HYDROGEOLOGICAL OPINION STUDY FOR THE MAJUBA ASH DISPOSAL FACILITY EXEMPTION AREA

MAJUBA POWER STATION
Prepared for: GGES

SLR Project No.: 710.07069.00001
Report No.: 1
Revision No.: 2
January 2020

DOCUMENT INFORMATION

Title	HYDROGEOLOGICAL OPINION STUDY FOR THE MAJUBA ASH DISPOSAL FACILITY EXEMPTION AREA
Project Manager	Mihai Muresan
Project Manager Email	mmuresan@slrconsulting.com
Author	Raymond Minnaar
Reviewer	Mihai Muresan
Keywords	Ash disposal facility, groundwater
Status	Final
DEA Reference	
DMR Reference	
DWS Reference	
Report No.	1
SLR Company	SLR Consulting (South Africa) (Pty) Ltd

DOCUMENT REVISION RECORD

Rev No.	Issue Date	Description	Issued By
1	10 January 2020	First draft issued for client comment	RM
2	30 January 2020	Revised draft issued to address client comments	RM
3	20 February 2020	Final	RM

BASIS OF REPORT

This document has been prepared by an SLR Group company with reasonable skill, care and diligence, and taking account of the manpower, timescales and resources devoted to it by agreement with **GGES** (the Client) as part or all of the services it has been appointed by the Client to carry out. It is subject to the terms and conditions of that appointment.

SLR shall not be liable for the use of or reliance on any information, advice, recommendations and opinions in this document for any purpose by any person other than the Client. Reliance may be granted to a third party only in the event that SLR and the third party have executed a reliance agreement or collateral warranty.

Information reported herein may be based on the interpretation of public domain data collected by SLR, and/or information supplied by the Client and/or its other advisors and associates. These data have been accepted in good faith as being accurate and valid.

SLR disclaims any responsibility to the Client and others in respect of any matters outside the agreed scope of the work.

The copyright and intellectual property in all drawings, reports, specifications, bills of quantities, calculations and other information set out in this report remain vested in SLR unless the terms of appointment state otherwise.

This document may contain information of a specialised and/or highly technical nature and the Client is advised to seek clarification on any elements which may be unclear to it.

Information, advice, recommendations and opinions in this document should only be relied upon in the context of the whole document and any documents referenced explicitly herein and should then only be used within the context of the appointment.

EXECUTIVE SUMMARY

Introduction

SLR Consulting South Africa (Pty) Ltd was appointed by GGES to undertake a hydrogeological study for the Majuba Power Station Ash Disposal Facility in order to provide a specialist groundwater opinion relating to the application by GGES to extend the time period, expiring in June 2020, for the Majuba ash dump facility (ADF) exemption from installing the required liner (a Class-C liner).

The existing exemption period from installing the required liner (a Class-C liner) lapses in June 2020 and Eskom is required to apply for an extension of the exemption period, without extending the area under the exemption.

The proposed terms of reference are to provide a specialist groundwater opinion relating to the application by GGES to extend the exemption period for the Majuba ash dump facility (ADF). The specialist opinion will confirm, on a desktop-level, if the required extension period would not have additional impacts on groundwater.

Scope of work

The proposed scope of work to achieve the proposed terms of reference is as follows:

- Review the monitoring data collected by Majuba around the ash disposal facility;
- Determine the contaminants levels monitored and compare with the predicted levels;
- Verify the potential impacts from the ash disposal facility exemption area; and
- Recommendation to address identified potential gaps.

General aquifer description

The Majuba site is underlain by Karoo sedimentary rocks and dolerite intrusions and the hydrogeological characteristics of the study area are a function of the geological formations. The aquifers of the Karoo Supergroup display characteristics of intergranular and fractured rock.

The aquifer units at the Majuba site can then be divided into two broad main hydrogeological units:

- A shallow, weathered rock aquifer referred to as the ‘shallow aquifer’; and
- An intermediate to deeper, hard rock fractured aquifer referred as the ‘deeper aquifer’.

Groundwater monitoring network

Majuba monitors several boreholes within and surrounding the site as part of its groundwater monitoring programme. The surface water and groundwater monitoring network at Majuba is divided into specific areas according to their location relative to main infrastructure.

Groundwater levels

Groundwater levels at the ADF area in 2014 ranged between artesian conditions and 11.75 mbgl (AB34), and average groundwater levels were 2.9 mbgl. Groundwater levels are possibly affected by surface water dams as noted by SLR (2014). The average groundwater level for the previous monitoring round in September 2019 were 4.3 mbgl.

Groundwater levels at the coal stockyard in 2014 area ranged between 0.59 mbgl (CB20) and 5.16 mbgl (CB27), and average groundwater levels were 3.3 mbgl. Relatively stable groundwater depth trends are observed in the boreholes of the Coal Stockyard Area. The average groundwater level for the previous monitoring round in September 2019 were 3.3 mbgl.

Groundwater levels at the power station and solid waste areas in 2014 ranged between 0.69 mbgl (PB15) and 7.23 mbgl (PB19), and average groundwater levels were 2.2 mbgl. Varying water levels were noticed in PB17 and was attributed to the potential influence by the water level fluctuations in dams PP10 and PP11. Groundwater levels for ten monitoring boreholes for the power station area varied between 0.04 mbgl (PB15) and 7.75 mbgl (PB19). The average groundwater level for the previous monitoring round in September 2019 were 3.3 mbgl. The groundwater levels were relatively stable.

Groundwater levels at the site overall are relatively shallow and ranged between 0.20 mbgl (PB15) and 14.31 mbgl (MJ17-01D) in September 2019. The local groundwater gradient is predominantly towards the north and towards the Palmiet Spruit located between the ADF and power station.

Groundwater quality

SLR (2014) found from previous monitoring data that the groundwater quality of the sites on the current ash disposal facility showed signs of contamination. The monitoring report by GHT (2013) was reviewed by SLR (2014) (38th routine monitoring investigations) and provided details for measurement collected in November 2012 (GHT, 2013).

SLR (2014) noted that the pollution indexes strongly suggested that most of the groundwater sites have been impacted upon by the power station and associated infrastructure. With regards to the groundwater quality objectives, the target objective for fluoride (F) was exceeded at most of the groundwater sites in 2012 (even at the background sites). However, the only sites at which the target objective for SO_4, which is the major pollutant associated with the ash and coal, were exceeded at predominantly at the ADF.

GHT (2013) stated that the sulphate (SO_4) showed an increasing trend since 2002 which indicate a definite impact on the groundwater from the ash water return dam AP01. The concentration of SO_4 in this dam is normally higher than 1000 mg/l. It was concluded by GHT (2013) that the permeability of the aquifer in the region below the dam AP01 is extremely low (as the pollutant took 10 years to reach borehole AB26 only a few metres downstream from the dam). It was concluded that the influence from the dam were due to spillages or seepage of water from the contact zone of the base of the dam.

Majuba monitors several boreholes within and surrounding the site as part of its groundwater monitoring programme. The water quality results after the previous SLR (2014) study, from September 2014 to September 2019.

Sulphate concentrations from the ADF borehole samples ranged between <1 mg/L and 342.5 mg/L (average 39 mg/L) and electrical conductivity ranged between 13 mS/m and 352 mS/m (average 58 mS/m). Contaminants of concern noted, compared to the SANS 241-1:2015 Drinking Water Standard (Edition 2), at the ADF included pH, EC, F, Al, Mn, and As.

Sulphate concentrations from the coal stockyard area borehole samples ranged between 6.6 mg/L and 1771 mg/L (average 101.7 mg/L) and electrical conductivity ranged between 27 mS/m and 311 mS/m (average 72.2 mS/m). Contaminants of concern noted at the coal stockyard area included EC, Na, SO_4, Al, Mn, and As.

Sulphate concentrations from the power station area borehole samples ranged between <1 mg/L and 338.3 mg/L (average 37 mg/L) and electrical conductivity ranged between 11.6 mS/m and 167.8 mS/m (average 70 mS/m). Contaminants of concern noted at the power station included pH, Cl, F, Mn, and As.

The only contaminants of concern identified during the 2019 hydrocensus investigation (Kimopax, 2019), compared to the SANS 241-1:2015 drinking water standard, included iron in borehole MBH02. Sulphate concentrations from the hydrocensus borehole samples ranged between 5.8 mg/L and 23.8 mg/L and electrical conductivity ranged between 13.3 mS/m and 70.3 mS/m.

The surface water quality results are consistent with conclusions made by GHT (2013) that surface water quality was negatively impacted as most indicator elements exceed the relevant guideline target limits. Sulphate concentrations between 2014 to 2019 from surface water site samples ranged between <1 mg/L and 4 149 mg/L (average 495 mg/L) and electrical conductivity ranged between 11 mS/m and 494 mS/m (average 157 mS/m).

The surface water monitoring points (PSR01 – PSR07) for the Palmiet Spruit, located between the power station and the ADF, showed signs of increased sulphate concentrations. PSR01, PSR02, and PSR03 located upstream generally had relatively low sulphate concentrations below the SANS 241-1:2015 acute health limit. The remaining monitoring points, located downstream of the ADF, had elevated sulphate concentrations generally above the SANS 241-1:2015 acute health limit, with PSR06 recording sulphate concentrations in excess of 3 000 mg/L in 2003. The sulphate concentrations in the Palmiet Spruit monitoring points downstream of the ADF were much higher than concentrations measured in the monitoring boreholes downstream of the ADF.

Geochemistry

The high SiO_2 content (which is mostly in the form of amorphous material formed due to the high temperatures during burning) lowers the solubility of the material with the low hydraulic conductivity of ash material also aiding in not allowing any elements that does dissolve to leave the system.

The major oxides present in the ash material are SiO_2, Al_2O_3, Fe_2O_3, CaO and MgO. The sulphur content is low with a higher lime content (CaO) indicating a possible low potential for acid generation with a high buffering capacity. On ignition of the test there was a low loss of material as the ash already went through a high temperature procedure with a low moisture content.

The following classification was made based on the leachable concentrations threshold (LCT) classes:

- Arsenic, barium, boron, cadmium, chromium, hexavalent chromium, manganese, molybdenum, selenium, vanadium, and total dissolved solids (TDS) exceeded the LCT0 guideline values and were within the limits of LCT1;
- Arsenic, barium, boron, cadmium, chromium, manganese, selenium, and TDS exceeded the SANS 241-1:2015 drinking water quality guideline limits; and
- All other elements were below the LCT0 and SANS 241-1:2015 guideline values.

The following classification was made based on the leachable concentrations threshold (LCT) classes:

- Arsenic, barium, boron, cadmium, chromium, hexavalent chromium, manganese, molybdenum, selenium, vanadium, and total dissolved solids (TDS) exceeded the LCT0 guideline values and were within the limits of LCT1;
- Arsenic, barium, boron, cadmium, chromium, manganese, selenium, and TDS exceeded the SANS 241-1:2015 drinking water quality guideline limits; and
- All other elements were below the LCT0 and SANS 241-1:2015 guideline values.

Constituents of concern from fly ash – Majuba site

Chemical constituents analysed during site monitoring by Majuba does not include all contaminants of concern identified from the 2019 geochemical testing, the previous Majuba waste classification study (Advisian, 2019), and other groundwater case studies conducted in South Africa as well as internationally. Additional parameters that should be included in the current Majuba site monitoring include:

- Barium (Advisian (2019) & 2019 geochemical testing);
- Boron (Advisian (2019) & 2019 geochemical testing);
- Molybdenum (Advisian (2019) & 2019 geochemical testing);
- Cadmium (2019 geochemical testing);
- Selenium (2019 geochemical testing); and
- Vanadium (2019 geochemical testing).

Potential impacts from ADF

The cumulative impacts from the ash disposal facility of all three phases (construction, operation and decommissioning) determined by SLR (2014) were summarised as:

- A rise in water table in the vicinity of the site due to increased recharge from stored water within the ash disposal facility and any associated surface water impoundments.
- Deterioration in groundwater quality.

The potential impacts of the proposed ash disposal facility on the local groundwater were also qualitatively assessed by SLR and the nature of the impacts were assessed using a standard significance rating scale. The significance rating for the cumulative impacts from the ash disposal facility with and without mitigation measures were determined by SLR as medium to low ("Impacts on groundwater limited to the site or to the local area, and moderate in nature")) respectively in terms of deterioration of groundwater quality due to leachate from the ADF.

Numerical groundwater modelling results from the SLR (2014) study were used to qualitatively estimate the potential zone of influence from the extension of the exemption time period. The numerical model results suggest that the movement of leachate away from the ash disposal facility as a groundwater plume should take place relatively slowly, with plume extents being generally between 750 metres and 1 250 metres from the ash disposal facility after ~150 years. Boreholes which could potentially be influenced and currently being used for domestic and livestock watering purposes (as reported during the Kimopax (2019) hydrocensus investigation) include:

- FBB48 – livestock watering
- FBB50 – livestock watering
- FBB51 – livestock watering
- MBH03 – livestock watering
- MBH04 – domestic (drinking water)

The available data in the previous hydrogeological study conducted by SLR (2014) together with the site information received are not sufficient to enable SLR to quantitatively determine the groundwater impacts that may result from the additional time used to ash over the same footprint under the ADF exemption area. Additional geochemical and hydrogeological work is recommended to be performed before SLR can determine the final changes in potential groundwater impacts and affected areas due to the additional time used to ash.

Conclusions

It can be concluded that, an extension in the duration of ashing within the exemption area will not change the groundwater impacts determined by SLR (2014), i.e. the 2014 identified impacts will remain in terms of groundwater levels and quality.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

Acronym / Abbreviation	Definition
ADF	Ash disposal facility
MW	Megawatt
UCG	Underground coal gasification
CGS	Council for geoscience
IDP	Integrated development plan
TDS	Total dissolved solids
TCT	Total concentration threshold
LCT	Leachable concentration threshold
EC	Electrical conductivity
XRF	X-ray fluorescence
XRD	X-ray diffraction
ABA	Acid-base accounting
NAG	Net acid generation
NEMWA	National environmental management waste act
EIP	Environmental integrity project

UNITS OF MEASURE

Unit of measure	Definition
L/s	Litres/second
m	Metre
m/d	Metre/day
m^2/d	$Metre^2/day$
mamsl	Metres above mean sea level
mbgl	Metres below ground level
mS/m	Milli-Siemens/metre
°C	Degrees Celsius
mg/L	Milligram per litre
kg	Kilogram

Unit of measure	Definition
mg	Milligram

CHEMICAL SYMBOLS

Chemical symbol	Definition
Al	Aluminium
Sb	Antimony
As	Arsenic
Ba	Barium
B	Boron
Ca	Calcium
Cd	Cadmium
Cl	Chloride
Cr	Chromium
Co	Cobalt
Cu	Copper
F	Fluoride
Fe	Iron
K	Potassium
Mg	Magnesium
Mn	Manganese
Na	Sodium
NO_3-N / NO_3	Nitrate as N
Pb	Lead
SO_4	Sulphate
Zn	Zinc
Hg	Mercury
Mo	Molybdenum
Ni	Nickel
Se	Selenium

Chemical symbol	Definition
V	Vanadium
CN	Cyanide

1. INTRODUCTION

SLR Consulting South Africa (Pty) Ltd was appointed by GGES to undertake a hydrogeological study for the Majuba Power Station Ash Disposal Facility in order to provide a specialist groundwater opinion relating to the application by GGES to extend the time period, expiring in June 2020, for the Majuba ash dump facility (ADF) exemption from installing the required liner (a Class-C liner). The Majuba Power Station is located southwest of Amersfoort in the Mpumalanga Province of South Africa.

1.1 BACKGROUND

Majuba Power Station has three 665 MW (mega-watt) dry-cooled units and three 716 MW wet-cooled units, and an installed capacity of 4110 MW. It receives its coal from various sources, much of it transported to the power station by road. The coal-fired power generation process gives rise to large quantities of ash, which are disposed of in an ash disposal facility. This process involves ash being transported from the power station by conveyors and disposed of on the ash disposal facility. Majuba Power Station currently disposes of ash (produced by the combustion of coal) in a dry format by means of conveyors, a spreader and a stacker system from the station terrace to the ash disposal site. The existing ashing facility is located approximately 1.5 km west of the station terrace. Figure 1-1 provides an overview of the where the ash disposal activities fit within the power generation process. The existing exemption period from installing the required liner (a Class-C liner) lapses in June 2020 and Eskom is required to apply for an extension of the exemption period, without extending the area under the exemption.

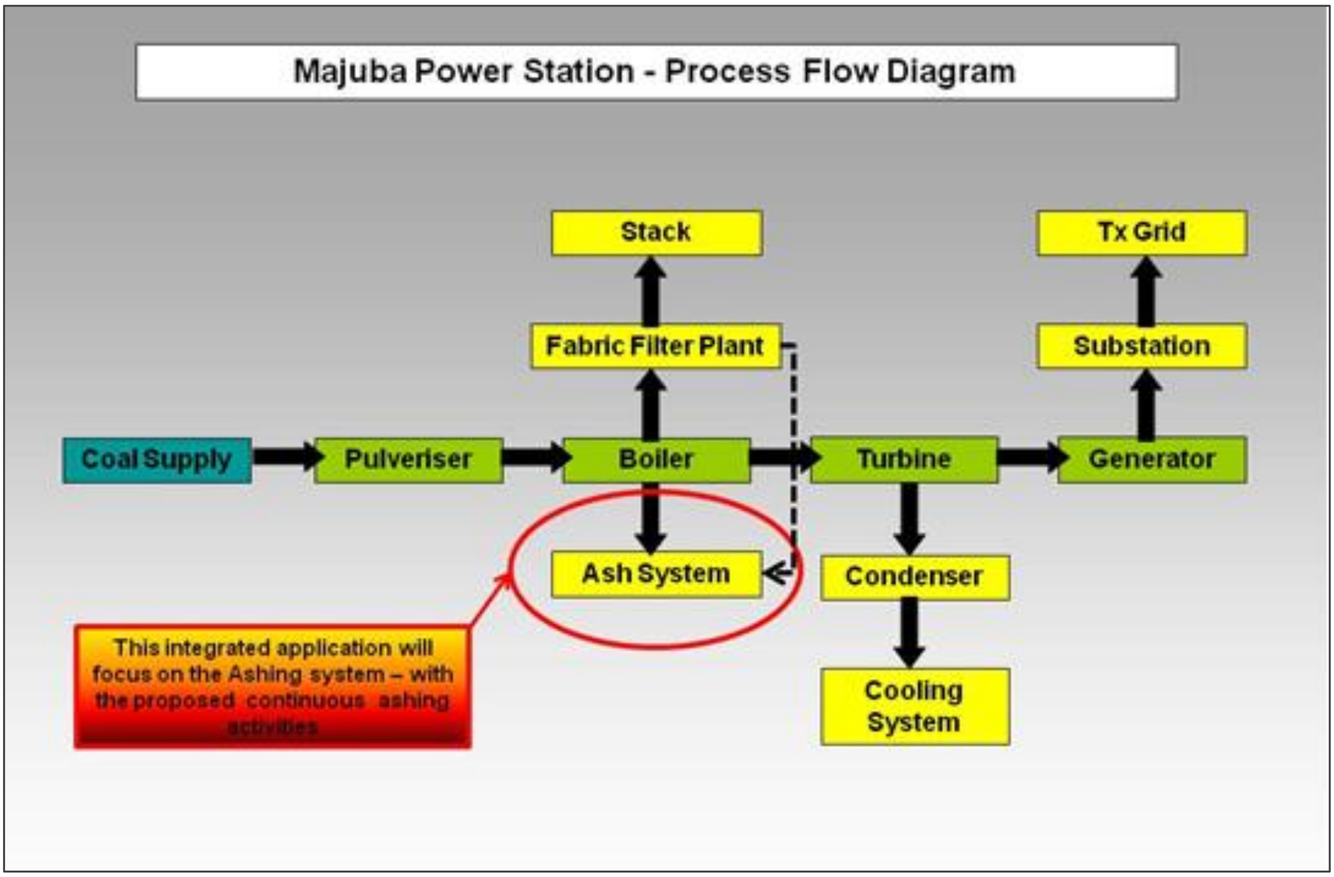


Figure 1-1: Majuba Power Station process flow diagram.

