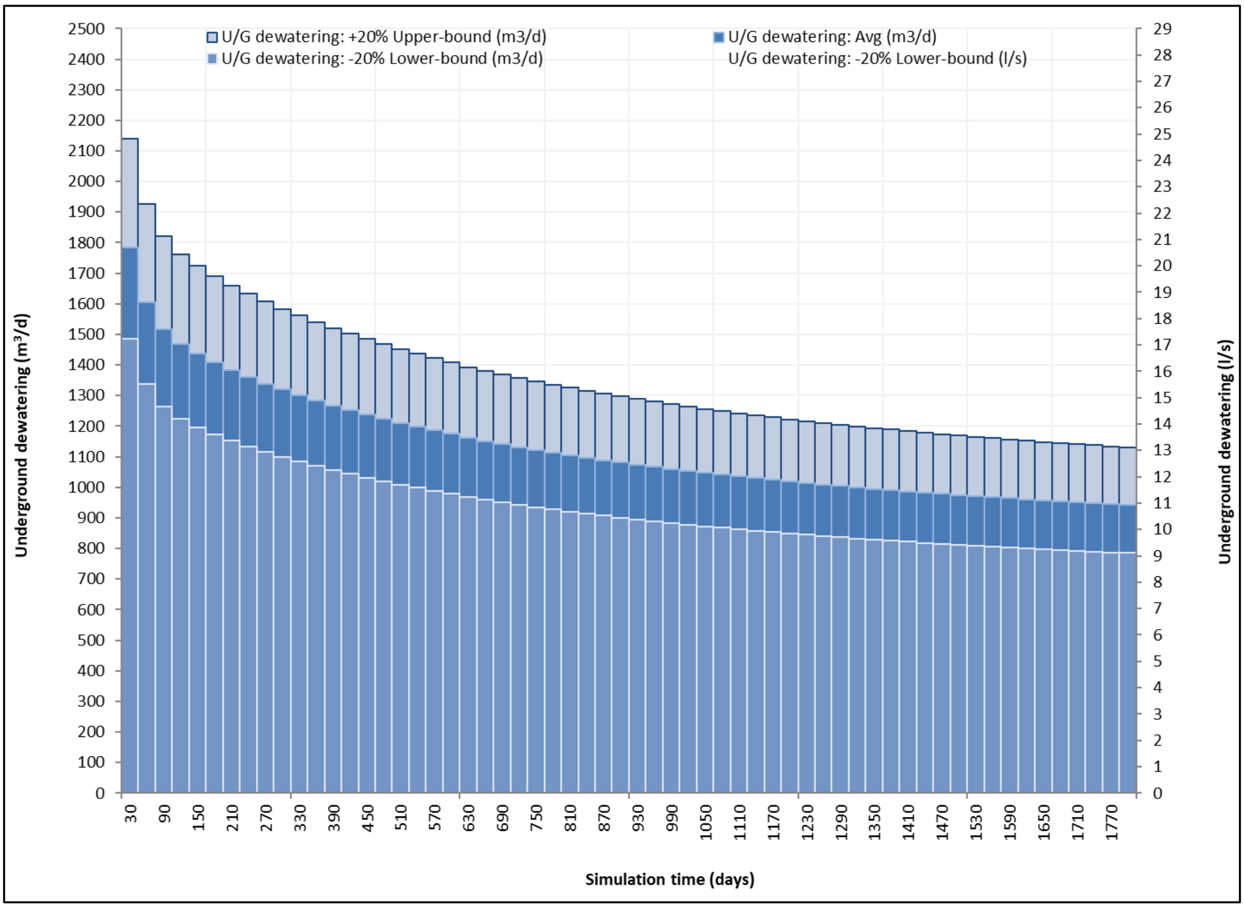


Figure 6.2: Estimated groundwater inflow volume – Block B

The groundwater inflow volumes are as follows:

- **Block A Initial Flow**: Lower Limit – 617 m^3/day; Average – 740 m^3/day; Upper Limit – 888 m^3/day.
- **Block A Steady Flow**: Lower Limit – 499 m^3/day; Average – 600 m^3/day; Upper Limit – 718 m^3/day.
- **Block B Initial Flow**: Lower Limit – 1 059 m^3/day; Average – 1 271 m^3/day; Upper Limit – 1 525 m^3/day.
- **Block B Steady Flow**: Lower Limit – 833 m^3/day; Average – 1 000 m^3/day; Upper Limit – 1 200 m^3/day.

6.2 Groundwater Level Drawdown and Recovery

The change in groundwater level at the end of an assumed 5-year mining period is shown in Figure 6.3. The groundwater level over the mining blocks is expected to drop to the mining elevation, approximately 10 m. The extent of the impact is within a radius of approximately 450m from the edge of the mining block.

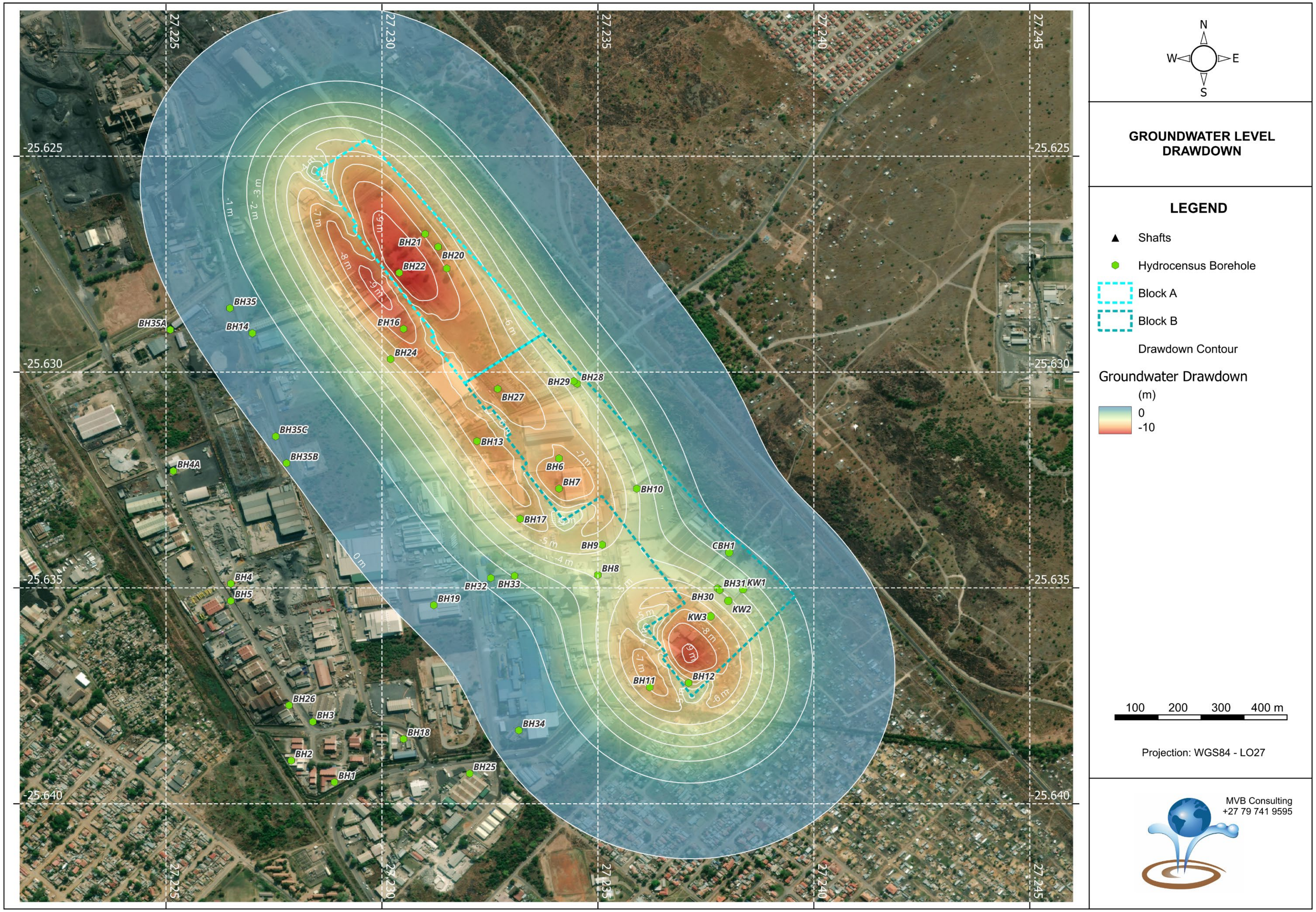


Figure 6.3: Simulated groundwater level drawdown within the Kwezi mining extension

Based on the extent of the simulated groundwater level drop, the risk to the hydrocensus boreholes were assessed. None of the boreholes are expected to be significantly affected and none of the boreholes will dry-up.

The groundwater level recovery will take approximately 3.5 years to fully recover post-closure, in the deeper boreholes. Figure 6.4 and Figure 6.5 shows the groundwater level drawdown and recovery in borehole BH22, which is located within the worst affected area.

The estimated drawdown and recovery in each borehole are attached as Appendix A.

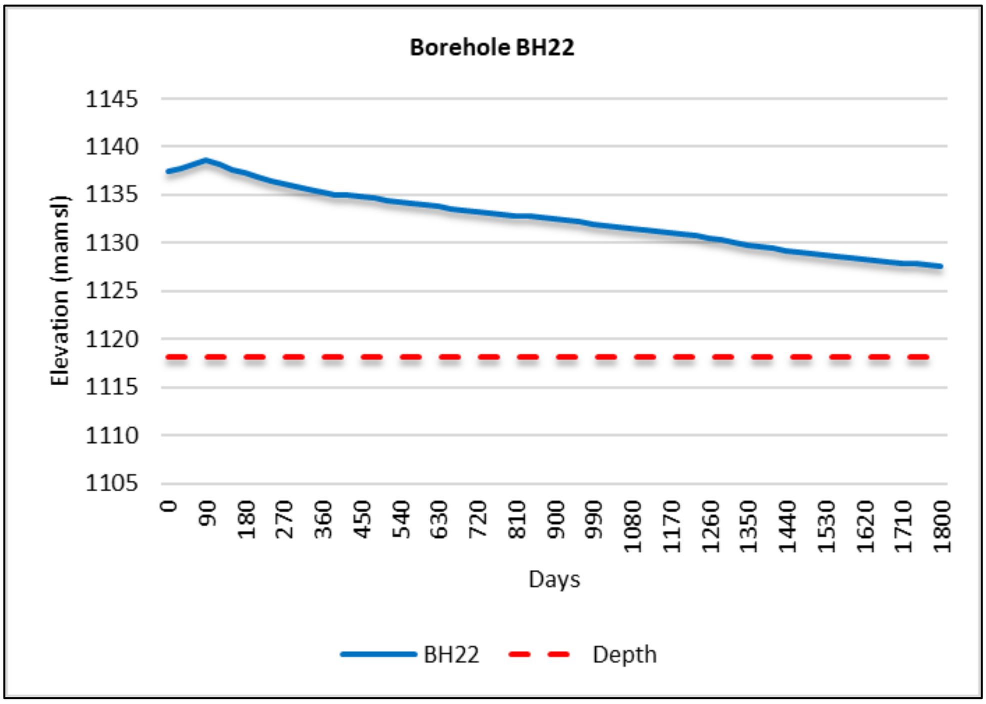


Figure 6.4: Simulated groundwater level drawdown in borehole BH22

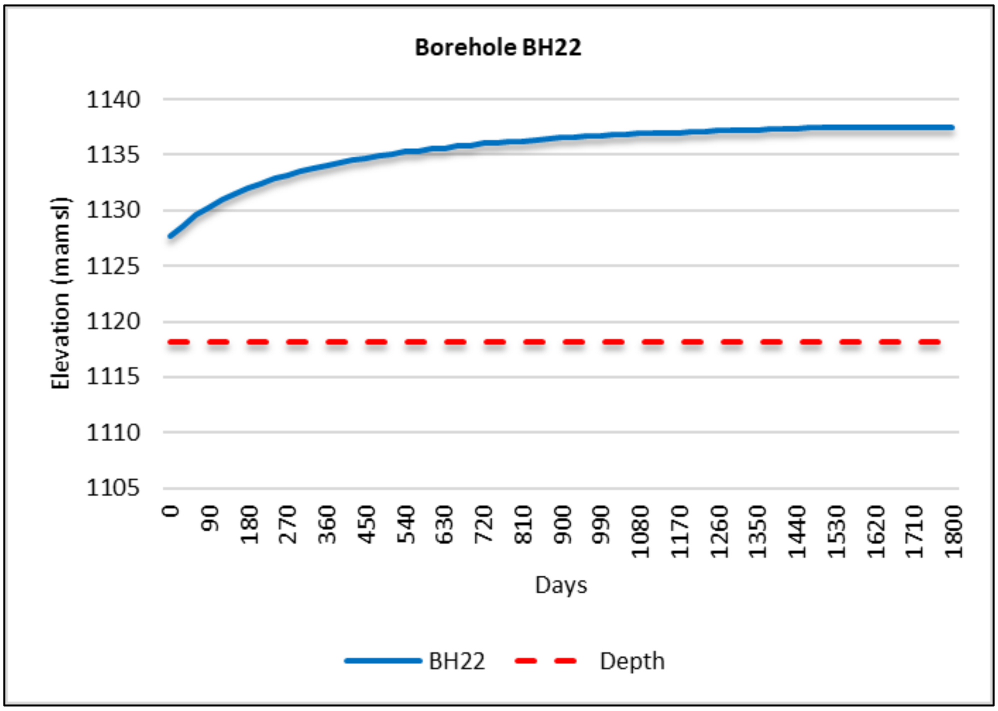


Figure 6.5: Simulated groundwater level recovery in borehole BH22

6.3 Groundwater Contamination

A concern was raised by the landowners on the possibility of groundwater contamination from the mining activities. The only mining related contaminant source that can potentially impact on the groundwater is after mine closure when the mine fills with water. The geochemical assessment, discussed in Section 4.3, however, indicated that there are no chemicals of concern expected in the flooded mine workings.

The potential impact from the mine, should any unexpected contamination occur, was therefore modelled as a percentage of the source concentration, rather than a specific contaminant parameter. This way the impacts can be related to a wide range of parameters by using the percentage of the source parameter concentration.

The result from this assessment is shown in Figure 6.6 and Figure 6.7 for 50 years and 100 years post closure respectively. It is evident that in the unlikely event of contamination occurring, the plume migration will be in a north-easterly direction, away from the industrial area. There are no other groundwater users within the expected contaminant migration path.

