

HYDROGEOLOGY ASSESSMENT FOR THE PROPOSED ACID MINE DRAINAGE TREATMENT AT THE BALLENGEICH COLLIERY, IN KWAZULU-NATAL

22 April 2025

COMPILED FOR

M² Environmental Connections (Pty) Ltd

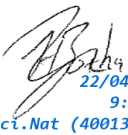


Directors: DuToit Wilken; Hendrik Botha
Registration Number: 2024/085036/07
email: henri@elemental-s.co.za
contact: +27 84 588 2322 / +27 71 102 3819
web: www.elemental-s.co.za

Gauteng Province Office
460 The Wishbone North
Lynnwood
Pretoria
0081

Free State Province Office
23 Roggeveld Street
Roodia
Sasolburg
1947

REPORT DETAILS

Report Title	Hydrogeology Assessment for the Proposed Acid Mine Drainage Treatment at the Ballengeich Colliery, in KwaZulu-Natal	
Client	M ² Environmental Connections (Pty) Ltd	
Report Number	EWS24-12_GW	
Report Revision	Final 1	
Date of Report	21 Apr. 25	
Author	Hendrik Botha MSc. Pr.Sci.Nat (400139/17) Elemental Water Services Proprietary Limited Head – Elemental Water Services 071 102 3819 henri@elemental-s.co.za	 22/04/2025 9:44:26 Pr.Sci.Nat (400139/17)
Reviewer	Lisa Botha BSc. Hons. Elemental Water Services Proprietary Limited +27 61 205 0203 lisa@elemental-s.co.za	

REPORT VERSION HISTORY

Final	22 April 2025
--------------	---------------

EXECUTIVE SUMMARY

Elemental Water Services Proprietary Limited (EWS) was appointed by M2 Environmental Connections (Pty) Ltd (MENCO) to undertake this hydrogeology assessment for the proposed Acid Mine Drainage (AMD) Treatment at the Ballengeich Colliery In KwaZulu-Natal.

The Ballengeich operation is located approximately 15 km south of Newcastle and consists of a historic open cast pit, discard dump, underground mine workings, adits and shafts, pollution control dams and infrastructure. The adits and shafts have been sealed, and sections of the open-cast mine have been backfilled and rehabilitated. The Ballengeich operation is currently not operational. The historic mining rights area falls within the farm Ballengeich Ptn. 19 - Sub 1 of Ballengeich 3299. The colliery falls within the upper catchment of the Horn River, which subsequently drains into the Ngagane River.

Ballengeich Siding needs water treatment technology following a DWS Directive. Kangra has inherited a settling pond system (7 ponds) that is seeping into the Horn River. Passive and self-sustainable treatment options are preferred. The settling ponds are subject to liner systems, but the feasibility is arguable. Kangra is looking for the Best Environmental Options to deal with the pollution problem.

The source control principle was used to determine the layout of the AMD treatment, and this is to ensure that the effluent is treated before it gets into the Rivers. The main pollution sources are (Bhekhani Pty Ltd, 2023):

1. Old underground workings decanting effluent water into the Horn River
2. Effluent discharge into the West decant sump and seepage from the old Horn River into the Ngagane and Horn River.

For Ballengeich, the passive treatment of AMD is proposed, consisting of anoxic limestone drains (ALD), successive alkalinity-producing systems (SAPS), oxidation ponds and aerobic wetlands.

This hydrogeology assessment was compiled to evaluate the existing and predicted future hydrogeological environments and groundwater risk associated with the proposed Project. This report is intended to supplement the Water Use License Application (WULA) for the water uses triggered by the proposed Project.

This hydrogeology study found that The Ballengeich surface operations are situated within quaternary catchment W31G, with the old underground workings extending into V31F and V31K of the Mtamvuna-Pongola Water Management Area. The MAP of the site is in the order of 739 mm/yr, MAE is in the order of 1200 mm/yr, and MAR is in the order of 104 mm/yr.

15 boreholes were identified during the field hydrocensus, of which 2 are used for domestic water supply, 1 is used for the decant management at Ballengeich, and the remaining are used for groundwater monitoring. The water level was observed to vary from artesian (decant area) to an average of 5.7 metres below ground level (mbgl).

Available hydrogeology data suggests that three (3) aquifers exist in the area:

-  An unconfined aquifer associated with the unconsolidated sands along the Horn River & Ingagane River, particularly in floodplain areas.
-  A shallower aquifer system is associated with weathered to partly consolidated sedimentary rock as well as moderately to partially weathered sandstone and shale of the Ecca Group.
-  A deeper confined fractured aquifer network associated with the Dwyka Group Tillite of the Karoo Sequence.

Historical underground workings have likely led to the formation of a hydrogeological unit in the mines that have undergone coal extraction. Significantly higher hydraulic conductivity and storage values are expected for the aquifer due to the presence of mine voids or backfilled material with higher permeability than surrounding sediment/rock. The flooded underground workings are believed to be in a pseudo-steady state and decanting near the Horn River.

From available literature data, the weathered zone for the area is estimated to be in the order of 5 - 28 m thick, followed by a subsequent thicker intergranular & fractured aquifer zone. The groundwater levels for the Ballengeich colliery range from artesian (decant area) to an average of 5.7 metres below ground level (mbgl). Groundwater is found within mined-out voids (underground workings beneath the regional water table), the weathered zone (perched), as well as fractures and bedrock contacts, contacts between lithologies or at unconformities and dolerite/diabase dyke contacts. The groundwater table mimics the topography, and groundwater flows from high-lying areas (water divides) to low-lying areas.

The main source of groundwater recharge is rainfall. The rainfall infiltrates into the ground to become groundwater through the Vadose Zone. The water then moves both vertically and horizontally in the weathered zone. Greater interflow is expected in a horizontal direction within the weathered zone matrix. Water flowing horizontally in the soil and the weathered zone may enter the surface water streams/rivers if hydraulically connected (i.e. gaining rivers/streams). Available data does suggest that the portion of the Ingagane and Horn Rivers bordering the site may be a losing river. Water that makes it through the weathered zone slowly percolates and recharges the deeper intergranular and fractured aquifers, with much lower permeabilities and storage potential.

The groundwater at the Ballengeich Mine can be classified as Na-Cl (GW16), Ca-HCO₃ (UGBH5) and Ca-SO₄ (GW12, GW6, GW1). These are typical attributes of fresh shallow groundwater, deep ancient groundwaters, and groundwater impacted by mine drainage. Surface water can be classified as water influenced by active ion exchange.

A groundwater flow and transport model was developed for the Site.

- ✚ The flow model suggests that the groundwater table mimics the topography. Groundwater flow is towards the south and west, towards the perennial river systems/topography lows. The flow model indicates groundwater flow velocities ranging from 0.001 (min) to 0.38 (max) m/day. The above suggests that groundwater is very slow-moving in the study area.
- ✚ The transport model suggests that the plumes remain in close proximity to the point sources at the site, with a concentration gradient from 4000 mg/l to 50mg/l towards the Ingagane River and higher SO₄ concentration gradient towards the Horn River ranging from 4000 to 1000 mg/l.

The Horn and Ingagane Rivers exhibit attributes relating to losing rivers. This means that the groundwater plumes are likely going underneath the river systems, and the baseflow to the rivers is marginal. If baseflow had been higher, an immediate impact on surface water quality would have been observed.

Two (2) stream profiles were completed for the Horn and Ingagane Rivers and are discussed in Section 7.6.2. A definite increase in EC and decrease in pH is observed at NH12 to NH7 (at the N11 bridge), which are downstream of the known decant area. The remainder of the Horn River shows little impact, with a decrease in EC as a result of the artificial wetland and phytoremediation. The pH and EC for the Ingagane River show marginal changes from upstream to downstream relative to the discard dump. A marginal impact is observed.

A hydrogeological risk assessment is available in Section 8, where site-specific and regional cumulative impacts have been assessed. Groundwater management and monitoring aspects have been addressed and are available in Sections 9 and 10.

No alternatives are available, and the proposed treatment system must be placed in the pre-defined areas in order to ensure optimum efficiency of the treatment of AMD. No hydrogeological buffers or offsets were identified. Based on the findings of this assessment, EWS believes that the proposed activities are to benefit the receiving groundwater and surface water environments. The approval of the activity should be considered to enable Kangra to mitigate the impacts associated with the Legacy Ballengeich Mine.

APPENDIX 6 OF THE EIA REGULATION – CHECKLIST AND REFERENCE FOR THIS REPORT

Requirements from Appendix 6 of GN 326 EIA Regulation 2017	Chapter
(a) Details of: (i) The specialist who prepares the reports; and (ii) the expertise of that specialist to compile a specialist report, including a curriculum vitae	Appendix F.
(b) Declaration that the specialist is independent in a form as may be specialities by the competent authority	Appendix F.
(c) Indication of the scope of, and purpose for which, the report was prepared	Section 1.
(cA) Indication of the quality and age of base data used for the specialist report	Sections 1, 2 and 3.
(cB) A description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change	Section 6.
(d) Duration, Date and seasons of the site investigation and the relevance of the season to the outcome of the assessment	Section 1.4.
(e) Description of the methodology adopted in preparing the report or carrying out the specialised process, including equipment and modelling used	Section 2.
(f) Details of an assessment of the specifically identified sensitivity of the site related to the proposed activity or activities and its associate's structures and infrastructure, inclusive of a site plan identifying alternative	Sections 1, 4 and 5.
(g) Identification of any areas to be avoided, including buffers	Section 6.4 and 11
(h) Map superimposing the activity and associated structures and infrastructure on environmental sensitivities of the site, including areas to be avoided, including buffers	Section 1, 3.
(i) Description of any assumptions made and uncertainties or gaps in knowledge	Sections 2, 4, and 5.
(j) A description of the findings and potential implications of such findings on the impact of the proposed activity, including identified alternatives on the environment or activities	Sections 8, 9 & 11
(k) Mitigation measures for inclusion in the EMPr	Section 11.2
(l) Conditions for inclusion in the environmental authorisation	Refer to Section 11
(m) Monitoring requirements for inclusion in the EMPr or environmental authorisation	Refer to Section 11
(n) Reasoned opinion – (i) as to whether the proposed activity, activities or portions thereof should be authorised. (a) regarding the acceptability of the proposed activity or activities and (ii) if the opinion is that the proposed activity, activities, or portions thereof should be authorised, and avoidance, management, and mitigation measures should be included in the EMPr, and where applicable, the closure plan	Section 10.2
(o) Description of any consultation process that was undertaken during preparing the specialist report	None required.
(p) A summary and copies of any comments received during any consultation process and, where applicable, all responses thereto	None required.
(q) Any other information requested by the competent authority	None required.

CONTENTS PAGE

REPORT DETAILS	2
Report Version History	2
EXECUTIVE SUMMARY	3
APPENDIX 6 OF THE EIA REGULATION – CHECKLIST AND REFERENCE FOR THIS REPORT	6
CONTENTS PAGE	7
List of Figures	9
List of Tables	10
List of Appendices	10
DETAILS OF AUTHOR	12
CONFIDENTIALITY	12
COPYRIGHT OF ELEMENTAL WATER SERVICES Propriety Limited – ALL RIGHTS RESERVED	12
DECLARATION OF INDEPENDENCE	12
General List Of Acronyms	14
list of KEY Definitions	16
1 Introduction	17
1.1 Project Background	17
1.1.1 Treatment of Old UG Workings	18
1.1.2 Treatment of Effluent from West Decant Sump	18
1.1.3 Anoxic Limestone drain (ALD)	19
1.1.4 Successive Alkaline Producing System (SAPS)	21
1.1.5 Sedimentation/Oxidation Pond	21
1.1.6 Aerobic wetland	22
1.1.7 Predicted impact on water quality of the treatment system proposed	22
1.2 Objectives	25
1.3 Study relevance to the season in which it was undertaken	25
1.4 The layout of this report	26
2 Scope of work	26
3 Area of investigation	28
3.1 Sub-catchments / groundwater resource units (GW HRU)	28
3.2 Climate	32
3.3 Rainfall and evaporation	32
3.4 Run-off	35
3.5 Climate change considerations	37
4 Methodology & approach	39
4.1 Hydrological overview	40
4.2 Catchment description and delineation	41
4.3 Literature review and desktop study	41
4.4 Groundwater and surface water users in the project area	42
4.5 Field investigation data	42
4.5.1 Field Hydrocensus	42
4.5.2 Slug testing/falling head tests	51
4.5.3 Geophysical Investigation	51
4.6 Groundwater recharge calculations	53
4.7 Groundwater quantity/availability assessment	53
4.8 Numerical model development	54
4.9 Model confidence level classification	56
4.10 Hydrogeological risk assessment	56

4.11	Water monitoring improvement plan & audit.....	59
5	Prevailing groundwater conditions.....	60
5.1	Local geology & soils	60
5.2	Structural geology.....	60
5.3	Geochemical overview	61
5.4	Hydrogeology and aquifer units	61
5.5	Preferential flow paths.....	62
5.6	Primary groundwater occurrence	63
5.7	Groundwater recharge	63
5.8	Aquifer yield & hydraulic conductivity	64
5.9	Aquifer storage/storativity	65
5.10	Groundwater levels.....	65
5.11	Groundwater velocities and flow rates	66
5.12	Aquifer classification	67
5.13	Aquifer contextualization and extent	67
5.14	Wetland areas.....	71
5.15	Present ecological state (PES), ecological importance and sensitivity (EIS), Ecological Water Reserve (EWR) and recommended ecological category (REC)	72
5.16	Groundwater quantity assessment.....	73
5.16.1	Groundwater balance	74
5.17	Hydrochemistry.....	75
5.17.1	Hydrocensus sample data	75
5.17.2	Monitoring network hydrochemistry	79
6	Conceptual hydrogeological model	86
6.1	Receivers in the local area	87
7	Numerical groundwater model	87
7.1	Model uncertainties and limitations	88
7.2	Model time	89
7.3	Model conceptualisation	89
7.4	Model sensitivity	93
7.5	Model calibration	95
7.6	Model outputs	97
7.6.1	Calibrated flow model 2025	97
7.6.2	Simulated 2025 sulphate plume and ZOlp	98
8	Hydrogeological impact assessment.....	103
8.1	Preparation phase	103
8.2	Operational Phase	104
8.3	Offsets and alternatives	104
8.4	Cumulative impacts on the groundwater reserve	105
8.4.1	Scale of abstraction.....	105
8.4.2	Water quantity stress index	105
9	Groundwater management.....	108
9.1	Monitoring	108
9.2	Groundwater closure objectives.....	109
10	Groundwater monitoring	109
11	Conclusions.....	112
11.1	Recommendations	114
11.2	Identification of any areas that should be avoided	114
11.3	Reasoned opinion on whether EA/WULA should be considered	114
12	Bibliography	115