1.2 TERMS OF REFERENCE

The proposed terms of reference are to provide a specialist groundwater opinion relating to the application by GGES to extend the exemption period for the Majuba ash dump facility (ADF). The specialist opinion will confirm, on a desktop-level, if the required extension period would not have additional impacts on groundwater.

2. SCOPE OF WORK

The proposed scope of work to achieve the proposed terms of reference is as follows:

- Review the monitoring data collected by Majuba around the ash disposal facility;
- Determine the contaminants levels monitored and compare with the predicted levels;
- Verify the potential impacts from the ash disposal facility exemption area; and
- Recommendation to address identified potential gaps.

2.1 ASSUMPTIONS, LIMITATIONS AND EXCLUSIONS

The following limitations, assumptions and exclusions apply based on the scope of work:

- No site visit was conducted by SLR, i.e. no reconnaissance site visit, hydrocensus (incl. groundwater level measurements and quality sampling), etc.;
- No intrusive studies were conducted during the SLR study, i.e. no drilling of boreholes;
- No aquifer hydraulic tests were conducted by SLR, i.e. no slug tests and pump tests;
- No geochemical assessment was conducted by SLR on the ash material;
- No groundwater numerical model was compiled and/or updated for the site by SLR;
- This assessment does not evaluate the existing groundwater monitoring and management programme at Majuba Power Station and the ash disposal facility;
- It is assumed that the data and information related to groundwater at the site (both data in the public domain and groundwater level and quality data made available by the client) are reasonably correct;
- It is assumed that the proposed ash disposal facility extension will be designed to function in a similar manner to the existing ash disposal facilities;
- It is assumed that no open mine workings are present beneath the ADF extension area – mine voids have not been considered in the conceptual model;
- No surface water quality and flow impact predictions or opinions are made in this study;
- The underground coal gasification (UCG) operational area and pilot plant have not been considered; and
- ADF and ADF exemption areas used in all figures in the report are approximations from the received non-georeferenced .PDF file. No georeferenced GIS files were received from the client.

3. METHODOLOGY

3.1 REVIEW PREVIOUS HYDROGEOLOGICAL STUDY

Previously hydrogeological studies conducted by SLR Consulting (Africa) (Pty) Ltd) focussing on the Ash Disposal Facility (ADF) included:

- Majuba Ash Dump Extension Groundwater Screening Study – SLR Project No.: 721.23003.00010 – October 2012.
    - The purpose of the scoping study was to distinguish less favourable from more favourable areas within a 12 km radius of the Majuba power station on which to site the proposed ash dump (a total study area of approximately 452 km^2).
- Proposed Continuous Disposal of Ash at the Majuba Power Station – Groundwater Specialist Study EIA Phase – SLR Project No.: 721.23003.00010 – May 2014.

  The objectives of this report were:
    - To develop hydrogeological conceptual and numerical models for the study area around Majuba Power Station and to document baseline groundwater conditions of the study area (the study area is primarily the 12 km radius of the power station, but extends to the boundaries of the relevant quaternary catchments for the purposes of the modelling).
    - To assess in detail the impacts on the groundwater resources that may result from the continued ash disposal at Majuba Power Station (with and without mitigation measures), considering construction, operation and decommissioning phases of the project.
    - To advise on mitigation of identified impacts.

3.2 REVIEW AVAILABLE SITE DATA

Data that was reviewed includes:

- Published 1:250 000 scale geological data and map (CGS,1986);
- Published hydrogeological data and map;
- Public domain climatic and topographic data for the site;
- Majuba WISH groundwater and surface water monitoring database;
    - Water quality data from 1990/10/12 to 2019/09/05.
    - Groundwater level data from 2018/06/29 to 2019/09/05.
- Majuba water level database;
    - Water level data from 1991/11/26 to 2017/09/07.
- Geochemical laboratory results for one (1) ash sample submitted to Talbot & Talbot Laboratories on 2019/03/18;
- Image indicating summary of water management system, indicating proposed ADF extension (not georeferenced);
- Electronic .DWG drawing of existing and southern expansion area of ADF (File name F224-13-001-R01.dwg);
- One (1) PDF-format map indicating sampled and not sampled monitoring points for May 2019;
- Hydrocensus data and report for Majuba Power Station conducted by Kimopax in July 2019;

- Data received from the client on a USB portable memory drive included:
    - Fig1_Majuba Locality_Regional_A3
    - Fig2_Proposed Development Layout_A3
    - Majuba Farm Deed Diagram
    - 8 Advisian personnel CVs
    - 01_Majuba_Ecological Assessment_EIA Report_11 June 2019_Final
    - 02_Majuba_Aquatics_EIA_JMDabrowski_11June2019
    - 03_Heritage Impact Assessment Majuba
    - 04_PIA report Majuba Ash 05Jun2019
    - 05_Majuba_Ground Water Specialist Study_June2019
    - C00800_FSR_PPP Combined Report_27032019
    - Appendix A_Fig1_Majuba Locality_Regional_A3
    - Appendix A_Fig2_Proposed Development Layout_A3
    - Appendix B_Ash Dump Monitoring Programme
    - C00800_DEMPr_Majuba ADF_20190613
    - C00800 DEA FSR Comments_20 May 2019
    - C00800_Majuba Draft EIA Report_20190612
- Majuba site surface water and groundwater monitoring reports:
    - GHT Consulting Scientists - Monitoring Report Phase 50 – November 2015
    - GHT Consulting Scientists - Monitoring Report Phase 51 – March 2016
    - GHT Consulting Scientists - Monitoring Report Phase 53 – September 2016
    - GHT Consulting Scientists - Monitoring Report Phase 54 – January 2017
    - GHT Consulting Scientists - Monitoring Report Phase 55 – March 2017
    - GHT Consulting Scientists - Monitoring Report Phase 56 – July 2017
    - GHT Consulting Scientists - Monitoring Report Phase 57 – September 2017
    - GHT Consulting Scientists - Monitoring Report Phase 58 – December 2017
    - Kimopax - Monitoring Report Phase 61 – October 2018
    - Kimopax - Monitoring Report Phase 62 – December 2018
    - Kimopax - Monitoring Report Phase 63 – April 2019
    - Kimopax - Monitoring Report Phase 64 – July 2019
    - Kimopax - Monitoring Report Phase 65 – September 2019
- Majuba LiDAR survey results:
    - CAD Files - .DGN site contour and project area files
    - Site image tiles - .ECW files
    - LiDAR .XYZ files (Ground and Non-Ground)

  - LiDAR survey report 27 August 2019
- Eskom Holdings SOC (Ltd): Majuba Power Station IWUL Licence Number 08/C11J/BGCI/9097;
- Jones and Wagener (2017). Borehole Geophysical Report for monitoring borehole drilling and borehole construction. February 2017. – referenced in Eskom (2019) - Majuba power station ash dump extension monitoring programme.
- The following hydrogeological study reports were requested by SLR for review, but was not received:
  - GHT Consulting Scientists (2017). Majuba Power Station Pollution Plume Model Final Report. Prepared by Staats S. and Makhanja C., Report No. RVN 665.22/1793. – referenced in Advisian (2019) - Majuba power station ash disposal facility rehabilitation and extension.
  - Jones and Wagener (2017). Geohydrological Assessment for the exemption area at the ash disposal facility at Majuba power station. February 2017. – referenced in Eskom (2019) - Majuba power station ash dump extension monitoring programme.

3.3 OPINION ON POTENTIAL GROUNDWATER IMPACTS

Information from the study conducted by SLR (2014) were used to develop preliminary conceptual models on the flow and geochemical functioning of the ash disposal facility (ADF), in order to determine the associated groundwater impacts. The previous conceptual models were used to guide the update of the flow and geochemical conceptual modelling. The conceptual model was also updated with the latest monitoring data since 2014 until present. The conceptual model was represented with the source-pathway-receptor system relevant to the footprint area of ADF.

4. GENERAL PHYSIOGRAPHICAL AND GEOLOGICAL DESCRIPTION

4.1 LOCALITY

Majuba power station is a coal-fired power station located approximately 16 km southwest (SW) of Amersfoort and approximately 40 km north-northwest (NNW) of Volksrust in the Mpumalanga Province of South Africa. The municipal Integrated Development Plan (IDP) provides an overall framework for developments within municipal jurisdiction. The Majuba Ash Disposal Facility (ADF) and Rehabilitation Dams site fall within the Pixley ka Seme Local Municipality IDP, part of Gert Sibande District Municipality. The site locality is given in Figure 4-1 and the existing ADF as well as the exemption areas (with topographic elevations) are shown in Figure 4-2. The exemption area as shown in Figure 4-2 has not yet been fully utilised by Eskom, necessitating the extension of the exemption period without extending the area under the exemption.

4.2 CLIMATE

The Majuba Power Station area is characterised by moderate summer rainfall with an average rainfall of 658 mm per annum. Local thunderstorms and showers are responsible for majority of the summer precipitation. Mean annual evaporation in the study area is estimated at 1 400 mm – 1 500 mm.

Mean temperatures reach a maximum during December/January of 37.6 ^{o}C and a minimum in June/July of - 1.6 ^{o}C. The study area falls within a summer rainfall region, with over 85% of the annual rainfall occurring during the October to March period. Between October 2011 and March 2012, monthly rainfall ranged between 21 mm and 128 mm.

4.3 TOPOGRAPHY AND DRAINAGE

The area of interest falls entirely within quaternary catchment C11J in the Vaal Water Management Area. All watercourses draining the project area and its immediate vicinity ultimately flow into the Geelklipspruit River which flows in a north-westerly direction and joins the Vaal River. The regional topography, surface water catchments, and river/stream are illustrated in Figure 4-3.

4.4 GEOLOGICAL SETTING

The Majuba power station and immediate surrounding area is underlain by sedimentary rocks of the Volksrust Formation, part of the Ecca Group of the lower Karoo Supergroup. These rocks are mainly bluish-grey or dark-grey mudstones and shales, with subordinate siltstones and calcium phosphate beds and nodules. Underlying the Volksrust Formation are coal-bearing rocks of the Vryheid Formation, consisting principally of deltaic and fluvial siltstones and mudstones, with subordinate sandstones (Johnson et al., 2006).

The coal seams (torbanite is also found) originated as peat swamps or similar environments and are confined to a limited thickness of strata near the middle of the Formation. The Vryheid Formation outcrops about 8 km north of the power station. The Volksrust Formation grades into the Vryheid Formation in places and the contact may not be distinct. In this area the Vryheid Formation may have been deposited directly onto rugged pre-Karoo topography (Ventersdorp Supergroup) and the thickness can be quite variable as a result. Both the Volksrust Formation and the Vryheid Formation rocks are well lithified (hard) and have little primary porosity (Johnson et al., 2006).

The Karoo sedimentary rocks are also extensively intruded by igneous Jurassic dolerite rocks of the Karoo Igneous Province, regarded as the uppermost unit of the Karoo Supergroup. These rocks form a network of dykes, sills and discordant sheets which can form complex shapes in three dimensions. Surface outcrops of Karoo dolerite is mapped both to the north and south of Majuba power station, but these rocks are also likely to underlie the power station area in places beneath the surface outcrop of sedimentary Karoo rocks. Four different dolerite intrusions (T1 to T4) that intersect the Karoo sediments at the Majuba Colliery have been identified (de Oliveira and Cawthorn, 1999). The geological model shows that the lateral extend of the two dolerite dykes is generally even across the study area. The dolerite intrusions have broken up the coal reserves into minor blocks (Mokhahlane, 2018).

No quaternary or unconsolidated deposits are mapped in the vicinity of Majuba power station, but there are likely to be relatively small deposits of such material associated with the larger river or stream courses in the study area (Johnson et al., 2006).

The geology of the project area is illustrated in Figure 4-4.

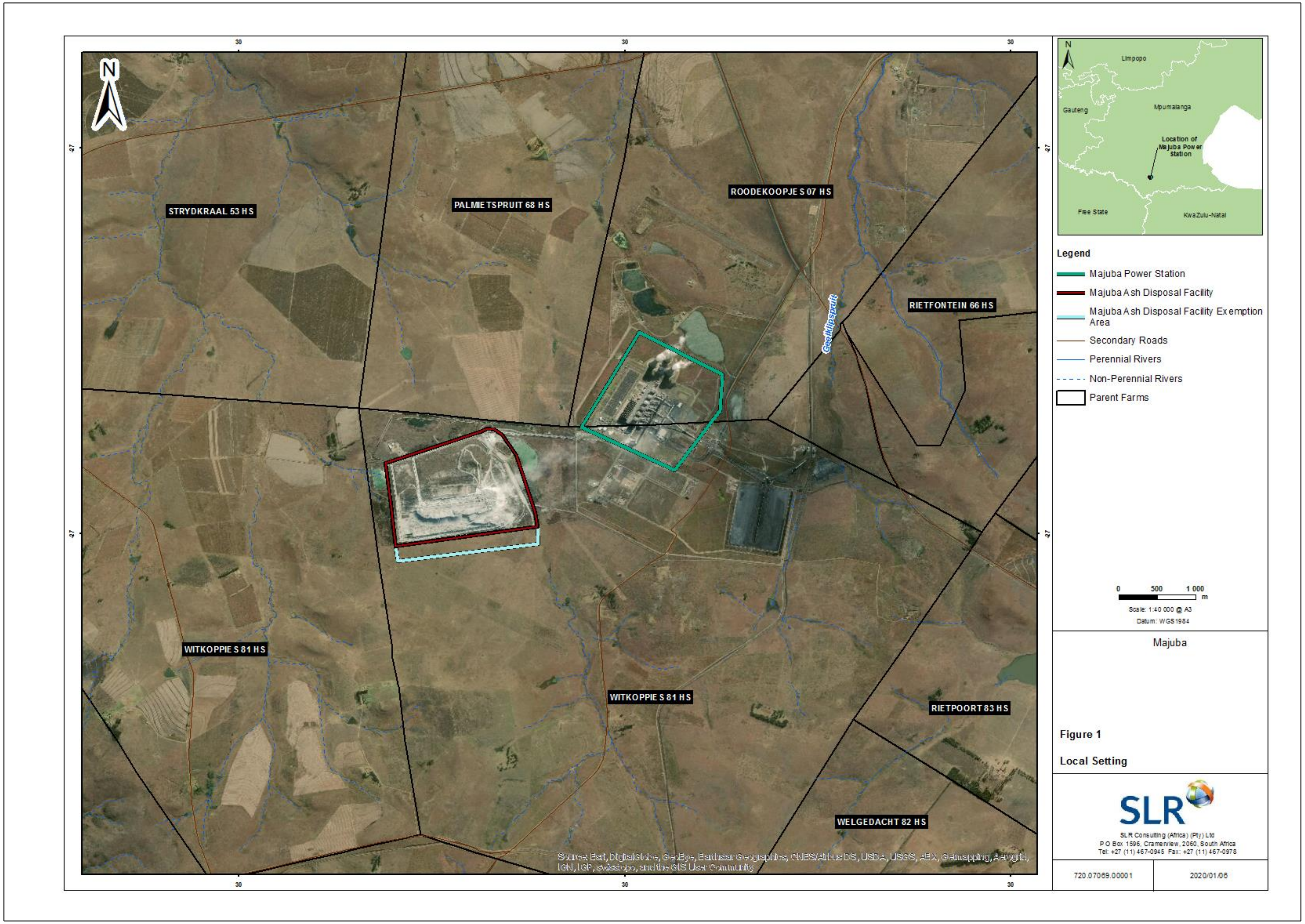


Figure 4-1: Majuba Power Station and Ash Disposal Facility locality.

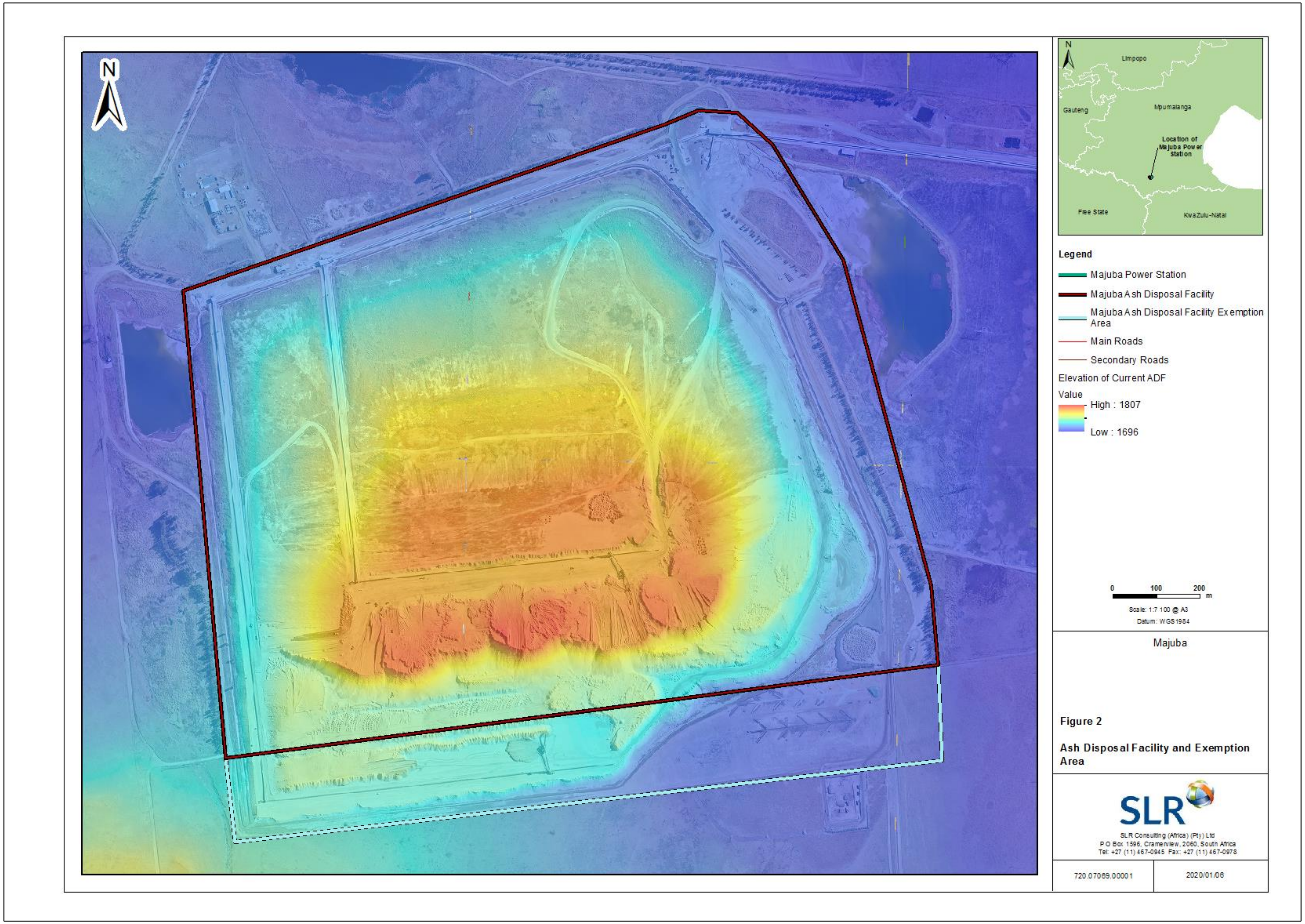


Figure 4-2: Majuba Power Station, existing Ash Disposal Facility, and Ash Disposal Facility exemption area.