The proposed mining extension is not expected to impact on the groundwater quality in the private boreholes within the industrial area.

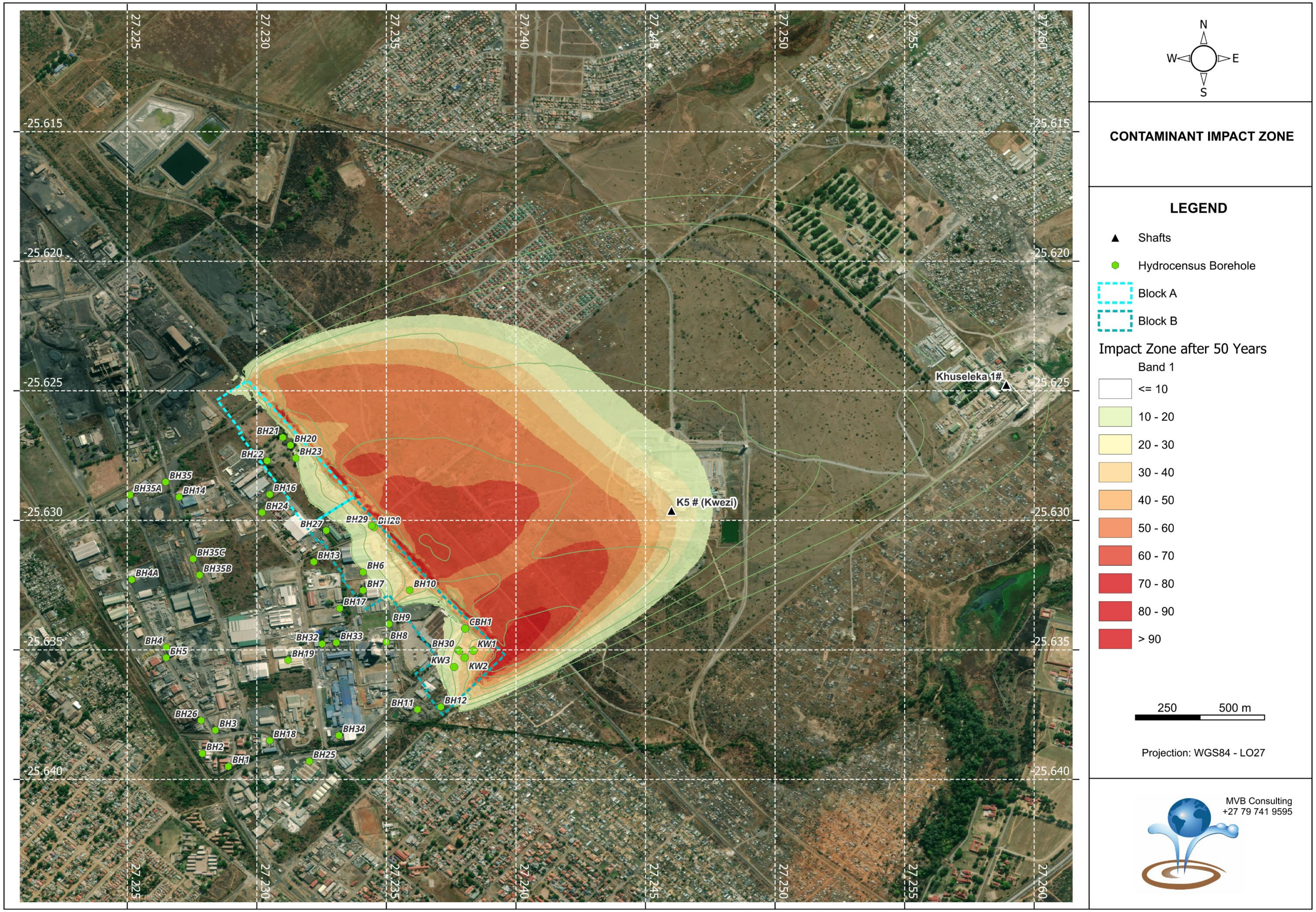


Figure 6.6: **Simulated contamination impact area after 50 years**

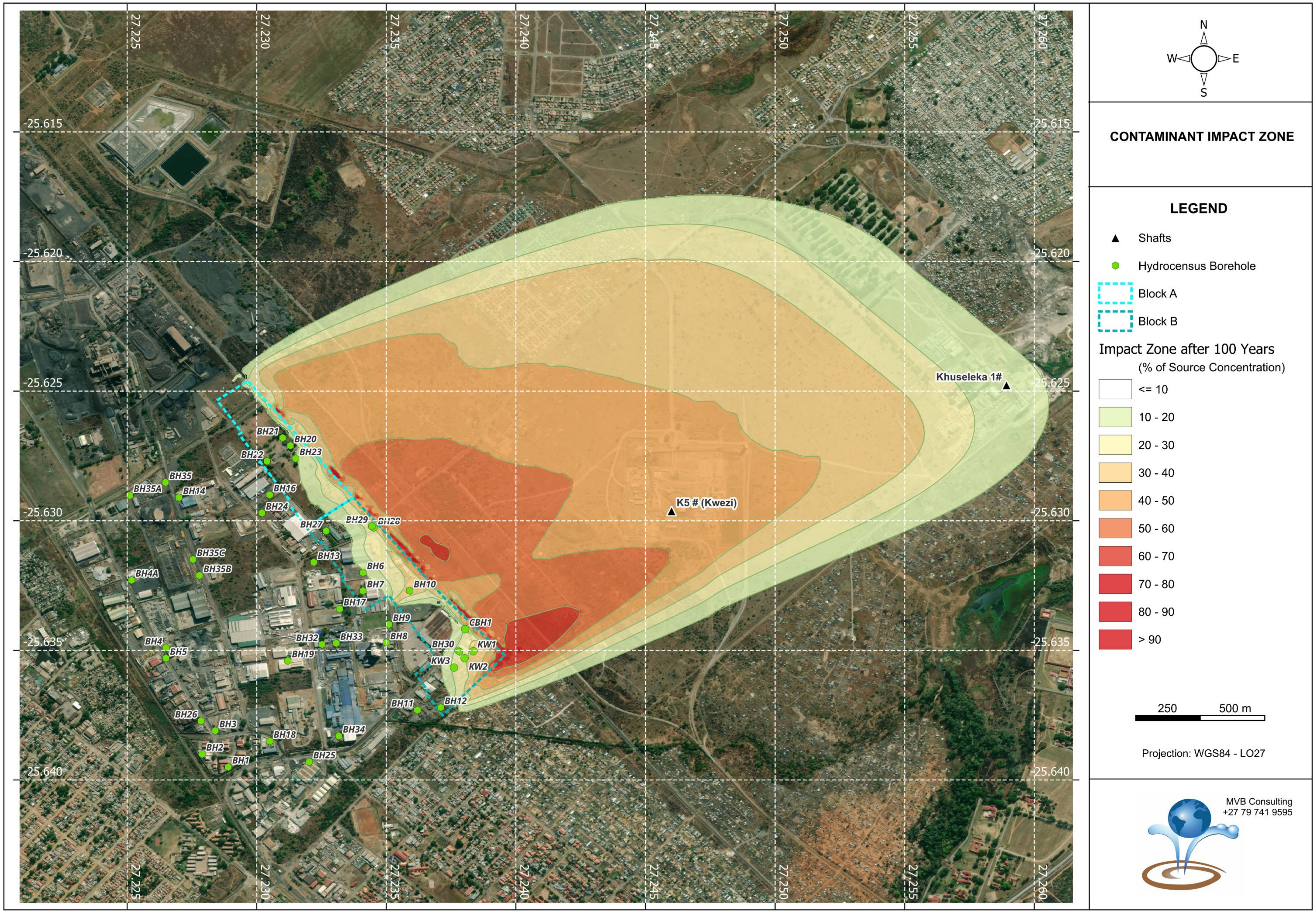


Figure 6.7: Simulated contamination impact area after 100 years

6.4 Mitigation Measures

The following measures may be considered to reduce the impacts to the private groundwater users in the region. The potential impact is as a result of groundwater inflow into the mine workings that may result in a drop in groundwater level.

1. Preventing the groundwater from entering the mine will negate all the resulting impacts, if it can be successfully implemented. The recommended approach is to seal any water intersection that may be encountered during the mining process. It is recommended to drill cover boreholes ahead of the mining face to identify any water-bearing features. If encountered, these should be sealed using chemical grout. The advantages of chemical grouts are that penetration can achieved at relatively low pressures and the depth of penetration can be controlled. The idea is to seal only the area around the mining and not extensively so as not to seal the boreholes.
2. Leaving pillars around the deeper boreholes to protect the borehole. There are only two boreholes that were drilled beyond the mining elevation, BH7 and 12. These boreholes are situated close to the edge of the mining block, but if there is a risk of mining through any of these boreholes it is recommended that pillars are included in the mine plan.
3. If any borehole is damaged through the mining process it is recommended that such a borehole be replaced with a shallower borehole. Boreholes that are outside the mining blocks can be drilled deeper if and when the groundwater level drops.
4. Water supply from an alternative source to affected owners may be considered in a worst-case scenario. The most likely alternative water source is a well field outside the affected area. This will have to be investigated to find the most suitable site.
5. It is recommended that Sibanye drill three to five monitoring boreholes within the potentially affected area to monitor the groundwater levels.

It is expected that the most suitable mitigation measures will be a combination of the measures above.

6.5 Risk Assessment

The impact assessment relates to the application for the expansion of the Kwezi Mining right (80 MR) to include the additional UG2 blocks A and B.

The significance of the identified impacts will be determined using an accepted methodology from the Department of Environmental Affairs and Tourism Guideline document on EIA Regulations, April 1998. As with all impact methodologies, the impact is defined in a semi-quantitative way and will be assessed according to methodology prescribed in the following section.

Table 6.1: Environmental risk rating scale

Evaluation Component	Rating	Scale	Description / criteria
MAGNITUDE of negative impact (at the indicated spatial scale)	**10**	**Very high**	Bio-physical and/or social functions and/or processes might be *severely* altered.
	8	**High**	Bio-physical and/or social functions and/or processes might be *considerably* altered.
	6	**Medium**	Bio-physical and/or social functions and/or processes might be *notably* altered.
	4	**Low**	Bio-physical and/or social functions and/or processes might be *slightly* altered.
	2	**Very low**	Bio-physical and/or social functions and/or processes might be *negligibly* altered.
	0	**Zero**	Bio-physical and/or social functions and/or processes will remain *unaltered*.
MAGNITUDE of POSITIVE IMPACT (at the indicated spatial scale)	**10**	**Very high**	Positive: Bio-physical and/or social functions and/or processes might be *substantially* enhanced.
	8	**High**	**Positive**: Bio-physical and/or social functions and/or processes might be *considerably* enhanced.
	6	**Medium**	**Positive**: Bio-physical and/or social functions and/or processes might be *notably* enhanced.
	4	**Low**	**Positive**: Bio-physical and/or social functions and/or processes might be *slightly* enhanced.
	2	**Very low**	**Positive**: Bio-physical and/or social functions and/or processes might be *negligibly* enhanced.
	0	**Zero**	**Positive**: Bio-physical and/or social functions and/or processes will remain *unaltered.*
DURATION	**5**	**Permanent**	**Impact in perpetuity. –**
	4	**Long term**	Impact ceases after operational phase/life of the activity > 60 years.
	3	**Medium term**	Impact might occur during the operational phase/life of the activity – 60 years.
	2	**Short term**	Impact might occur during the construction phase - < 3 years.
	1	**Immediate**	**Instant impact.**
EXTENT (or spatial scale/influence of impact)	**5**	**International**	**Beyond the National boundaries.**
	4	**National**	Beyond provincial boundaries, but within National boundaries.
	3	**Regional**	Beyond 5 km of the mine area and within the provincial boundaries.
	2	**Local**	Within a 5 km radius of the mine area.
	1	**Site-specific**	**On site or within 100 meters of the site boundaries.**
	0	**None**	**Zero extent.**
IRREPLACEABLE loss of resources	**5**	**Definite**	**Definite** loss of irreplaceable resources.
	4	**High potential**	**High** potential for loss of irreplaceable resources.
	3	**Moderate potential**	**Moderate** potential for loss of irreplaceable resources.
	2	**Low potential**	**Low** potential for loss of irreplaceable resources.
	1	**Very low potential**	**Very low** potential for loss of irreplaceable resources.

Evaluation Component	Rating	Scale	Description / criteria
	0	**None**	**Zero potential.**
REVERSIBILITY of impact	5	**Irreversible**	Impact **cannot** be reversed.
	4	**Low irreversibility**	**Low** potential that impact might be reversed.
	3	**Moderate reversibility**	**Moderate** potential that impact might be reversed.
	2	**High reversibility**	**High** potential that impact might be reversed.
	1	**Reversible**	Impact **will be** reversible.
	0	**No impact**	No impact.
PROBABILITY (of occurrence)	5	**Definite**	>95% chance of the potential impact occurring.
	4	**High probability**	75% - 95% chance of the potential impact occurring.
	3	**Medium probability**	25% - 75% chance of the potential impact occurring
	2	**Low probability**	5% - 25% chance of the potential impact occurring.
	1	**Improbable**	<5% chance of the potential impact occurring.
	0	**No probability**	**Zero probability.**

Evaluation Component	Rating scale and description / criteria
CUMULATIVE impacts	**High**: The activity is one of several similar past, present or future activities in the same geographical area, and might contribute to a very significant combined impact on the natural, cultural, and/or socio-economic resources of local, regional or national concern. ***Medium:*** The activity is one of a few similar past, present or future activities in the same geographical area, and might have a combined impact of moderate significance on the natural, cultural, and/or socio-economic resources of local, regional or national concern. ***Low:*** The activity is localised and might have a negligible cumulative impact. ***None:*** No cumulative impact on the environment.

Once the Environmental Risk Ratings have been evaluated for each potential environmental impact, the Significance Score of each potential environmental impact is calculated by using the following formula:

SS (Significance Score) = (magnitude + duration + extent + irreplaceable + reversibility) x probability.

The maximum Significance Score value is 150.

The Significance Score is then used to rate the Environmental Significance of each potential environmental impact as per Table 7.3. The Environmental Significance rating process is completed for all identified potential environmental impacts both before and after implementation of the recommended mitigation measures.