LIST OF FIGURES

Figure 1-1:	Passive treatment system proposed (Bhekhani Pty Ltd, 2023)	17
Figure 1-2:	Area with underground workings to receive full treatment train (Bhekhani Pty Ltd, 2023)	18
Figure 1-3:	West Decant Sump area to be treated with ALD and cut off Aerobic Wetland along Horn River boundary	19
Figure 1-4:	Typical section of Anoxic Limestone drainage system	20
Figure 1-5:	Site layout	24
Figure 3-1:	Typical cross section of surface topography (30m DTM based)	28
Figure 3-2:	Topography and drainage	29
Figure 3-3:	Sub-catchments & land cover types	30
Figure 3-4:	Sub-catchments & slope rise %	31
Figure 3-5:	Average yearly temperatures (Meteoblue, 2025)	32
Figure 3-6:	Average rainfall for Station 0370834W & WR2012 evaporation	33
Figure 3-7:	CHIRPS rainfall data for the site (2010 to 2024)	34
Figure 3-8:	CHIRPS daily data for the site (2010 to 2024)	34
Figure 3-9:	Simulated run-off distribution for V31G	35
Figure 3-10:	Simulated run-off distribution for V31F	36
Figure 3-11:	Simulated run-off distribution for V31K	36
Figure 3-12:	Yearly Temperature Change (Meteoblue, 2025)	37
Figure 3-13:	Yearly Precipitation Change (Meteoblue, 2025))	38
Figure 3-14:	Monthly Anomalies of Temperature and Precipitation (Meteoblue, 2025))	38
Figure 4-1:	Fieldwork, proposed drilling positions and hydrocensus boreholes identified in the project area	52
Figure 4-2:	Numerical groundwater modelling process	55
Figure 4-3:	Monitoring Process	59
Figure 5-1:	Groundwater elevation vs topographic elevation – correlation	66
Figure 5-2:	Local surface geology	68
Figure 5-3:	Local hydrogeological setting	69
Figure 5-4:	Bayesian estimation of groundwater table, groundwater sphere of influence and CSM	70
Figure 5-5:	Wetland areas identified by MENCO (2022)	71
Figure 5-6:	Groundwater baseflow concept	72
Figure 5-7:	Groundwater reserve overview (DWS, 2025) – V31K	73
Figure 5-8:	Groundwater reserve overview (DWS, 2025) – V31F	74
Figure 5-9:	Groundwater reserve overview (DWS, 2025) – V31G	74
Figure 5-10:	Field hydrocensus hydrochemistry – Piper plot	77
Figure 5-11:	Ballengeich groundwater level graph	79
Figure 5-12:	Ballengeich groundwater pH graph	80
Figure 5-13:	Ballengeich groundwater sulphate graph	81
Figure 5-14:	Ballengeich surface water sulphate graph for the monthly monitoring points	82
Figure 5-15:	Ballengeich surface water pH graph for the quarterly monitoring points	83
Figure 5-16:	Ballengeich surface water sulphate graph for the quarterly monitoring points	84
Figure 5-17:	Groundwater and surface water monitoring network	85
Figure 6-1:	Conceptual hydrogeology cross-section	86
Figure 7-1:	Model grid & property zones	91
Figure 7-2:	Model boundary conditions	92
Figure 7-3:	PEST run simulation histogram	94
Figure 7-4:	Model sensitivity (Jacobian matrix)	94
Figure 7-5:	Calibrated steady-state model	95
Figure 7-6:	Calibrated transient-state model (the year 2025)	96
Figure 7-7:	Calibrated transport model (2025)	97

Figure 7-8:	River profile upstream to downstream in the Horn River.....	98
Figure 7-9:	River profile upstream to downstream in the Ingagane Reiver, up to the confluence area downstream of the discard dump.....	99
Figure 7-10:	Calibrated flow model	100
Figure 7-11:	Simulated sulphate plume as of 2025.....	101
Figure 7-12:	Stream profiles for the Ingagane and Horn Rivers	102
Figure 10-1:	Proposed additional groundwater monitoring points	111

LIST OF TABLES

Table 1-1:	Assimilated capacity for Ngagane River (MENCO, 2022).....	23
Table 1-2:	Assimilated capacity for Horn River inclusive of decant (MENCO, 2022).....	23
Table 3-1:	Summary of GW HRU attributes	28
Table 3-2:	Summary of MAP recorded at nearest rainfall stations.....	32
Table 4-1:	Project methodology flow diagram.....	40
Table 4-2:	Boreholes identified within a 5km radius of the site	42
Table 4-3:	WARMS users within the GW HRU	42
Table 4-4:	Summary of field hydrocensus boreholes	43
Table 4-5:	Summary of slug test results	51
Table 4-6:	Borehole locations targeted from geophysical survey	51
Table 4-7:	Proposed Criteria and Rating Scales to be used in the Assessment of the Potential Impacts	57
Table 4-8:	Explanation of Assessment Criteria.....	58
Table 5-1:	Summary of SCS soil type hydrological characteristics (Muthu, 2015).....	60
Table 5-2:	RECHARGE Program (Van Tonder & Yongxin Xu, 2000)	63
Table 5-3:	Summary of slug test data for Ballengeich.....	64
Table 5-4:	Summary of other boreholes tested at neighbouring mines.....	64
Table 5-5:	Hydraulic gradient calculation	67
Table 5-6:	Flow velocity calculation	67
Table 5-7:	Summary of PES, EIS and EWR	72
Table 5-8:	Summarised Quaternary Catchment Information.....	73
Table 5-9:	Groundwater reserve determination.....	75
Table 5-10:	Summary of field hydrocensus water quality data.....	78
Table 7-1:	Water recharge characteristics for opencast mining	88
Table 7-2:	Numerical model time	89
Table 7-3:	Numerical modal constructs and initial conditions.....	89
Table 8-1:	Risk rating scale	103
Table 8-2:	The estimated scale of abstraction	105
Table 8-3:	Level of the stress of proposed abstraction	105
Table 8-4:	Impacts during the preparation phase.....	106
Table 8-5:	Impacts during the closure operational & decommissioning phase	107
Table 10-1:	Proposed additional groundwater boreholes.....	109

LIST OF APPENDICES

Appendix A:	Slug Test Data	117
Appendix B:	Geophysical investigation data	123
	Magnetic Investigation Methodology.....	123
	Electrical Resistivity Tomography Methodology	123
	Mag Line 1	125
	Mag Line 2	127
	Mag Line 3	128
Appendix C:	Laboratory Certificates.....	129

Appendix D:	Numerical groundwater flow and transport model confidence	133
Appendix E:	Disclaimer	135
Appendix F:	CV of Specialist	136

DETAILS OF AUTHOR

Mr Hendrik Botha

MSc Environmental Science – Geohydrology and Geochemistry (Pr.Sci.Nat.)

Hendrik (Henri) Botha is a Principal Hydrogeologist with over twelve (12) years of experience. He holds a BSc Hons. Degree in Hydrology and an MSc in Environmental Science in Geohydrology and Geochemistry. A registered SACNASP Professional Natural Scientist (400139/17) in the Earth Science Field, Henri is also a member of the Groundwater Division of GSSA, GAKZN and IMWA. Henri's expertise includes groundwater, geochemistry and surface hydrology, as well as knowledge of water chemistry together with GIS and analytical and numerical modelling skills. General and applied logical knowledge are his key elements in problem-solving. Henri has a long-standing relationship with multiple clients in the mining and private sector and has completed various specialist hydrogeology and hydrology studies in South Africa, Nigeria, Namibia, Liberia, Malawi and Botswana.

CONFIDENTIALITY

The contents of this Report are of a confidential nature and intended for M² Environmental Connections (Pty) Ltd (hereinafter referred to as the Client or "MENCO"), permitting authorities, if applicable, and South African law. Any unauthorised use, alteration, or dissemination of the contents of this Report is strictly prohibited. The protection of the information in this Report is awarded in terms of the *Promotion of Access to Information Act, 2002 (Act No. 2 of 2002)* and without limiting this claim, especially the protection afforded by Chapter 4 of the Act.

COPYRIGHT OF ELEMENTAL WATER SERVICES PROPRIETY LIMITED – ALL RIGHTS RESERVED

This document contains information proprietary to Elemental Water Services Proprietary Limited (2024/085036/07) and, as such, should be treated as confidential unless specifically identified as a public document by law. Elemental Water Services Proprietary Limited owns all copyright and all other intellectual property rights in this Report. The document may not be copied, reproduced in whole or in part, or used in any manner without prior written consent from Elemental Water Services Proprietary Limited. Copyright is specifically reserved in terms of the *Copyright Act 98 of 1987*, which includes amendments thereto. By viewing this disclaimer and by accepting this document, you acknowledge that you have read and accepted these Terms of Use and undertake to keep the information contained herein confidential and not to do any act or allow any act which is in breach of these Terms of Use.

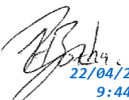
DECLARATION OF INDEPENDENCE

Elemental Water Services Proprietary Limited (EWS) was appointed to conduct this specialist surface water study and to act as the independent specialist. EWS objectively performed the work, even if this resulted in views and findings that were not favourable. EWS has the expertise to conduct the specialist investigation and does not have a conflict of interest in undertaking this study. This Report presents the findings of the investigations, which include the activities set out in the scope of work.

This specialist report, based on the independent assessment, as per the requirements set out by the *National Environmental Management Act 107 of 1998 (NEMA)* and the Department of Water and Sanitation (DWS), is independent and free of any external prejudice or influence. The contents of this specialist report are based solely on observations made during the physical site inspection and review of documents, as presented by the mine. The specialist further declares that, as a representative of Elemental Water Services Proprietary Limited:

- I act as the independent specialist for the Specialist Report.
- All work undertaken in relation to the assessment was conducted in an objective, independent and uninfluenced manner, even if this results in views and findings that are not favourable to the Licensee.
- There is no compromise on the objectivity exercised in undertaking the assessment.

- The relevant knowledge, expertise, and experience required to undertake this assessment are held by the specialist, including but not limited to NEMA and NWA, as well as relevant regulations and guidelines relevant to the activity.
- All information furnished in this Report is true and correct at the time of the assessment being finalised.
- I have expertise in conducting/compiling independent specialist assessments, including knowledge of NWA and any relevant legislation and guidelines that are relevant to the activity.
- I have no and have not engaged in conflicting interests while undertaking the assessment.
- I have undertaken to disclose to the Licensee and the Competent Authority all material information in my possession that reasonably has or may have the potential of influencing any decision to be taken with respect to the project by the Competent Authority and the objectivity of any report, plan or document prepared by myself for submission to the Competent Authority.
- All the particulars I furnished in this Report are true and correct.
- I realise that a false declaration is an offence in terms of Regulation 48 and is punishable in terms of section 24F of the Act.
- I do not have and will not have any vested interest (either business, financial, personal or other) in the project other than remuneration for work performed.

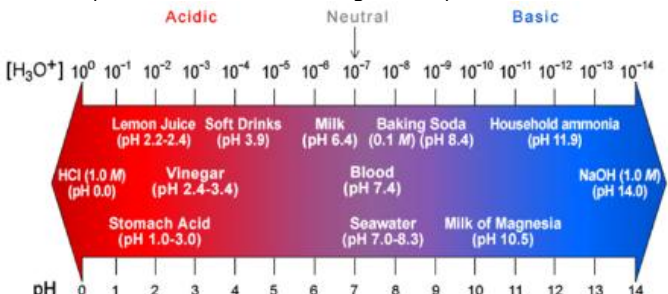


22/04/2025
9:44:26
Pr.Sci.Nat (400139/17)

Hendrik Botha
22 April 2025

GENERAL LIST OF ACRONYMS

Acronym	Description
ABA	Acid-Base Accounting
AD	Acid Drainage
AMD	Acid Mine Drainage
AMDMP	Acid Mine Drainage Management Plan
ANC	Acid Neutralising Capacity
ARD	Acid Rock Drainage
CAMDMP	Conceptual Acid Mine Drainage Management Plan
CGM	Conceptual Groundwater Model
Class I	A mixture of overburden, inter burden and underburden rock that is PAG
Class II	A mixture of overburden, inter burden and underburden rock that is non-PAG
CSM	Conceptual Site Model
DW&S (DWS)	Department of Water and Sanitation (previously DWA and DWAF)
DWA	Department of Water Affairs
DWAF	Department of Water and Forestry
EC	Electronic Conductivity
EIA	Environmental Impact Assessment
EMPR	Environmental Management Plan Report
ENE	East North East
ES	Environmental Significance
GRIP	Groundwater Resources Information Project
GW	Groundwater
HDPE	High-Density Polyethylene
HMP	Hydrogeological Management Plan
HRU	Hydrological Response Unit
IGRD	Integrated Recourses Integration
INAP	The International Network for Acid Prevention
IWULA	Integrated Water Use License Application
IWWMP	Integrated Water and Waste Management Plan
km/h	Kilometres per hour
l/s	Litres per seconds
LOM	Life of Mine
MAE	Mean Annual Evaporation
mamsl	Meters above mean sea level
MAP	Mean Annual Precipitation
mbgl	Meters below ground level
mbPMWL	Metres below pre-mining groundwater levels
MIW	Mine-influenced water
ml	millilitres
mm	millimetres
mm/yr	millimetres per year
Mm³/yr	Mega cubic Meters per year
MP	Management Plan
N	North
NAG	Net Acid Generation
ND	Neutral Drainage
NE	North East
NEMA	National Environmental Management Act
NGA	National Groundwater Act
NMAR	Normalized Mean Annual run-off
NNE	North North East
NNP	Net Neutralization Potential
Non-PAG	Non-Potentially Acid Generation
NWA	National Water Act
O/C	Open Cast
OC (O/C)	Opencast Workings
PAF	Potentially Acid Forming
PAG	Potentially Acid Generating
PAN	Potentially Acid Neutralising
PCD	Pollution Control Dam

pCO₂	Partial Pressure at Carbon Dioxide
PEST	Parameter Estimation Simulation
pH	The negative log of the H₃O⁺ concentration [H₃O⁺] in a water sample. Numerically equal to ±7 for neutral solutions, pH decreases with increasing H⁺, but pH increases as H⁺ decrease  The diagram illustrates the pH scale from 0 to 14. The top axis represents the concentration of hydronium ions [H₃O⁺] in moles per liter, ranging from 10⁰ to 10⁻¹⁴. The bottom axis represents the pH value, ranging from 0 to 14. The scale is color-coded: red for acidic (pH < 7), blue for neutral (pH = 7), and blue for basic (pH > 7). Various substances are plotted along the scale with their corresponding pH values: - Acidic (pH < 7): - Stomach Acid (pH 1.0-3.0) - HCl (1.0 M) (pH 0.0) - Vinegar (pH 2.4-3.4) - Lemon Juice (pH 2.2-2.4) - Soft Drinks (pH 3.9) - Milk (pH 6.4) - Neutral (pH = 7): - Blood (pH 7.4) - Seawater (pH 7.0-8.3) - Basic (pH > 7): - Milk of Magnesia (pH 10.5) - Baking Soda (0.1 M) (pH 8.4) - Household ammonia (pH 11.9) - NaOH (1.0 M) (pH 14.0)
RMS	Root Mean Squared / Normalised Distribution
RO	Reverse Osmosis
ROM	Run of Mine
RWQO	Resource Water Quality Objectives
SADAC	Southern African Development Community
SD	Saline Drainage
SMD	Saline Mine Drainage
SPR	Source Pathway Receiver Principle
STP	Sewer Treatment Plants
STP	Sewage Treatment Plant
tpH	Total Petroleum Hydrocarbons
WARMS	Water Allocation Registry Management System
WMA	Water Management Area
WQ	Water Quality
WQO	Water Quality Objectives
WUL	Water Use License
WULA	Water Use License Application
XRD	X-Ray Diffraction
XRD	X-Ray Diffraction
XRF	X-Ray Fluorescence
Zoif	Zone of Influence
ZOip	Zone of Impact