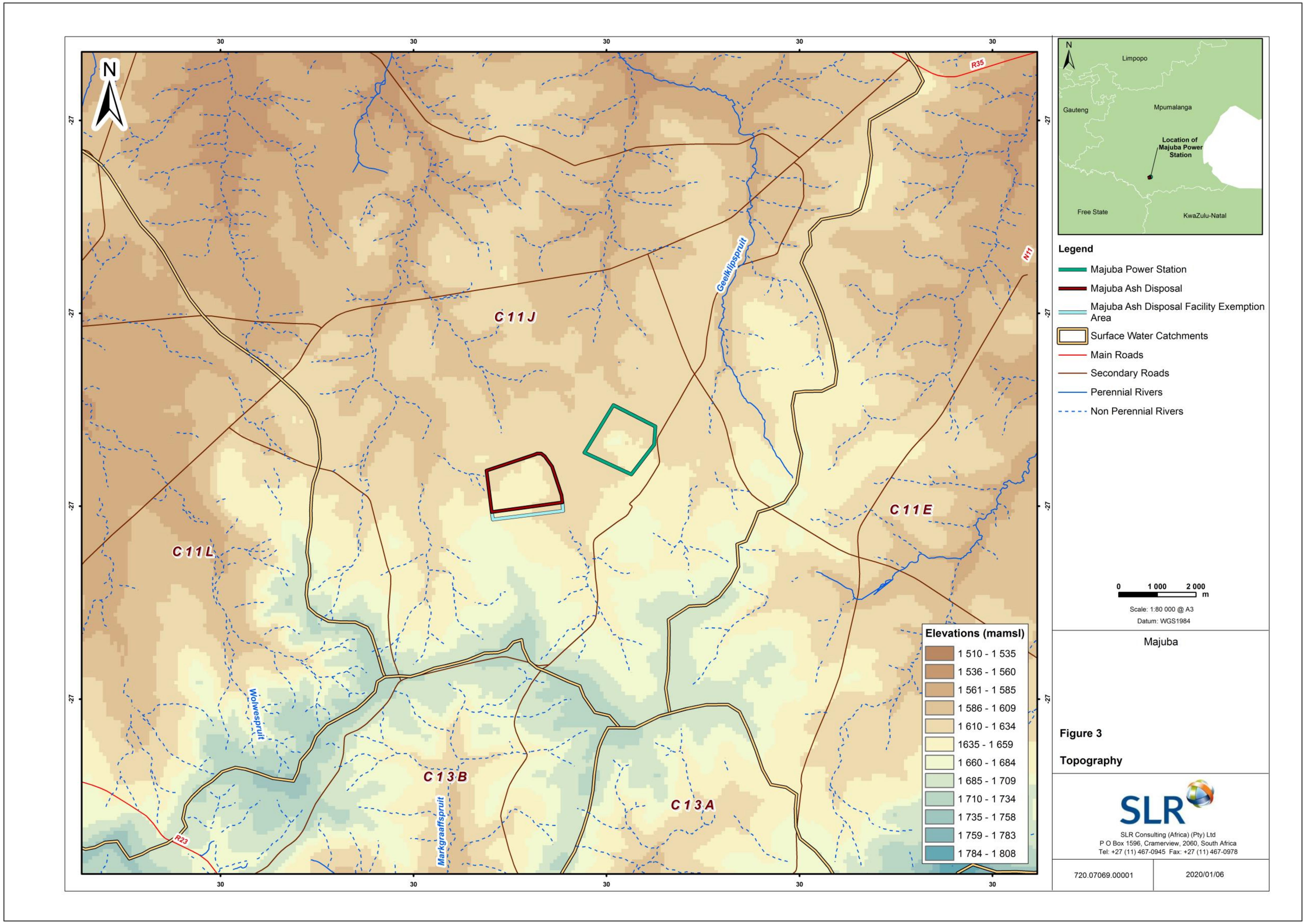
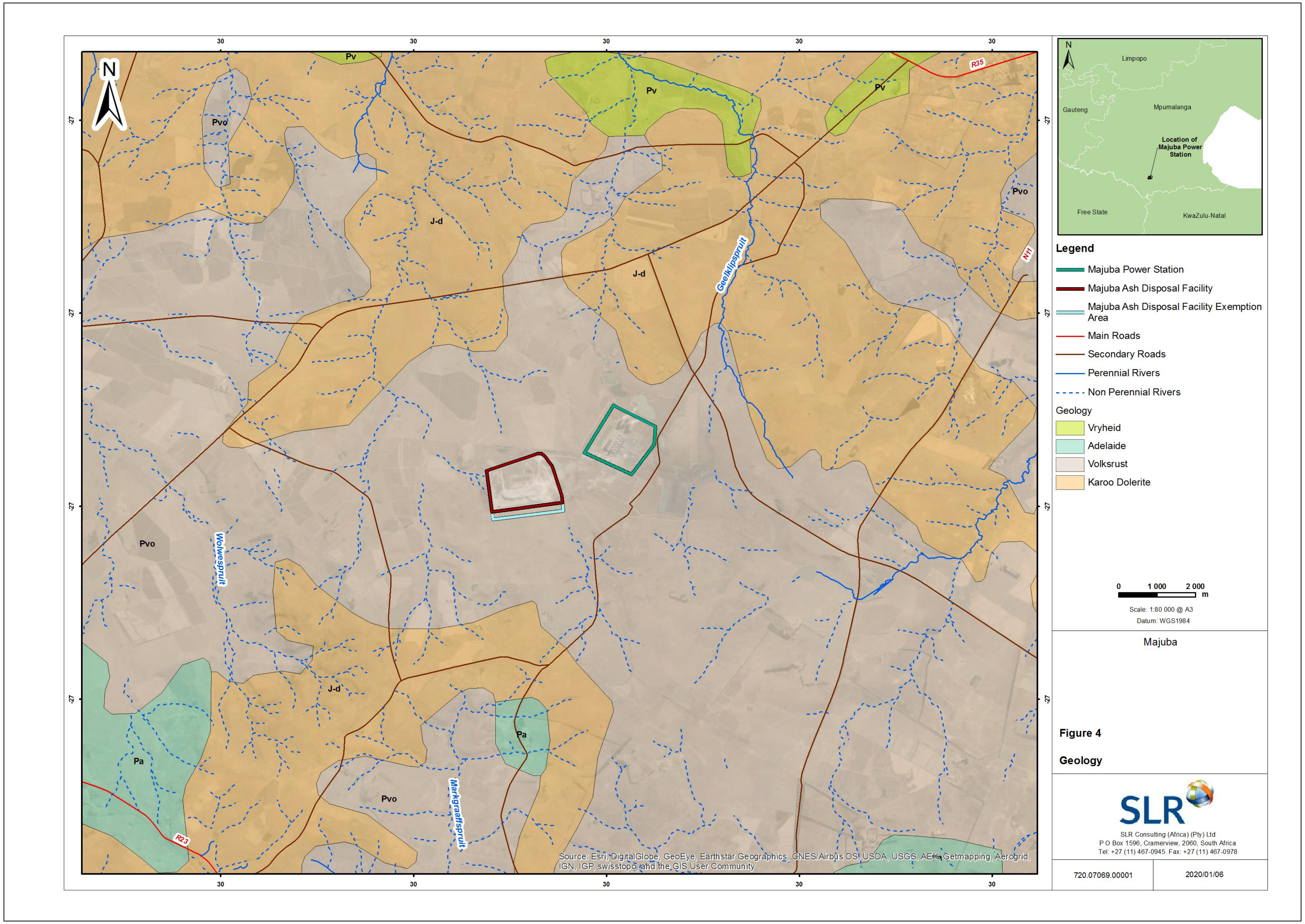


Figure 4-3: Majuba Power Station and Ash Disposal Facility regional topography and river/streams.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 4-4: Majuba Power Station and Ash Disposal Facility regional geology.

5. HYDROGEOLOGICAL SETTING

5.1 GENERAL AQUIFER DESCRIPTION

The Majuba site is underlain by Karoo sedimentary rocks and dolerite intrusions (section 4.4) and the hydrogeological characteristics of the study area are a function of the geological formations. The aquifers of the Karoo Supergroup display characteristics of intergranular and fractured rock. The borehole yielding potential of the aquifer is classified as D2, which implies an average borehole yield varying between 0.1 and 0.5 l/s. According to Barnard (2000), there are typically six different modes of groundwater occurrence associated with these formations:

- Weathered and fractured sedimentary rocks not associated with dolerite intrusions;
- Indurated and jointed sedimentary rocks alongside dykes;
- Narrow weathered and fractured dolerite dykes;
- Basins of weathering in dolerite sills and highly jointed sedimentary rocks enclosed by dolerite;
- Weathered and fractured upper contact-zones of dolerite sills; and
- Weathered and fractured lower contact-zones of dolerite sills.

Barnard (2000) found that the groundwater yield potential is classed as low since 83% of the boreholes on record (at that time) produce less than 2 L/s. The static groundwater level is generally encountered between 5 mbgl and 25 mbgl. Numerous springs occur at lithological contacts such as where sandstone overlies an impervious shale horizon, along fault zones or along impermeable dolerite dykes. Groundwater seepage in lower lying areas contributes substantially to sustaining the dry season flow in the stream systems that drain these landscapes.

In general, the aquifers are considered to constitute a minor aquifer, with some abstractions of local importance (Parsons and Conrad, 1998).

The aquifer units at the Majuba site can then be divided into two broad main hydrogeological units and are illustrated in Figure 5-1:

- A shallow, weathered rock aquifer referred to as the ‘shallow aquifer’; and
- An intermediate to deeper, hard rock fractured aquifer referred as the ‘deeper aquifer’.

The upper weathered (shallow) aquifer is usually low-yielding (range 1–10 m^3/d) owing to its trivial thickness but contains good quality water due to years of groundwater flow through the weathered strata. The shallow aquifer is estimated to go as deep as 70 m and is underlain by the deep aquifer (SLR (2014) and Mokhahlane (2018)).

Groundwater flow through the deep aquifer is mainly through fractures, cracks, and joints induced in the Karoo sediments by the intrusive dolerite sills. To some extent, increased groundwater storage in the upper weathered zone will provide a resource of groundwater for the underlying fractured aquifer along with relatively thin local accumulations of alluvium. Boreholes targeting either formation for water supply are generally no deeper than 35 – 40 m, and where dolerite intrusions are targeted boreholes are generally deeper at 50 – 60 m (SLR, 2014). Groundwater storage and transport in the un-weathered (deeper aquifer) Volksrust and Vryheid Formations and in the Karoo dolerites are likely to be mainly via fractures, bedding planes, joints and other secondary discontinuities. Fracturing of the edges of dolerite intrusions where they are in contact with the Karoo country rock are popular drilling targets. The success of a water supply borehole in these rocks would depend on whether one or more of these structures are intersected by the borehole. Neither the Vryheid nor the Volksrust Formations are particularly prolific, and the argillaceous Volksrust Formation is thought to have a low permeability (SLR, 2014).

The confined nature of the coal seam aquifer means the water is under pressure and hence the water level (head) stabilises at around ~180 m below ground level (mbgl). Any fractures in the strata overlying the coal seam can act as a zone of groundwater transmission between the coal seam aquifer and the intermediate aquifer, leading to groundwater mixing. The groundwater in the coal seam aquifer is of poor quality and can generally be classified as saline, while the intermediate aquifer has better quality water (Mokhahlane, 2018).

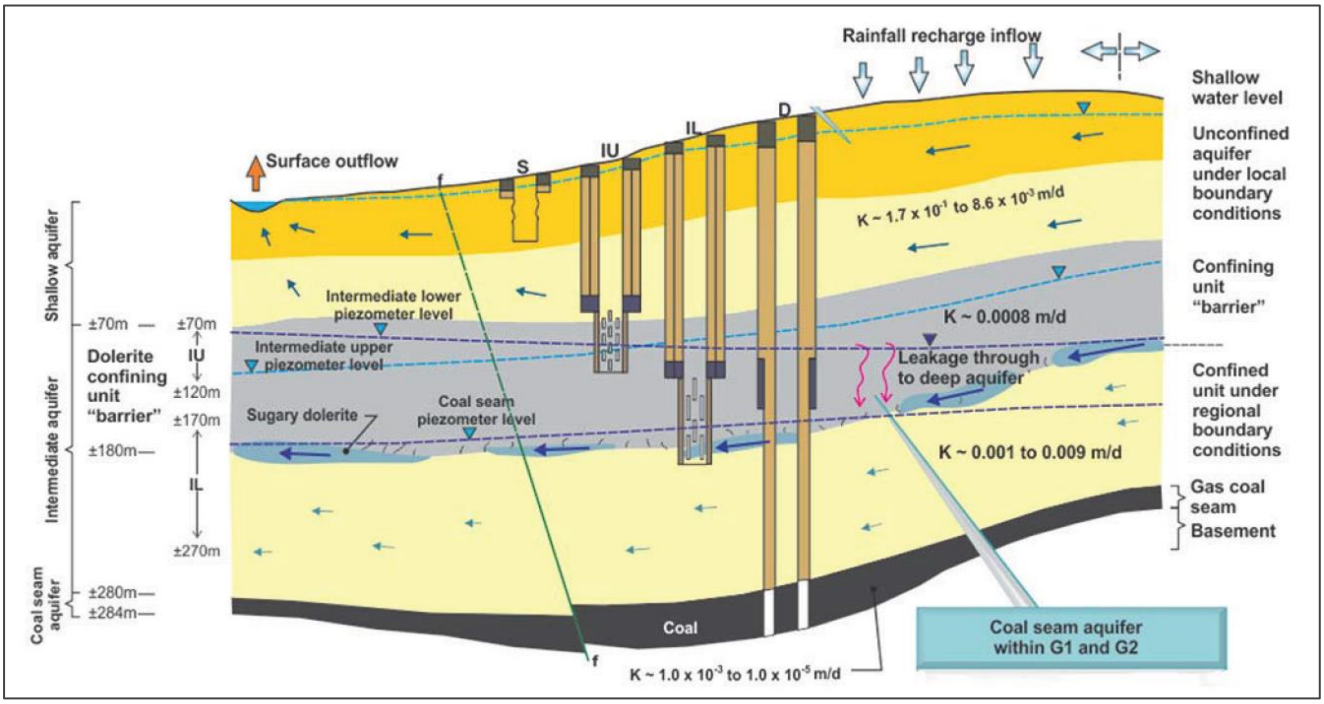


Figure 5-1: Majuba Power Station and Ash Disposal Facility aquifer units (Mokhahlane, 2018).

5.2 GROUNDWATER MONITORING NETWORK

Majuba monitors several boreholes within and surrounding the site as part of its groundwater monitoring programme. The surface water and groundwater monitoring network at Majuba is divided into specific areas according to their location relative to main infrastructure and is illustrated in Figure 5-2. Seven different monitoring areas are identified at the power station, of which the first four areas include groundwater monitoring boreholes:

- The Ash Disposal Facility Area;
- The Coal Stockyard Area;
- The Power Station Area;
- Solid Waste Site Area;
- Palmiet Spruit;
- Witbank Spruit; and
- Geelklip Spruit.

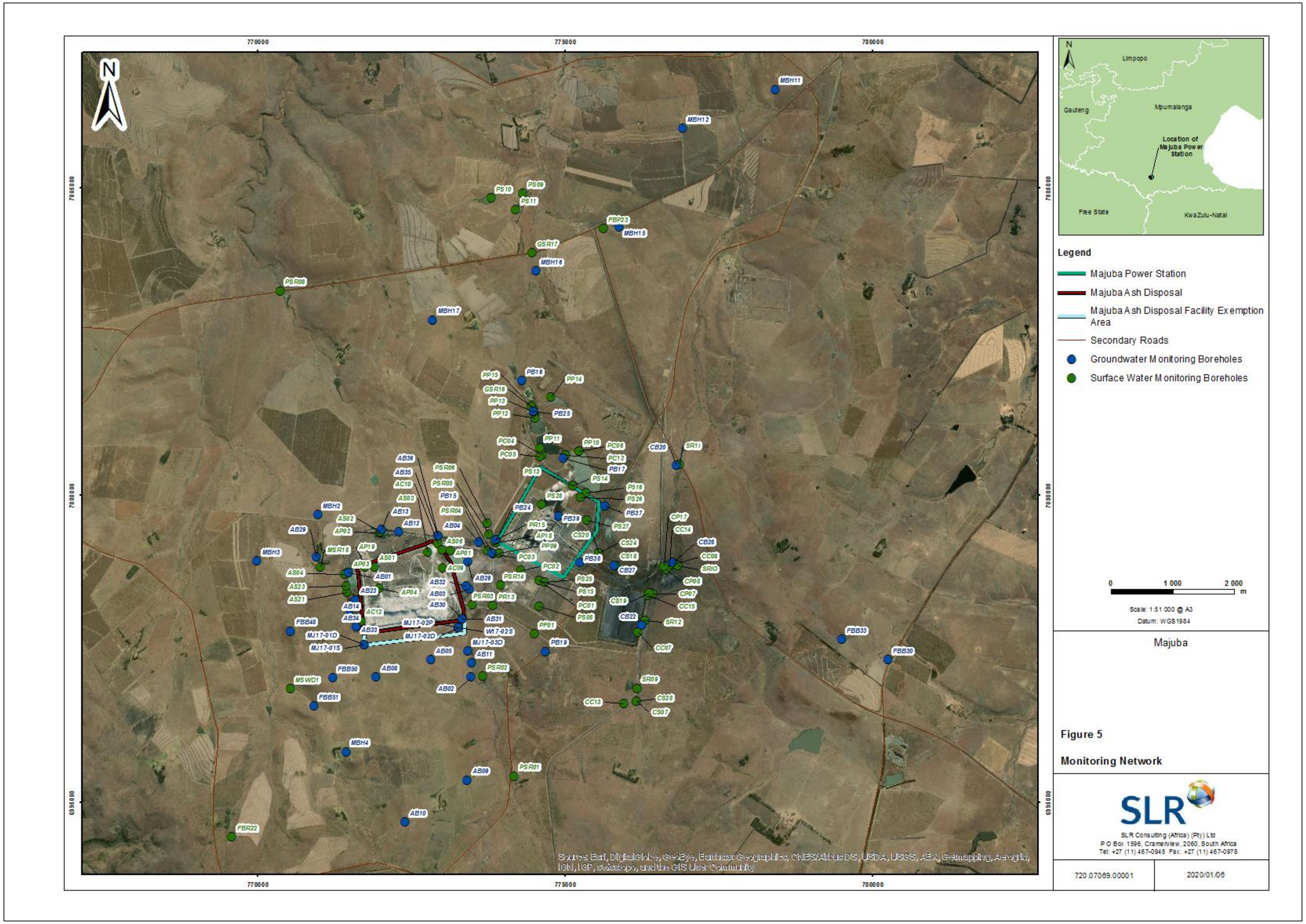


Figure 5-2: Majuba site groundwater and surface water monitoring network.