Table 6.2: Environmental significance rating scale

Significance Score	Environmental Significance	Description / criteria
125 – 150	Very high (VH)	An impact of very high significance will mean that the project cannot proceed, and that impacts are irreversible, regardless of available mitigation options.
100 – 124	High (H)	An impact of high significance which could influence a decision about whether or not to proceed with the proposed project, regardless of available mitigation options.
75 – 99	Medium-high (MH)	If left unmanaged, an impact of medium-high significance could influence a decision about whether or not to proceed with a proposed project. Mitigation options should be relooked at.
40 – 74	Medium (M)	If left unmanaged, an impact of moderate significance could influence a decision about whether or not to proceed with a proposed project.
<40	Low (L)	An impact of low is likely to contribute to positive decisions about whether or not to proceed with the project. It will have little real effect and is unlikely to have an influence on project design or alternative motivation.
+	Positive impact (+)	A positive impact is likely to result in a positive consequence/effect and is likely to contribute to positive decisions about whether or not to proceed with the project.

6.6 Impact Assessment Result

There are potentially two (2) significant post-closure risks that may impact the groundwater regime. These are as follows:

- **Reduction in the groundwater levels.** During underground mining groundwater flows into the workings, which is then be pumped out. This results in the lowering of the groundwater levels in the vicinity of the mine during the operational phase of the mining operation. The extent of this dewatering cone is important as it can potentially impact on private groundwater users and in extreme situations may cause boreholes to dry up. After mining ceases the groundwater levels are expected to recover and this risk will no longer be applicable.
- **Deterioration of the groundwater quality due to contaminant seepage from the mining operations.** Rainwater and groundwater seepage into the mining operations may become contaminated and when entering the groundwater system, the contaminants will migrate from these facilities. Due to contaminant migration from re-watered workings or decant from the workings, down-gradient receptors may be impacted on. Receptors include surface streams and private groundwater users.

The risk assessment result is summarised in Table 6.3.

With reference to Table 6.3 the following is concluded:

- The potential lowering of the groundwater level is regarded as the most significant risk associated with this project. It has the potential to impact on private groundwater users, who are solely reliant upon groundwater as their only source of water. If, however, the mitigation measures are implemented this risk can be greatly reduced.
- The potential impact on the groundwater quality is regarded as low and only continued monitoring is recommended.

Table 6.3: Groundwater impact assessment table

DEVELOPMENT PHASE	POTENTIAL ENVIRONMENTAL IMPACT	ACTIVITY	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION								CUMULATIVE	STATUS	RECOMMENDED MITIGATION MEASURES / REMARKS	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION							
			M	D	S	I	R	P	TOTAL	SS				M	D	S	I	R	P	TOTAL	SS
Groundwater																					
Operational Phase	Potential over abstraction from groundwater dewatering of the aquifer	Groundwater abstraction	8	5	2	4	3	4	88		Medium-High	Negative	Sealing of water ingress point Drilling of new or deeper boreholes Alternative water source	4	2	2	2	3	2	26	
Operational Phase	Water quality impacts from the underground mine rewatering	Re-watering of the mine workings	4	5	1	3	3	2	32		Low	Negative	Geochemical study showed that the water in the mine void will be good quality This water will remain in the void with little potential impact to neighbouring areas Groundwater and contaminant flow is away from private groundwater users	2	3	1	2	2	2	20	
Post-Closure Phase	Potential over abstraction from groundwater dewatering of the aquifer	Groundwater abstraction	4	2	2	2	3	2	26		Low	Negative	The groundwater level, if remedial options are implemented, will recover within 10-15 years post closure	2	5	2	2	1	1	12	
Post-Closure Phase	Water quality impacts from the underground mine rewatering	Re-watering of the mine workings	2	3	1	2	2	2	20		Low	Negative	The mine water quality is expected to be good The groundwater level will recover and users will only be abstracting unaffected groundwater	2	2	1	2	2	2	18	

7. SUMMARY AND CONCLUSIONS

It is the intention of SRPM to expand the Kwezi Mining Right Area and to mine the UG2 Shallows Blocks (Blocks A and B). These mining blocks are shallow, varying between 40 – 60 m below surface.

MVB Consulting was initially appointed to undertake a hydrogeological study to assess the potential impact from the proposed mining on the groundwater. An existing numerical groundwater model that was developed for the larger SRPM was used in this initial assessment. This model was, however, calibrated according to the mine monitoring data and very limited site-specific data was available. Due to the sensitivity of the project and the concerns from landowners, MVB was requested to update the model following the acquisition of more site-specific information. This data includes:

- Update of the hydrocensus.
- Test pumping of 28 boreholes.
- Sampling and analysis of 33 boreholes.

The aim of the updated study was to develop a new numerical groundwater model for the study area, with specific attention to the proposed mining extension. The newly acquired test pumping results and aquifer parameters were incorporated into the model.

Conceptual geohydrological model

- The geology of the region is dominated by the layered rocks of the Bushveld Igneous Complex (BIC). The BIC intruded concordantly into the volcano-sedimentary Pretoria Group strata of the Transvaal Supergroup about 2 060 million years ago. The Magaliesberg formation (upper Pretoria Group) is the floor to the BIC in the region.

- The following aquifers are present in the study area:
    - Weathered Aquifer. The mafic intrusive norite that outcrops over most of the study area is characterized by weathering in the first few meters from surface and is described as a “highly weathered, yellowish white to yellowish brown norite. The unit generally has low to moderate transmissivity but high storativity.
    - Primary Alluvial Aquifer. Along the course of the Hex River and other streams, the weathered aquifer has been partially or totally replaced by alluvial aquifers which were deposited by the river and retained hydraulic connectivity with it.
    - Secondary Fractured Aquifer. A deeper fractured semi-confined rock aquifer is formed by bedding planes, faults and joint planes of the unweathered norites, anorthosites and pyroxenites of the Rustenburg Layered Suite.
- Within the study area the groundwater table generally mimics the topography. There are very small and localised dewatering cones where groundwater enters the underground mine workings.

Underground mining environment

- The extent of the existing underground mine workings is shown below.

Reef	Mining Elevation
Merensky Reef	1 160 mamsl to -180 mbmsl
UG2 Reef	1 210 mamsl to 170 mamsl

- The current groundwater inflow into the mines in this region is approximately 3.8 ML/day.
- The waste classification conducted by SRK Consulting (2023) concluded the following:
    - The Leachable Concentrations in the Kwezi waste rock shows that the only metal that exceed the LCT0 threshold is manganese. It should be noted that Kwezi WRD was leached using acetic acid instead of distilled water.
    - The Total Concentrations in the Kwezi waste rock shows that the only metals that exceed the TCT0 threshold are copper and nickel.
    - The Kwezi waste rock samples are classified as Type 3 waste which corresponds to a Class C disposal facility.
- The geochemical risk assessment (GeoDyn, 2021) indicated that the mineral waste is unlikely to leach metal and metalloid contaminants into the groundwater in a post-closure scenario.
- The geochemical model results for the underground mine voids, indicates that the risk of the development of AMD (Acid Mine Drainage) conditions is negligible. The post-closure underground mine void geochemical system has acid neutralisation capacity, which is far more than the acid production capacity. The quality of the water that will fill the mine void post-closure is therefore expected to be good.
- When mining stops the mine void will fill with water. Once the mine workings are completely re-watered the ingress water will push-up into the shafts and some of the shafts may become free-flowing, dependent on its collar elevation in relation to the elevation of the hydraulic gradient. The shaft collars were re-evaluated based on closer spaced topographical contours and the regional groundwater level was refined with the additional groundwater level information from the hydrocensus boreholes. Based on these assessments it was concluded that all the shaft collars are above the expected static groundwater elevation. Thembelani 2 Shaft was previously considered a potential decant point, but the current study shows that the groundwater level will stabilise ±2m below the shaft collar. The current groundwater level in borehole NBH04, which is approximately 100m down-gradient from this shaft, is 1 095.14 mamsl (1.16 mbgl). This is confirmation that the updated assessment is accurate. This and the fact that the shafts will be plugged during rehabilitation significantly reduces the risk of mine water decant.
- Any dewatering cone that may develop in the Kwezi extension area is expected to fully recover after mining ceases.

Numerical groundwater model and risk assessment

A new numerical groundwater model was developed for the Kwezi underground extension. A numerical groundwater model is a useful tool to assess the current and potential future impacts from the project on the groundwater regime. In this instance the potential impacts are:

- Estimated groundwater inflow volumes into the underground workings.
- Impact on the groundwater levels during the operational and post-closure phase of the mine.
- Potential contaminant migration from the mine workings.

The primary risk that the proposed mining extension poses is the risk of dewatering and disruption of private groundwater supply. The hydrocensus identified thirty-nine (39) private boreholes in the industrial area to overlying or close to the proposed mining extension.

The numerical model was used to simulate the following:

- Expected groundwater inflow volume into the mining extension.
- The expected groundwater level drawdown as a result of the groundwater inflow.
- The groundwater level recovery post-closure, assuming no decant.

The groundwater inflow volumes are as follows:

- **Block A Initial Flow**: Lower Limit – 617 m^3/day; Average – 740 m^3/day; Upper Limit – 888 m^3/day.
- **Block A Steady Flow**: Lower Limit – 499 m^3/day; Average – 600 m^3/day; Upper Limit – 718 m^3/day.
- **Block B Initial Flow**: Lower Limit – 1 059 m^3/day; Average – 1 271 m^3/day; Upper Limit – 1 525 m^3/day.
- **Block B Steady Flow**: Lower Limit – 833 m^3/day; Average – 1 000 m^3/day; Upper Limit – 1 200 m^3/day.

The groundwater level over the mining blocks is expected to drop to the mining elevation, approximately 10 m. The extent of the impact is within a radius of approximately 450m from the edge of the mining block.

Based on the extent of the simulated groundwater level drop, the risk to the hydrocensus boreholes were assessed. None of the boreholes are expected to be significantly affected and none of the boreholes will dry-up.

The groundwater level recovery will take approximately 3.5 years to fully recover post-closure, in the deeper boreholes.

A concern was raised by the landowners on the possibility of groundwater contamination from the mining activities. The only mining related contaminant source that can potentially impact on the groundwater is after mine closure when the mine fills with water. The geochemical assessment, however, indicated that there are no chemicals of concern expected in the flooded mine workings.

The potential impact from the mine, should any unexpected contamination occur, was therefore modelled as a percentage of the source concentration, rather than a specific contaminant parameter. This way the impacts can be related to a wide range of parameters by using the percentage of the source parameter concentration.

The result from this assessment shows that in the unlikely event of contamination occurring, the plume migration will be in a north-easterly direction, away from the industrial area. There are no other groundwater users within the expected contaminant migration path.

The proposed mining extension is not expected to impact on the groundwater quality in the private boreholes within the industrial area.

The study concluded the following:

- The potential lowering of the groundwater level is regarded as the most significant risk associated with this project. It has the potential to impact on private groundwater users, who are solely reliant upon groundwater as their only source of water.
- The updated modelling, however, showed that the groundwater level drawdown will not be as severe as initially thought, and none of the private boreholes are expected to dry up.
- This risk can also be further reduced if the mitigation measures discussed below, are implemented.
- The potential impact on the groundwater quality is regarded as low and only continued monitoring is recommended.

8. RECOMMENDATIONS

The following measures may be considered to reduce the impacts to the private groundwater users in the region. The potential impact is as a result of groundwater inflow into the mine workings that may result in a drop in groundwater level.

1. Preventing the groundwater from entering the mine will negate all the resulting impacts, if it can be successfully implemented. The recommended approach is to seal any water intersection that may be encountered during the mining process. It is recommended to drill cover boreholes ahead of the mining face to identify any water-bearing features. If encountered, these should be sealed using chemical grout. The advantages of chemical grouts are that penetration can achieved at relatively low pressures and the depth of penetration can be controlled. The idea is to seal only the area around the mining and not extensively so as not to seal the boreholes.
2. Leaving pillars around the deeper boreholes to protect the borehole. There are only two boreholes that were drilled beyond the mining elevation, BH7 and 12. These boreholes are situated close to the edge of the mining block, but if there is a risk of mining through any of these boreholes it is recommended that pillars are included in the mine plan.
3. If any borehole is damaged through the mining process it is recommended that such a borehole be replaced with a shallower borehole. Boreholes that are outside the mining blocks can be drilled deeper if and when the groundwater level drops.
4. Water supply from an alternative source to affected owners may be considered in a worst-case scenario. The most likely alternative water source is a well field outside the affected area. This will have to be investigated to find the most suitable site.
5. It is recommended that Sibanye drill three to five monitoring boreholes within the potentially affected area to monitor the groundwater levels. The recommended borehole positions are shown in Figure 8.1. Existing boreholes may also be used, but the monitoring borehole cannot be a production borehole. It must be a dedicated monitoring borehole to measure the static groundwater level. The groundwater levels in these boreholes should be monitored monthly and the monitoring data should be communicated to the property owners.

It is expected that the most suitable mitigation measures will be a combination of the measures above.