LIST OF KEY DEFINITIONS

Acronym	Description
HRU	A Hydrologic Response Unit (HRU) is a spatial unit that combines land use, soil, and slope characteristics to represent areas that will respond similarly to weather and precipitation events.
MAE	Mean annual evaporation is the average amount of water that evaporates over a specific period of time, calculated by adding up the total evaporation over that period and dividing by the number of years.
MAR	Mean annual runoff (MAR) is the average amount of water that flows down a river per year
n-Value	Roughness coefficients represent the resistance to flow in channels and floodplains. Roughness is usually presented in the form of a Manning's n value in HEC-RAS.
IFR	Instream flow requirements (IFR) are the minimum amount of water needed to maintain the health of aquatic ecosystems.
EWR	Ecological water requirements (EWRs) are the amount, quality, and timing of water needed to maintain the health of ecosystems like rivers, lakes, wetlands, and estuaries
EIS	Ecological sensitivity refers to the adaptability of an ecosystem to changes in the natural environment and disturbances from human activities on the premise that the quality of the ecological environment is not damaged
NMAR	Naturalised MAR removes the effects of human activities to estimate what the water flow would be in natural conditions
nMAR	Normalised MAR adjusts runoff for basin size, so different basins can be compared regardless of their area.
RU	A group of areas with similar physical characteristics that are expected to respond to weather and precipitation in a similar way.
PES	Ecological status described in terms of Ecological Categories: A – near natural, B – largely natural C – moderately modified D – largely modified E – seriously modified F - critically modified.
REC	a resource is a component of an ecosystem that maintains it, while ecological condition is the state of that ecosystem
TEC	A Target Ecological Category (TEC) is the goal to achieve a sustainable system that is both ecologically and economically sound
SQ	A sub-quaternary catchment reach (SQR) is a unit of information used to assess the aquatic ecology of a region
NDWF	Dry weather flow (DWF) is the average daily flow of sewage into a sewer or wastewater treatment plant during a period without rain

1 INTRODUCTION

Elemental Water Services Proprietary Limited (EWS) was appointed by M2 Environmental Connections (Pty) Ltd (MENCO) to undertake this hydrogeology assessment for the proposed Acid Mine Drainage (AMD) Treatment at the Ballengeich Colliery in KwaZulu-Natal (refer to Figure 1-5).

1.1 Project Background

The Ballengeich operation is located approximately 15 km south of Newcastle and consists of a historic open cast pit, discard dump, underground mine workings, adits and shafts, pollution control dams and infrastructure. The adits and shafts have been sealed, and sections of the open-cast mine have been backfilled and rehabilitated. The Ballengeich operation is currently not operational. The historic mining rights area falls within the farm Ballengeich Ptn. 19 - Sub 1 of Ballengeich 3299. The colliery falls within the upper catchment of the Horn River, which subsequently drains into the Ngagane River.

Ballengeich Siding needs water treatment technology following a DWS Directive. Kangra has inherited a settling pond system (7 ponds) that is seeping into the Horn River. Passive and self-sustainable treatment options are preferred. The settling ponds are subject to liner systems, but the feasibility is arguable. Kangra is looking for the Best Environmental Options to deal with the pollution problem.

The source control principle was used to determine the layout of the AMD treatment, and this is to ensure that the effluent is treated before it gets into the Rivers. The main pollution sources are (Bhekhani Pty Ltd, 2023):

1. Old underground workings decanting effluent water into the Horn River
2. Effluent discharge into the West decant sump and seepage from the old Horn River into the Ngagane and Horn River.

For Ballengeich, the passive treatment of AMD is proposed, consisting of anoxic limestone drains (ALD), successive alkalinity-producing systems (SAPS), oxidation ponds and aerobic wetlands.

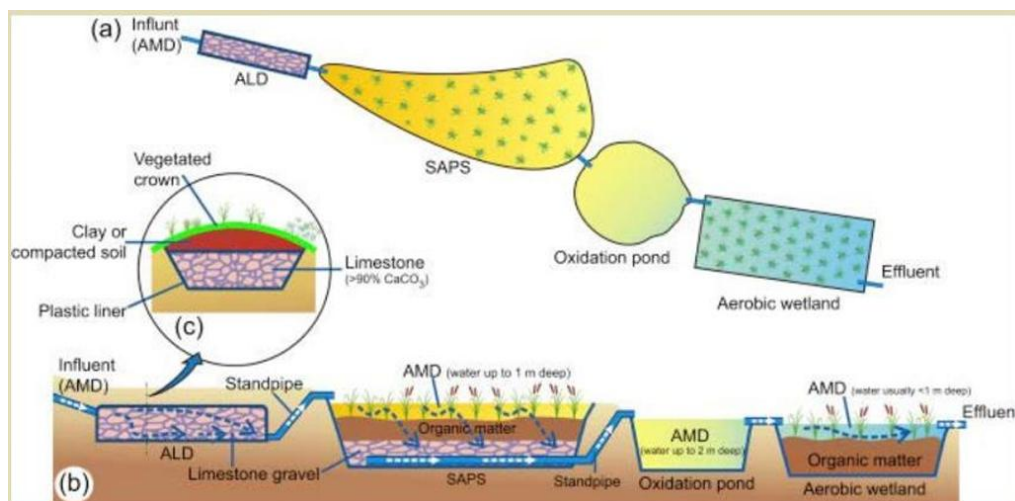


Figure 1-1: Passive treatment system proposed (Bhekhani Pty Ltd, 2023)

1.1.1 Treatment of Old UG Workings

The proposed AMD treatment will be constructed in two areas. The full treatment train (ALD to SAPS to Oxidation Pond and Aerobic wetland) will be constructed to treat effluent from the decanting of old underground workings .6 hectares of land is available in this area for treatment of effluent from underground workings. The conceptual layout of the AMD treatment from the old underground workings is shown in Figure 1-2.

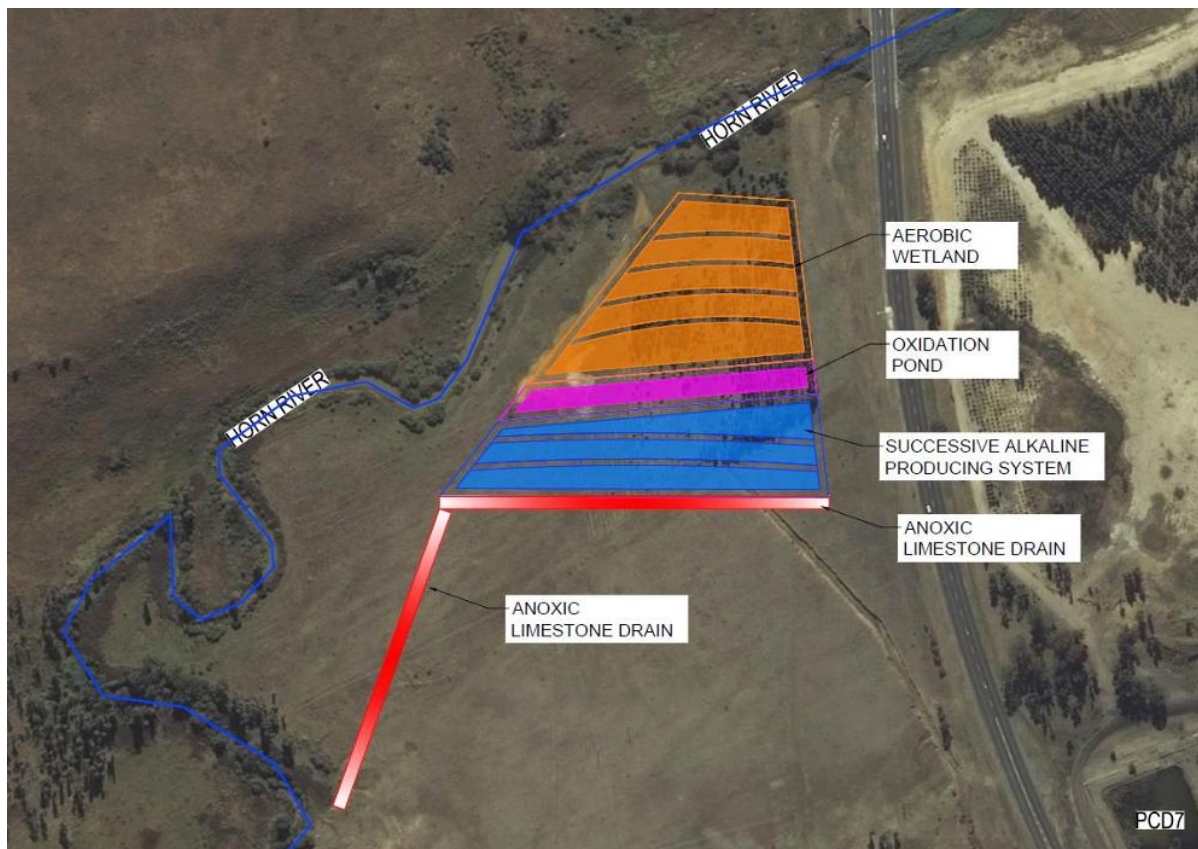


Figure 1-2: Area with underground workings to receive full treatment train (Bhekhani Pty Ltd, 2023)

1.1.2 Treatment of Effluent from West Decant Sump

An average of 1 198 155 kg/annum of sulphate salt ends up in the West Decant Sump on the Ballengeich Mine, and this salt load may discharge/seep into the Horn River or transpire through the surrounding tree area. Due to the space available between the West Decant Sump and the Horn River, two treatment methods will be constructed to treat effluent from Old open-cast workings and Unger ground workings to prevent further degradation of the Horn River. An anoxic limestone drain will be constructed after the west decant, along with an Aerobic wetland, which will treat all seepage water from the Old Horn River and the existing pollution control dams. A stormwater berm will be constructed along the Ngagane River to ensure that there is no spillage of the 1:100-year storm into the Ngagane River. The proposed west discard sump is shown in Figure 1-3.



Figure 1-3: *West Decant Sump area to be treated with ALD and cut off Aerobic Wetland along Horn River boundary*

1.1.3 Anoxic Limestone drain (ALD)

An Anoxic Limestone Drain (ALD) is a passive treatment system that is typically used to treat net acidic, anoxic mine drainage of low to moderate flow with low to moderate acidity (range) and dissolved metals. The ALD is constructed to intercept subsurface mine water flows and prevent/ minimise exposure to atmospheric oxygen. Keeping oxygen out of the water prevents the oxidation of metals and armouring of the limestone. The sole purpose of an ALD is to provide alkalinity through the limestone dissolution process. The increase in alkalinity helps reduce the acidity of the AMD. Retaining carbon dioxide in the drain can improve limestone dissolution and, thus, alkalinity generation.

An ALD is essentially a buried trench or basin filled with limestone overlain by a soil cover. The trench can be rectangular in shape with vertical side walls or can be constructed as an inverted trapezoidal prism (basin). The limestone is wrapped like a “burrito” in a synthetic liner to prevent water leaking, minimize the introduction of air and prevent the surrounding soil from migrating into the limestone layer. An influent pipe transports water into one end or side of the ALD, and an effluent pipe discharges water from the opposite downstream end or side. The effluent pipe carries water to the surface and is positioned at an elevation to ensure the limestone layer remains fully submerged and anoxic (minimal or no headspace within the ALD).

The ALD will meet the following design requirements.

- ✚ Shallow in depth (1-2m)
- ✚ Limestone layer 1-2m thick
- ✚ 0.6m compacted impermeable soil cover

ALD maintenance proposed (Bhekhani Pty Ltd, 2023):

Limestone: The limestone can require maintenance and periodic partial replacement, mostly due to clogging from metal precipitate. Therefore, the default recommendation in AMD Treatment is to replace 50% of the limestone every 10 years.

Liner: Often, liners are destroyed, especially synthetic ones, while maintenance is being done on passive treatment systems. Thus, AMD Treatment recommends planning to replace a portion of the liner while the limestone is being replaced. The default assumption is to replace 50% of the Limestone every 10 years, so the same assumptions are recommended for Liner recapitalization.

Pipe: Piping is often exposed at the surface and can become damaged by vandalism, falling trees, and other factors. AMD Treatment assumes 50% of the piping will require replacement after 25 years of service.

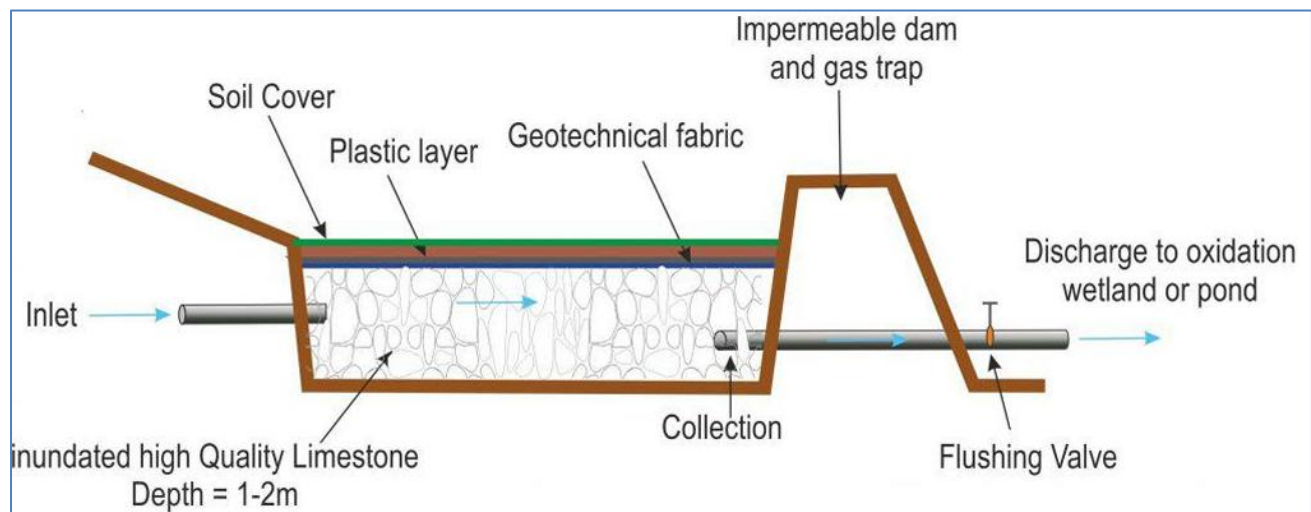


Figure 1-4: Typical section of Anoxic Limestone drainage system

1.1.4 Successive Alkaline Producing System (SAPS)

The SAPS systems combine ALD and compost wetland systems with a vertical flow of water. First, the acidic water flows through the low hydraulic conductivity compost part of the SAPS, where dissolved oxygen is consumed, and ferric iron (Fe^{3+}) is reduced to ferrous iron (Fe^{2+}). As a result, the water becomes anoxic and will flow through the anoxic layer of limestone, resulting in alkaline water without any iron precipitating on the limestone. The removal capacity of the SAPS system is approximately 10 g acidity /m²/d and has an estimated lifetime of 20-30 years. The area-adjusted contaminant removal rate was derived by Hedin et al. (1994a). For systems that must meet regulatory standards, a value of 10 g/m²/d for iron and 0.5 g/m²/d for manganese is recommended. The effluent discharged from Ballengeich has a design loading of 1000 m³/d 189 mg/L iron and 4.0 mg/L manganese. The minimum required area is 18 900 m².