5.3 GROUDNWATER LEVELS

5.3.1 Previous SLR groundwater study recorded groundwater levels

Routine surface water and groundwater monitoring reports completed by GHT Consulting Scientists and were reviewed by SLR (2014) as part of the previous study. These monitoring reports discussed groundwater levels and quality in the vicinity of Majuba power station (GHT, 2012 and GHT, 2013).

The most recent report (at that time) made available to SLR (2014) as part of that study (38th routine monitoring investigation report) detailed the results of the November 2012 study. The conclusions are briefly summarised below in order to provide background to groundwater conditions at the Majuba site.

ADF area

Groundwater levels at the ADF area ranged between artesian conditions and 11.75 mbgl (AB34), and average groundwater levels were 2.9 mbgl. Boreholes AB01, AB03 and AB29 were artesian during the time period. The artesian and shallow nature of the boreholes were interpreted by SLR (2014) to be attributed to potential artificial recharge from dam AP01 influencing the groundwater depth in the vicinity of the dam. However, the Palmiet Spruit could also have possibly influenced water levels in these boreholes. SLR (2014) also noted that the influence of pollution control dam AP03 was evident from the artesian condition at AB01.

Coal stockyard area

Groundwater levels at the coal stockyard area ranged between 0.59 mbgl (CB20) and 5.16 mbgl (CB27), and average groundwater levels were 3.3 mbgl. Relatively stable groundwater depth trends were observed in the boreholes of the Coal Stockyard Area.

Power station and solid waste areas

Groundwater levels at the power station and solid waste areas ranged between 0.69 mbgl (PB15) and 7.23 mbgl (PB19), and average groundwater levels were 2.2 mbgl. Varying water levels were noticed in PB17 and was attributed to the potential influence by the water level fluctuations in dams PP10 and PP11. Decreasing water level depth was apparent at boreholes PB15, PB16, PB17, PB25 and PB37.

SLR site visit

Six groundwater samples and water level measurements were taken by SLR (2014) during a second field visit to Majuba in October 2012. Groundwater levels measured by SLR (2019) were compared to the latest measurements received from site in 2019 and are given in Table 5-1. Groundwater levels decreased from the SLR (2014) and latest September 2019 measurements. However, groundwater levels are still shallow with the deepest groundwater level measured in AB13 (4.16 mbgl).

Table 5-1: Majuba site water level comparison between SLR (2014) and 2019 site measurements.

Borehole Name	Diameter (mm)	Water level (mbgl)		Increase/ Decrease
		SLR (2014)	Site monitoring (2019)	
AB01	-	Artesian	Artesian	-
AB03	0.17	Artesian	Artesian	-
AB04	0.30	0.54	1.14	Decrease
AB12	0.51	3.71	4.14	Decrease

Borehole Name	Diameter (mm)	Water level (mbgl)		Increase/ Decrease
		SLR (2014)	Site monitoring (2019)	
AB13	0.27	3.46	4.16	Decrease
AB24	0.32	1.60	N/A	-

5.3.2 Site groundwater level data

The water level results from November 1991 to September 2019 were made available and are discussed per infrastructure area.

ADF area

Groundwater levels for 27 monitoring boreholes for the ADF area varied between artesian conditions and 14.4 mbgl. Artesian conditions were recorded at AB01, AB03, AB04, AB10, AB11, AB26, AB29, AB31, and AB32. Relatively deep groundwater level was recorded at AB34 (10.1 mbgl) and MJ17-01D (14.4 mbgl). The average groundwater level for the previous monitoring round in September 2019 were 4.3 mbgl. The groundwater levels were relatively stable, apart from erratic changes observed in November 2018 and February 2019. Groundwater levels for the ADF area boreholes are illustrated in Figure 5-3 between 2012 and 2019.

The recorded groundwater levels of AB08 were not reviewed as measurements were extremely erratic, with groundwater level changes in excess of 10 metres in subsequent quarters being recorded. Borehole AB08 is equipped with a wind pump, and without abstraction volumes the groundwater level response data were not interpreted.

Majority of the ADF area boreholes showed an erratic and sharp increase or decrease in November 2018 and February 2019. This data should be verified with additional site and climate data and has been removed from the ADF area groundwater level graph.

Coal stockyard area

Groundwater levels for four monitoring boreholes for the coal stockyard area varied between 0.32 mbgl (CB20) and 13.9 mbgl (CB20). The average groundwater level for the previous monitoring round in September 2019 were 3.3 mbgl. The groundwater levels were relatively stable, apart from erratic changes observed in July 2018 and November 2018 for CB20. This data should be verified with additional site and climate data. Groundwater levels for the coal stockyard area boreholes are illustrated in Figure 5-4 between 2012 and 2019.

Power station and solid waste areas

Groundwater levels for ten monitoring boreholes for the power station area varied between 0.04 mbgl (PB15) and 7.75 mbgl (PB19). The average groundwater level for the previous monitoring round in September 2019 were 3.3 mbgl. The groundwater levels were relatively stable, apart from erratic changes observed in November 2018 for all boreholes. This data should be verified with additional site and climate data. Groundwater levels for the power station area boreholes are illustrated in Figure 5-5 between 2012 and 2019.

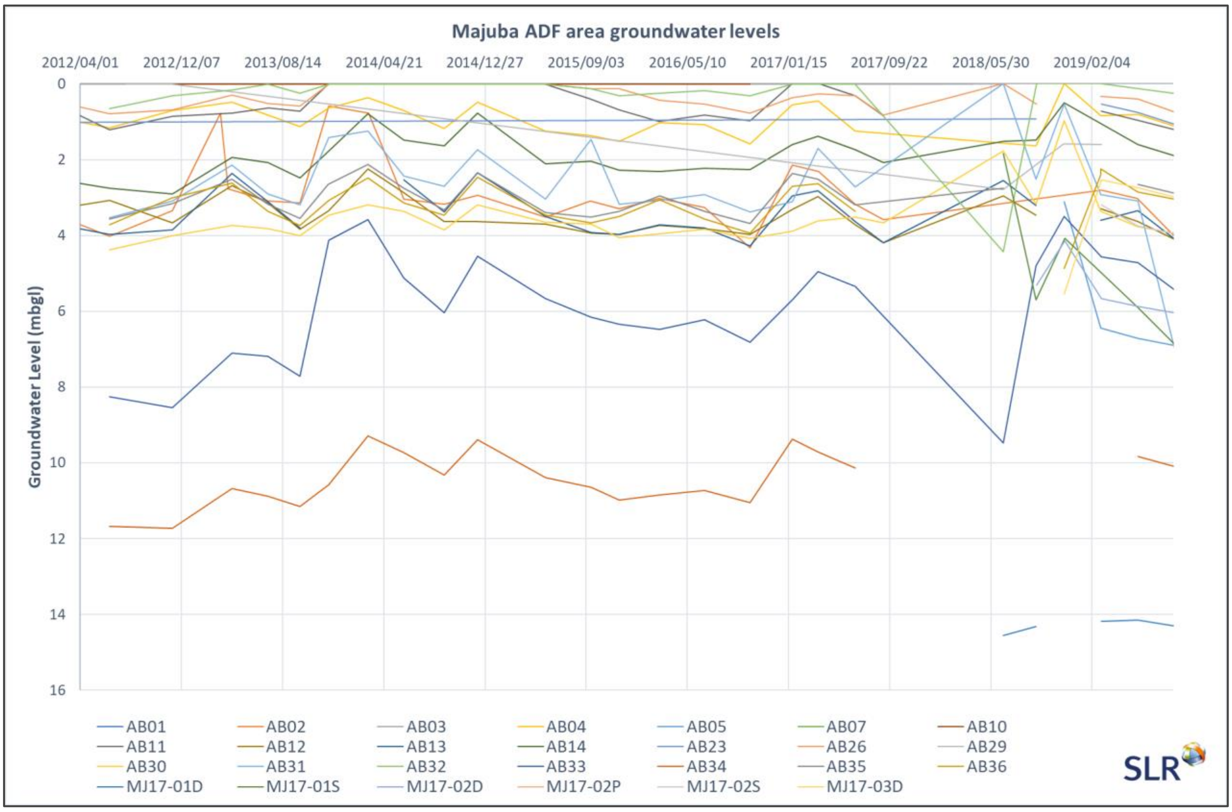


Figure 5-3: Majuba ADF area groundwater levels recorded between 2012 and 2019.

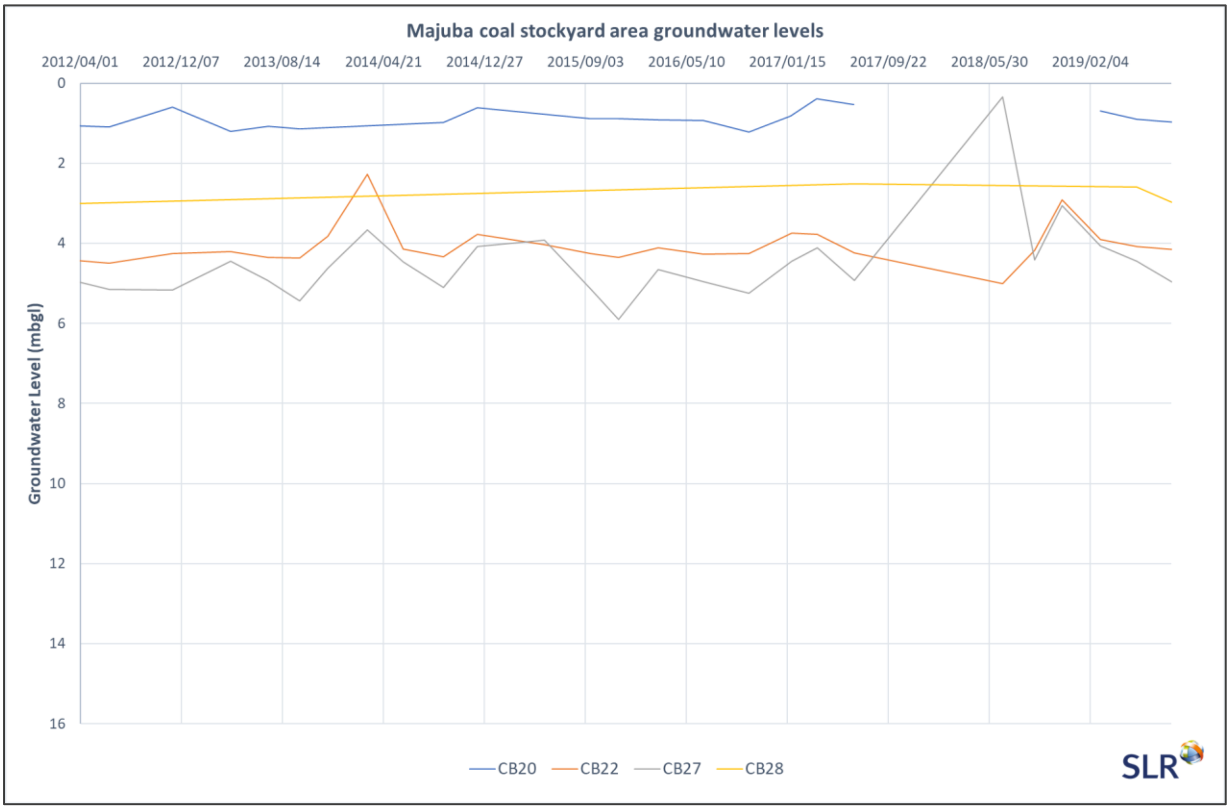


Figure 5-4: Majuba coal stockyard area groundwater levels recorded between 2012 and 2019.

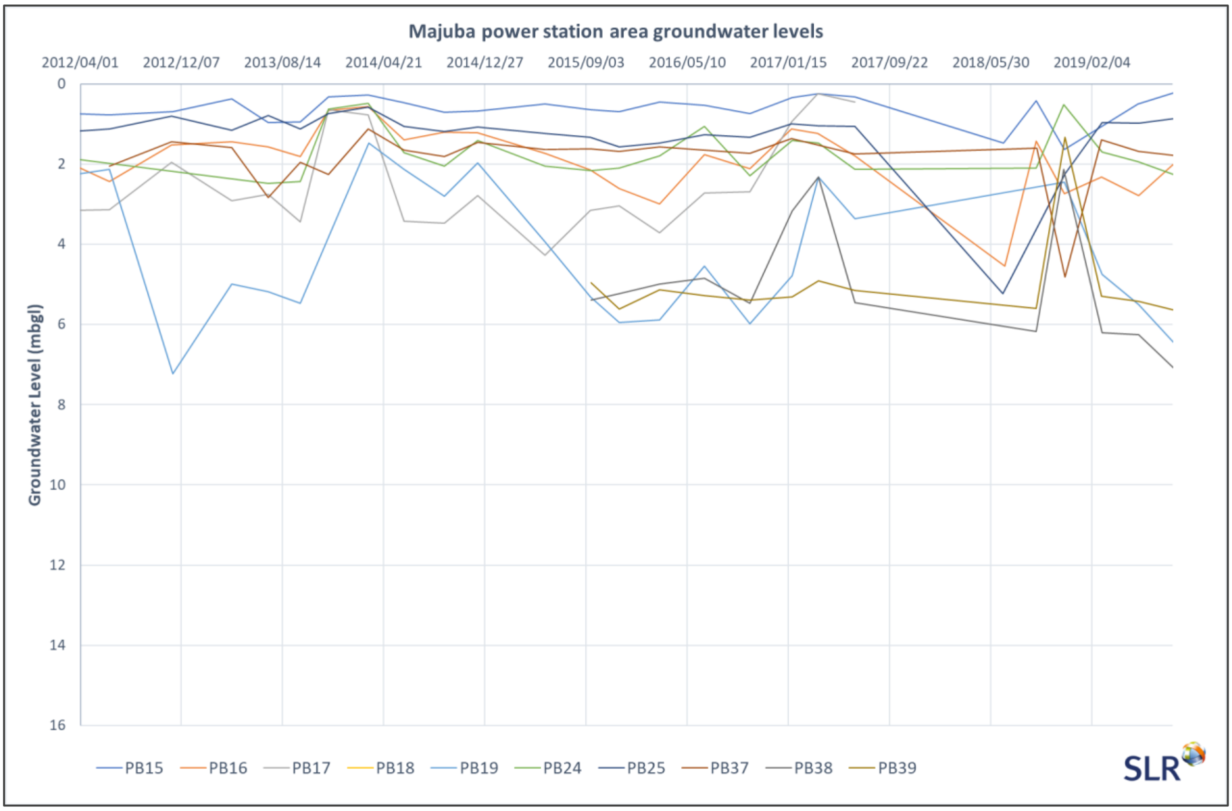


Figure 5-5: Majuba power station area groundwater levels recorded between 2012 and 2019.

5.3.3 Site hydrocensus investigation – July 2019

Kimopax (Pty) Ltd conducted a hydrocensus study covering the area surrounding the Majuba Power Station. The hydrocensus was undertaken by Kimopax to assess the status of the groundwater and surface water sources quality in the project area. The hydrocensus investigation for groundwater points was conducted from boreholes, while surface water points hydrocensus was conducted from rivers and dams. The hydrocensus study was conducted from the 3rd to the 6th of June 2019. During the hydrocensus a total number of 34 sites were identified from which 16 sites were sampled and analysed. The sampled sites consisted of 13 groundwater points, and 3 surface water points. The hydrocensus included boreholes on farms surrounding the project area and uses include drinking water and livestock watering.

Kimopax (2019) did not measure any groundwater levels during the 2019 hydrocensus investigation. Kimopax (2019) indicated that the possibility of water level measurements was restricted due to most boreholes being fitted with equipment and did not allow for insertion of water level measuring equipment. Some boreholes identified as sampling points were fitted with equipment such as submersible pumps, hand pumps, and most had windmills, therefore water level were not be measured from such boreholes.

5.3.4 Conclusions

Groundwater levels at the ADF area in 2014 ranged between artesian conditions and 11.75 mbgl (AB34), and average groundwater levels were 2.9 mbgl. Groundwater levels are possibly affected by surface water dams as noted by SLR (2014). The average groundwater level for the previous monitoring round in September 2019 were 4.3 mbgl.

Groundwater levels at the coal stockyard in 2014 area ranged between 0.59 mbgl (CB20) and 5.16 mbgl (CB27), and average groundwater levels were 3.3 mbgl. Relatively stable groundwater depth trends are observed in the boreholes of the Coal Stockyard Area. The average groundwater level for the previous monitoring round in September 2019 were 3.3 mbgl.

Groundwater levels at the power station and solid waste areas in 2014 ranged between 0.69 mbgl (PB15) and 7.23 mbgl (PB19), and average groundwater levels were 2.2 mbgl. Varying water levels were noticed in PB17 and was attributed to the potential influence by the water level fluctuations in dams PP10 and PP11. Groundwater levels for ten monitoring boreholes for the power station area varied between 0.04 mbgl (PB15) and 7.75 mbgl (PB19). The average groundwater level for the previous monitoring round in September 2019 were 3.3 mbgl. The groundwater levels were relatively stable.

Groundwater levels at the site overall are relatively shallow and ranged between 0.20 mbgl (PB15) and 14.31 mbgl (MJ17-01D) in September 2019. The local groundwater gradient is predominantly towards the north and towards the Palmiet Spruit located between the ADF and power station. The groundwater elevations are illustrated in Figure 5-6.