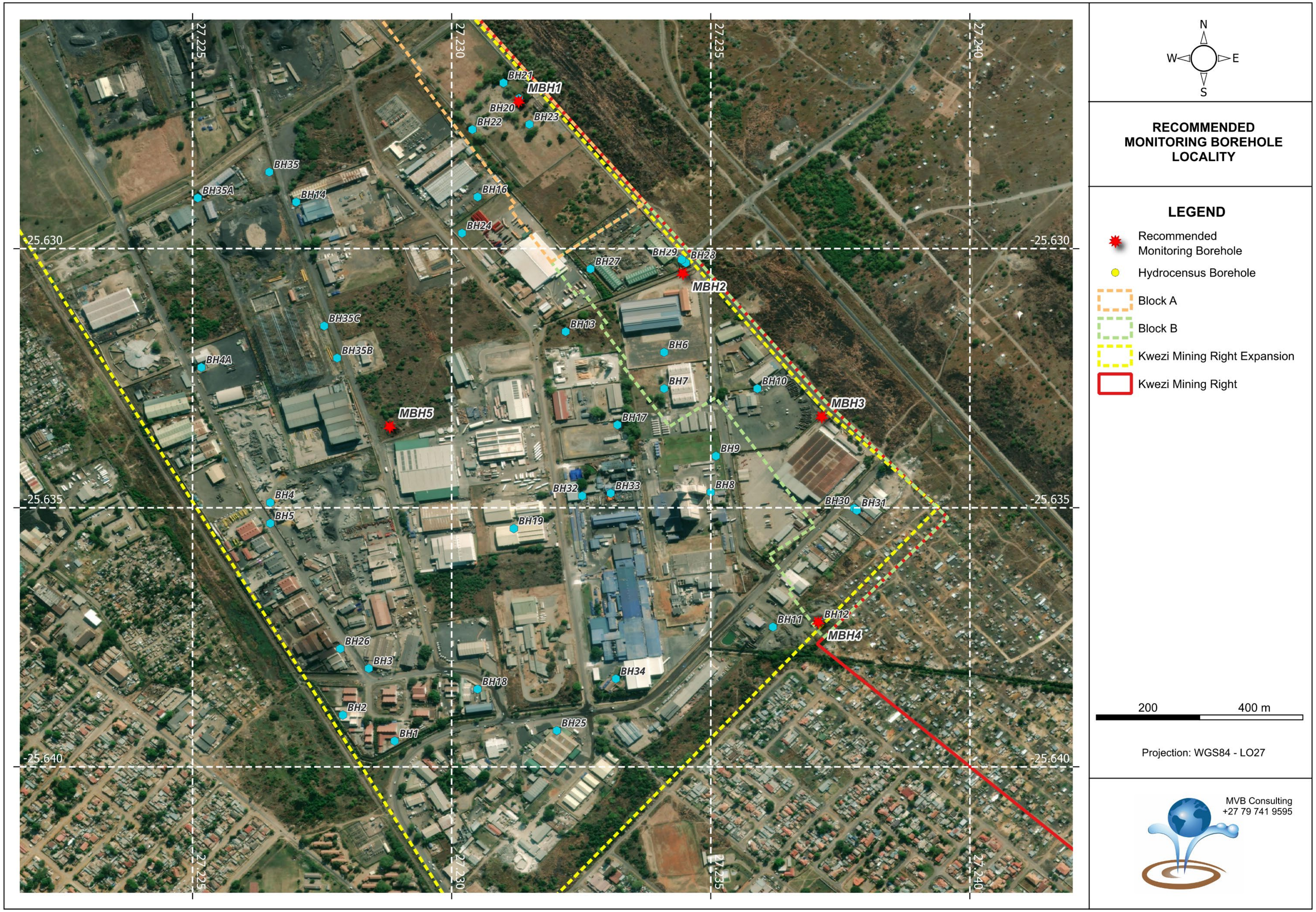


Figure 8.1: **Recommended monitoring points**

9. REFERENCES

Blight, G., Copeland, A., Jardine, P. and MacRobert, C., (2012). Measurements on freshly deposited surfaces of two platinum tailings dams. The Journal of the Southern African Institute of Mining and Metallurgy, 112, 911-917

Brantley, S.L., (2008), Kinetics of mineral dissolution. In, Brantley, S.L., Kubicki, J.D. and White, A.F. (Eds.). Kinetics of water-rock interactions. Springer, New York, 151-210

Dzombak, D.A. and Morel, F.M.M., 1994. Surface complexation modelling: Hydrous ferric oxide. Wiley, New York.

Hansen, R. (2021). Kroondal and Marikana Platinum Mines. Post-Closure Mine Water Quality Assessment. GeoDyn Report Number: 20211201.

Hydrocensus Data (2004). Borehole map showing private boreholes.

Mine Monitoring Data. Excel spreadsheets.

Nxumalo, S. Adadzi, P and Sahadeo, B. (2023). Geochemical and Waste Classification of Mine Residue Deposits at Rustenburg: Kroondal Operation. SRK Project Number 588695_Kroondal.

Steenekamp G, (2013). Rustenburg Section – Water Action Plan Phase 1 Baseline Study. Groundwater Model Report. Anglo American Platinum Report No. RC12004-RSWAPPH1-CS Volume 11.

Van Biljon, M (2021). Sibanye-Stillwater. Geohydrological Assessment for Closure of the Rustenburg Platinum Mines. MVB Consulting Report No.: MvB064/21/A052.

Van Biljon, M (2024). Alta Van Dyk Environmental Consultants (Pty) Ltd. Geohydrological Impact Assessment of the Proposed Underground Mining Extension at Kwezi Mine, Northwest Province. MVB Consulting Report No.: MVB159/24/B047

Van Biljon, M (2025). Alta Van Dyk Environmental Consultants (Pty) Ltd. Geohydrological Impact Assessment of the Proposed Underground Mining Extension at Kwezi Mine, Northwest Province - Hydrocensus and Pump Test Assessment. MVB Consulting Report No.: MVB169/25/B047

Viljoen MJ and Schürmann LW (1998). Platinum Group Metals. The Mineral Resources of South Africa (M.G.C. Wilson and C.R. Anhaeusser, eds). Handbook, Council for Geoscience.

White, A.F. and Brantley, S.L., 2003. The effect of time on the weathering of silicate minerals: why do weathering rates differ in the laboratory and field? Chemical Geology, 202, 479-506

Williamson, M.A. and Rimstidt, J.D., 1994. The kinetics and electrochemical rate-determining step of aqueous pyrite oxidation. Geochimica et Cosmochimica Acta, 58, 5443-5454

SIBANYE - STILLWATER

UPDATED GEOHYDROLOGICAL IMPACT ASSESSMENT OF THE PROPOSED UNDERGROUND MINING EXTENSION AT KWEZI MINE, NORTHWEST PROVINCE

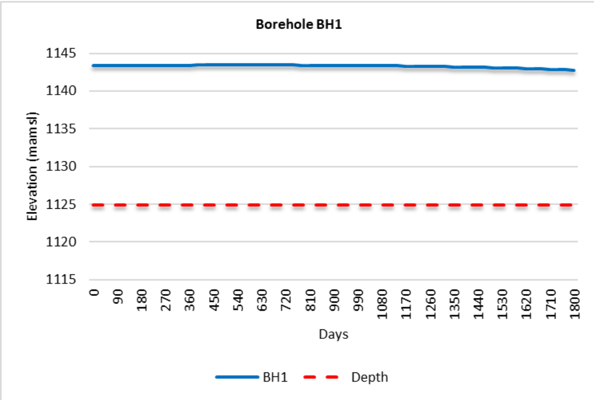
REVISION 1 REPORT

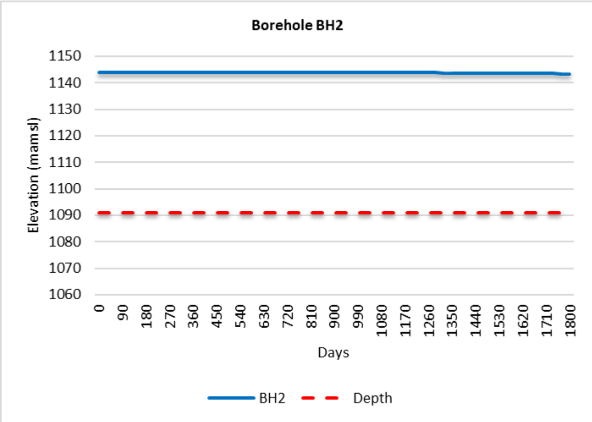
REPORT NO: MVB178/25/B047

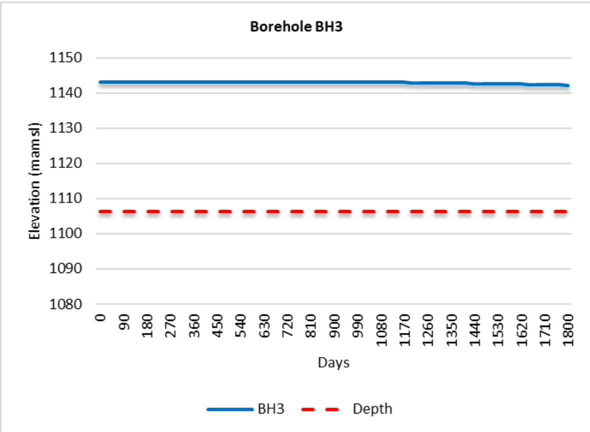
APPENDIX A

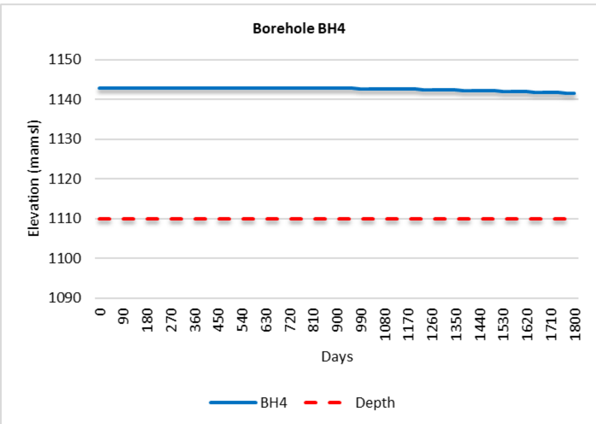
HYDROCENSUS BOREHOLE DRAWDOWN AND RECOVERY