1.1.5 Sedimentation/Oxidation Pond

Oxidation ponds, also called lagoons or stabilization ponds, are large, shallow ponds designed to treat wastewater through the interaction of sunlight, bacteria, and algae. Algae grow using energy from the sun and carbon dioxide and inorganic compounds released by bacteria in water. During the process of photosynthesis, the algae release oxygen needed by aerobic bacteria. Mechanical aerators are sometimes installed to supply yet more oxygen, thereby reducing the required size of the pond.

The sedimentation/oxidation pond is designed based on a 24-hour retention time at the design flow of 1000 m³/day, a water depth of 1500 mm and a 600 mm freeboard. The pond shall feature the following:

- ✚ total surface area: 670 m²;
- ✚ flow distributing inlets; • maximum length to breadth ratio of 3:1;
- ✚ side slopes of 1:2;
- ✚ scour valves for desludging;
- ✚ No. of ponds: at least two ponds are proposed;
- ✚ HDPE lining is constructed to the same detail as the aerobic wetland.

1.1.6 Aerobic wetland

Aerobic wetlands are relatively shallow, either constructed or natural ponds that are filled with flooded gravel, soil and organic substrate for plant growth. The cells are usually 30 cm deep or less, lined with impermeable sediments, and water flows above the substrate. Constructed aerobic wetlands are based on the aeration of the water to be treated, resulting in the transformation of dissolved Fe to the solid phase via oxidation. Thus, aerobic wetland treatment is very effective in treating Iron-rich mine waters, yet they have commonly limited capability to neutralize acidity. In addition, commonly accompanying manganese requires specific conditions for removal: circum-neutral to basic pH, and Fe²⁺ will be oxidized to prevent manganese from reducing.

The proposed wetlands will have the following properties (Bhekani Pty Ltd, 2023):

- ✚ Soil depth to be 400 mm. Important aspects of soil quality are as follows:
 - It does not contain excessively large stones or other sharp objects, which may puncture pond liners and impede plant growth;
 - The soil is not contaminated. The best way to ensure this is to ensure a reliable analysis is made of it;
 - It contains sufficient nutrients, in appropriate proportions, to support reed growth;
- ✚ The depth of water above the soil surface will be 1 m plus 600 mm freeboard;
- ✚ Aquatic plants, typically reeds, are to be planted at a density of 3-4/m²;
- ✚ Flow distributing inlets;
- ✚ maximum length-to-breadth ratio of 3:1;
- ✚ side slopes of 1:2;
- ✚ The subgrade shall be prepared with a 150 mm G7 sand layer with a maximum particle size of 3 mm. A 2 mm thick, smooth HDPE lining, complying with SANS 10409, overlaying A4 geotextile with the anchor trench detailed below, is proposed.

1.1.7 Predicted impact on water quality of the treatment system proposed

The current situation at Ballengeich Colliery is that acidic decant (AMD) is allowed to enter the Horn River uncontrolled, from where it is further diluted at the confluence with the Ngagane River. AMD Characterisation:

- ✚ Net acidic: pH <4.5
- ✚ DO : >5mg/l
- ✚ Fe²⁺ / Fe³⁺ ratio : >25% (35%)

✚ Al: <25mg/l

✚ Flow (ℓ/min) : < 200 l/min.

The predicted water quality changes after treatment and assimilation by the passive wetland system are captured in Table 1-1 and Table 1-2. An improvement in the raw and water quality is simulated. However, If the modelled results are compared to an RQO Class III category as per GN 1873 of March 2022, it is found that the heavy metals (Fe, Al and Mn) exceed the set RQOs. Total Dissolved Solids (TDS) and sulphate (SO₄) have the potential to exceed the more stringent RQO as contained in GN 1873 (MENCO, 2022)

Table 1-1: Assimilated capacity for Ngagane River (MENCO, 2022)

Variable	Unit (mg/l)	Predicted USEPA Model	Predicted RWQ Model	RQO	RQO Class III
Total Dissolved Solids	mg/l	337.56	353.08	≤350	≤1200
Total Alkalinity	mg/l	41.04	57.57		
Chloride	mg/l	8.52	9.71	≤120	≤300
Sulphate	mg/l	147.30	137.08	≤165	≤500
Sodium	mg/l	20.20	17.09		≤200
Potassium	mg/l	2.33	2.71		
Calcium	mg/l	33.78	38.19		≤150
Magnesium	mg/l	21.34	23.44		≤70
Aluminium	mg/l	0.36	0.48	≤0.105	
Iron	mg/l	5.36	3.54	≤0.1	
Manganese	mg/l	0.92	0.79	≤0.15	

Table 1-2: Assimilated capacity for Horn River inclusive of decant (MENCO, 2022)

Variable	Unit (mg/l)	Predicted USEPA Model	Predicted RWQO Model	RQO	RQO Class III
Total Dissolved Solids	mg/l	449.99	546.40	≤350	≤1200
Total Alkalinity	mg/l	43.90	74.57		
Chloride	mg/l	9.81	13.75	≤120	≤300
Sulphate	mg/l	204.56	239.02	≤165	≤500
Sodium	mg/l	35.11	28.50		≤200
Potassium	mg/l	2.27	3.14		
Calcium	mg/l	35.43	52.07		≤150
Magnesium	mg/l	27.84	39.32		≤70
Aluminium	mg/l	0.13	0.24	≤0.105	
Iron	mg/l	7.47	5.23	≤0.1	
Manganese	mg/l	0.22	0.75	≤0.15	

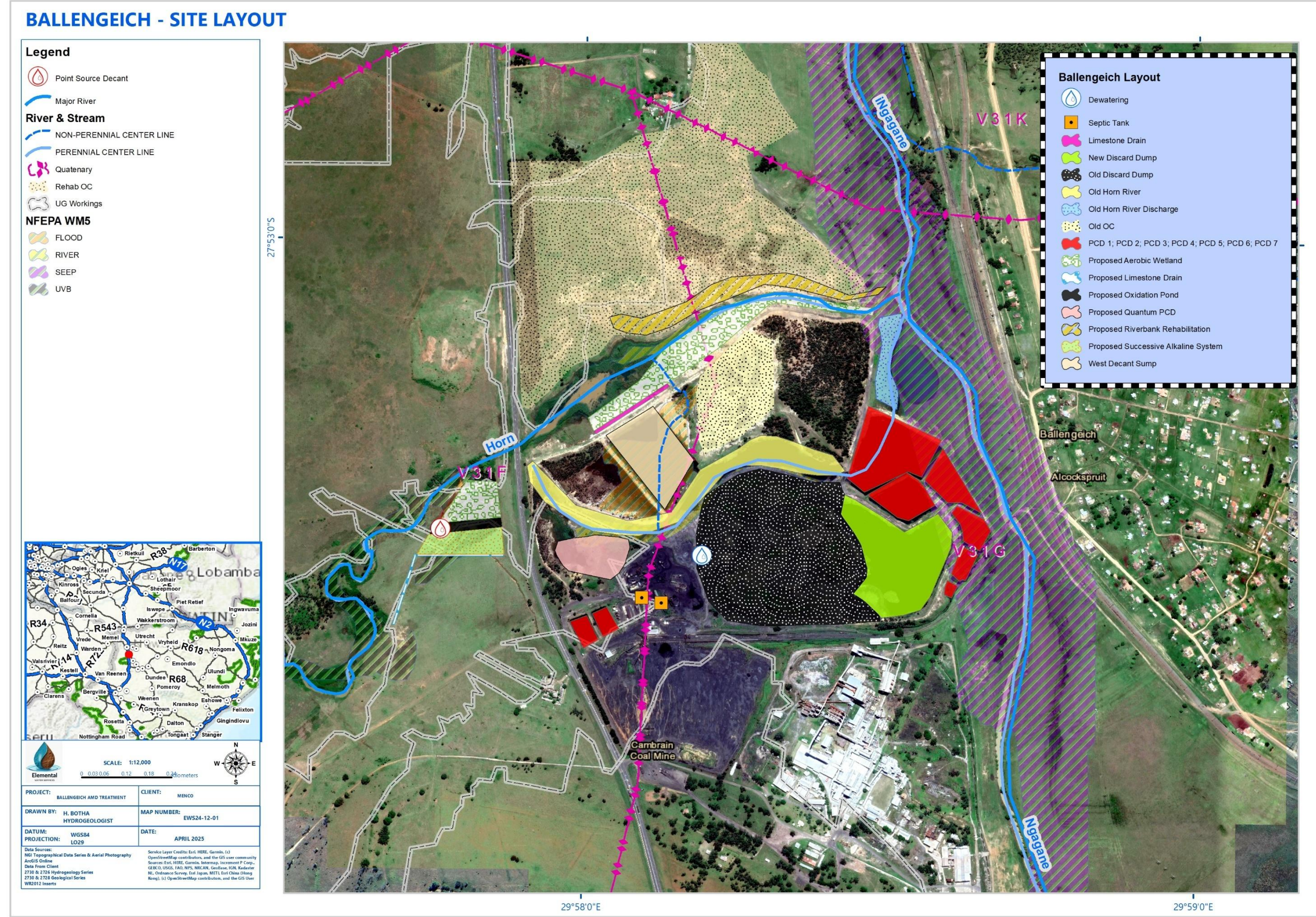


Figure 1-5: Site layout

1.2 Objectives

This hydrogeology assessment was compiled to evaluate the existing and predicted future hydrogeological environments and groundwater risk associated with the proposed Project. This report is intended to supplement the Water Use License Application (WULA) for the water uses triggered by the proposed Project.

The objectives of this study were as follows:

- ✚ Evaluate the site's hydrological setting (i.e., climate, rainfall, drainage, etc.).
- ✚ Understand and characterize the hydrogeological setting to set a basis for evaluating potential impacts relating to the existing site and surrounding activities.
- ✚ Review existing specialist groundwater reports for the proposed operations and monitoring data for the existing groundwater monitoring system to verify groundwater quantity, quality and impacts thereon.
- ✚ Undertake a hydrocensus within a 5 km radius of the site to confirm the status of groundwater users in the project area.
- ✚ Develop a site conceptual model (CSM) to illustrate the hydrogeological setting, underlying aquifers, and groundwater flow paths.
- ✚ Conceptualise and groundwater risks associated with the proposed operations on the groundwater environment:
 - A groundwater model was developed to characterize the groundwater flow systems more fully (i.e. particle flow analyses).
 - The flow model was calibrated with 2025 water level data for monitoring boreholes at the Site, and the 2025 sulphate contamination plume for the Ballengeich operations was simulated and calibrated.
 - The Australian Groundwater Modelling Guidelines (Barnett, et al., 2012) were considered to ensure that the numerical model adheres to international norms and standards.
- ✚ Groundwater management and water monitoring requirements to minimize and monitor the impact associated with the proposed activities were explored.

1.3 Study relevance to the season in which it was undertaken

This study was undertaken as a once-off study and relies on field-generated data backed by historical hydrogeological, water monitoring and climate data for the site, as well as recognised geo-hydrological and water resource databases for South Africa. Data generated during the time of this study is not seasonally bound, other than the water monitoring and hydrogeological data that was extracted from available monitoring reports.

1.4 The layout of this report

The Report has been structured as far as possible, as per Annexure D of the Government Gazette (GN267 of 24 March 2017), and is applicable to hydrogeological studies for environmental impacts assessment/water use license applications. This Report further considers Appendix 6 of EIA guidelines (*as outlined in Table 1 in front of the Report*).

2 SCOPE OF WORK

The scope of work completed is as follows:

1. Desktop data review:

- a. All available reports relating to the site were assessed, including a review of all hydrogeology, hydrology, hydrochemistry, and geology literature data.
- b. Eskom water monitoring data, where it was made available, was incorporated into this Report.
- c. A desktop-level hydrocensus was conducted. The National Groundwater Archive (NGA, 2025), Groundwater Resource Information Project (GRIP, 2016) and the Southern African Development Community Groundwater Information Portal (SADAC GIP, 2025) databases were assessed to identify existing groundwater users in the area.

2. Baseline hydrology review:

- a. Hydro-meteorological data collection and analysis.
- b. Catchment delineation and drainage characteristics.
- c. Determination of catchment hydraulic and geometric parameters.

3. Field investigation:

- a. A site walk-over assessment was undertaken to map sensitive groundwater-surface water interaction zones identified on a desktop level. The visit took place on 01-02-2025.
- b. A groundwater hydrocensus was conducted within a 2.5 km radius of the proposed activity.
- c. Slug testing of boreholes was completed to verify groundwater hydraulic permeabilities for the project site.
- d. A geophysical investigation was undertaken to determine additional groundwater monitoring positions, as well as preferential groundwater flow paths.

4. Hydrogeological and geological conceptual model development:

- a. Hydrogeological and geological site conceptual models for the Site were developed with data obtained for the study area.

5. Groundwater numerical flow and transport model developed:

- a. A groundwater model was developed to characterize the groundwater flow systems more fully (i.e. particle flow analyses).
- b. A pseudo-steady state and transient state model were developed with an associated transport model. The 2025 sulphate pollution plume was simulated.

6. Hydrogeological risk and impact assessment:

- a. A risk assessment was conducted based on the source-pathway-receptor principle.
- b. The potential impacts associated with the proposed activities on the groundwater and subsequent surface water environments were evaluated.
- c. A groundwater management plan was developed.

7. Monitoring plan:

- a. A groundwater monitoring plan or improvement plan was developed for the Site based on the baseline assessment of the site conditions.

8. Reporting:

- a. This Report, which encompasses all the work done, was compiled.

3 AREA OF INVESTIGATION

The Ballengeich Colliery is situated on the southern side of the Horn River and the western side of the Ingagane River, at the confluence of the two (2) rivers, about 12km South of the Town of Newcastle in the KwaZulu-Natal Province. The Ballengeich surface operations are situated within quaternary catchment W31G, with the old underground workings extending into V31F and V31K of the Mtamvuna-Pongola Water Management Area (DWS, 2016). Based on the topography, the drainage is towards the northeast. Elevations on the site typically range from 1184 to 1325 metres above mean sea level (mamsl). A typical topography cross-section is shown in Figure 3-1.