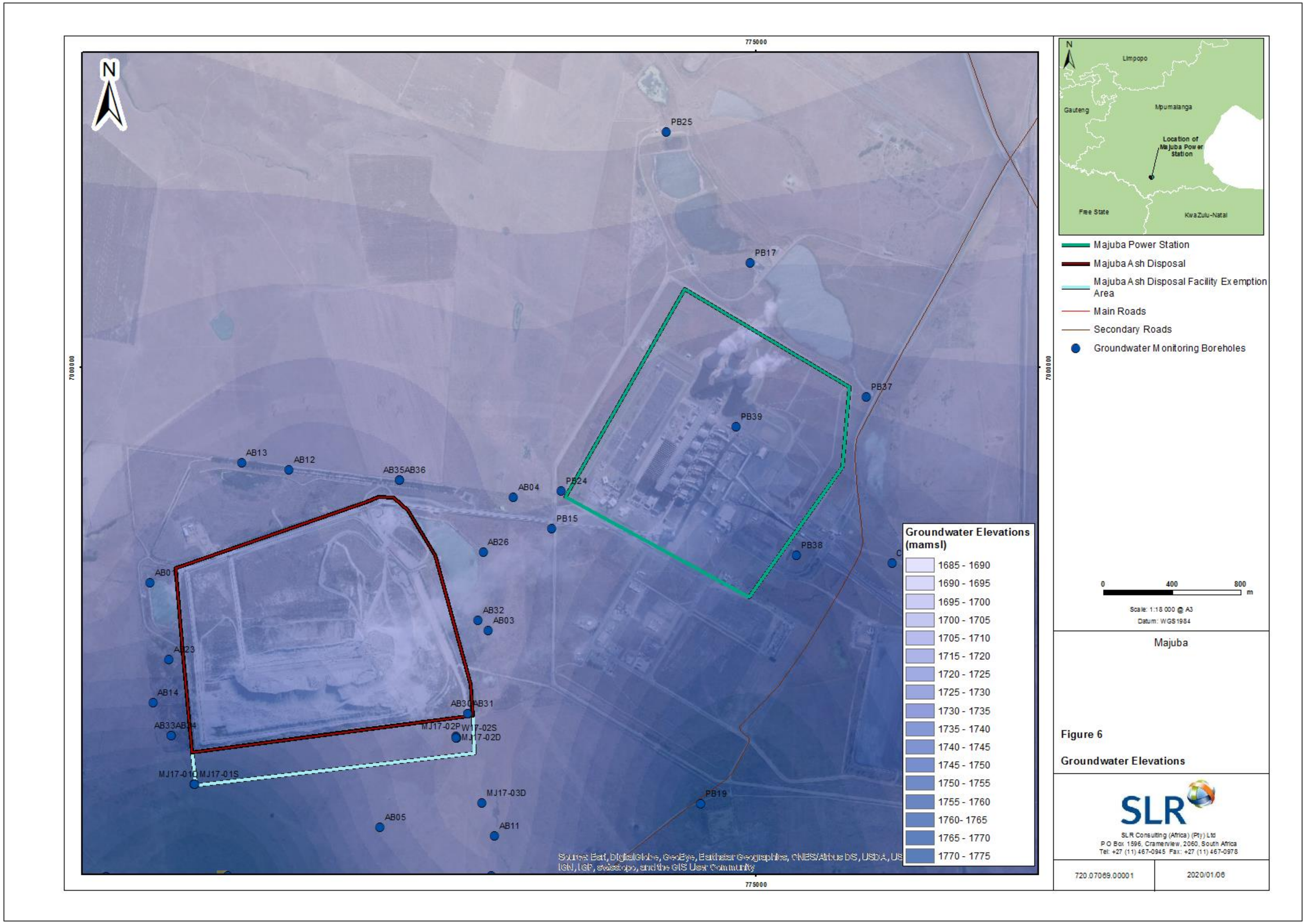


Figure 5-6: Majuba site local groundwater levels and gradient.

5.4 GROUNDWATER QUALITY

5.4.1 Previous SLR groundwater study groundwater quality

SLR (2014) found from previous monitoring data that the groundwater quality of the sites on the current ash disposal facility showed signs of contamination. The monitoring report by GHT (2013) was reviewed by SLR (2014) (38th routine monitoring investigations) and provided details of the results for the November 2012 study (GHT, 2013). Although the concentrations of more than 20 inorganic chemical parameters in the water samples were determined during the chemical analyses, GHT Consultants concentrated on six main parameters as indicators of contamination in the monitoring of the pollution potential in this system. These six parameters included electrical conductivity (EC), sodium (Na), calcium (Ca), chloride (Cl), sulphate (SO_4), and iron (Fe).

The water quality results were classified by GHT Consulting Scientist according to:

- South Africa Water Quality Guidelines, Volume 1: Domestic Use, DWA&F, First Edition 1993 and Edition 1996.
- Quality of Domestic Water Supplies, DWAF, Second Edition 1998.
- SABS South African National Standard: Drinking water SANS 241-2:2011 Edition 1 and SANS 241:2006 Edition 6.1.
- Majuba Power Station Water Use License.

SLR (2014) noted that the pollution indexes strongly suggested that most of the groundwater sites have been impacted upon by the power station and associated infrastructure. Only boreholes AB10 and PB17 seemed unaffected. With regards to the groundwater quality objectives, the target objective for fluoride (F) was exceeded at most of the groundwater sites (even at the background sites). However, the only sites at which the target objective for SO_4, which is the major pollutant associated with the ash and coal, were exceeded at AB03 (east of ash disposal facility AP01), AB04 (N East - Between road and fence north of bridge), AB26 (east and below AP01), AB35 (north of ash stack next to fence), PB19 (at solid waste site, next to gravel road) and CB22 (east of the Coal Stockyard).

The results provided in the November 2012 monitoring report (GHT, 2013) per infrastructure area are summarised below:

ADF area

Contaminants of concern, compared to the SANS 241-1:2015 drinking water standard, included fluoride in borehole AB03.

Sulphate concentrations from the ADF borehole samples ranged between 1 mg/L and 163 mg/L and electrical conductivity ranged between 34 mS/m and 80 mS/m.

GHT (2013) stated that the sulphate (SO_4) showed an increasing trend since 2002 which indicate a definite impact on the groundwater from the ash water return dam AP01. The concentration of SO_4 in this dam was stated to be higher than 1000 mg/l. It was concluded by GHT (2013) that the permeability of the aquifer in the region below the dam AP01 is extremely low (as the pollutant took 10 years to reach borehole AB26 only a few metres downstream from the dam). It was concluded that the influence from the dam were due to spillages or seepage of water from the contact zone of the base of the dam. GHT (2013) recommended several surface water control measures to prevent future spillages from the dam.

Coal stockyard area

No contaminants of concern, compared to the SANS 241-1:2015 drinking water standard, were reported for the coal stockyard area.

Sulphate concentrations from the coal stockyard borehole samples ranged between 8 mg/L and 76 mg/L and electrical conductivity ranged between 45 mS/m and 64 mS/m.

GHT (2013) found that most of the indicator elements showed a decreasing trend since 2009. Some surface interaction may potentially have taken place at CB22 due to sulphates being released from coal dust on the surface during rainstorm events. GHT (2013) found an increasing trend in the SO_4 concentrations. However, all the other indicator elements exhibit a constant trend. GHT (2013) noted that the upper part of the geology at borehole CB22 comprised of dark carbonaceous shale and attributed that the SO_4 concentrations may be partly released from the geology.

Power station and solid waste areas

Contaminants of concern, compared to the SANS 241-1:2015 drinking water standard, included fluoride in borehole PB15 and manganese in borehole PB37.

Sulphate concentrations from the power station area borehole samples ranged between 3 mg/L and 80 mg/L and electrical conductivity ranged between 22 mS/m and 94 mS/m.

Surface water

GHT (2013) concluded that surface water quality impacts were evident as increases in the indicator elements concentrations were observed. GHT (2013) noted that these increases occurred as the water flowing from upstream were contaminated as it moved past the site pollution source. GHT (2013) also concluded:

- The indicator element concentrations along the Palmiet Spruit between PSR03 and PSR08 displayed elevated EC, Ca and SO_4 concentrations. Sites PSR01 and PSR02 were the exception. This observation showed that contaminant impacts from the Ashing Area and/or the Power Station Area were impacting on the surface water quality of the Palmiet Spruit at these sites.
- There was a sharp increase in the sulphate concentrations downstream along the Witbank Spruit monitoring sites. The SO_4 concentrations exceeded the prescribed standard water quality limit. This observation showed that contaminant impacts from the Coal Stockyard Area were impacting on the water quality of the Witbank Spruit at these sites.
- Potential overflow might have occurred (possibly in the past) at the pump back sump at site GSR16, which influenced the water quality at the Geelklip Spruit negatively. Sites PP12 and PP13 were dirty water dams and the elevated concentrations were expected. Sites PP14, PP10 and GSR17 along the Geelklip Spruit were virtually free from impacts of the Power Station.

5.4.2 Hydrocensus investigation (Kimopax, 2019)

The only contaminant of concern identified by Kimopax during the 2019 hydrocensus investigation, compared to the SANS 241-1:2015 drinking water standard, was iron in borehole MBH02.

Sulphate concentrations from the hydrocensus borehole samples ranged between 5.8 mg/L and 23.8 mg/L and electrical conductivity ranged between 13.3 mS/m and 70.3 mS/m.

5.4.3 Groundwater quality monitoring

Majuba monitors several boreholes within and surrounding the site as part of its groundwater monitoring programme. The water quality results from available monitoring reports and site data from September 2014 to September 2019, are discussed per infrastructure area below. The site Integrated Water Use Licence (IWUL) does not contain groundwater quality parameter limits. Therefore, the water quality results were compared to the SANS 241-1:2015 Drinking Water Standard (Edition 2) for reference purposes and not for compliance purposes.

ADF area

Sulphate concentrations from the ADF borehole samples ranged between <1 mg/L and 342.5 mg/L (average 39 mg/L) and electrical conductivity ranged between 13 mS/m and 352 mS/m (average 58 mS/m). The monitoring boreholes surrounding the ADF were divided into four broad regions, namely areas west, north, east, and south of ADF.

The average sulphate concentrations for the previous monitoring round conducted in September 2019 were 13.3 mg/L, 117.1 mg/L, 43.5 mg/L, and 21.52 mg/L for the west, north, east, and south areas of the ADF respectively. The sulphate concentration data from the ADF monitoring boreholes compared to the SANS 241-1:2015 sulphate acute health limit are illustrated in Figure 5-7, Figure 5-8, Figure 5-9, and Figure 5-10 for the west, north, east, and south areas of the ADF respectively. Impact on groundwater quality, in terms of sulphate concentrations, are evident as an increase in sulphate concentrations were noticed from approximately 2012 in monitoring boreholes north and east of the ADF.

The monitoring boreholes AB04 (December 2004) and AB35 (September 2019) had the highest recorded sulphate concentrations of 366 mg/L and 342.5 mg/L respectively. However, these concentrations were erratic spikes in concentrations and no continuous increasing trend in concentrations were noticed. Furthermore, an increasing trend in sulphate concentrations were observed from January 2012 to January 2017. However, a large decrease in sulphate concentrations were recorded from January 2017 to September 2019.

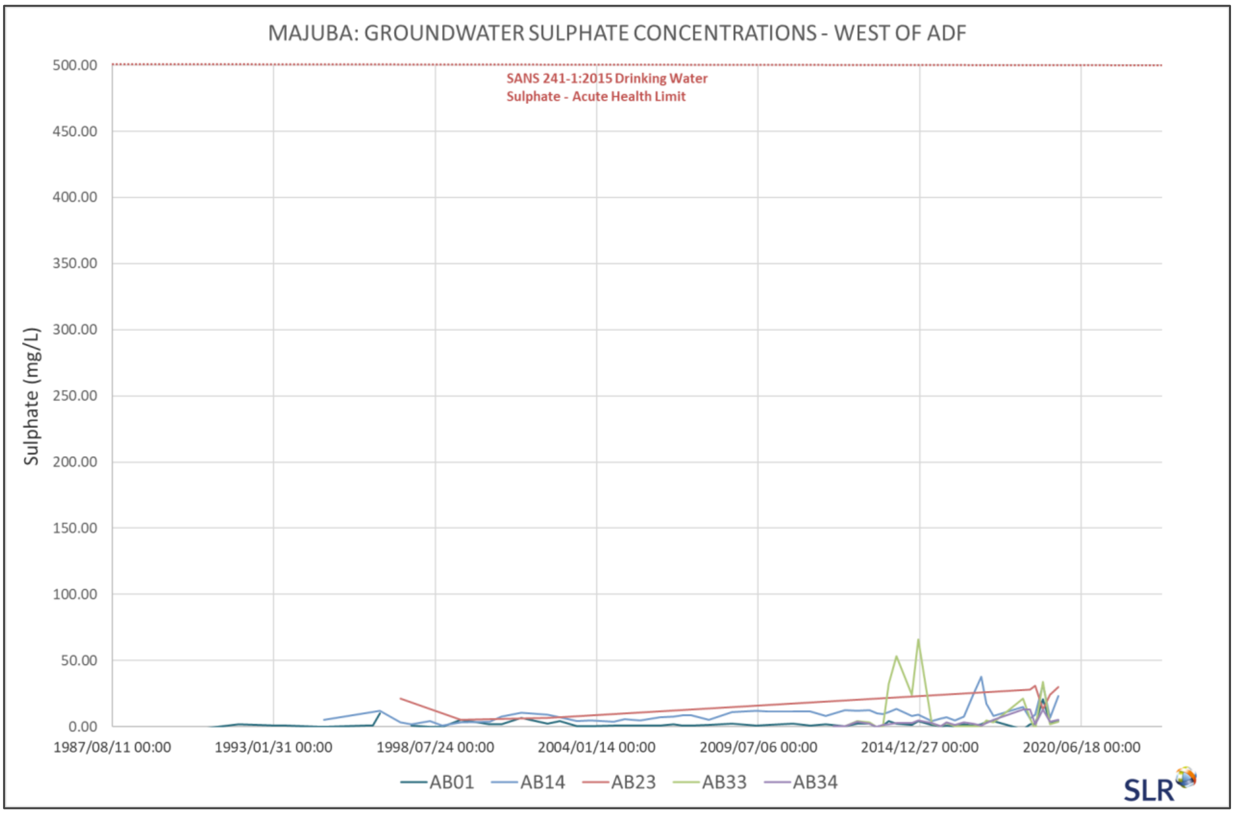


Figure 5-7: Majuba Power Station sulphate concentrations in ADF monitoring boreholes – western area.

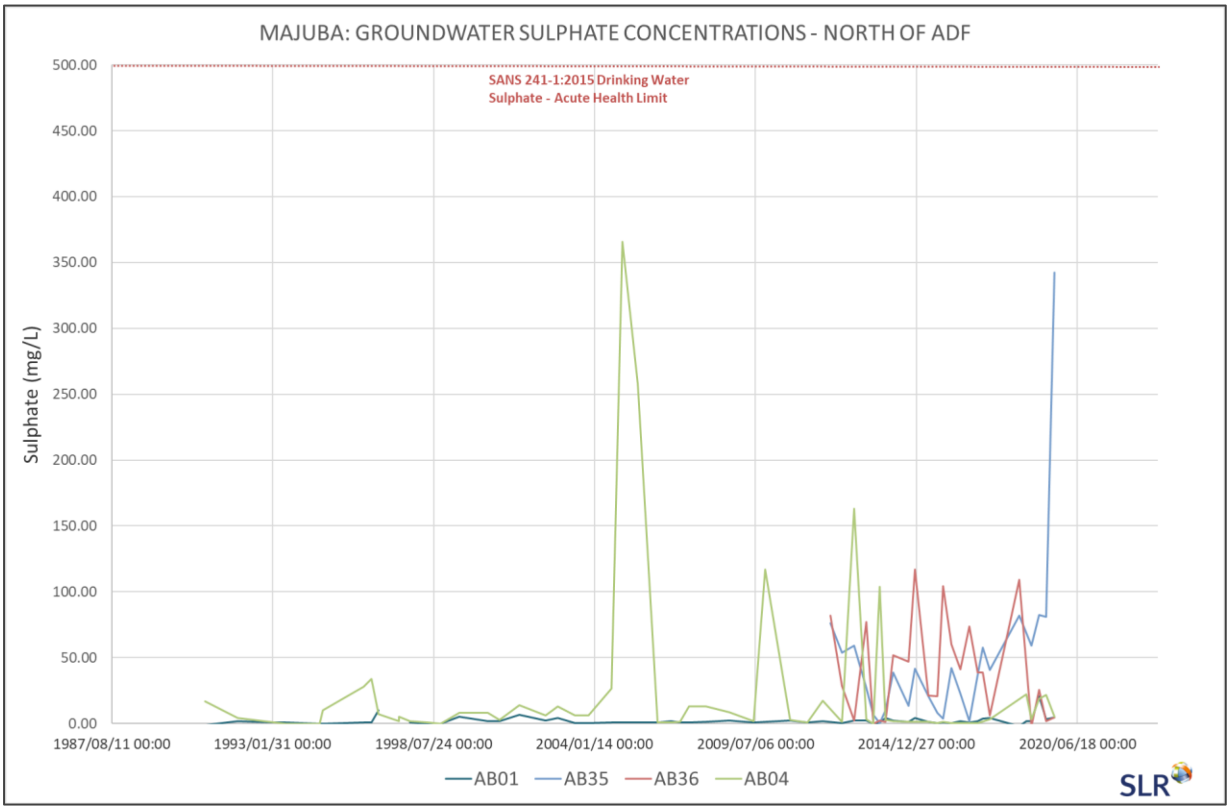


Figure 5-8: Majuba Power Station sulphate concentrations in ADF monitoring boreholes – northern area.