Simulated Groundwater Level Drawdown

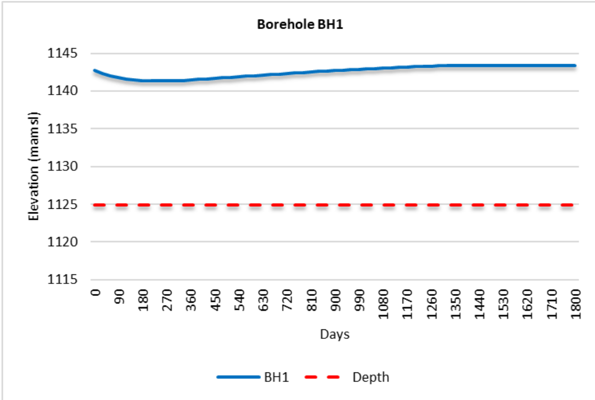


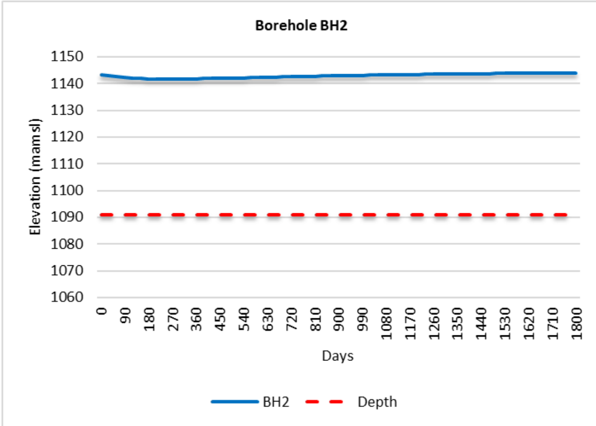


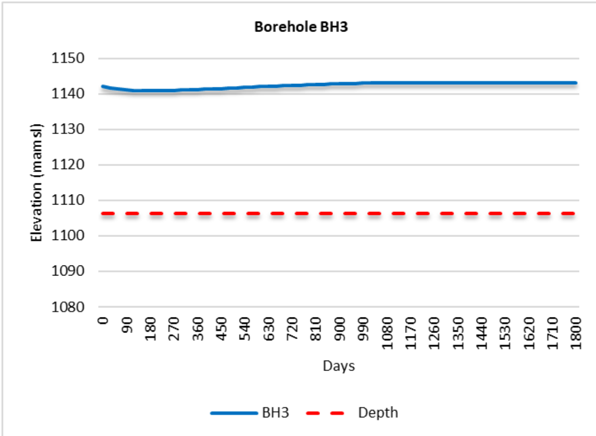


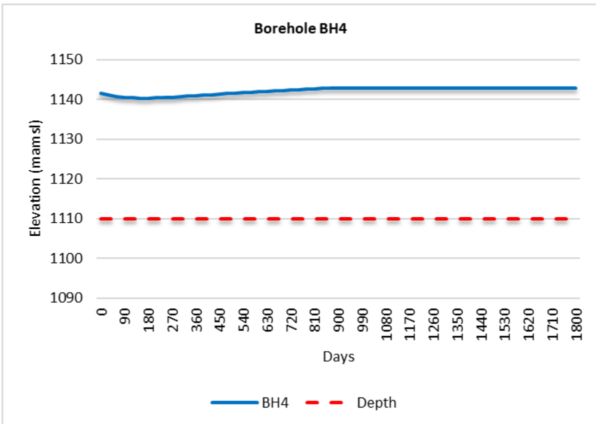


Simulated Groundwater Level Recovery

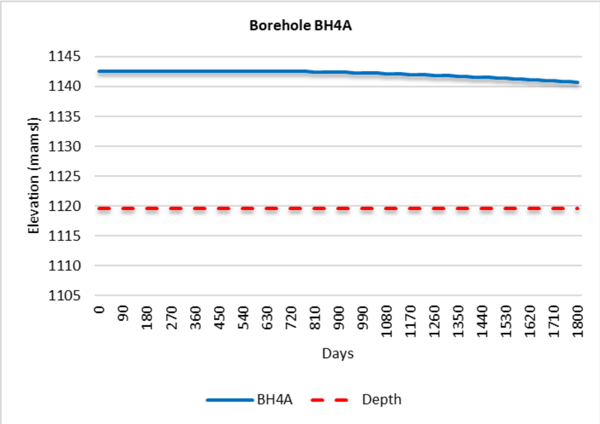


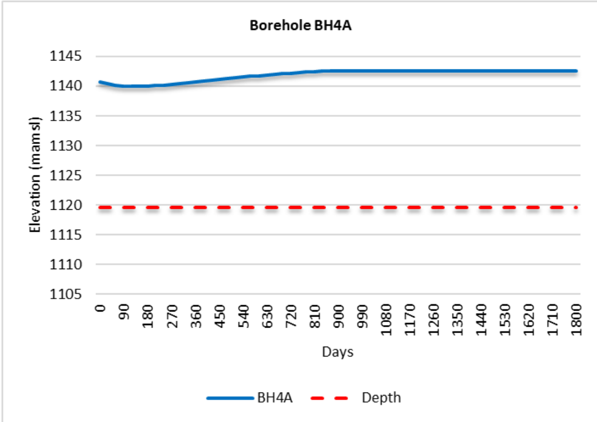


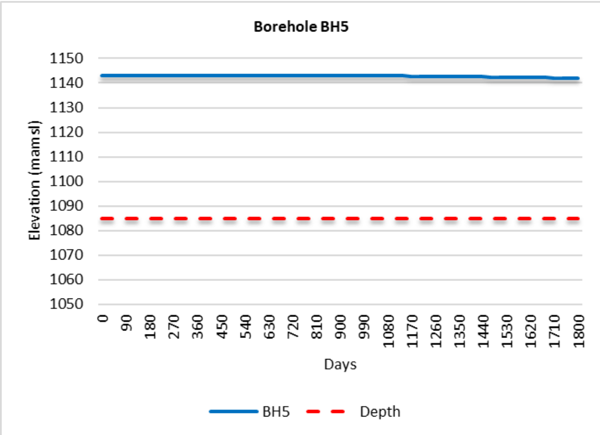


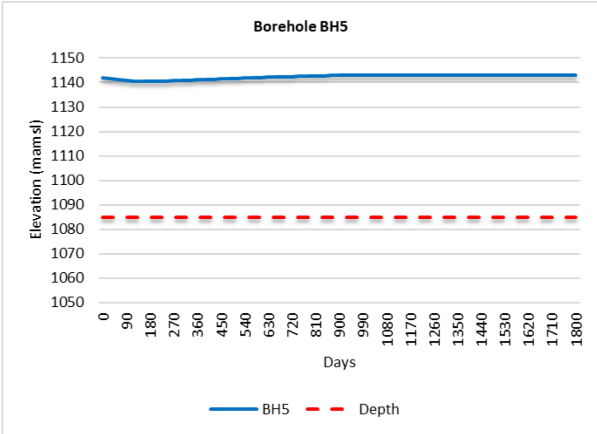


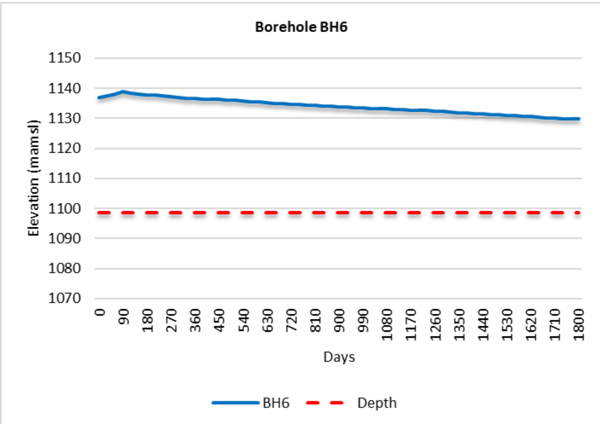
Simulated Groundwater Level Drawdown	Simulated Groundwater Level Recovery

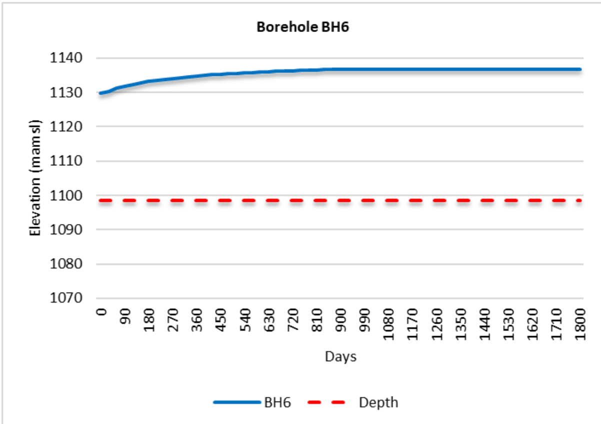


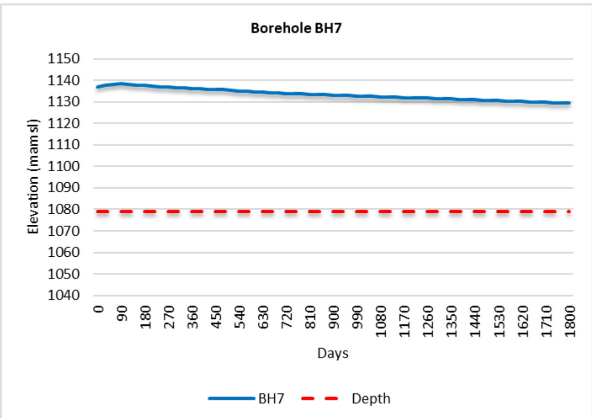


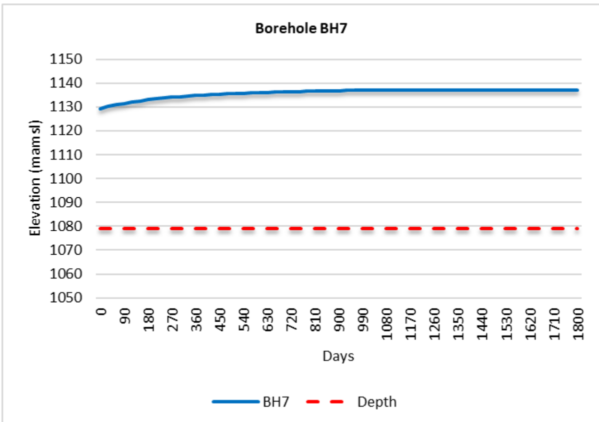




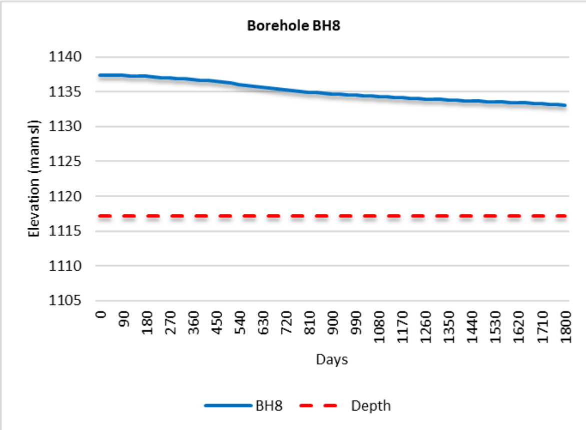


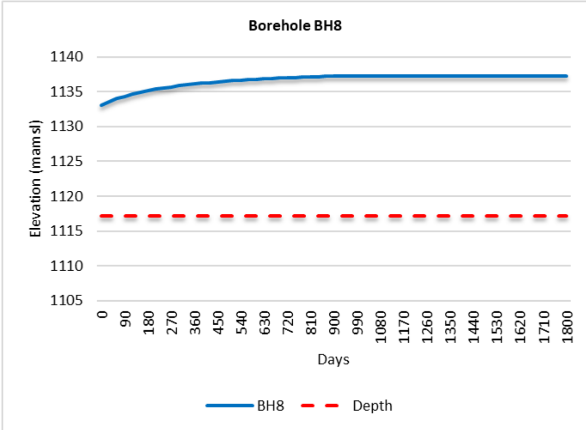


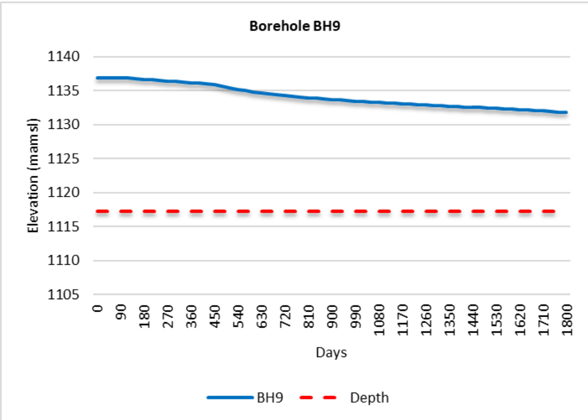


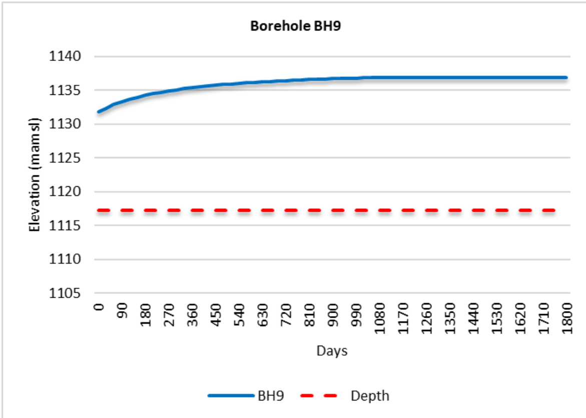


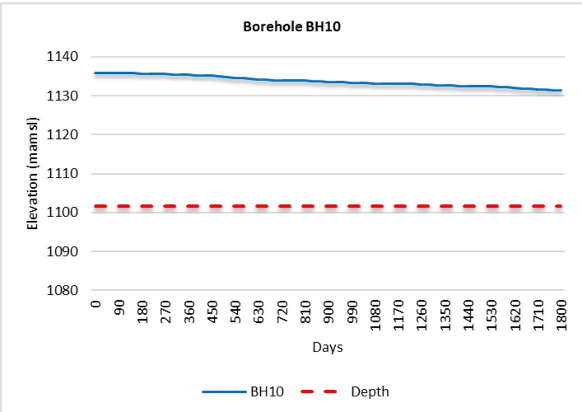
Simulated Groundwater Level Drawdown	Simulated Groundwater Level Recovery

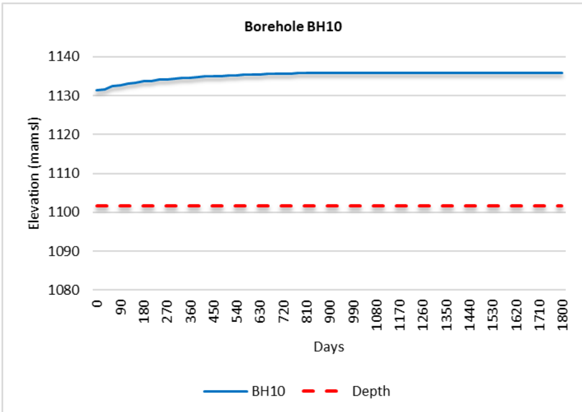


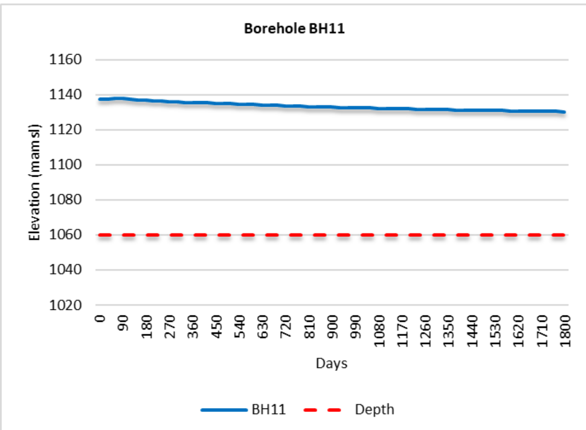


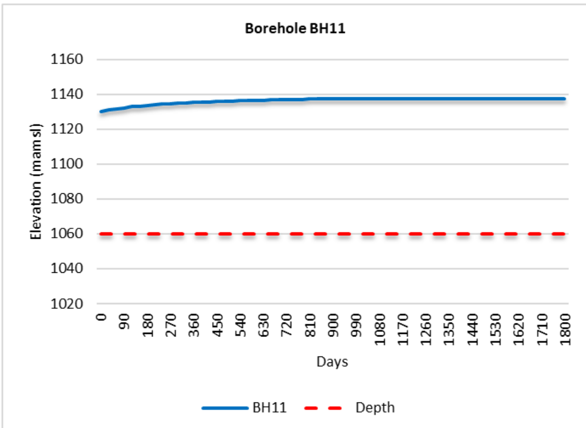




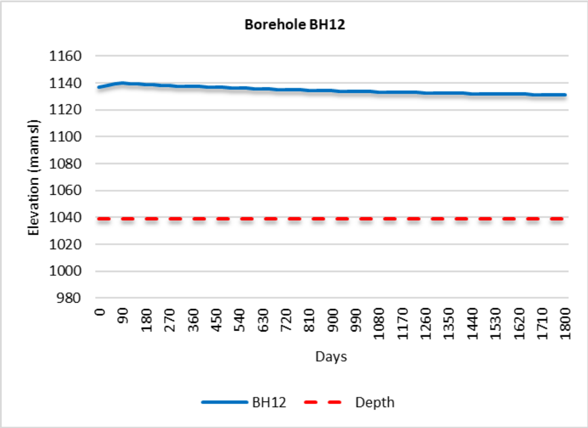


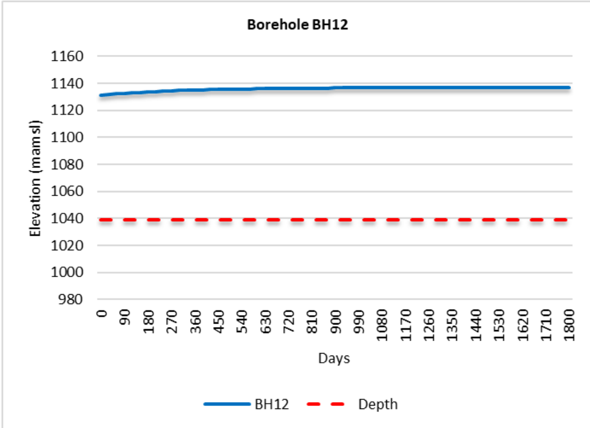


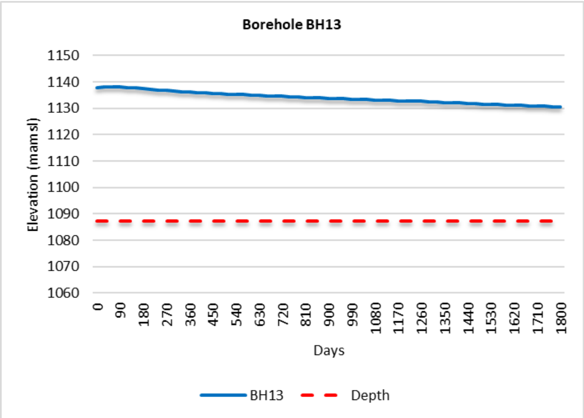


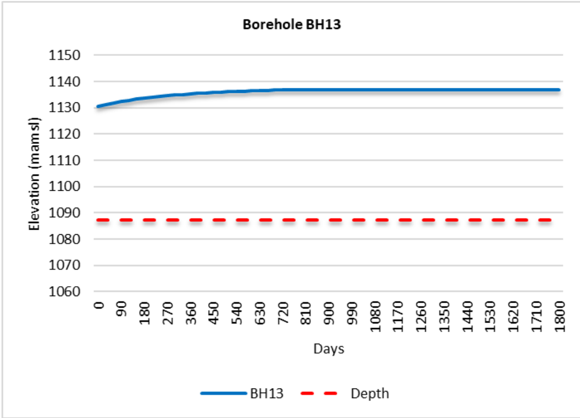


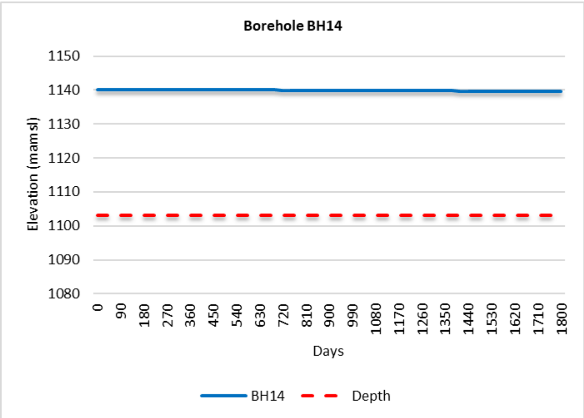
Simulated Groundwater Level Drawdown	Simulated Groundwater Level Recovery