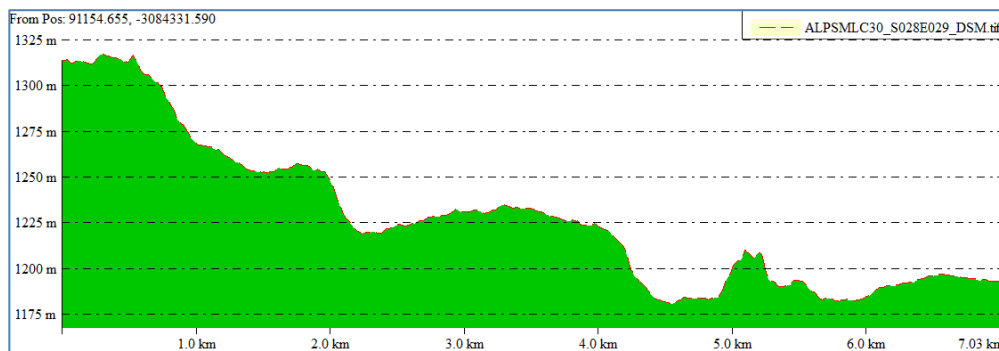


Figure 3-1: Typical cross section of surface topography (30m DTM based)

3.1 Sub-catchments / groundwater resource units (GW HRU)

One (1) groundwater hydrological response unit/resource unit (GW HRU) (1:10 000 stream count, 30m DTM fill) was delineated for the project area – refer to Figure 3-2. The sub-catchments describe the groundwater and surface water drainage from the Ballengeich Operations and relate to real-world surface water/groundwater topographical boundaries. The land cover types associated with the GW HRU are shown in Figure 3-3, and the topography slope rise % is shown in Figure 3-4. Table 3-1 provides a summary of the physical attributes associated with the GW HRU.

A 2.5 km buffer relative to the combined extent of the GW HRU can be considered the expected sphere of groundwater influence and forms the hydrogeological boundaries for the project area (also termed the sphere of influence "SOIf").

Table 3-1: Summary of GW HRU attributes

Sub-Catchment		GW HRU
Area (km ²)		27.995
Longest Drainage Line (km)		NA
Average Slope (%)		2.40%
Slope (%)	<3	17.26%
	3-10	58.29%
	10-30	22.35%
	>30	2.10%
Land Cover	Thick bush & plantation	3.66%
	Light bush & farm-lands	27.46%
	Grasslands	60.81%
	No Vegetation	8.07%

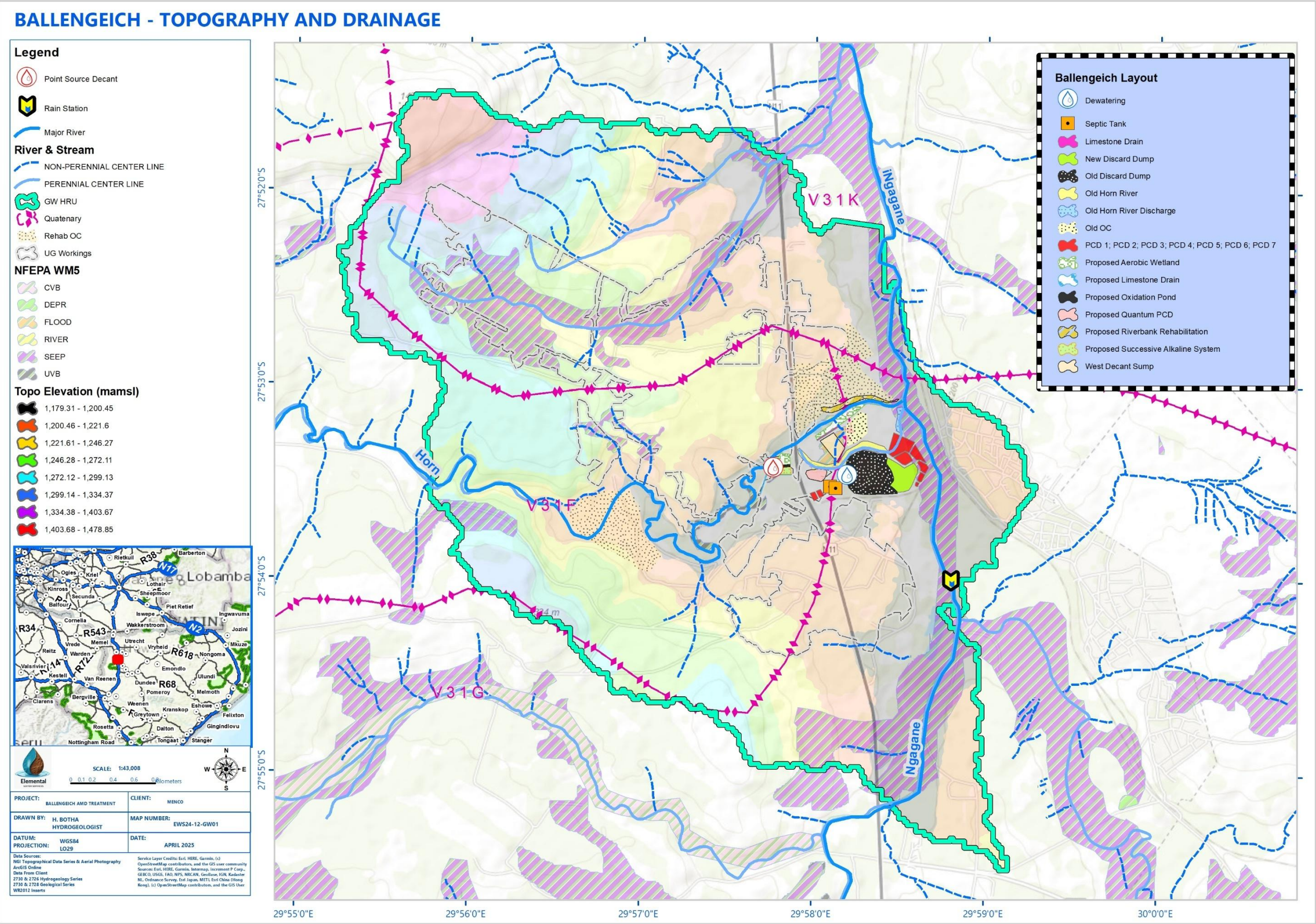


Figure 3-2: Topography and drainage

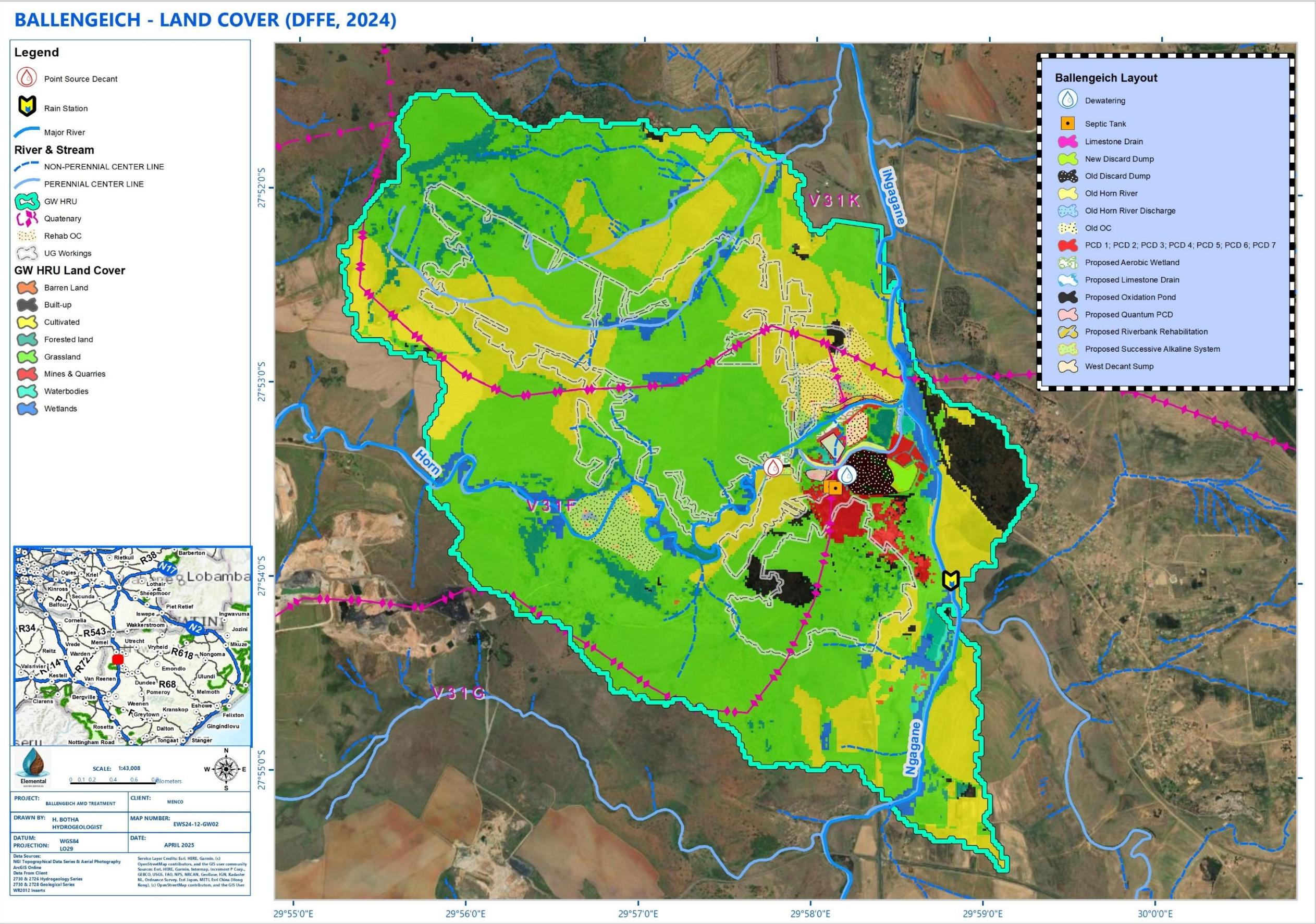


Figure 3-3: Sub-catchments & land cover types

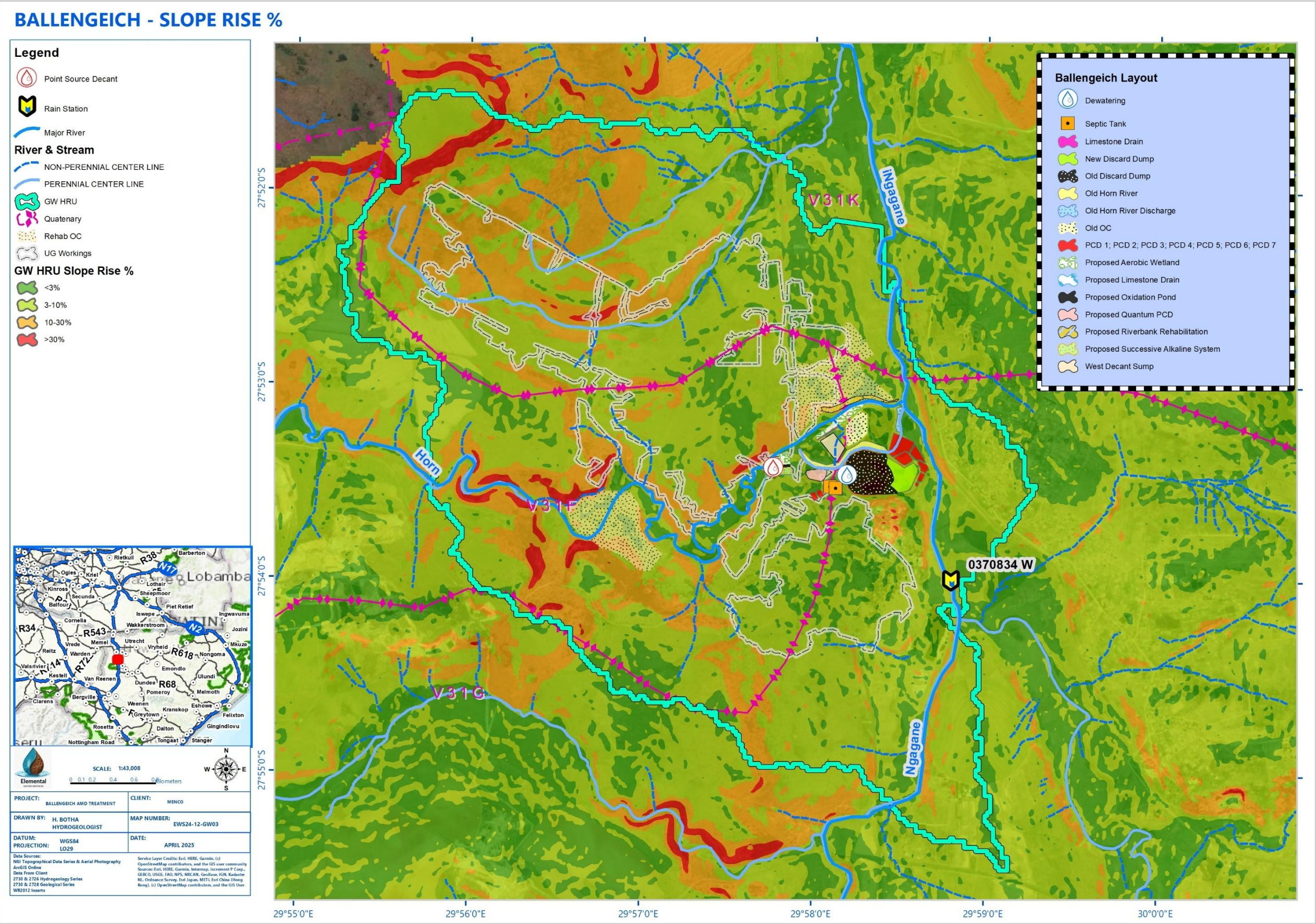


Figure 3-4: Sub-catchments & slope rise %

3.2 Climate

The average yearly temperature (refer to Figure 3-5) for the project area ranges from 27 to 35°C (high) and 1 to 4°C (Low). As per the Köppen Climate Classification (Kottek, et al., 2006), the study area is situated in a humid subtropical climate (Köppen: Cfa).