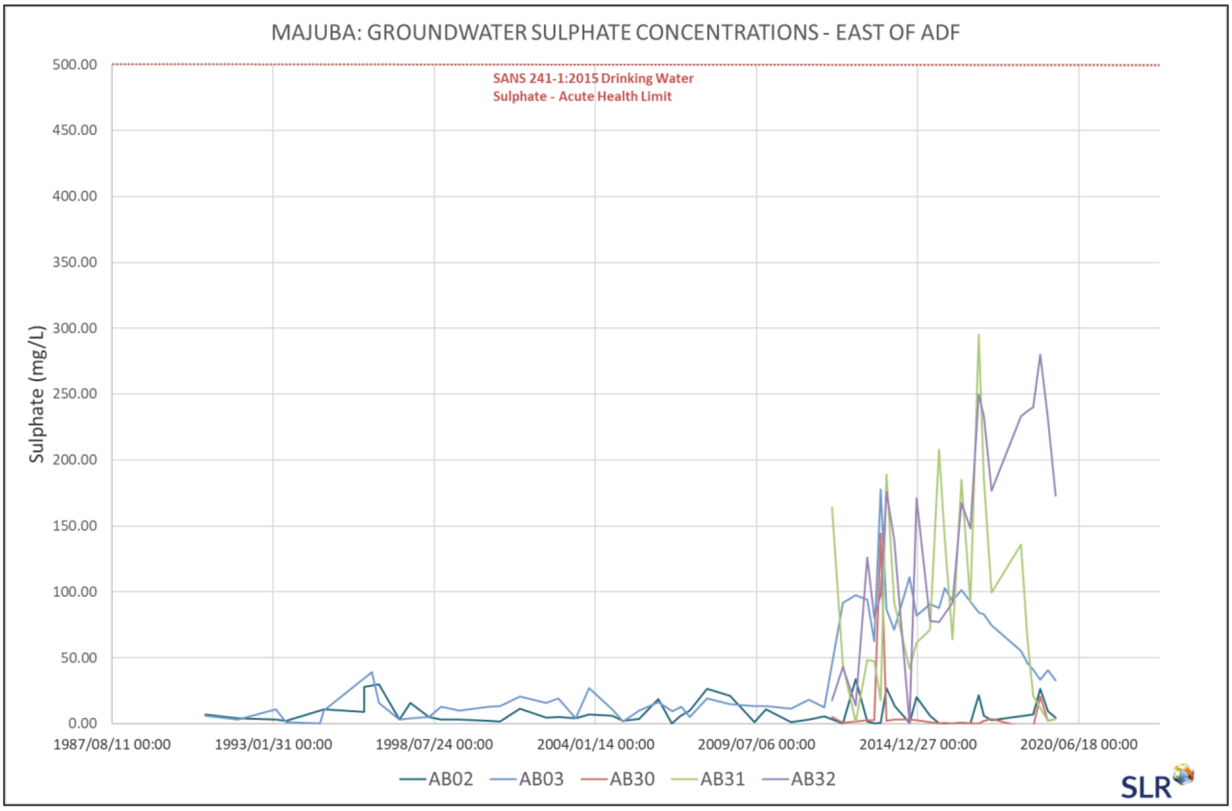


Figure 5-9: Majuba Power Station sulphate concentrations in ADF monitoring boreholes – eastern area.

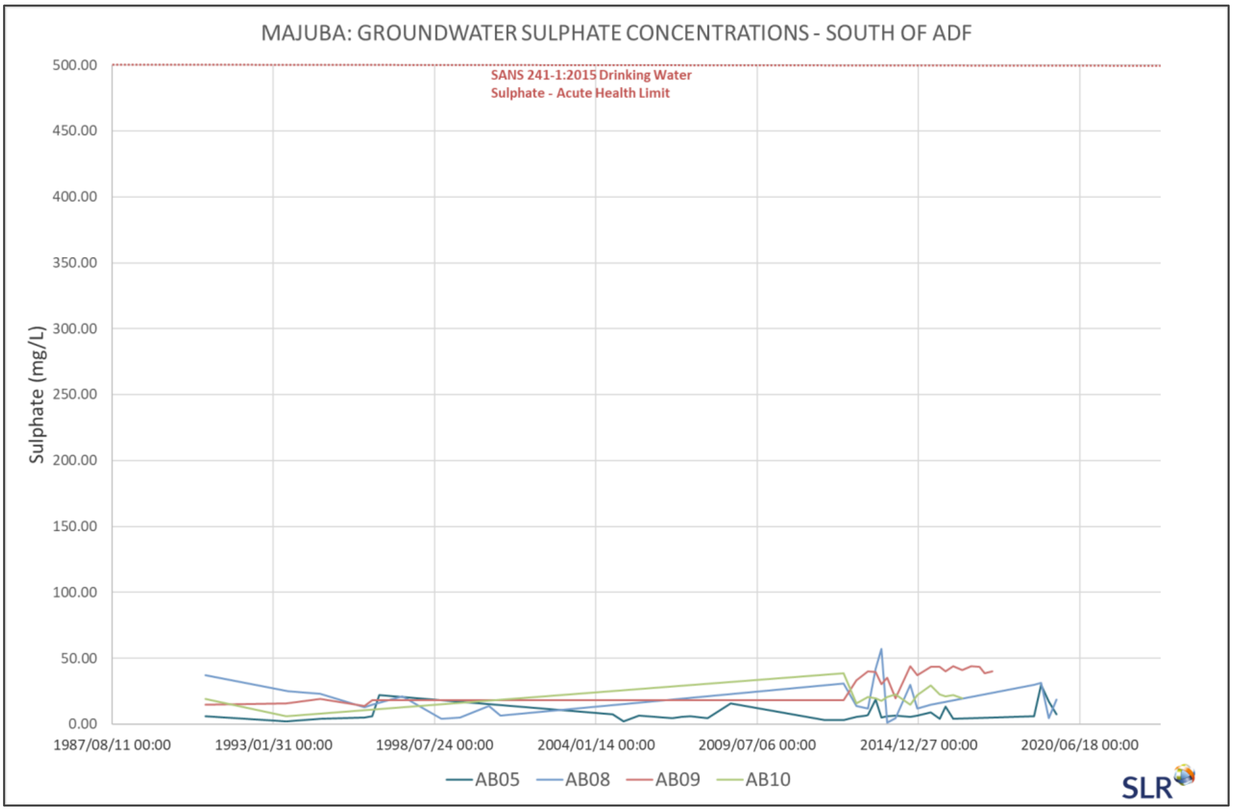


Figure 5-10: Majuba Power Station sulphate concentrations in ADF monitoring boreholes – southern area.

Contaminants of concern identified from the monitoring data at the ADF area, with maximum concentrations highlighted, included:

- pH – AB04 (9.73)
- EC – AB05 (352 mg/L)
- F – AB01 (1.7 mg/L), AB03 (1.88 mg/L), AB04 (2.3 mg/L), AB30 (2.34 mg/L), AB36 (1.9 mg/L)
- Al – AB02 (0.46 mg/L), AB04 (0.42 mg/L), AB30 (1.74 mg/L)
- Mn – AB05 (1.15 mg/L), AB08 (1.12 mg/L), MJ17-02P (0.64 mg/L)
- As – AB03 (0.03 mg/L), AB12 (0.03 mg/L), AB13 (0.05 mg/L), AB14 (0.04 mg/L), AB24 (0.02 mg/L), AB26 (0.06 mg/L), AB29 (0.04 mg/L), AB31 (0.014 mg/L), AB32 (0.05 mg/L), AB33 (0.04 mg/L), AB34 (0.02 mg/L), AB35 (0.05 mg/L), AB36 (0.05 mg/L)

Coal stockyard area

Sulphate concentrations from the coal stockyard area borehole samples ranged between 6.6 mg/L and 1771 mg/L (average 101.7 mg/L) and electrical conductivity ranged between 27 mS/m and 311 mS/m (average 72.2 mS/m).

Contaminants of concern identified from the monitoring data at the coal stockyard area, with maximum concentrations highlighted, included:

- EC – CB28 (311 mS/m)
- Na – CB28 (428 mg/L)

- SO_4 – CB28 (1771 mg/L)
- Al – CB27 (0.35 mg/L)
- Mn – CB22 (0.48 mg/L)
- As – CB22 (0.05 mg/L), CB27 (0.03 mg/L)

Power station and solid waste area

Sulphate concentrations from the power station area borehole samples ranged between <1 mg/L and 338.3 mg/L (average 37 mg/L) and electrical conductivity ranged between 11.6 mS/m and 167.8 mS/m (average 70 mS/m).

Contaminants of concern identified from the monitoring data at the power station area, with maximum concentrations highlighted, included:

- pH – PB37 (9.73)
- Cl – PB25 (419.68 mg/L)
- F – PB15 (2.2 mg/L)
- Mn – PB24 (0.46 mg/L), PB25 (0.97 mg/L)
- As – PB16 (0.04 mg/L), PB25 (0.04 mg/L), PB37 (0.04 mg/L), PB38 (0.05 mg/L), PB39 0.03 mg/L)

5.4.4 Surface water quality monitoring

The surface water quality results are consistent with conclusions made by GHT (2013) that surface water quality was negatively impacted as most indicator elements exceed the relevant guideline target limits. Sulphate concentrations from surface water site samples ranged between <1 mg/L and 4 149 mg/L (average 495 mg/L) and electrical conductivity ranged between 11 mS/m and 494 mS/m (average 157 mS/m).

The surface water monitoring points (PSR01 – PSR07) for the Palmiet Spruit, located between the power station and the ADF, showed signs of increased sulphate concentrations. PSR01, PSR02, and PSR03 located upstream generally had relatively low sulphate concentrations below the SANS 241-1:2015 acute health limit. The remaining monitoring points, located downstream of the ADF, had elevated sulphate concentrations generally above the SANS 241-1:2015 acute health limit, with PSR06 recording sulphate concentrations in excess of 3 000 mg/L in 2003. The sulphate concentrations in the Palmiet Spruit monitoring points downstream of the ADF were much higher than concentrations measured in the monitoring boreholes downstream of the ADF. This coincides with general conclusions by GHT (2013) that there was a definite impact on the groundwater from the ADF return water dams. It was concluded that the influence from the dam were due to spillages or seepage of water from the contact zone of the base of the dam. The sulphate concentrations of the surface water monitoring points of the Palmiet Spruit are illustrated in Figure 5-11.

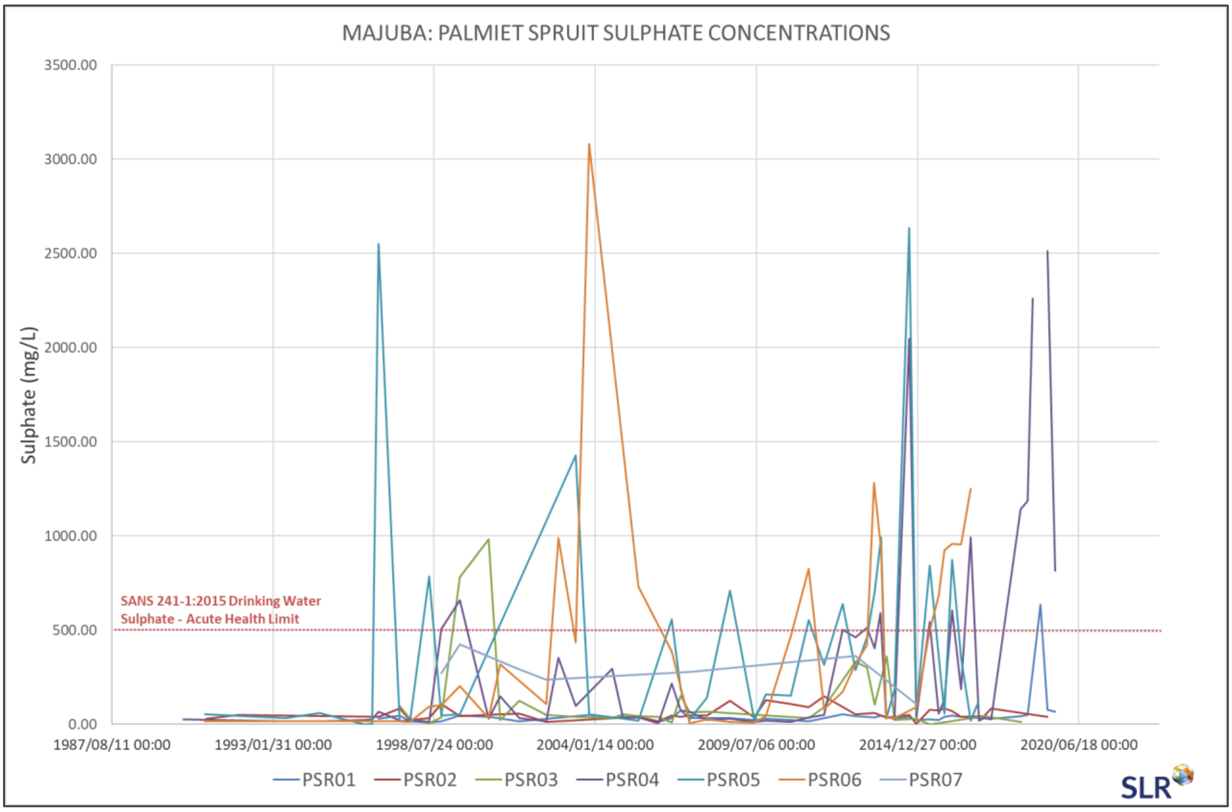


Figure 5-11: Majuba Power Station sulphate concentrations in Palmiet Spruit surface water monitoring points.

5.4.5 Conclusions

SLR (2014) found from previous monitoring data that the groundwater quality of the sites on the current ash disposal facility showed signs of contamination. The monitoring report by GHT (2013) was reviewed by SLR (2014) (38th routine monitoring investigations) and provided details for measurement collected in November 2012 (GHT, 2013).

SLR (2014) noted that the pollution indexes strongly suggested that most of the groundwater sites have been impacted upon by the power station and associated infrastructure. With regards to the groundwater quality objectives, the target objective for fluoride (F) was exceeded at most of the groundwater sites in 2012 (even at the background sites). However, the only sites at which the target objective for SO_4, which is the major pollutant associated with the ash and coal, were exceeded at predominantly at the ADF.

GHT (2013) stated that the sulphate (SO_4) showed an increasing trend since 2002 which indicate a definite impact on the groundwater from the ash water return dam AP01. The concentration of SO_4 in this dam is normally higher than 1000 mg/l. It was concluded by GHT (2013) that the permeability of the aquifer in the region below the dam AP01 is extremely low (as the pollutant took 10 years to reach borehole AB26 only a few metres downstream from the dam). It was concluded that the influence from the dam were due to spillages or seepage of water from the contact zone of the base of the dam.

Majuba monitors several boreholes within and surrounding the site as part of its groundwater monitoring programme. The water quality results after the previous SLR (2014) study, from September 2014 to September 2019.

Sulphate concentrations from the ADF borehole samples ranged between <1 mg/L and 342.5 mg/L (average 39 mg/L) and electrical conductivity ranged between 13 mS/m and 352 mS/m (average 58 mS/m). Contaminants of concern noted, compared to the SANS 241-1:2015 Drinking Water Standard (Edition 2), at the ADF included pH, EC, F, Al, Mn, and As.

Sulphate concentrations from the coal stockyard area borehole samples ranged between 6.6 mg/L and 1771 mg/L (average 101.7 mg/L) and electrical conductivity ranged between 27 mS/m and 311 mS/m (average 72.2 mS/m). Contaminants of concern noted at the coal stockyard area included EC, Na, SO_4, Al, Mn, and As.

Sulphate concentrations from the power station area borehole samples ranged between <1 mg/L and 338.3 mg/L (average 37 mg/L) and electrical conductivity ranged between 11.6 mS/m and 167.8 mS/m (average 70 mS/m). Contaminants of concern noted at the power station included pH, Cl, F, Mn, and As.

The only contaminants of concern identified during the 2019 hydrocensus investigation (Kimopax, 2019), compared to the SANS 241-1:2015 drinking water standard, included iron in borehole MBH02. Sulphate concentrations from the hydrocensus borehole samples ranged between 5.8 mg/L and 23.8 mg/L and electrical conductivity ranged between 13.3 mS/m and 70.3 mS/m.

The surface water quality results are consistent with conclusions made by GHT (2013) that surface water quality was negatively impacted as most indicator elements exceed the relevant guideline target limits. Sulphate concentrations between 2014 to 2019 from surface water site samples ranged between <1 mg/L and 4 149 mg/L (average 495 mg/L) and electrical conductivity ranged between 11 mS/m and 494 mS/m (average 157 mS/m). The surface water monitoring points (PSR01 – PSR07) for the Palmiet Spruit, located between the power station and the ADF, showed signs of increased sulphate concentrations. PSR01, PSR02, and PSR03 located upstream generally had relatively low sulphate concentrations below the SANS 241-1:2015 acute health limit. The remaining monitoring points, located downstream of the ADF, had elevated sulphate concentrations generally above the SANS 241-1:2015 acute health limit, with PSR06 recording sulphate concentrations in excess of 3 000 mg/L in 2003. The sulphate concentrations in the Palmiet Spruit monitoring points downstream of the ADF were much higher than concentrations measured in the monitoring boreholes downstream of the ADF.

5.5 GEOCHEMISTRY

One sample of ash material was submitted by Enviro Xcellence Services CC to Talbot and Talbot Laboratories (Pty) Ltd on 18 March 2019 for waste classification analyses.

The distilled water tests performed on the ash sample were in accordance with the classification guidelines for mono-disposal sites and were classed against the various thresholds for total concentrations (TC) and leachable concentrations (LC). The sample was submitted for XRF analysis to indicate the oxide distribution of the material.

5.5.1 XRF

The high SiO_2 content (which is mostly in the form of amorphous material formed due to the high temperatures during burning) lowers the solubility of the material with the low hydraulic conductivity of ash material also aiding in not allowing any elements that does dissolve to leave the system.

The major oxides present in the ash material are SiO_2, Al_2O_3, Fe_2O_3, CaO and MgO. The sulphur content is low with a higher lime content (CaO) indicating a possible low potential for acid generation with a high buffering capacity. On ignition of the test there was a low loss of material as the ash already went through a high temperature procedure with a low moisture content. The XRF results indicating the major oxide concentrations are given in Table 5-2.

Table 5-2: Majuba Power Station ash dump sample XRF result summary.

Major Elements		Major element concentration (weight %)
Determinant	Units	
Silica	SiO_2	46.44
Aluminium	Al_2O_3	29.14
Calcium	CaO	5
Iron	Fe_2O_3	4.81
Titanium	TiO_2	1.8
Magnesium	MgO	1.07
Potassium	K_2O	0.82
Phosphorous	P_2O_5	0.38
Sulphur	SO_3	0.04
Manganese	MnO	0.03
Chromium	Cr_2O_3	0.01
Sodium	Na_2O	<0.01
Loss of Ignition (1000°C)	LOI	0.7
Total	Total	100.06
Loss of Moisture (105°C)	H_2O^-	10.31

5.5.2 Total concentration threshold

The following classification, also shown in Table 5-3 was made based on the total concentrations threshold (TCT) classes:

- Arsenic and barium exceeded the TCT0 guideline values and were within the limits of TCT1; and
- All other elements were below the TCT0 guideline values.

Table 5-3: Total concentration threshold (TCT) results.

Parameters	NEMWA Total Concentration Thresholds			Sample ID
	TCT0	TCT1	TCT2	Majuba ash sample
	mg/kg			
Antimony (Sb)	10	75	300	<0.9
Arsenic (As)	5.8	500	2 000	11.6

Parameters	NEMWA Total Concentration Thresholds			Sample ID
	TCT0	TCT1	TCT2	Majuba ash sample
	mg/kg			
Barium (Ba)	62.5	6 250	25 000	194
Boron (B)	150	15 000	60 000	60
Cadmium (Cd)	7.5	260	1 040	<2
Chromium (Cr)	46 000	800 000	-	25
Hex Chromium (Cr6)	6.5	500	2 000	1.58
Cobalt (Co)	50	5 000	20 000	2.12
Copper (Cu)	16	19 500	78 000	8.53
Lead (Pb)	20	1 900	7 600	9.68
Manganese (Mn)	1 000	25 000	100 000	71
Mercury (Hg)	0.93	160	640	<0.2
Molybdenum (Mo)	40	1 000	4 000	<11
Nickel (Ni)	91	10 600	42 400	7.64
Selenium (Se)	10	50	200	<7
Vanadium (V)	150	2 680	10 720	38
Zinc (Zn)	240	160 000	640 000	8.55
Cyanide (CN total)	14	10 500	42 000	0.19
Fluoride (F)	100	10 000	40 000	<0.3
pH @ 25°C	6 < pH < 12			10.8

5.5.3 Leachable concentration threshold

The following classification also shown in Table 5-4 was made based on the leachable concentrations threshold (LCT) classes:

- Arsenic, barium, boron, cadmium, chromium, hexavalent chromium, manganese, molybdenum, selenium, vanadium, and total dissolved solids (TDS) exceeded the LCT0 guideline values and were within the limits of LCT1;
- Arsenic, barium, boron, cadmium, chromium, manganese, selenium, and TDS exceeded the SANS 241-1:2015 drinking water quality guideline limits; and
- All other elements were below the LCT0 and SANS 241-1:2015 guideline values.