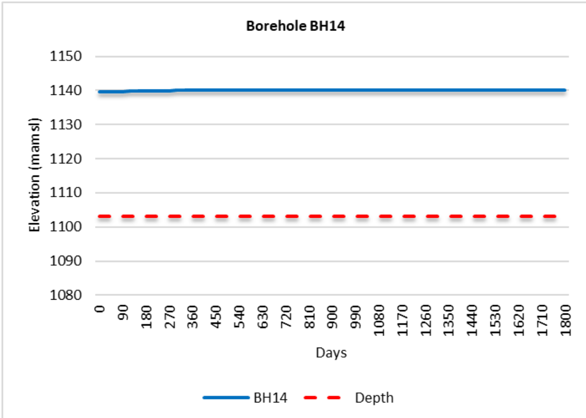


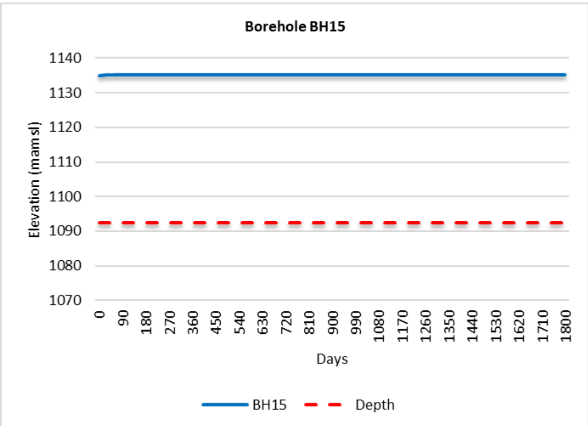


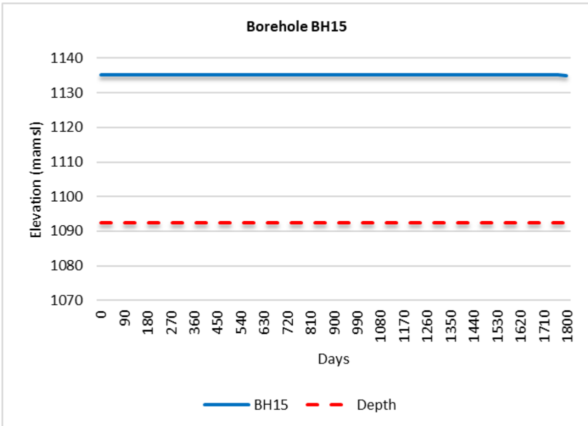




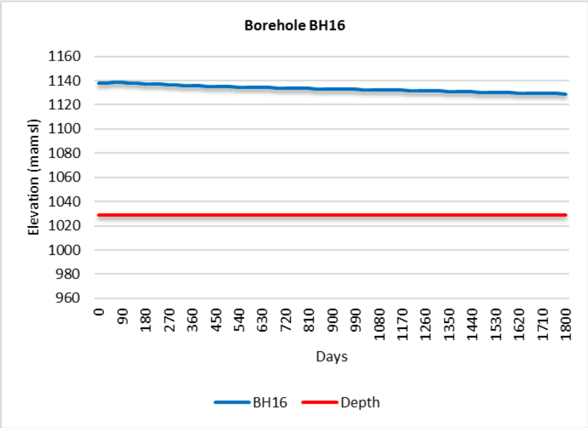


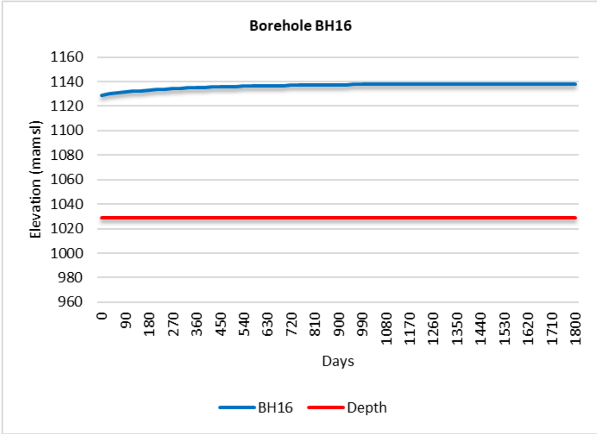


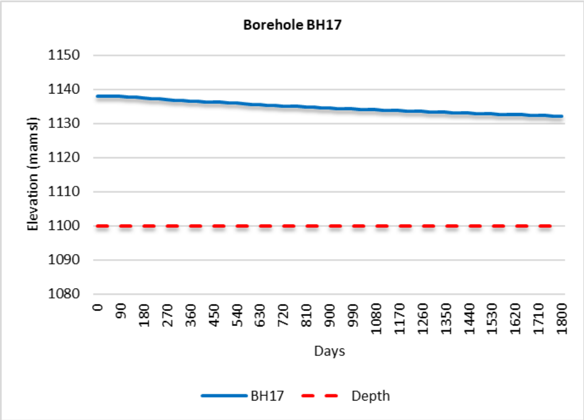


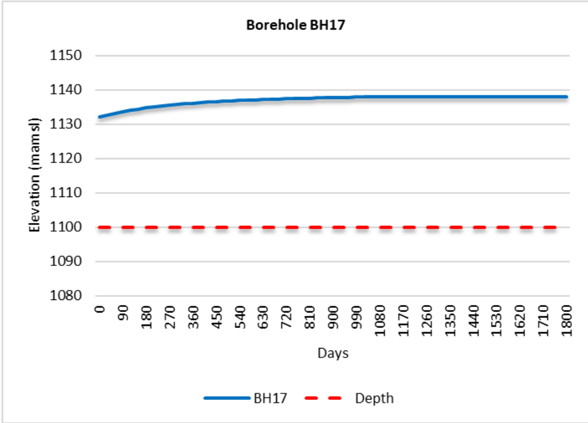


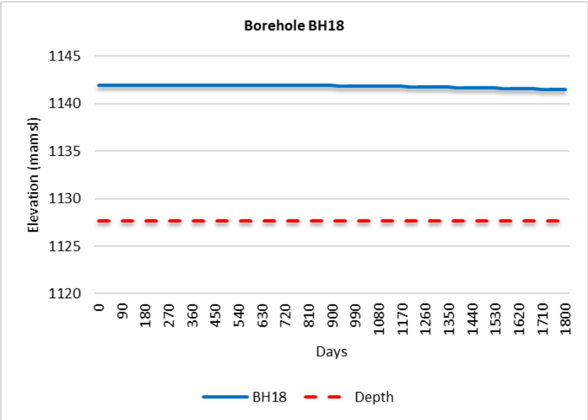
Simulated Groundwater Level Drawdown	Simulated Groundwater Level Recovery

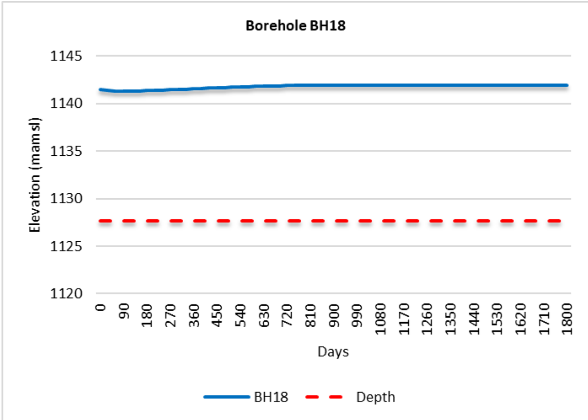


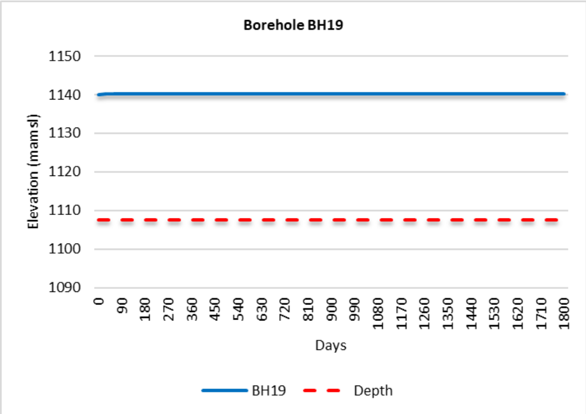


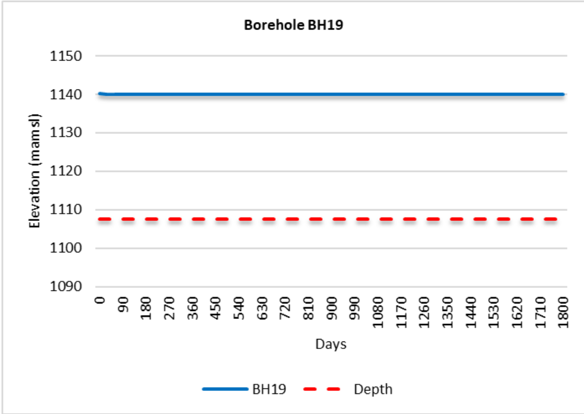




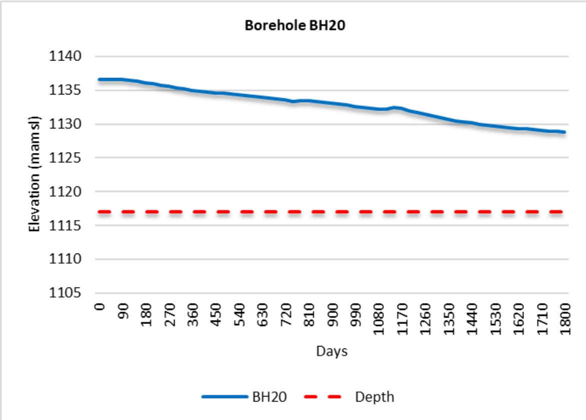


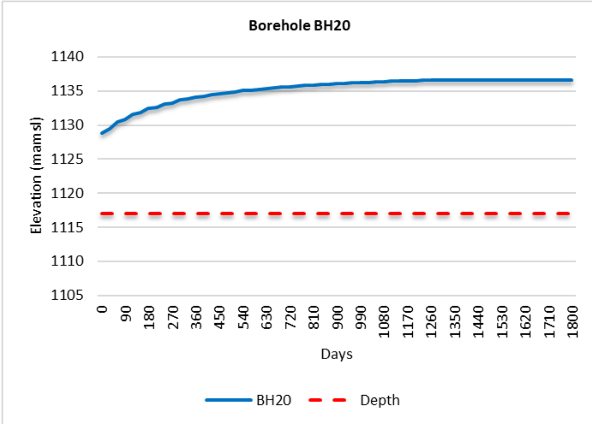


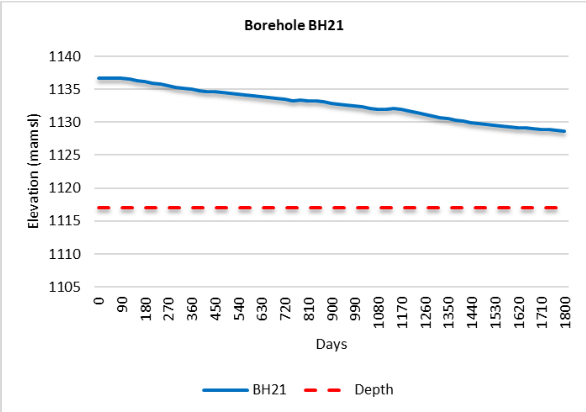


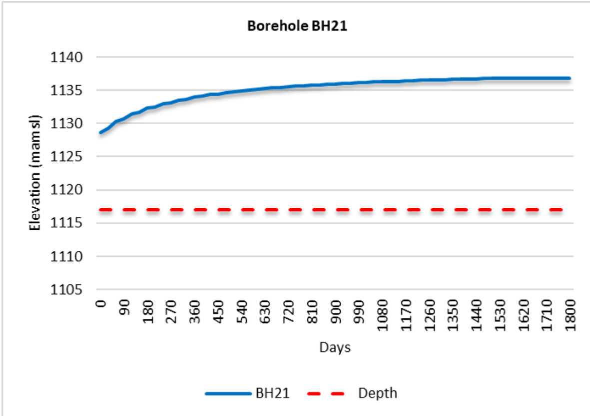


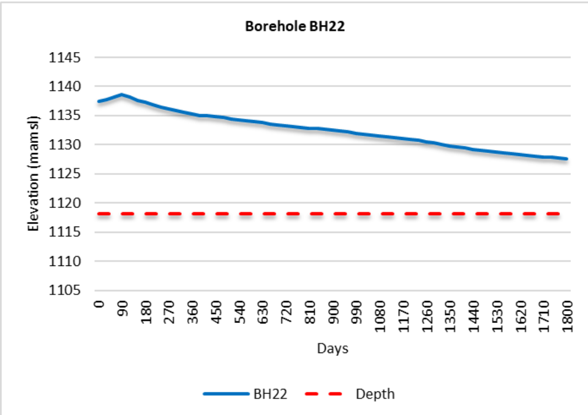
Simulated Groundwater Level Drawdown	Simulated Groundwater Level Recovery