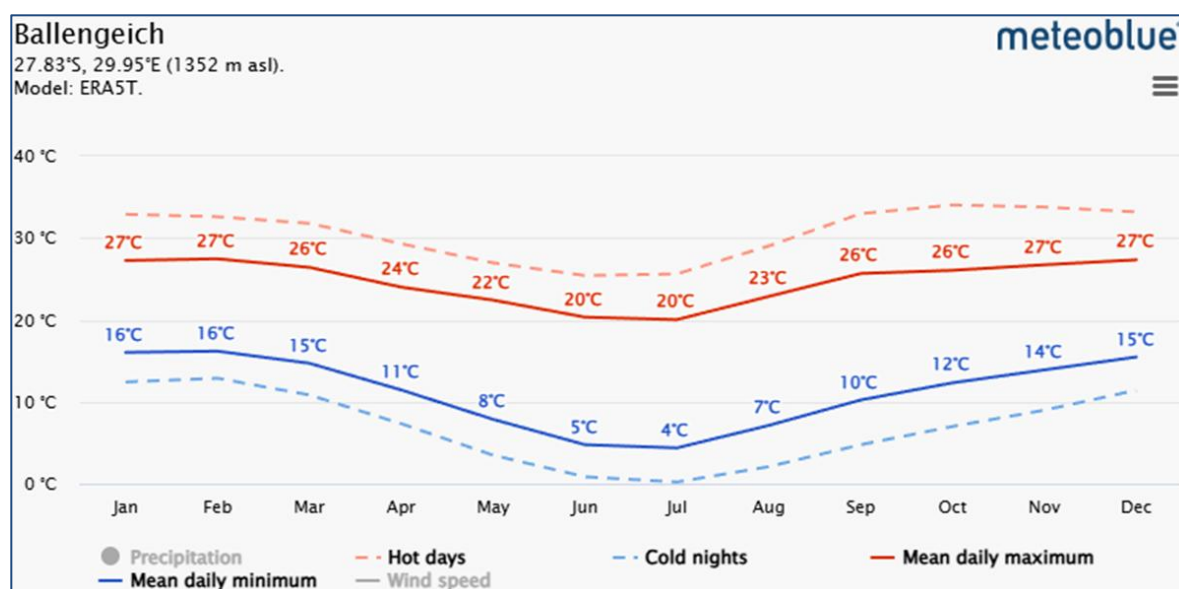


Figure 3-5: Average yearly temperatures (Meteoblue, 2025)

3.3 Rainfall and evaporation

The project area is situated in rainfall zone V3B. The Mean Annual Precipitation (MAP) recorded at the nearest rainfall stations is summarised in Table 3-2 (WRC, 2015). The MAP for several sites is within the same order of magnitude.

Table 3-2: Summary of MAP recorded at nearest rainfall stations

Site	ID	Record (Yrs)	MAP (mm/yr)
BALLENGEICH	0370834_W	52	858
CHELMSFORD DAM	0370807_W	39	794
CECILIA, NEWCASTLE	0370655_A	31	931
BOARDLANDS, DANNHAUSER	0371029_A	25	753
Average			834

The monthly rainfall that represents the site was obtained from WR2012 rainfall station 0370834W. The rainfall record is for the period 1920 to 1972 (52 years). Monthly rainfall for the site is likely to be distributed, as shown in Figure 3-6. Available rainfall data suggest a MAP ranging from 503 (30th percentile) to 1517 (90th percentile) mm/yr.

To further refine the rainfall of the site, satellite rainfall data from the Climate Hazards group IR Precipitation with Stations (CHIRPS) was applied ((SERVIR, 2025) & (ClimateSERV 2.0, 2025)). This dataset, known as CHIRPS, offers a spatially and temporally consistent view of global rainfall patterns, enabling accurate monitoring and assessment of large-scale trends. The annual rainfall record for the Site [Ballengeich] from 2010 to 2024 is shown in Figure 3-7, and the daily average rainfall is shown in Figure 3-8. The average annual rainfall for the Project Site is in the order of 739 mm/yr.

The project area falls within evaporation zone 21A, of which Mean Annual Evaporation (MAE) ranges from 1 200 to 1 300 mm/yr. The MAE far exceeds the MAP for the site, which implies greater evaporative losses when compared to incident rainfall. Monthly evapotranspiration for the site is likely to be distributed, as shown in Figure 3-6.

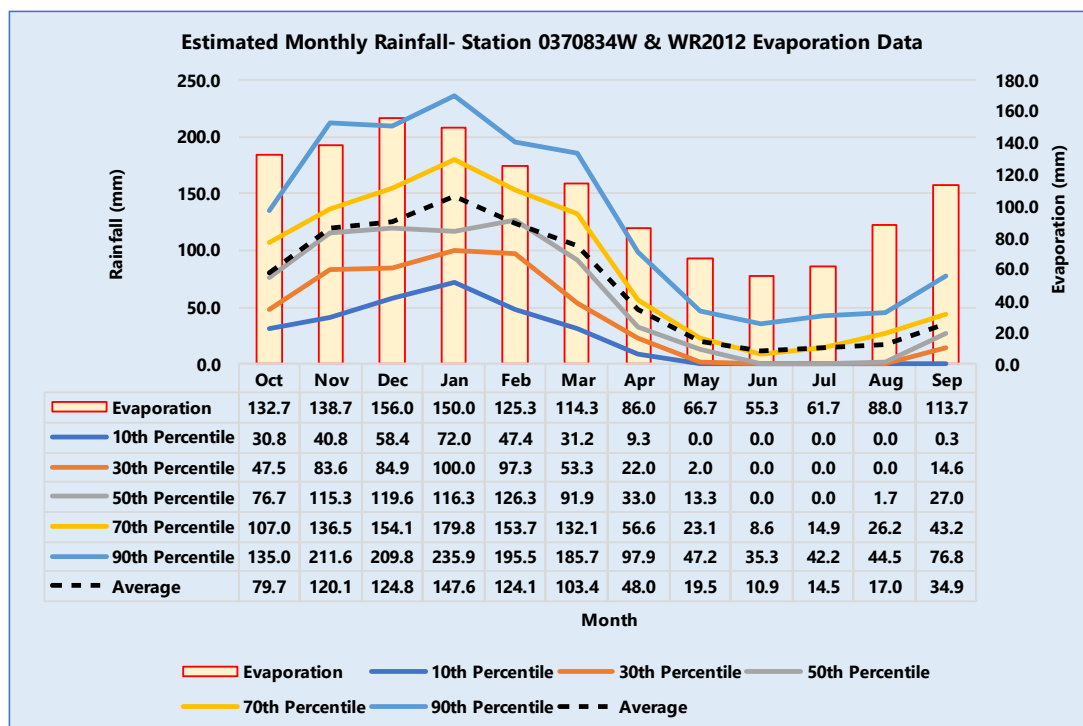


Figure 3-6: Average rainfall for Station 0370834W & WR2012 evaporation

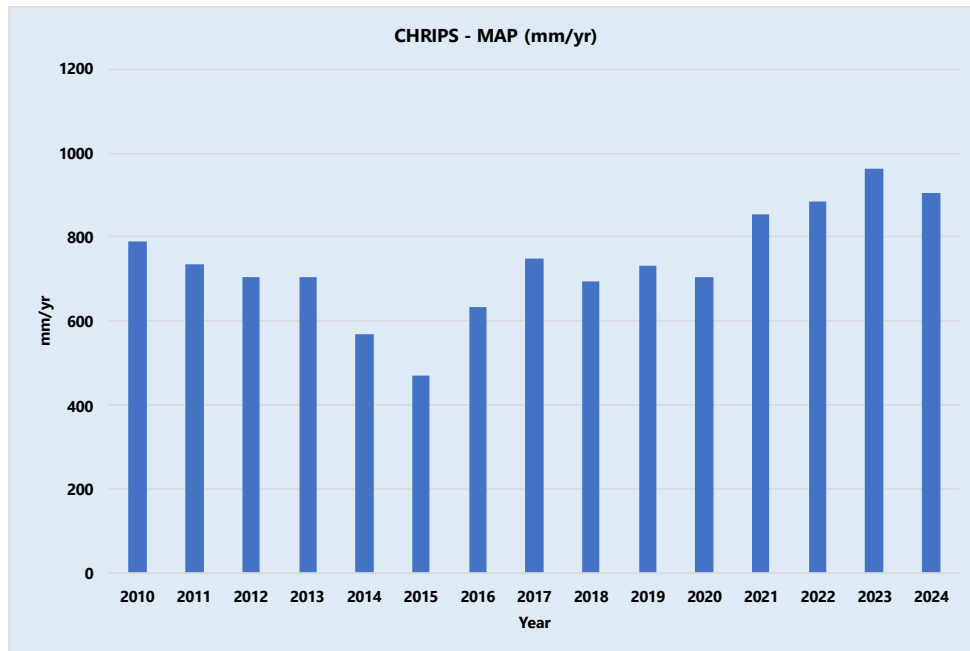


Figure 3-7: CHIRPS rainfall data for the site (2010 to 2024)

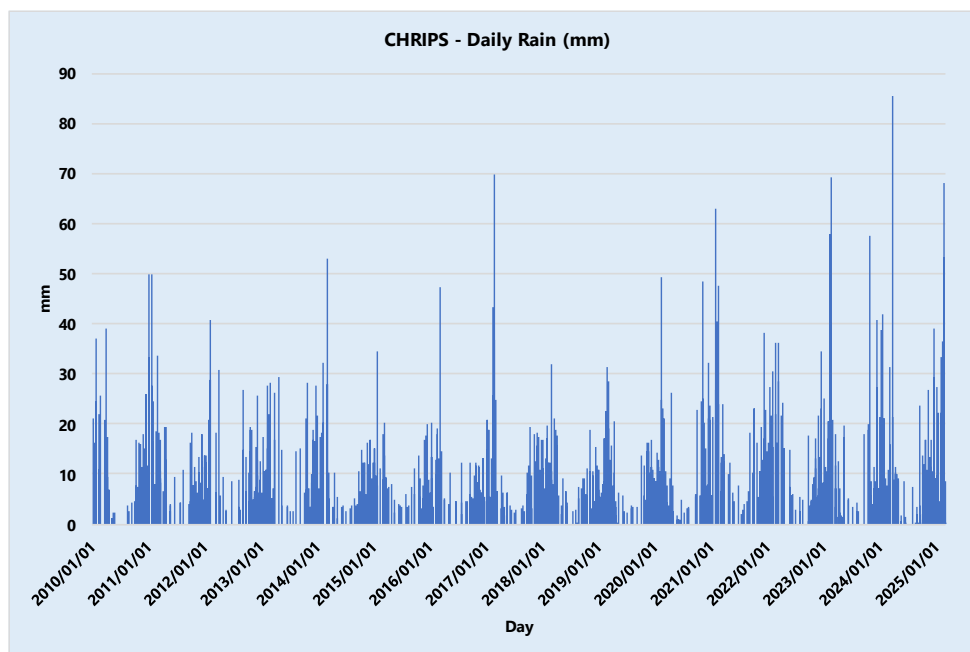


Figure 3-8: CHIRPS daily data for the site (2010 to 2024)

3.4 Run-off

Run-off from natural (unmodified) catchments for the quaternary, as simulated in WR2000/WR2012 models (WRC, 2015), is (refer to Figure 3-9 to Figure 3-11):

- ✚ 57.8 mm/yr for V31K.
- ✚ 114.5 mm/yr for V31F.
- ✚ 89.7 mm/yr for V31G.