Table 5-4: Leachable concentration threshold (LCT) results.

Parameters	NEMWA Leachable Concentration Thresholds				SANS 241-1: 2015	Sample ID
	LCT0	LCT1	LCT2	LCT3		Majuba ash sample
	mg/L					
Antimony (Sb)	0.02	1.0	2	8	0.02	<0.009
Arsenic (As)	0.01	0.5	1	4	0.01	0.148
Barium (Ba)	0.7	35	70	280	0.7	0.988
Boron (B)	0.5	25	50	200	2.4	4.643
Cadmium (Cd)	0.003	0.15	0.3	1.2	0.003	0.006
Chromium (Cr)	0.1	5	10	40	0.05	0.466
Hex Chromium (Cr6)	0.05	2.5	5	20	-	0.361
Cobalt (Co)	0.5	25	50	200	-	<0.02
Copper (Cu)	2.0	100	200	800	2.0	0.072
Lead (Pb)	0.01	0.5	1	4	0.01	<0.01
Manganese (Mn)	0.5	25	50	200	0.4	0.512
Mercury (Hg)	0.006	0.3	0.6	2.4	0.006	<0.002
Molybdenum (Mo)	0.07	3.5	7	28	-	0.10
Nickel (Ni)	0.07	3.5	7	28	0.07	0.056
Selenium (Se)	0.01	0.5	1	4	0.04	0.06
Vanadium (V)	0.2	10	20	80	-	0.270
Zinc (Zn)	5.0	250	500	2 000	5.0	0.259
Chloride (Cl)	300	15 000	30 000	120 000	300	4.02
Cyanide (CN total)	0.07	3.5	7	28	0.2	<0.01
Fluoride (F)	1.5	75	150	600	1.5	<0.03
Nitrate (NO_3-N)	11	550	1 100	4 400	11	0.26
Sulphate (SO_4)	250	12 500	25 000	100 000	500	107
Total Dissolved Solids	1 000	12 500	25 000	100 000	1 200	2 610

5.5.4 Geochemistry limitations

The following limitations regarding the waste classification testing should be noted:

- It is not clear if the fly ash sample submitted represents fresh material originating from the power plant or material from the existing ash dump (and depth of sample). Fly ash material will have different chemistry compared to fresh fly ash material after leaching and reactions have taken place on the ash dump;
- Sampling methodology and preservation methods are not known;
- No XRD analysis was conducted. XRD results indicate the minerals formed through the combination of trace elements and oxides identified by full XRF analyses;
- No Acid Base Accounting (ABA) or Net Acid Generation (NAG) tests were performed. ABA and NAG tests allow for the evaluation of any potential for acid generation from the ash material;
- Waste classification testing only allows for preliminary screening to identify potential constituents of concern. Additional geochemical testing is required to fully characterise the material;
- XRF analysis did not include trace element analysis;
- The sample’s fluid phase was not submitted for organic analysis;
- The main limitation of the leaching procedure analyses is that they only provide representative leaching data for the pH values under which the tests are carried out, and therefore may not provide information on the long-term leaching behaviour of the material being tested under a range of conditions that could be experienced at the Majuba site. Additionally, the tests are biased for acidic conditions which may give conservative values of leaching potential for chemical constituents present as cations in solution, but which also may greatly underestimate the concentrations of anionic substances under neutral to alkaline pH conditions (as expected for the Majuba ash material and groundwater quality); and
- No long-term kinetic leach tests were performed. Kinetic column leaching tests indicate the chemicals that will leach out from the material over time as well as the oxidation rate of the sulphide minerals in the material, if no interference is present from secondary sulphate minerals.

5.6 CONCEPTUAL HYDROGEOLOGICAL MODEL

The coal-fired power generation process gives rise to large quantities of ash, which are disposed of in an ash disposal facility. This process involves ash being transported from the power station by conveyors and disposed of on the ash disposal facility. Majuba Power Station currently disposes of ash (produced by the combustion of coal) in a dry format by means of conveyors, a spreader and a stacker system from the station terrace to the ash disposal site.

Recharge moving through the soil zone combines with leachate from the ash storage facility and migrates downwards through the unsaturated zone to the water table. The volume of leachate produced by each ash storage facility depends partly on the hydraulic properties of the compacted ash. For the ash disposal facility (ADF), extension to the ash dams and the new rehabilitation dams, the ash from the dams and water seeping in and flowing off the ash dams will be the source of contaminants with the potential to reach and pollute the groundwater. Water into these dams will come from natural rainwater, infiltration from dust suppression and irrigation.

Following the precautionary principle, the post-closure recharge rate is considered constant despite planned surface coverage of the disposal facilities, which will reduce the actual recharge rate over time. Note that little information is available as to the actual rates of leakage from the bases of ash disposal facilities where dry ash disposal is practised. It is likely that some leakage does take place however (i.e. in excess of normal ambient recharge) – possibly associated with nearby toe drains and other surface water impoundments - as shown by artesian conditions in some of the boreholes near to the existing ash disposal facility at Majuba power station (e.g. boreholes AB01 and AB03). Groundwater below the water table moves with the local groundwater gradient towards discharge zones (most likely surface water resources such as nearby streams, wetlands and dams).

Groundwater gradients are likely to be primarily controlled by surface drainage features and the water table is likely to be a subdued reflection of the topography. Due to the shallow depth to groundwater in the immediate vicinity of the ash disposal facilities (existing and proposed) and associated infrastructure it is assumed that some leakage from the base of the ash disposal facility reaches local groundwater. This is supported by signs of groundwater quality being negatively affected in some boreholes close to the existing ash disposal facility, reported by GHT (2013) and from the site monitoring database. However, SLR (2014) noted that it was difficult to separate the effects of leakage from the ash disposal facility from the effects of leakage from return water dams, toe drains and other surface water impoundments, and these have been lumped together for the purposes of impact identification.

Groundwater will flow via fractures, faults, fissures and other secondary discontinuities in the rock. Locally the groundwater gradients are expected to be modified because shallower groundwater depths (“mounding”) are associated with the ash disposal facilities and other surface water infrastructure sources.

6. CONSTITUENTS OF CONCERN FROM COAL FLY ASH

Several case studies publicly available relating to typical contaminants of concern potentially emanating from coal ash and coal combustion residues were evaluated. The main findings are summarised below for each case study.

6.1 CASE STUDIES

Majuba Power Station (Advisian, 2019)

A previous groundwater study conducted by Advisian in May 2019 noted that the ash from the Majuba Power Station was provisionally classified as hazardous. This was because the minimum requirements classify the energy sector, specifically the production of electricity from coal, as an industrial sector which may generate hazardous waste. Based on the results obtained from the distilled water leach performed on the leach solution and total concentration analyses performed on the ash, the ash sample is classified as a Type 3 waste requiring disposal on a waste disposal facility with a Class C barrier system provided there are no site-specific risks that require a more conservative barrier system (Advisian, 2019).

Advisian (2019) also found that the Type 3 waste classification done by Jones and Wagner in 2013 was the result of the concentrations of chromium VI (Cr^{+6}), arsenic (As), barium (Ba), molybdenum (Mo) and fluoride (F). From a geochemical perspective, the old fly ash material was classified as Type 4 based upon the leachable concentrations (B, Mo, As, Ba, F and Cr^{+6})) and the fresh ash material as Type 3 as no concentrations exceeded the leachable or total thresholds. The older fly ash may contain elevated metals due to poorer quality coal use in the past or weathering which has exposed metals in the ash (Advisian, 2019).

Kendal Power Station (Zitholele Consulting, 2018)

The waste classification of Kendal Power Station’s ash was undertaken in 2014 by Jones and Wagener. The contaminants of concern (COCs) were compared to the total concentration thresholds and leachable concentration thresholds detailed in the GN R. 635 of 2013 (National Norms and Standards for the assessment of waste for Landfill Disposal), and included, amongst others, aluminium, antimony, arsenic, barium, boron, cadmium, chlorine, chromium (total), chromium VI, cobalt, copper, fluoride, lead, manganese, mercury, molybdenum, nickel, selenium, vanadium, zinc, polycyclic aromatic hydrocarbons, sulphate and nitrate.

Matla Power Station (Dalton et al., 2018)

A site assessment was conducted at Matla coal fired power plant to determine whether surrounding soils were being enriched with trace metals resulting from activities at the power plant. It was found that deposition of fly ash from the flue stacks and the ash dump along with deposition of coal dust from the coal stock yard were the activities most likely to lead to such enrichment. Eighty (80) topsoil samples were gathered and analysed for total metal content. Results were interpreted within the context of background values. It was found that concentrations of arsenic, copper, manganese, nickel and lead exceeded local screening levels, but only arsenic and lead could be confidently attributed to anthropogenic intervention and actual enrichment.

Thabametsi Power Station (Geo Pollution Technologies, 2014)

Geo Pollution Technologies (Pty) Ltd (GPT) conducted a hydrogeological impact study for the proposed Thabametsi Coal Fired Power Station Project at the Grootgeluk coal mine in 2014. Potential contaminants of concern identified by GPT potentially emanating from an ash dump included calcium, sulphate, chloride, sodium, and mercury. Sulphate was identified as the most significant solute in drainage from the ash dump. A starting concentration of 2 000 mg/L was used in numerical transport modelling by GPT. GPT recommended that the ash material should be summited for geochemical analysis to determine the leachability, acid generation capacity and contamination potential.

Thabametsi Power Station (Downstream Strategies, 2018)

Downstream Strategies focused on the potential risks to water resources from the coal ash dump, including its pollution control dams (PCDs). A full set of Coal Combustion Residues (CCR)-related pollutants were recommended to be included in the groundwater monitoring programme. The following CCR-related pollutants were identified: antimony, arsenic, barium, beryllium, boron, cadmium, cobalt, lead, lithium, molybdenum, radium-226 and radium-228 combined, selenium, and thallium.

Kriel Power Station (Aurecon, 2016)

Aurecon undertook a geohydrological evaluation as part of an environmental impact assessment for the proposed expansion of the ash dam facility at Kriel Power Station. The study found high pH values due to the influence of the ash disposal facility. Elevated sulphate and sodium were also listed as contaminants of concern in the study. The main source of sulphate in fly ash water was found to be from the demineralisation effluent. Sulphate concentrations were stated to range between 200 – 1000 mg\L.

Tutuka Power Station (Akinyemi, 2011)

The study aimed to provide a comprehensive characterisation of weathered dry disposed ash cores, to reveal mobility patterns of chemical species as a function of depth and age of ash, with a view to assessing the potential environmental impacts. Fifty-nine samples were taken from 3 drilled cores obtained respectively from the 1 year, 8 year and 20-year-old sections of sequentially dumped, weathered, dry disposed ash in an ash dump site at Tutuka Power Station. Results showed older ash cores are enriched in arsenic, boron, chromium, molybdenum and lead were enriched in the residual fraction of older ash cores.

Georgia State - United States of America (EIP, 2018)

The Environmental Integrity Project (EIP) and Earthjustice examined state-wide monitoring data and determined that 92 percent (11 of 12) of Georgia’s coal-fired power plants have contaminated groundwater with one or more toxic pollutants. Ten of the 11 plants had unsafe levels of one or more of the following pollutants:

- Antimony, which causes developmental toxicity (reduced fetal growth) and metabolic toxicity (reduced blood glucose levels). Antimony can also irritate the skin.
- Arsenic, which causes multiple types of cancer, neurological damage, and other health effects.
- Boron, which poses developmental risks to humans, such as low birth weight, and can result in stunted growth and plant toxicity in aquatic ecosystems.
- Cobalt, which harms the heart, blood, thyroid, and other parts of the body.
- Lithium, which presents multiple health risks including neurological impacts.
- Molybdenum, which damages the kidney and liver at high concentrations.

- Radium, which causes cancer and is a radioactive element.
- Selenium, which harms fish and other aquatic organisms at very low concentrations and is bioaccumulative. Selenium can also be toxic to humans.
- Sulphate, which causes diarrhoea, and can be very dangerous to young children.

6.2 MAJUBA GROUNDWATER QUALITY MONITORING PARAMETERS

Chemical constituents analysed during site monitoring by Majuba does not include all contaminants of concern identified from the 2019 waste classification testing (section 5.5), the previous Majuba waste classification study (Advisian, 2019), and other groundwater case studies conducted in South Africa as well as internationally. Additional parameters that should be included in the current Majuba site monitoring include:

- Barium (Advisian (2019) & 2019 waste classification testing);
- Boron (Advisian (2019) & 2019 waste classification testing);
- Molybdenum (Advisian (2019) & 2019 waste classification testing);
- Cadmium (2019 waste classification testing);
- Selenium (2019 waste classification testing); and
- Vanadium (2019 waste classification testing).

7. POTENTIAL IMPACTS FROM ASH DISPOSAL FACILITY

7.1 PREVIOUS PREDICTED GROUNDWATER IMPACTS

7.1.1 Groundwater levels

SLR (2014) anticipated that water table mounding beneath the site and the potential alteration of local groundwater flow directions were the main groundwater related impacts associated with the Majuba ADF. SLR (2014) noted that the mitigate these impacts were to maintain the ash disposal facility in good condition (especially the drainage system, including toe drains and return water facilities) and to ensure that only ash is disposed of on the ADF. SLR (2014) stated that once the ash disposal facility was fully decommissioned, topsoil installation and re-vegetation done during operation should be maintained and consolidated to minimise infiltration and to improve runoff quality, and the drainage system maintained to reduce downward movement of leachate from the base of the ash disposal facility.

7.1.2 Groundwater quality

The main impact on groundwater of the proposed ash disposal facility (or combination of facilities) identified by SLR (2014) was likely to be a reduction in water quality beneath the ADF and alternative site, and in the vicinity of the power station. The SLR (2014) numerical model results suggested that the movement of leachate away from the ash disposal facility as a groundwater plume should take place relatively slowly, with plume extents being generally less than 1 km from the ash disposal facility after 150 years. Furthermore, SLR (2014) also noted that runoff water contaminated by the ash leaking into surface drainage systems has the potential to contaminate groundwater at some distance from the ash disposal facility.

7.1.3 Groundwater impact summary

The cumulative impacts from the ash disposal facility of all three phases (construction, operation and decommissioning) determined by SLR (2014) were summarised as:

- A rise in water table in the vicinity of the site due to increased recharge from stored water within the ash disposal facility and any associated surface water impoundments.
- Deterioration in groundwater quality.

The potential impacts of the proposed ash disposal facility on the local groundwater were also qualitatively assessed by SLR and the nature of the impacts were assessed using a standard significance rating scale. The significance rating for the cumulative impacts from the ash disposal facility with and without mitigation measures were determined by SLR as medium to low ("Impacts on groundwater limited to the site or to the local area, and moderate in nature")) respectively in terms of deterioration of groundwater quality due to leachate from the ADF.

7.2 VERIFICATION OF PREVIOUS GROUNDWATER IMPACTS

The previous hydrogeological study conducted by SLR (2014) was reviewed together with the site information received (as listed in section 3.2) in order to provide an opinion on whether or not previously predicted groundwater impacts will change or not due to additional time used to ash over the same footprint under the ADF exemption area.

Regarding groundwater levels, SLR (2014) concluded that there was a risk that a rise in water table in the vicinity of the site due to increased recharge from stored water within the ash disposal facility and any associated surface water impoundments could occur. The artesian and shallow nature of the ADF boreholes were interpreted by SLR (2014) to be attributed to potential artificial recharge from dam AP01 influencing the groundwater depth in the vicinity of the dam. However, the Palmiet Spruit could also have possibly influenced water levels in these boreholes. SLR (2014) also noted that the influence of pollution control dam AP03 was evident from the artesian condition at AB01.

During the operational, decommissioning and post closure phases the main impact on groundwater that may result from the additional time used to ash over the same footprint under the exemption area is the contamination of the groundwater as a result of seepage from the ADF.

Based on the results from the previous SLR (2014) study and on-site monitoring the following can be concluded related to groundwater quality:

- SLR (2014) noted that local increases in groundwater levels were possibly due to nearby surface water dams. The average groundwater level for the previous monitoring round in September 2019 were 4.3 mbgl. Groundwater levels at the site overall were relatively shallow and ranged between 0.20 mbgl (PB15) and 14.31 mbgl (MJ17-01D) in September 2019. The local groundwater gradient is predominantly towards the north and towards the Palmiet Spruit located between the ADF and power station.
- SLR (2014) found from previous monitoring data that the groundwater quality of the sites on the current ash disposal facility showed signs of contamination. SLR (2014) noted that the pollution indexes strongly suggested that most of the groundwater sites have been impacted upon by the power station and associated infrastructure. With regards to the groundwater quality objectives, the target objective for fluoride (F) was exceeded at most of the groundwater sites in 2012 (even at the background sites). However, the only sites at which the target objective for SO_4, which is the major pollutant associated with the ash and coal, were exceeded at predominantly at the ADF.
- GHT (2013) stated that the sulphate (SO_4) showed an increasing trend since 2002 which indicate a definite impact on the groundwater from the ash water return dam AP01. The concentration of SO_4 in this dam is normally higher than 1000 mg/l.
- It was concluded by GHT (2013) that the permeability of the aquifer in the region below the dam AP01 is extremely low (as the pollutant took 10 years to reach borehole AB26 only a few metres downstream

from the dam). It was also concluded that the influence from the dam were due to spillages or seepage of water from the contact zone of the base of the dam.