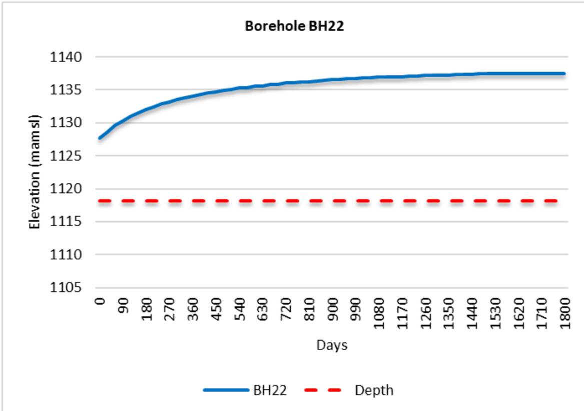


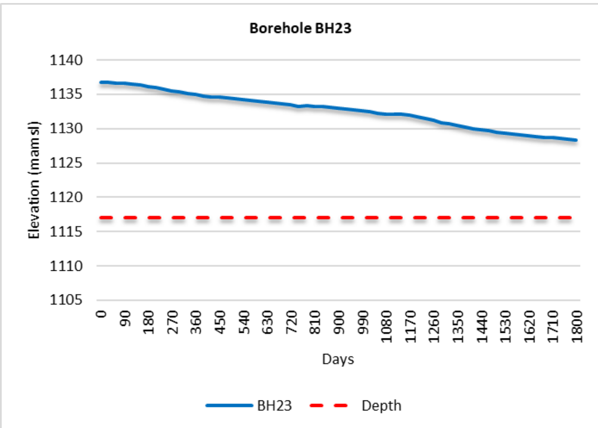


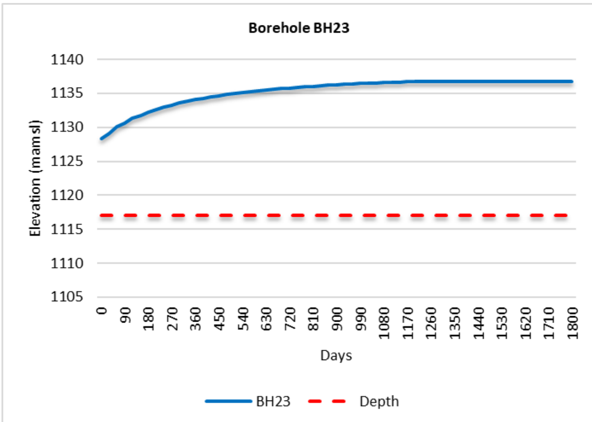




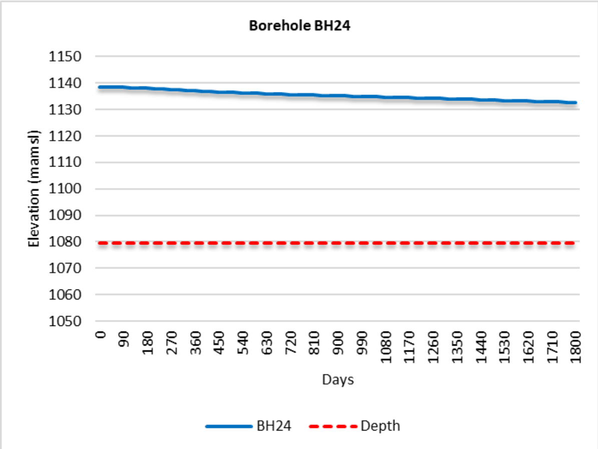


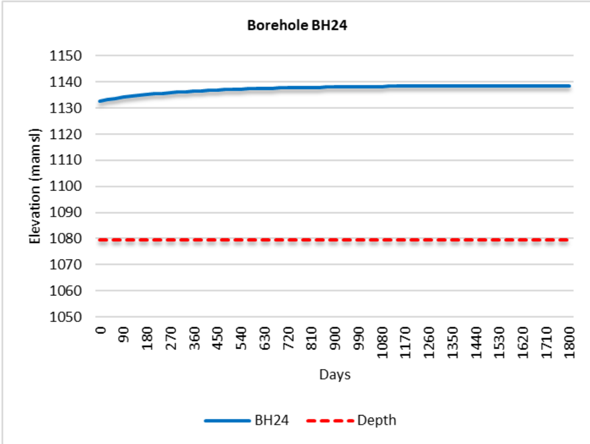


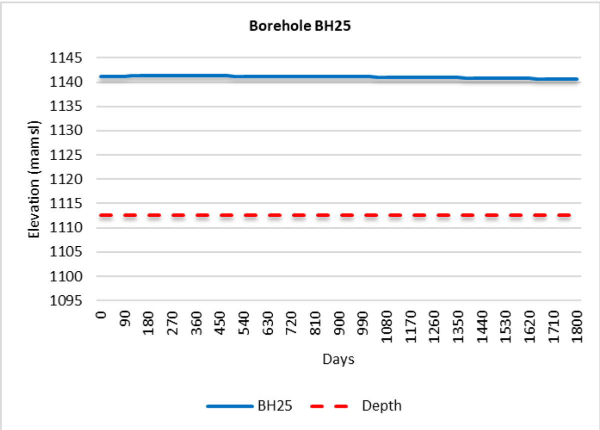


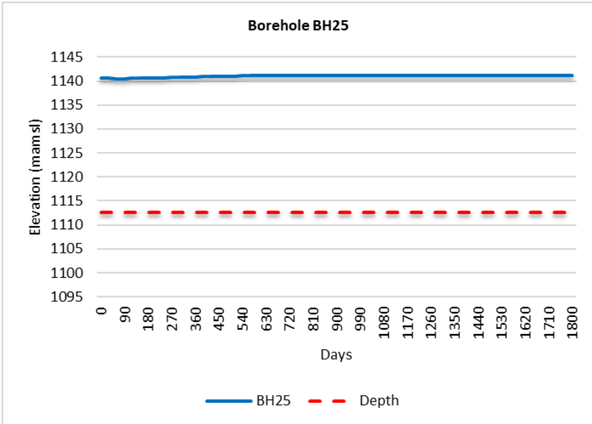


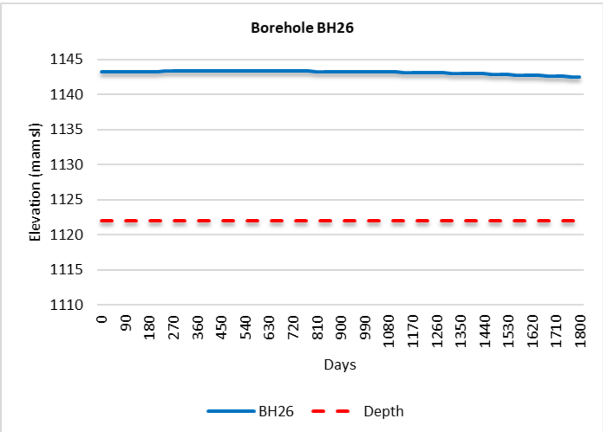
Simulated Groundwater Level Drawdown	Simulated Groundwater Level Recovery

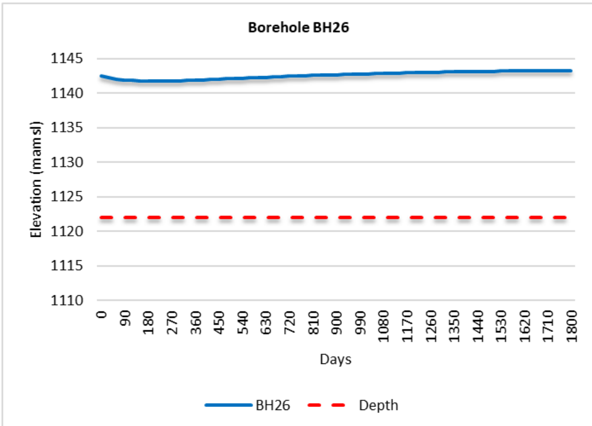


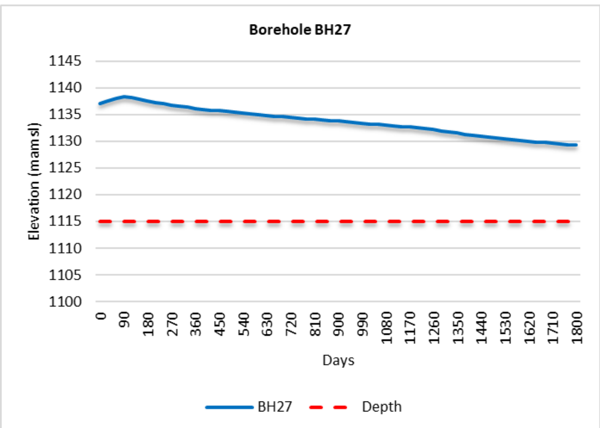


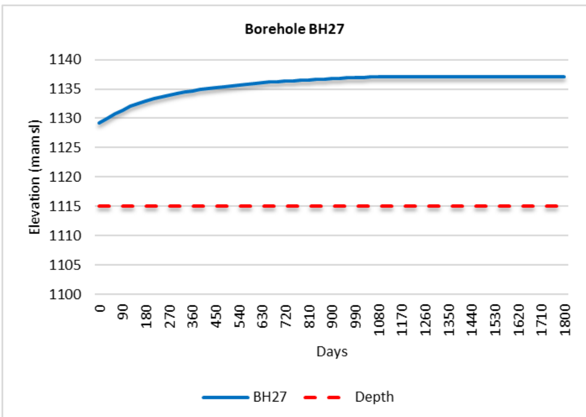




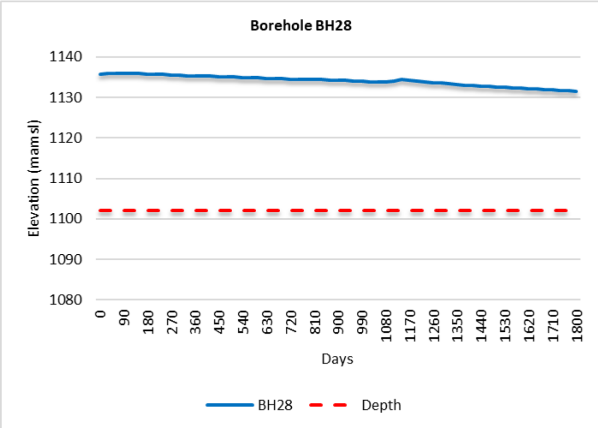


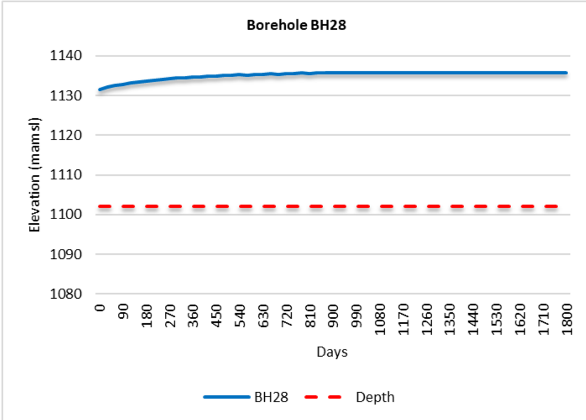


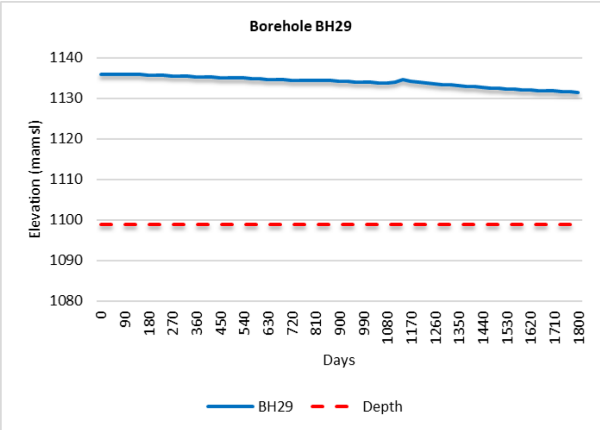


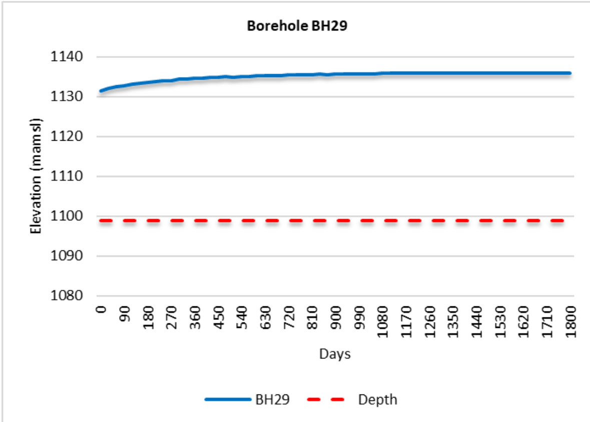


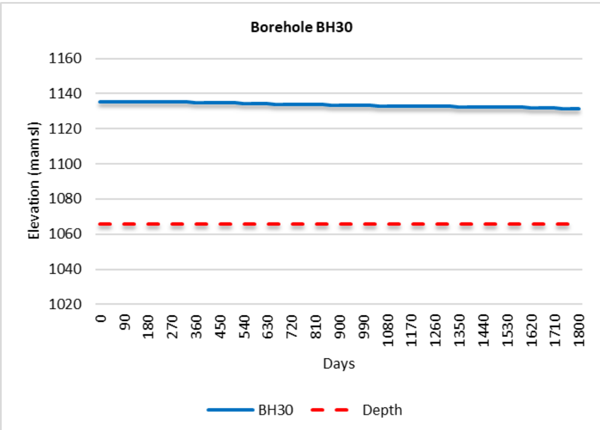
Simulated Groundwater Level Drawdown	Simulated Groundwater Level Recovery