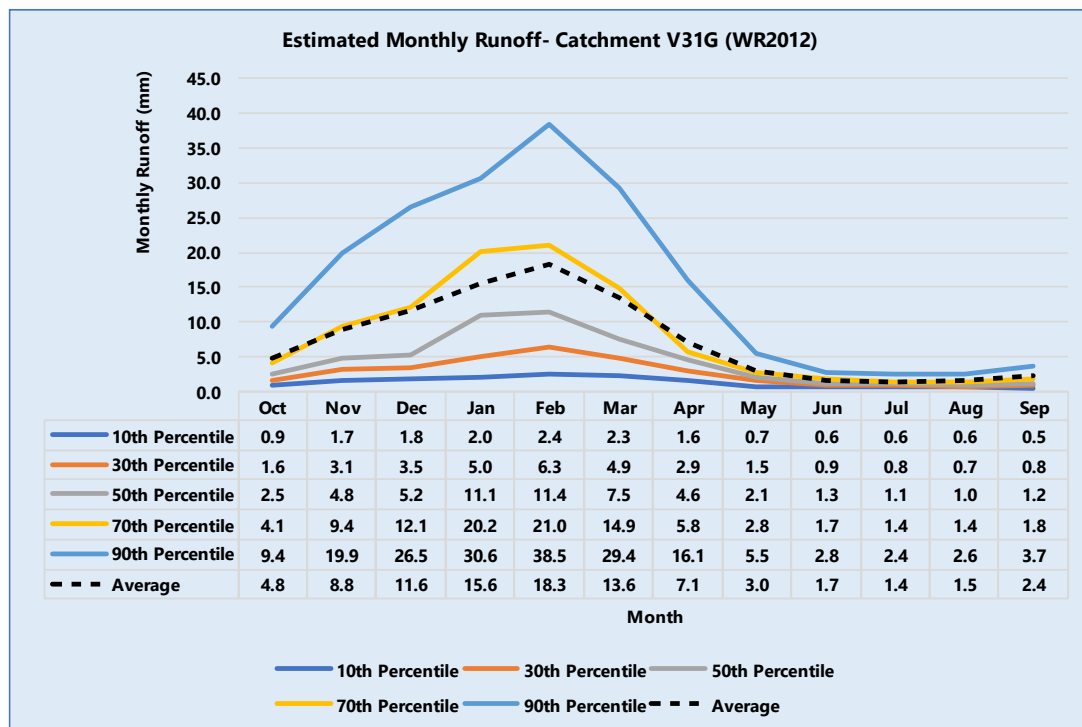


Figure 3-9: Simulated run-off distribution for V31G

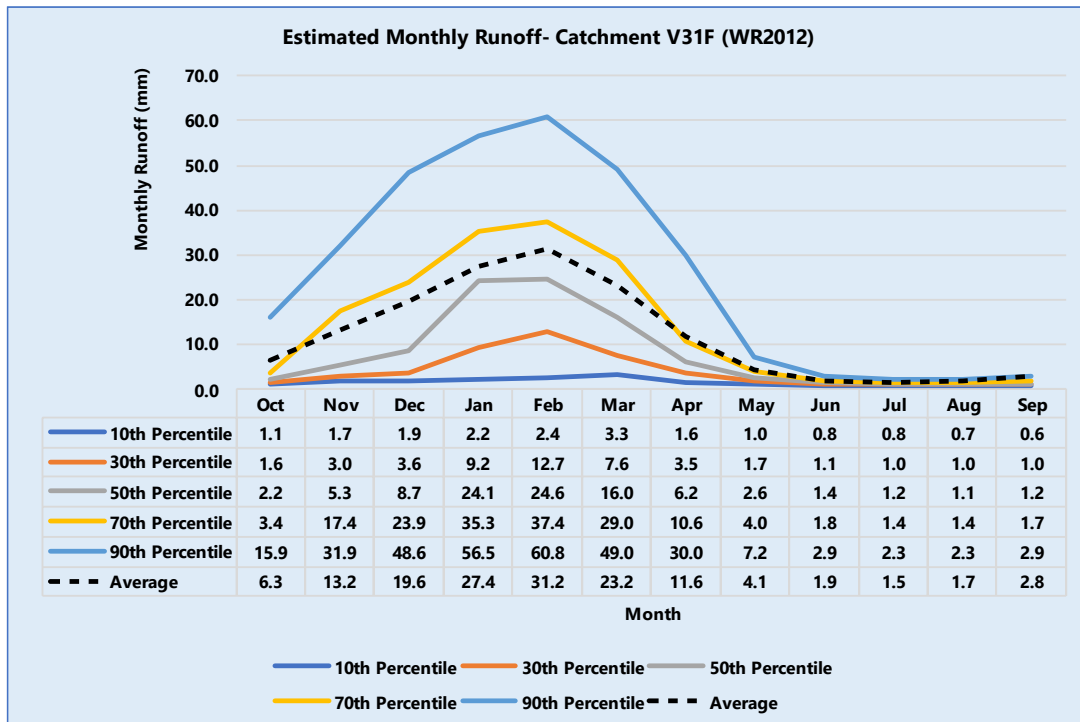


Figure 3-10: Simulated run-off distribution for V31F

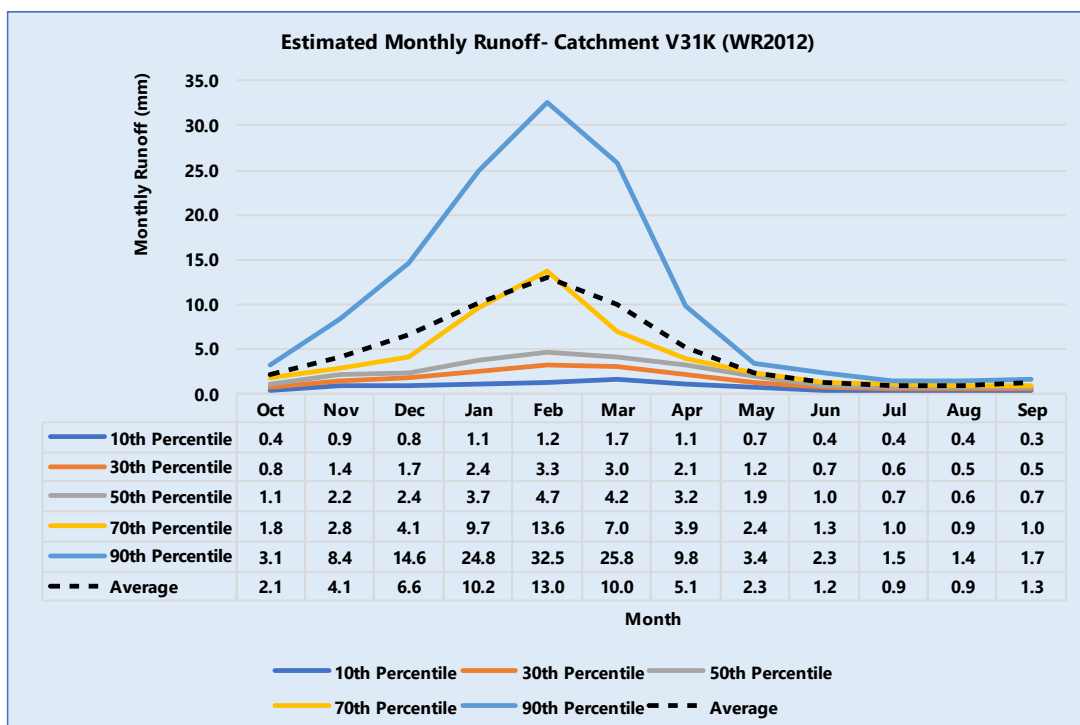


Figure 3-11: Simulated run-off distribution for V31K

3.5 Climate change considerations

The Paris Agreement of 2015 sets out a global framework to limit global warming to well below 2°C, preferably to 1.5°C (degrees Celsius), compared to pre-industrial levels. To achieve this global temperature goal, countries aim to reduce the growth of greenhouse gas emissions as soon as possible and rapidly reduce them, thereafter, based on the best available science.

The effects of climate change are already well visible by increasing air temperatures, melting glaciers, decreasing polar ice caps, rising sea levels, and increasing desertification, as well as by more frequent extreme weather events such as heat waves, droughts, floods, and storms. Climate change is not globally uniform and affects some regions more than others. In the following diagrams, you can see how climate change has already affected the region of Ballengeich during the past 40 years. The data source used is ERA5, the fifth-generation ECMWF atmospheric reanalysis of the global climate, covering the time range from 1979 to 2021, with a spatial resolution of 30 km.

Figure 3-5 shows the estimate of the mean annual temperature for the larger region of Ballengeich. The dashed blue line shows the linear climate change trend. If the trend line goes up from left to right, the temperature trend is positive, and Ballengeich is getting warmer due to climate change. If it is horizontal, no clear trend is seen, and if it is going down, conditions in Ballengeich are becoming colder over time. In the lower part, the graph shows the so-called warming stripes. Each coloured stripe represents the average temperature for a year - blue for colder and red for warmer years.

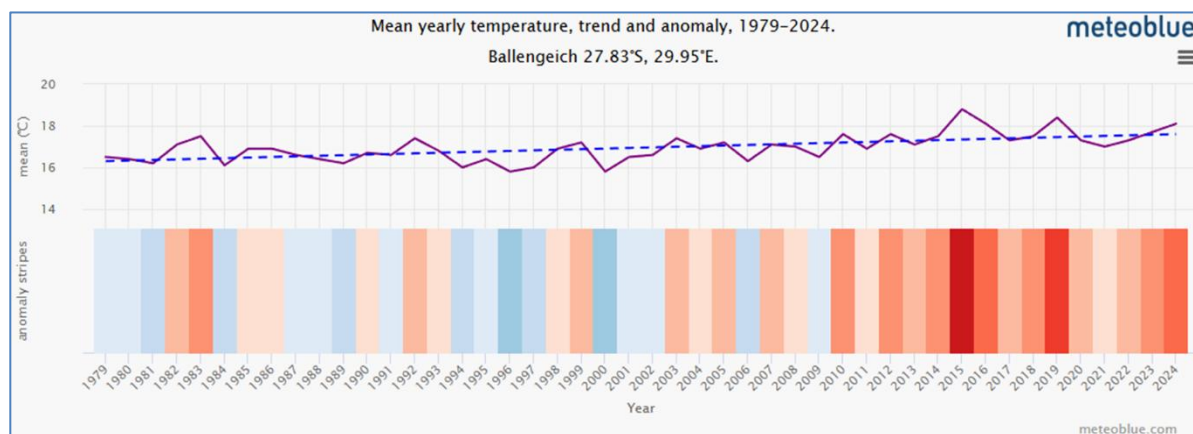


Figure 3-12: Yearly Temperature Change (Meteoblue, 2025)

Figure 3-13 shows an estimate of the mean total precipitation for the larger region of Ballengeich. The dashed blue line shows the linear climate change trend. If the trend line goes up from left to right, the precipitation trend is positive, and Ballengeich gets wetter due to climate change. If it is horizontal, no clear trend is seen, and if it is going down, conditions are becoming drier in Ballengeich over time. In the lower part, the graph shows the so-called precipitation stripes. Each coloured stripe represents the total precipitation of a year - green for wetter and brown for drier years.

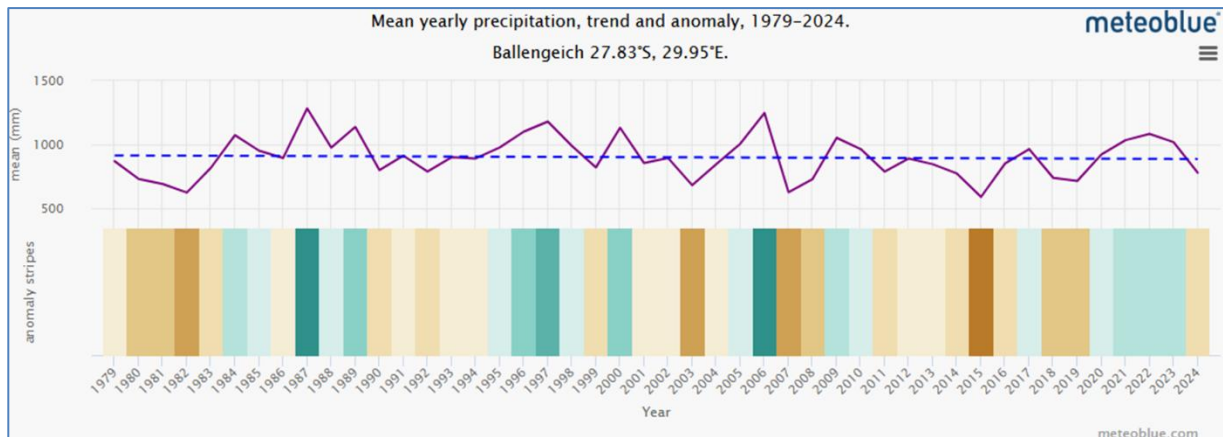


Figure 3-13: Yearly Precipitation Change (Meteoblue, 2025)

Figure 3-14 shows the temperature anomaly for every month since 1979 up to now. The anomaly tells you by how much it was warmer or colder than the 30-year climate mean of 1980-2010. Thus, red months were warmer and blue months were colder than normal. In most locations, you will find an increase in warmer months over the years, which reflects the global warming associated with climate change. The precipitation anomaly for every month since 1979 up to now is also shown in Figure 3-14. The anomaly tells you if a month had more or less precipitation than the 30-year climate mean of 1980-2010. Thus, green months were wetter and brown months were drier than normal.

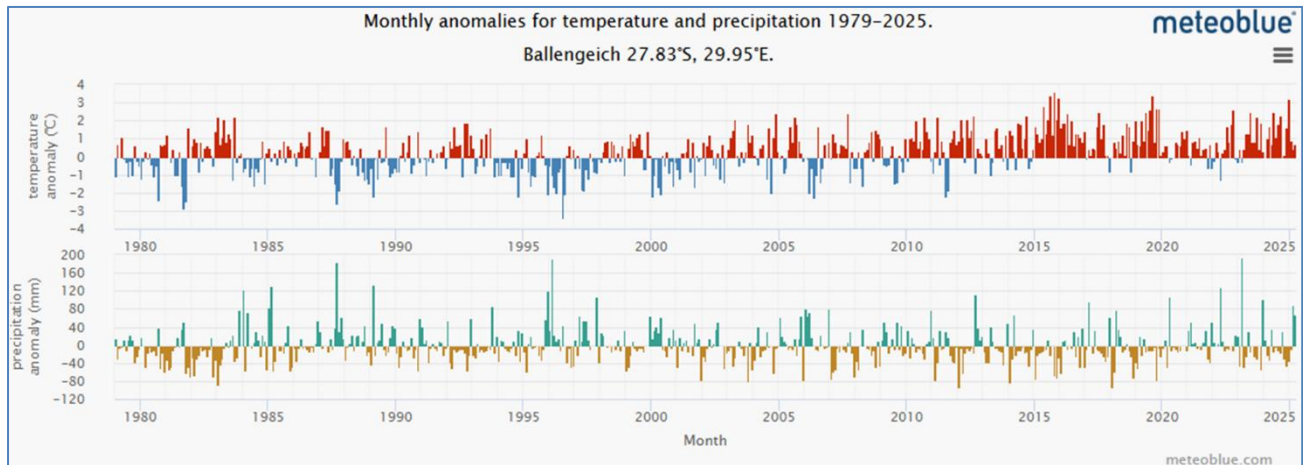


Figure 3-14: Monthly Anomalies of Temperature and Precipitation (Meteoblue, 2025)

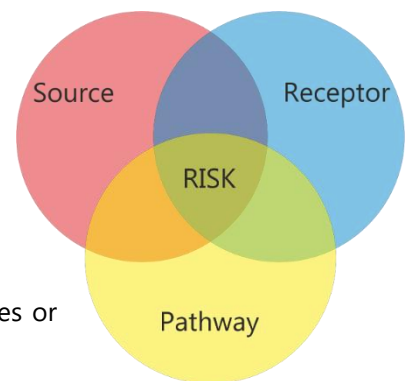
Based on the above, it is predicted that there will be future temperature increases with more frequent extreme temperatures, which will result in fewer days of rainfall. Based on the rainfall decrease projections, it is concluded that there will be less frequent storm events (though not extreme) to facilitate the projected decreases in annual rainfall.

4 METHODOLOGY & APPROACH

The study followed a logical and holistic approach, whereby all existing and new hydrogeological data for the site was assessed. The aim was to re-assess previously identified risks in the groundwater environment and update new potential risks identified. A systematic phased approach was followed to adhere to the objectives and agreed-upon scope of work for the assessment. The tasks were subdivided into different project phases, as presented in Table 4-1.

A logical and holistic approach was adopted to assess the study area. The “Best Practice Guidelines for Impact Prediction (G4)” (DWAF, 2008) were considered to define and understand the three basic components of the hydrogeological risk (also referred to as “SPR”):

- ✚ **Source term** - The source of the risk (i.e., operational risk associated with the activities at the site).
- ✚ **Pathway** - The pathway along which the risk propagates (i.e., percolation to the groundwater aquifer or overland runoff).
- ✚ **Receptor** - The target that experiences the risk (i.e., water bodies or groundwater users).