- Sulphate concentrations collected during routine monitoring from the ADF monitoring borehole samples ranged between <1 mg/L and 342.5 mg/L (average 39 mg/L) and electrical conductivity ranged between 13 mS/m and 352 mS/m (average 58 mS/m). Contaminants of concern noted, compared to the SANS 241-1:2015 Drinking Water Standard (Edition 2), at the ADF included pH, EC, F, Al, Mn, and As.
- The only contaminants of concern identified during the 2019 hydrocensus investigation (Kimopax, 2019), compared to the SANS 241-1:2015 drinking water standard, included iron in borehole MBH02. Sulphate concentrations from the hydrocensus borehole samples ranged between 5.8 mg/L and 23.8 mg/L and electrical conductivity ranged between 13.3 mS/m and 70.3 mS/m.
- The surface water quality results are consistent with conclusions made by GHT (2013) that surface water quality was negatively impacted as most indicator elements exceed the relevant guideline target limits. Sulphate concentrations between 2014 to 2019 from surface water site samples ranged between <1 mg/L and 4 149 mg/L (average 495 mg/L) and electrical conductivity ranged between 11 mS/m and 494 mS/m (average 157 mS/m). The surface water monitoring points (PSR01 – PSR07) for the Palmiet Spruit, located between the power station and the ADF, showed signs of increased sulphate concentrations. PSR01, PSR02, and PSR03 located upstream generally had relatively low sulphate concentrations below the SANS 241-1:2015 acute health limit. The remaining monitoring points, located downstream of the ADF, had elevated sulphate concentrations generally above the SANS 241-1:2015 acute health limit, with PSR06 recording sulphate concentrations in excess of 3 000 mg/L in 2003. The sulphate concentrations in the Palmiet Spruit monitoring points downstream of the ADF were much higher than concentrations measured in the monitoring boreholes downstream of the ADF.

Numerical groundwater modelling results from the SLR (2014) study were used to qualitatively estimate the potential zone of influence from the extension of the exemption time period. The numerical model results suggest that the movement of leachate away from the ash disposal facility as a groundwater plume should take place relatively slowly, with plume extents being generally between 750 metres and 1 250 metres from the ash disposal facility after ~150 years. The potential influence zones are illustrated in Figure 7-1. Boreholes which could potentially be influenced and currently being used for domestic and livestock watering purposes (as reported during the Kimopax (2019) hydrocensus investigation) include:

- FBB48 – livestock watering
- FBB50 – livestock watering
- FBB51 – livestock watering
- MBH03 – livestock watering
- MBH04 – domestic (drinking water)

The available data in the previous hydrogeological study conducted by SLR (2014) together with the site information received (as listed in section 3.2) are not sufficient to enable SLR to quantitatively determine the groundwater impacts that may result from the additional time used to ash over the same footprint under the ADF exemption area. Additional geochemical and hydrogeological work is recommended to be performed before SLR can determine the final changes in potential groundwater impacts and affected areas due to the additional time used to ash. The additional work is described in section 8.

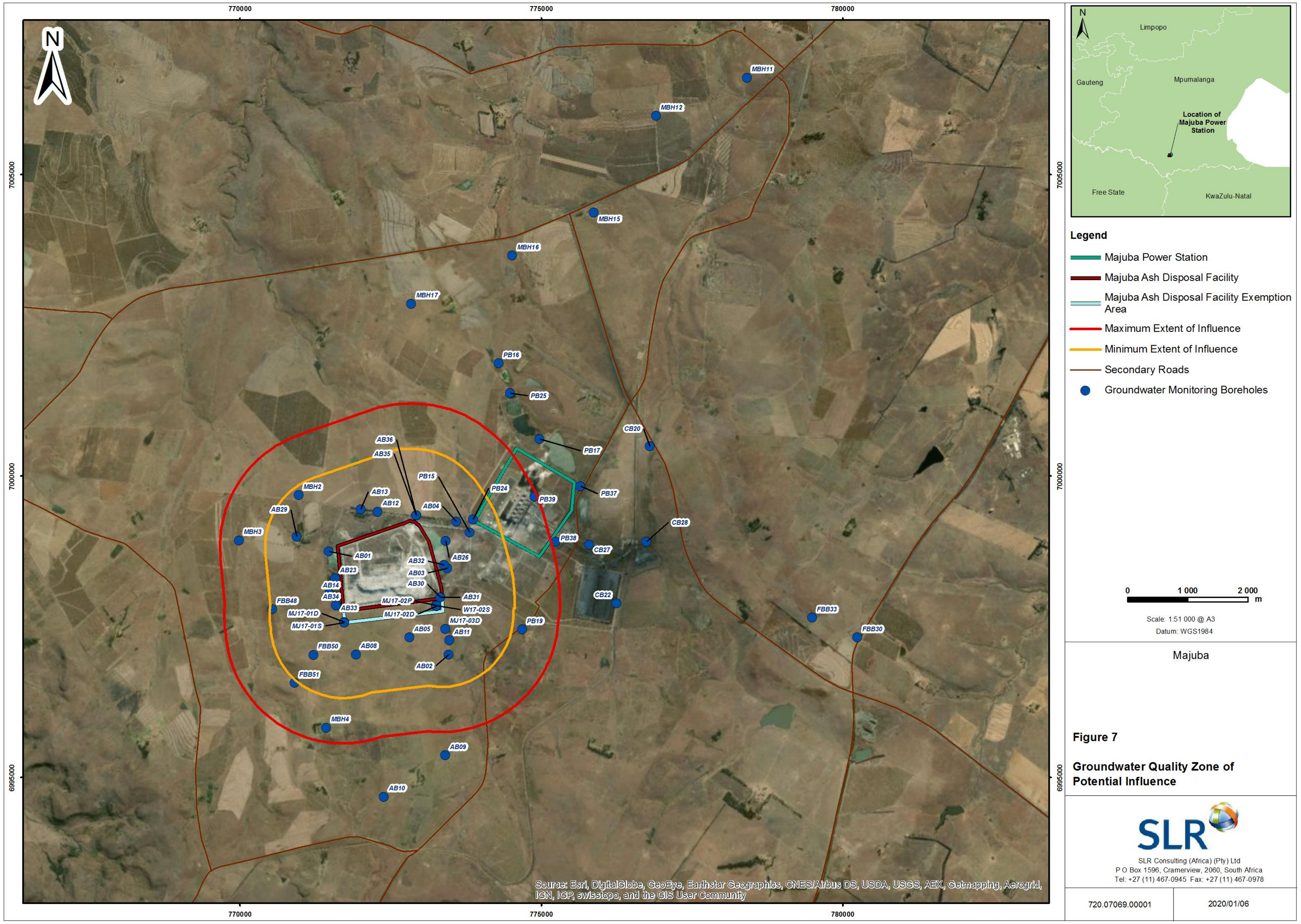


Figure 7-1: Potential minimum and maximum influence zone on groundwater quality from the Majuba Power Station ADF and exemption area.

8. RECOMMENDATIONS

The groundwater impacts determined by SLR (2014) will remain in terms of groundwater levels and quality. Should the site require to better characterise and predict the changes to future groundwater quality due to the use of the current ash dump facility and the extension area, SLR recommends that the site consider conducting additional hydrological and hydrogeological work in future. The additional work is not required for the purposes of this opinion study, but will enable the site to better characterise and predict the future changes to groundwater quality due to the use of the current ash dump facility and the extension area. Additional recommended geochemical, hydrogeological, and hydrological work are discussed in more detail below.

8.1 GROUNDWATER MONITORING

Continuous groundwater monitoring is recommended in order to quantify ongoing impacts and provide early warning of any potential contamination. Chemical constituents analysed during site monitoring by GHT Consulting Scientists and Kimopax did not include all contaminants of concern identified from other groundwater case studies, conducted in South Africa as well as internationally, that may potentially be present in leachate emanating from similar ash disposal facilities.

SLR recommends that the site consider the inclusion of pH, EC, total alkalinity, chloride, sulphate, nitrate, ammonium, orthophosphate, fluoride, calcium, magnesium, sodium, potassium, aluminium, arsenic, selenium, iron, manganese, cobalt, nickel, and total hardness to future quarterly groundwater quality monitoring analyses. Parameters should ideally include any metals identified from future geochemical assessments that may potentially leach out from the ash material. The annual analysis should include the proposed quarterly parameters as well as the following parameters: antimony, barium, boron, cadmium, chromium (total), chromium VI, cobalt, lead, lithium, mercury, molybdenum, radium, vanadium, zinc. These parameters should be reviewed during the annual site monitoring phase.

A groundwater monitoring database should be created and updated with all available historic data and as new information becomes available. It is recommended that the data is stored in a dedicated database and that quarterly and annual reports are generated for the site's environmental management.

8.2 GEOCHEMICAL ASSESSMENT

Source term quantification is required to assess the level of existing and future contaminants and their contribution to the development of a contaminant plume. Figure 8-1 shows the components of the source term and data requirements.

The site should consider conducting a geochemical assessment in future and to analyse at least 10 (ten) geochemical samples from the ash material. The samples should be submitted to a SANAS accredited laboratory. The following tests should be performed to characterise the ash material and determine the expected elements that may pose a risk to groundwater quality:

- Whole rock/sample analyses;
    - X-ray diffraction (XRD);
    - X-ray fluorescence (XRF) of major oxides;
    - Acid digestion with ICP on trace elements;
- Acid-mine drainage potential;
    - Acid-base accounting - paste pH, total %S and neutralisation potential (ASTM E1915-11);
    - Sulphur speciation (ASTM E1915-11);
    - Net acid generation (NAG) test (ASTM E1915-11);

- Leach tests;
    - Peroxide water extraction 1:4 and 1:20 ratio (250g sample 1L water; 18h) * (similar to ASTM D3987-06); and

    **The following analyses should be performed on the leachate: pH, EC, Total Alkalinity, Cl, NO3, NH4, SO4, F as well as ICP which should include at least the following: Ca, Mg, Na, K, Si, Al, Fe, Mn, As, Ba, Be, Bi, Cd, Co, Cr, Cu, Li, Mo, Ni, Pb, Sb, Se, Sn, Sr, Ti, U, V, W, Zn.*
- Ten (10) week humidity cell leach test (ASTM D5744-07) should be conducted and should be used to calibrate the geochemical models. Kinetic column leaching tests indicate the chemicals that will leach out from the rock material over time as well as the oxidation rate of the sulphide minerals in the material if no interference is present from secondary sulphate minerals.

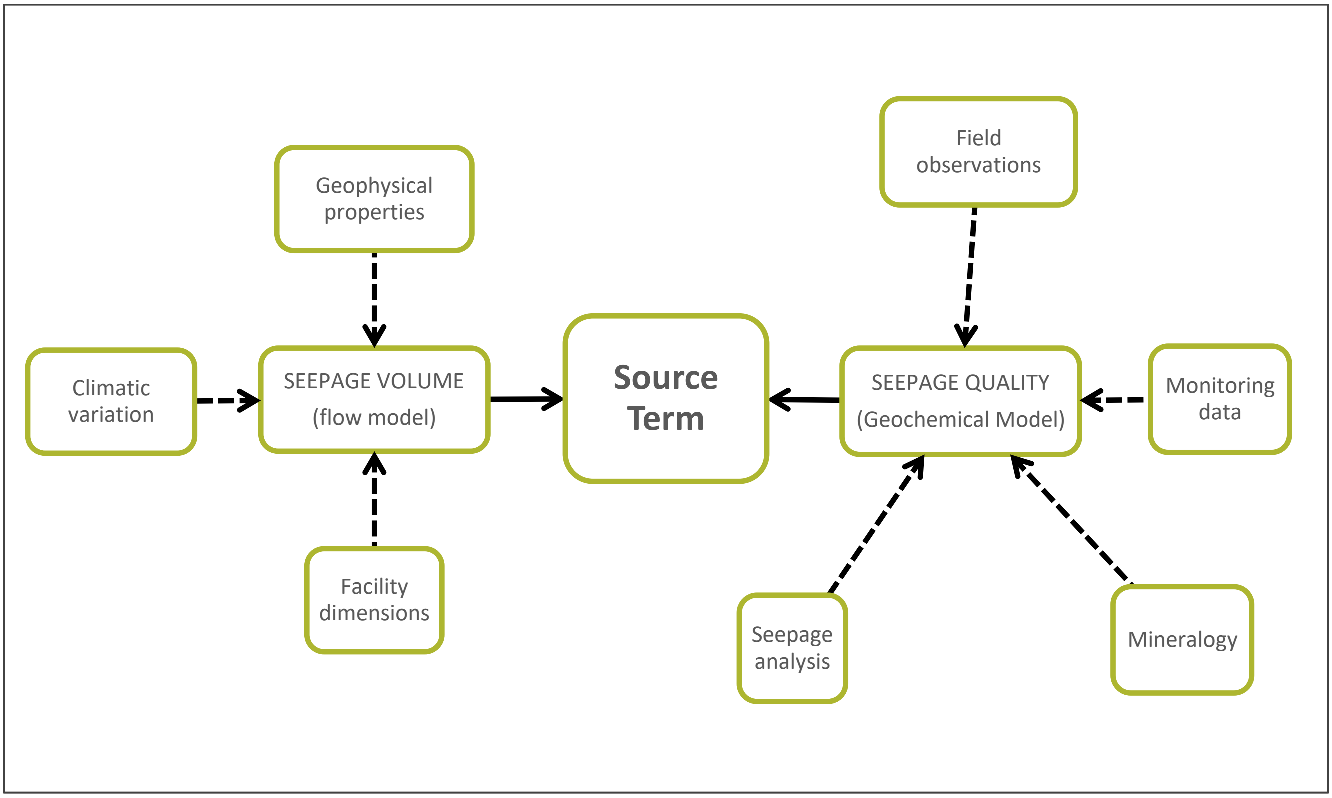


Figure 8-1: Data requirements and geochemical modelling process.

The test results should be screened in order to determine the long-term acid generation potential of the samples, the expected elements that may be present at elevated concentrations in the ADF seepage, and to prepare input for the geochemical model.

Laboratory test work should be followed by geochemical modelling to provide a quantitative estimate of the expected ash water quality. Laboratory test data cannot be used directly to represent field conditions. The actual water-rock ratio, oxidation rate and chemical residence times can only be incorporated into a numerical geochemical model. Several of these factors depend also on the geometry of the ADF, its interaction with the atmosphere (oxidation) and the ADF water balance.

The following should be evaluated during geochemical modelling:

- The oxygen diffusion into the residue waste should be modelled.

- Geochemical reaction modelling should be performed in order to determine the actual ADF seepage water that will be expected.
- Equilibrium and mineral kinetic modelling should be performed.

Contaminants of concern identified from the geochemical assessment should be included into the groundwater monitoring network.

8.3 UPDATED CONCEPTUAL AND NUMERICAL GROUNDWATER FLOW AND TRANSPORT MODELLING

A high-level desktop study should be completed for the site prior to the conceptual and numerical model update, during which previous consultant reports as supplied by the client, as well as public domain data that is available for the site area will be analysed. Based on all compiled and reviewed data a gap analysis should be carried out to identify critical gaps in the available information. Based on the gap analysis recommendations for additional data collection and analysis should be provided, including any fieldwork and laboratory analyses that may need to be performed.

Updated site and monitoring data should be reviewed and integrated to construct an updated conceptual and numerical groundwater model for the ADF and whole site that describe and quantify aquifers, groundwater flow, boundary conditions and contaminant transport.

Groundwater modelling tools will also be employed in quantifying potential impacts. Risks to be investigated include:

- Groundwater contamination risk posed by the ADF seepage;
- Influence of the position of the site infrastructure (including dirty and clean water dams) on contaminant risk; and
- Post-closure groundwater scenarios.

8.4 UPDATED GROUNDWATER IMPACT ASSESSMENT

The potential groundwater impacts for the additional time used to ash should be quantified based on the results of updated site information, the geochemical assessment, and the numerical groundwater flow and contaminant transport modelling. A significance rating should be used to class the impacts.

Groundwater management measures should be formulated based on the results of the above impact assessment. Such management measures should be discussed with the environmental project team and client. The Majuba groundwater monitoring programme should be reviewed and recommendations to potential changes should be formulated as part of a site water management plan.

9. CONCLUSIONS

The existing ADF exemption period from installing the required liner (a Class-C liner) lapses in June 2020 and Eskom is required to apply for an extension of the exemption period, without extending the area under the exemption.

SLR conducted a desktop study level hydrogeological assessment in order to provide a specialist groundwater opinion relating to the application by GGES to extend the exemption period for the Majuba ash dump facility (ADF).

The cumulative impacts from the ash disposal facility of all three phases (construction, operation and decommissioning) determined by SLR (2014) were summarised as:

- A rise in water table in the vicinity of the site due to increased recharge from stored water within the ash disposal facility and any associated surface water impoundments.
- Deterioration in groundwater quality within a contained zone of influence.

It can be concluded that, an extension in the duration of ashing within the exemption area will not change the groundwater impacts determined by SLR (2014), i.e. the 2014 identified impacts will remain valid in terms of groundwater levels and quality.

Majuba must continue with the monitoring programme, and the following 3rd party boreholes must be included in the monitoring plan:

- FBB48 – livestock watering
- FBB50 – livestock watering
- FBB51 – livestock watering
- MBH03 – livestock watering
- MBH04 – domestic (drinking water)

Raymond Minnaar
(Report Author)

Mihai Muresan
(Project Manager)

Mihai Muresan
(Reviewer)

10.REFERENCES

Advisian. 2019. Proposed Upgrade of Two Existing Ash Dams and the Construction of Two Rehabilitation Dams at the Majuba Power Station's Ash Disposal Facility. Draft Scoping Report. January 2019.

Barnard. 2000. Department of Water Affairs and Forestry, South Africa, 2000: An Explanation of the 1:500 000 General Hydrogeological Map – Johannesburg 2526. Government Printers Pretoria.

De Oliveira, D.P.S. and Cawthorn, R.G. 1999. Dolerite intrusion morphology at Majuba Colliery, northeast Karoo Basin, Republic of South Africa. International Journal of Coal Geology, vol. 41, no. 4. pp. 333-349.

Johnson MR, Van Vuuren CJ, Visser JNJ, Cole DI, de Wickens HV, Christie ADM, Roberts DL, Brandl G. Sedimentary rocks of the Karoo supergroup. In: Johnson MR, Anhaeusser CR, Thomas RJ, editors. The geology of South Africa. Pretoria, Johannesburg: Geol Soc S Afr, Council for Geoscience; 2006. p. 461–99.

Kimopax. 2019. Hydrocensus study at the Eskom Majuba Power Station Mpumalanga. July 2019. PRJ_R_1/Rev0.

Mokhahlane, L. 2018. Determination of acid rock drainage from underground coal gasification at a pilot plant in Majuba. In: Wolkersdorfer, Ch.; Sartz, L.; Weber, A.; Burgess, J.; Tremblay, G. (eds.) 11th ICARD IMWA MWD Conference – "Risk to Opportunity".

Parsons, R., and Conrad, J. (1998). Explanatory notes for the aquifer classification map of South Africa. WRC Report No KV 116/98, Water Research Commission, Gezina, Pretoria.

SLR. 2012. SLR Consulting (Africa) (Pty) Majuba Ash Dump Extension Groundwater Screening Study – SLR Project No.: 721.23003.00010 – October 2012.

SLR. 2014. SLR Consulting (Africa) (Pty) Proposed Continuous Disposal of Ash at the Majuba Power Station – Groundwater Specialist Study EIA Phase – SLR Project No.: 721.23003.00010 – May 2014.

AFRICAN OFFICES

South Africa

CAPE TOWN
T: +27 21 461 1118

FOURWAYS
T: +27 11 467 0945

SOMERSET WEST
T: +27 21 851 3348

Namibia

WINDHOEK
T: + 264 61 231 287

Issued By

Raymond Minnaar