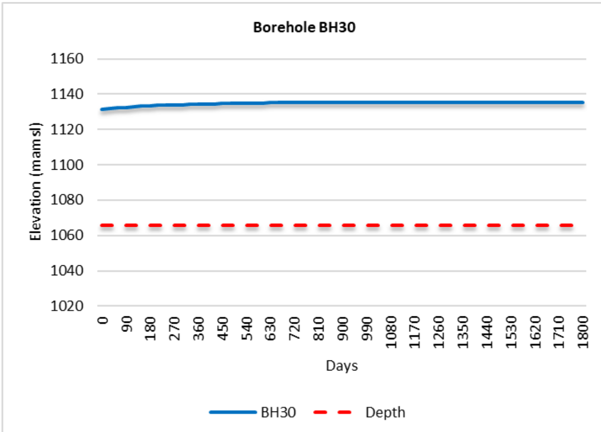


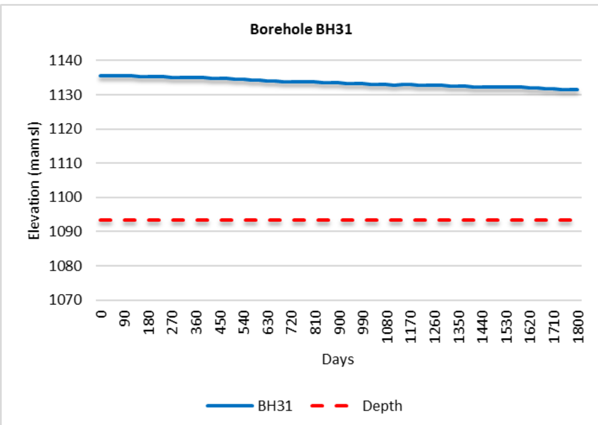


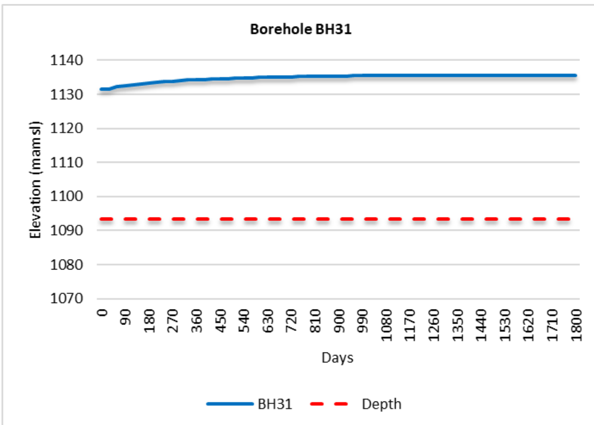




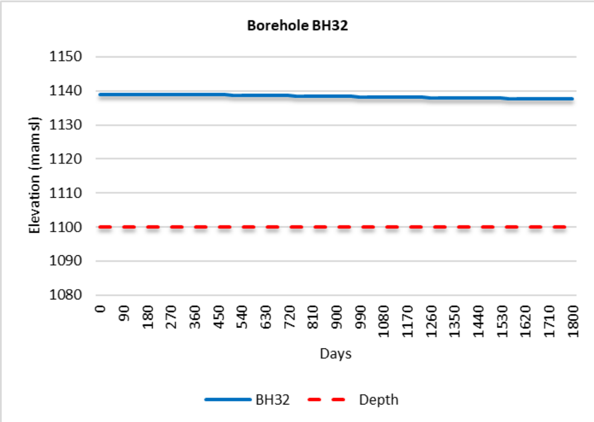


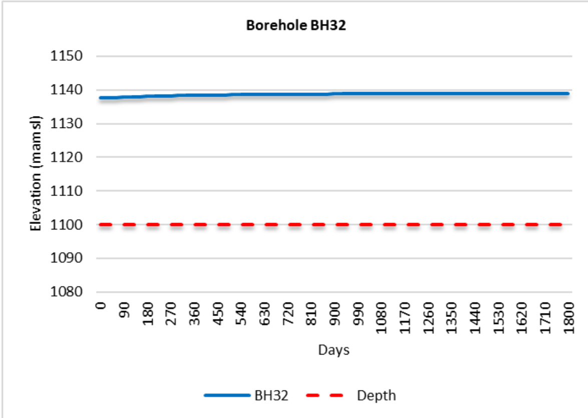


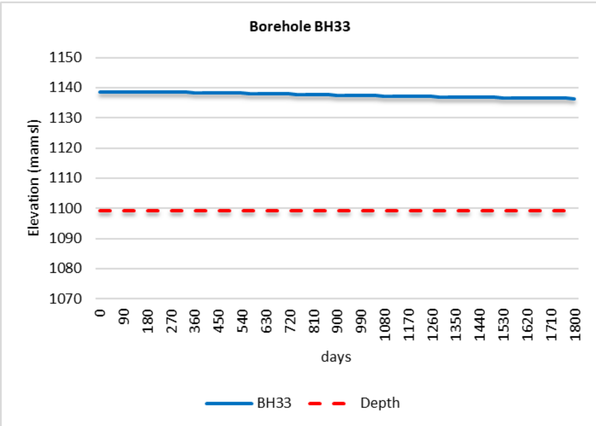


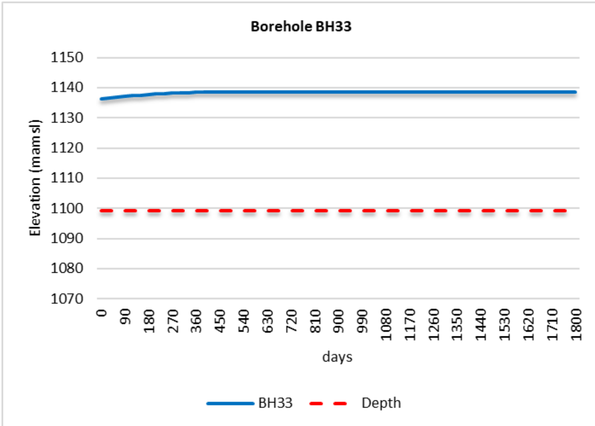


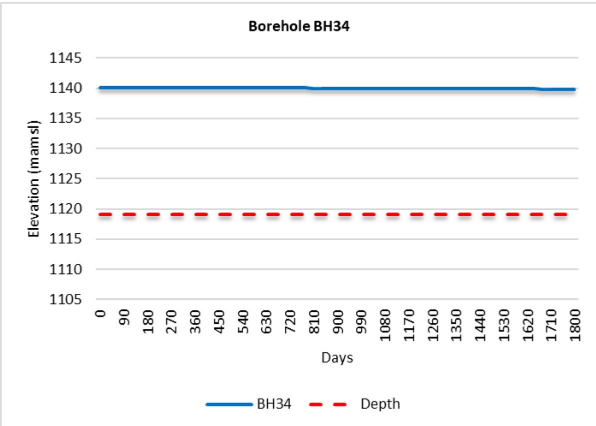
Simulated Groundwater Level Drawdown	Simulated Groundwater Level Recovery

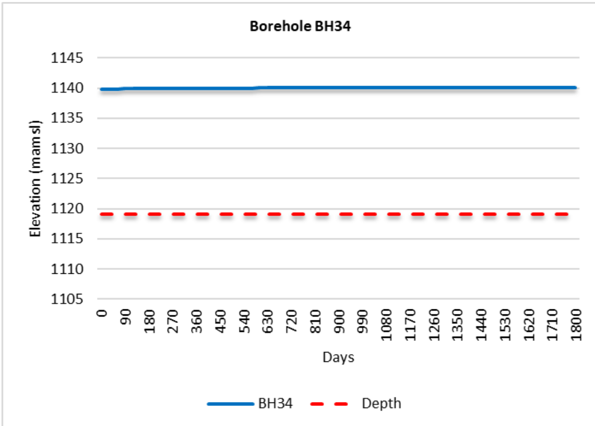


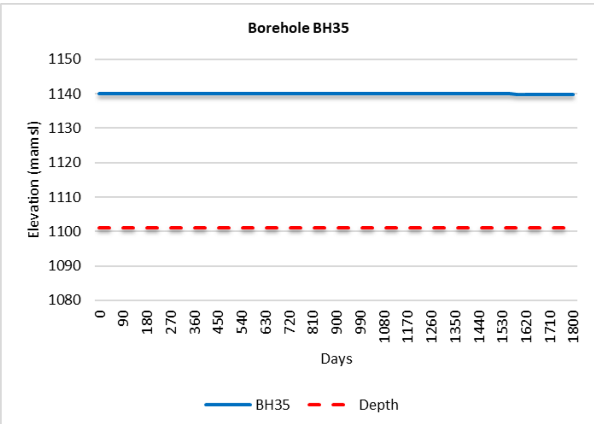


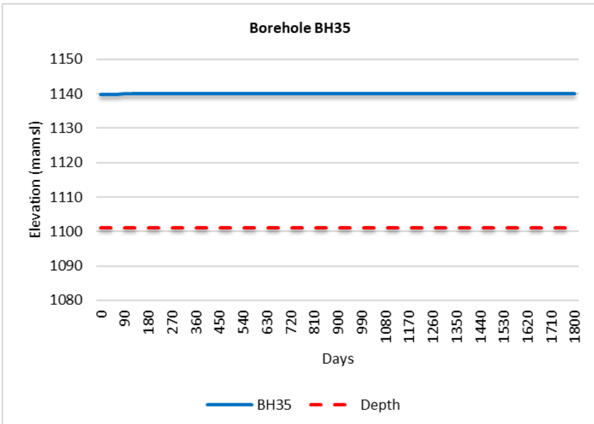


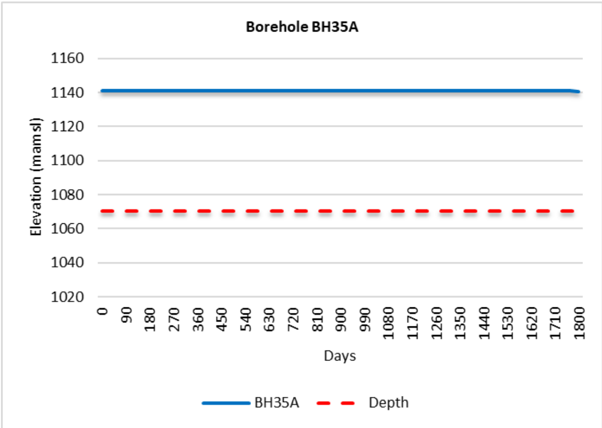


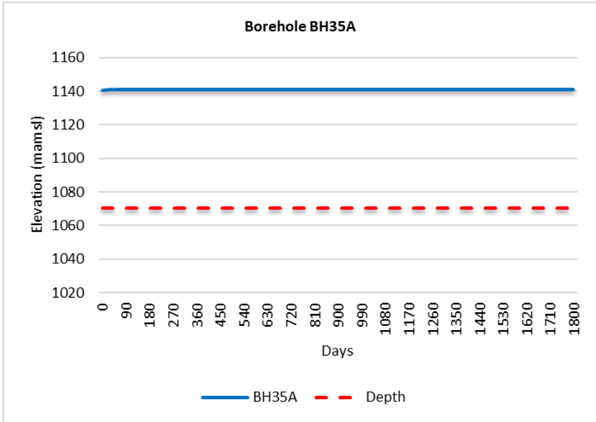


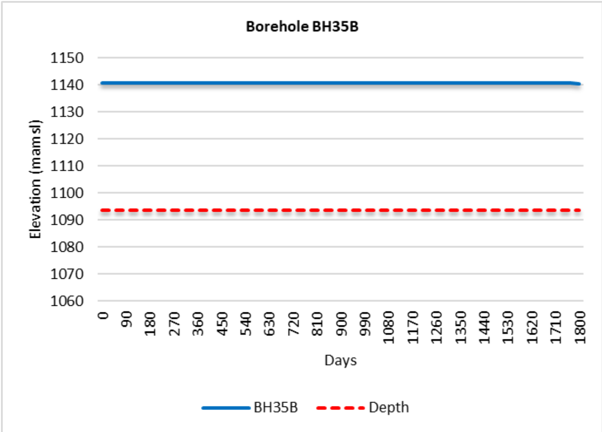


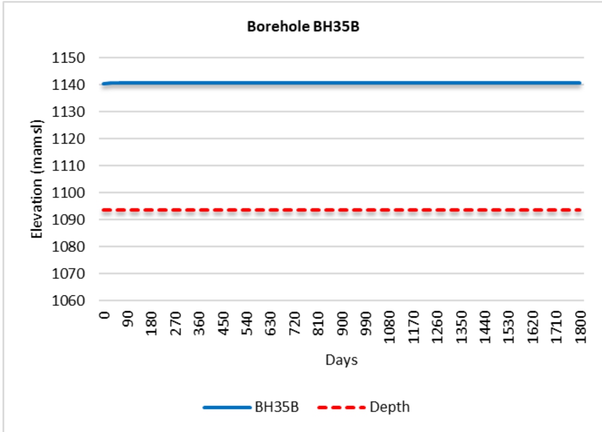


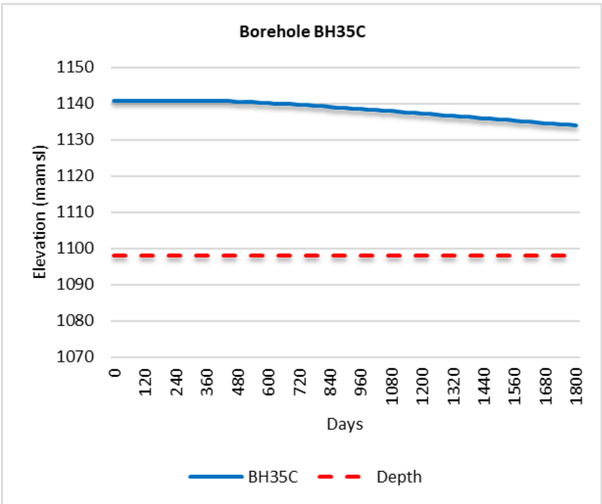


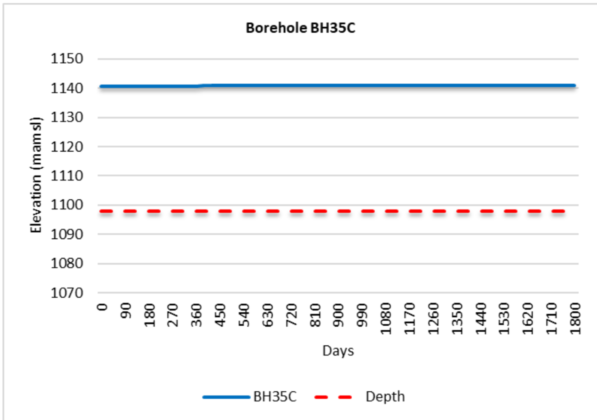
<table>
<tr><th>Simulated Groundwater Level Drawdown</th><th>Simulated Groundwater Level Recovery</th></tr>
<tr><td>


</td><td>


</td></tr>
<tr><td>


</td><td>


</td></tr>
<tr><td>


</td><td>


</td></tr>
</table>

Note: Boreholes KW1, KW3, and CBH1 were added after completion of the numerical modelling. Drawdown and recovery graphs are therefore not available. The closest boreholes that were included in the model mesh are BH30 and BH31. Similar drawdowns are expected in these boreholes.