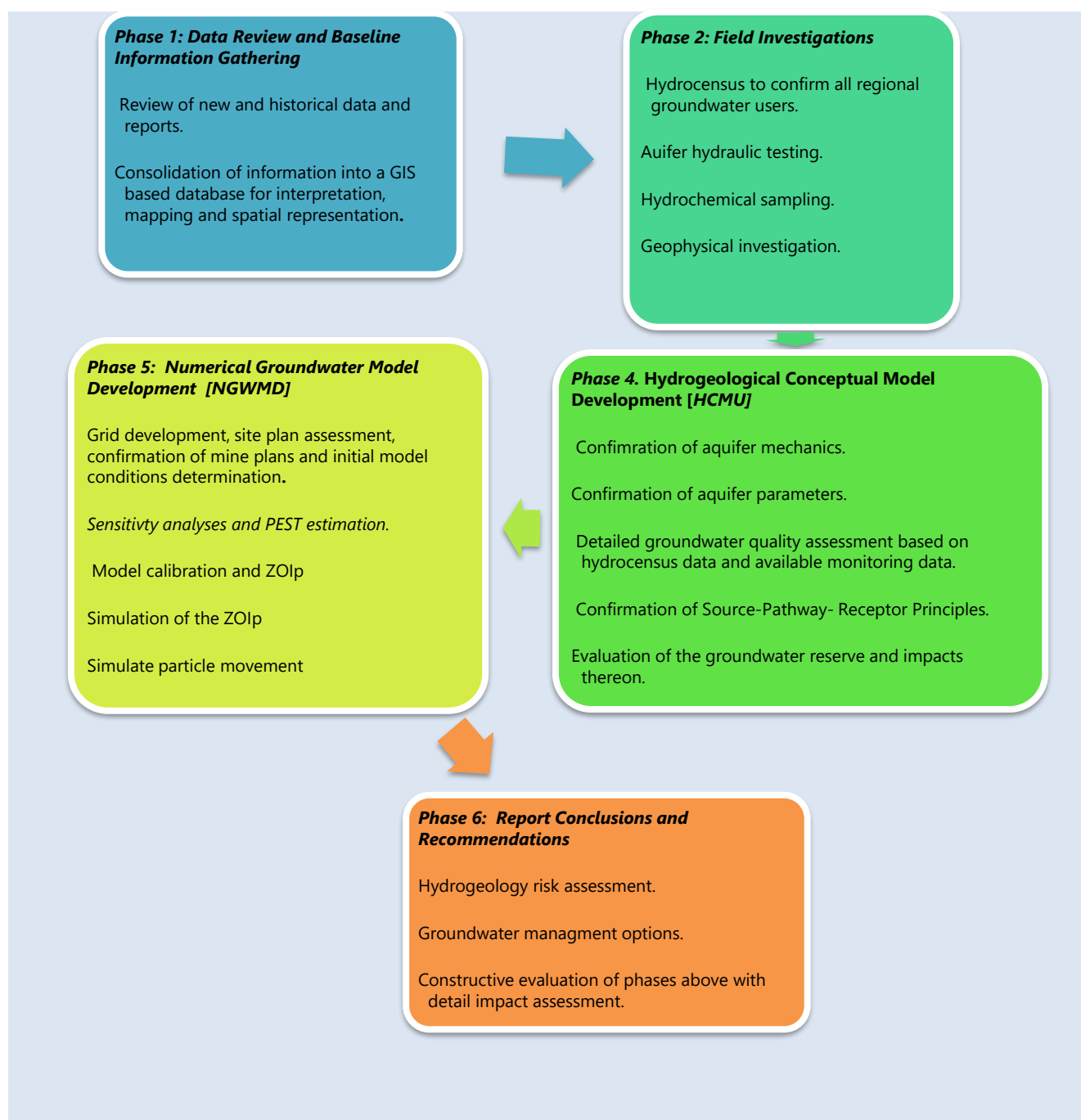


The approach was used to assess:

1. How the existing site activities could/have impacted groundwater *Quality*.
2. How the existing site activities could/have affected the groundwater *Quantity*.

Subsequently, a groundwater model was developed to illustrate the conceptual understanding of the groundwater flow system. Groundwater modelling is an efficient tool for groundwater management and remediation. Models are a simplification of reality to investigate certain phenomena or to predict future behaviour. The challenge is to simplify the reality in a way that does not adversely influence the accuracy and ability of the model output to meet the intended objectives. In terms of quality control, the Australian Groundwater Modelling Guidelines (Barnett, et al., 2012) were considered to ensure that the numerical model adheres to international norms and standards.

Table 4-1: Project methodology flow diagram



4.1 Hydrological overview

Hydrometeorological data for the study area was obtained from various sources, including the South African Water Resources Study WR2012 database (Bailey & Pitman, 2015), South African Atlas of Agrohydrology and Climatology (Schulze, 1997), and the Daily Rainfall Data Extraction Utility (Lynch, 2004). Moreover, sources such as the Köppen Climate Classification (Kottek, et al., 2006), World Climate Data CMIP6 V2.1 (Eyring, 2016), and Meteoblue (Meteoblue, 2025) were used to refine hydrological data.

These sources provided means of determining the Mean Annual Precipitation (MAP), Mean Annual Run-off (MAR), and Mean Annual Evaporation (MAE) of the study site as well as the design rainfall data.

4.2 Catchment description and delineation

A 30 m Digital Terrain Model (DTM) data from the Advanced Land Observing Satellite (ALOS) (Meteoblue, 2025) were used to delineate the area draining to the streams relevant to this study, sub-catchment flow path as well as to derive river geometry characteristics. These characteristics (area, slopes, and hydraulic parameters) are used to parameterise the site. The ALOS DTM was further refined by applying SRTM 1-Arc degree topography elevation and 5 m National Raster contour data in areas where drainage channels did not correspond to satellite imagery or actual field-recorded positions. No topography survey data was made available for this assessment. 2022 South African (SA) National Land Cover Data (DFFE, 2024) was used to characterise the sub-catchment vegetation and derive Manning's surface roughness (n-values) coefficients.

4.3 Literature review and desktop study

The following sources supply an overview of the hydrogeological conditions of the project area, as per the desktop information reviewed for this assessment:

✚ Site-specific specialist reports:

- Kangra Coal (Pty) Ltd: Ballengeich Colliery Determination of the Assimilative Capacity of V30 Catchment (MENCO, 2022).
- Wetland delineation assessment for Kangra Coal (Pty) Ltd Ballengeich Colliery (MENCO, 2022).
- Ballengeich Colliery Preliminary Civil Design Report for Acid Mine Drainage Passive Treatment Design (Bhekani Pty Ltd, 2023).
- Hydrological Assessment of Ballengeich Mine (GCS, 2016).
- Water Quality Monitoring Report for the Kangra Coal KwaZulu-Natal Operations: Second Quarter, 2024 Monitoring Period (GCS, 2024).

✚ SADC Groundwater Information Portal (SADC GIP) borehole data (SADAC GIP, 2025)

✚ National groundwater archive borehole data (NGA, 2022).

✚ 2730 Vryheid – 1:500 000 Hydrogeological map series (King, et al., 1998).

✚ 2726 Kroonstad – 1:500 000 Hydrogeological map series (King, et al., 1998).

✚ 2728 Frankfort – 1:250 000 Geological map series (DMEA, 1998).

✚ 2730 Vryheid – 1:250 000 Geological map series (DMEA, 1998g).

✚ Literature on similar geology and hydrogeology:

- A South African Aquifer System Management Classification (Parsons, 1995);
- Aquifer Classification of South Africa (DWA, 2012);
- The relationship between South African geology and hydrogeology (Lourens, 2013).

4.4 Groundwater and surface water users in the project area

A review of SADC GIP (2025) data for the study area indicates that there are eight (8) boreholes within a 5km radius of the site. The groundwater users identified are listed in Table 4-2, and their positions are shown in Figure 4-1. WARMS 2024 data, however, also suggest that there are 2 registered boreholes and, further to this, 4 surface water users – refer to Table 4-3.

Table 4-2: Boreholes identified within a 5km radius of the site

ID	Source	Latitude (WGS84) Decimal Degrees	Longitude (WGS84) Decimal Degrees	Elevation (mamsl)	Water Level (mbgl)
736524	SADAC GIP / NGA	-27.91295	29.98307	1215	20
736558	SADAC GIP / NGA	-27.90462	29.89252	1309	10.2
736561	SADAC GIP / NGA	-27.94878	29.94863	1250	5.1
737405	SADAC GIP / NGA	-27.86712	30.01641	1227	6

Table 4-3: WARMS users within the GW HRU

ID	Latitude (WGS84)	Longitude (WGS84)	Resource Type	Registered Volume (m ³ /yr.)
21039332	-27.89167	29.97083	RIVER/STREAM	10960
21099810	-27.883333	29.936111	RIVER/STREAM	0
21126586	-27.88279	29.94371	RIVER/STREAM	0
21194887	-27.875	29.973889	SCHEME	80000
21205688	-27.863639	29.957806	BOREHOLE	25000
21222295	-27.917894	29.981744	BOREHOLE	0

4.5 Field investigation data

4.5.1 Field Hydrocensus

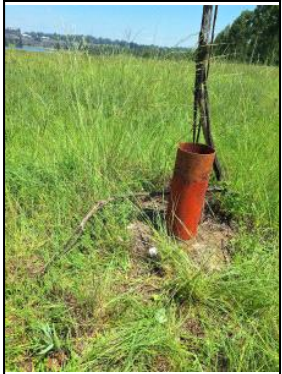
The results of the follow-up hydrocensus are summarised in Table 4-4. The spatial distribution of the boreholes is shown in Figure 4-1. 15 boreholes were identified, of which 2 are used for domestic water supply, 1 is used for the decant management at Ballengeich and the remaining are used for groundwater monitoring. The water level was observed to vary from artesian (decant area) to an average of 5.7 metres below ground level (mbgl).

Table 4-4: Summary of field hydrocensus boreholes

BH ID	Lat	long	elevation	water level	collar	pH	EC	TDS	Temp	Comment	Photo
	(WGS84)	(WGS85)	(mamsl)	(mbgl)	(m)		uS/cm	mg/L	C		
GW1	-27.890424	29.962933	1193	Artesian	0.15	5.8	6515	3292	21.56	This borehole is located west of the Disposal dump within old underground workings. This borehole is artesian and decants into the Horn River. Decant flow rate is 2.25 L/s	
GW6	-27.879779	29.971797	1216	3.98	0.39	7.2	250	160	25.9	GW Monitoring borehole	

BH ID	Lat	long	elevation	water level	collar	pH	EC	TDS	Temp	Comment	Photo
	(WGS84)	(WGS85)	(mamsl)	(mbgl)	(m)		uS/cm	mg/L	C		
GW12	-27.885248	29.97472	1195	3.33	0.7	2.7	4568	2289	27.8	GW Monitoring borehole, Located north of PCDs	
GW13	-27.885251	29.971342	1215	7.24	0.56	2.6	3950	2560	25.6	The GW Monitoring Borehole is located north of the Ballengeich Discard area.	

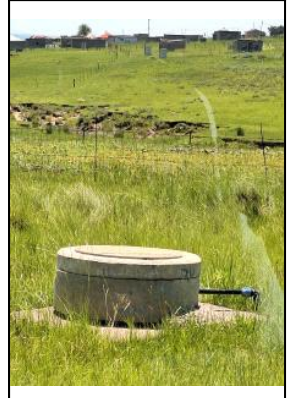
BH ID	Lat	long	elevation	water level	collar	pH	EC	TDS	Temp	Comment	Photo
	(WGS84)	(WGS85)	(mamsl)	(mbgl)	(m)		uS/cm	mg/L	C		
GW15	-27.88271	29.968542	1218	9.93	0.4	3.7	2600	1400	26.4	GW Monitoring Borehole, Located between the Horns River and the Ballengeich discard dump.	
GW16	-27.888514	29.966887	1209	0.97	0.35	7.1	1890	949	23.51	The borehole is located Downstream and west of the Discard dump and decant sump.	

BH ID	Lat	long	elevation	water level	collar	pH	EC	TDS	Temp	Comment	Photo
	(WGS84)	(WGS85)	(mamsl)	(mbgl)	(m)		uS/cm	mg/L	C		
GW17	-27.891685	29.963245	1195	3.04	0.36	7.2	192	203	28.15	The borehole located on the underground workings west of the Discard dump and N11	
UGBH1	-27.88419	29.965717	1205	21	0.5	5.2	2060	1030	27.9	Boreholes are located on the underground workings north of the Discard dump and east of the N11.	

BH ID	Lat	long	elevation	water level	collar	pH	EC	TDS	Temp	Comment	Photo
	(WGS84)	(WGS85)	(mamsl)	(mbgl)	(m)		uS/cm	mg/L	C		
UGBH3	-27.879209	29.949463	1263	8.625	0.63	6.7	250	120	25.9	The borehole is located on the old underground workings northwest of the Discard dump and west of the N11.	
UGBH5	-27.898445	29.967222	1210	6.9	0.62	6.9	450	190	24.5	The borehole is located southwest of the disposal dump and has old underground workings.	

BH ID	Lat	long	elevation	water level	collar	pH	EC	TDS	Temp	Comment	Photo
	(WGS84)	(WGS85)	(mamsl)	(mbgl)	(m)		uS/cm	mg/L	C		
PZ01	-27.879772	29.971738	1216	3.61	0	7.2	270	180	26.7	This borehole is located 1.68 m from GW6.	
PZ02	-27.890498	29.964031	1198	3.24	0.26	5.7	3050	1550	26.2	This borehole is located on the underground workings west of the disposal dump and N11.	

BH ID	Lat	long	elevation	water level	collar	pH	EC	TDS	Temp	Comment	Photo
	(WGS84)	(WGS85)	(mamsl)	(mbgl)	(m)		uS/cm	mg/L	C		
BH1	-27.891642	29.966286	1207	2.85	0.56	5.5	2563	1299	20.38	This Borehole is located west of the discard dump and north of the old stockpile area.	
HBH1	-27.898566	29.991891	1216	No Data	No Data	No Data	No Data	No Data	No Data	Broken Hand pump borehole	

BH ID	Lat	long	elevation	water level	collar	pH	EC	TDS	Temp	Comment	Photo
	(WGS84)	(WGS85)	(mamsl)	(mbgl)	(m)		uS/cm	mg/L	C		
HBH2	-27.908696	29.998817	1232	No access	No Data	No Data	No Data	No Data	No Data	The pump was switched off during hydrocensus, and borehole water was used for irrigation in the nearby gardens.	

4.5.2 Slug testing/falling head tests

Slug tests were used to estimate the hydraulic parameters of the existing boreholes in the study area. Six (6) boreholes were subjected to a slug test with a 60-minute duration. The slug had dimensions of 2m long and a diameter of 90mm. The water level response over time was then recorded manually by taking water level measurements with a dip meter. The results were then analysed using the AQTESOLV software to estimate the hydraulic conductivity (K) and transmissivity (T) of each borehole. The results of the tests are summarised in Table 4-5. Aquifer test data is available in **Appendix A**.

Table 4-5: Summary of slug test results

Borehole	Comment	Geology	K (m/day)
GW12	Only a small seepage of water was found at 6m.	Pv SND	0.3491
GW13	The blow yield was 2.80 l/s at 12m	Alluvium/OC	13.9
GW16	The blow yield was 0.83 l/s at 12m	Alluvium/OC	15.58
BH1		Alluvium	5.183
GW17	Drilled through the underground workings at 21m.	VOID	4.823
UGBH5		Jd Contact	2.424
Average			11.55

4.5.3 Geophysical Investigation

Three (3) Magnetic (Mag) survey lines were conducted around the discard dump with their spatial orientation and resulting profiles displayed in Figure 4-1. The findings are briefly summarised as follows:

- Transition zones from an abrupt low magnetic field to a high magnetic field indicate contact zones between the sub-surface rock units. The contact zones are regarded as preferential groundwater flow paths. Areas of low parabola magnetic fields are likely due to weathering and/or fracturing or faults associated with groundwater movement. Distinct magnetic anomalies are generally associated with dolerite intrusions where groundwater flow paths can be formed in the fracture zones.
- Two (2) peak anomalies were identified on Line 1, and two (2) monitoring boreholes were proposed to be drilled, as captured in Table 4-6.

Table 4-6: Borehole locations targeted from geophysical survey

Site	Type	Latitude	Longitude	Proposed Depth
EWS BH1	Proposed Groundwater	-27.888936	29.977264	30m
EWS BH2	Proposed Groundwater	-27.886541	29.976321	30m

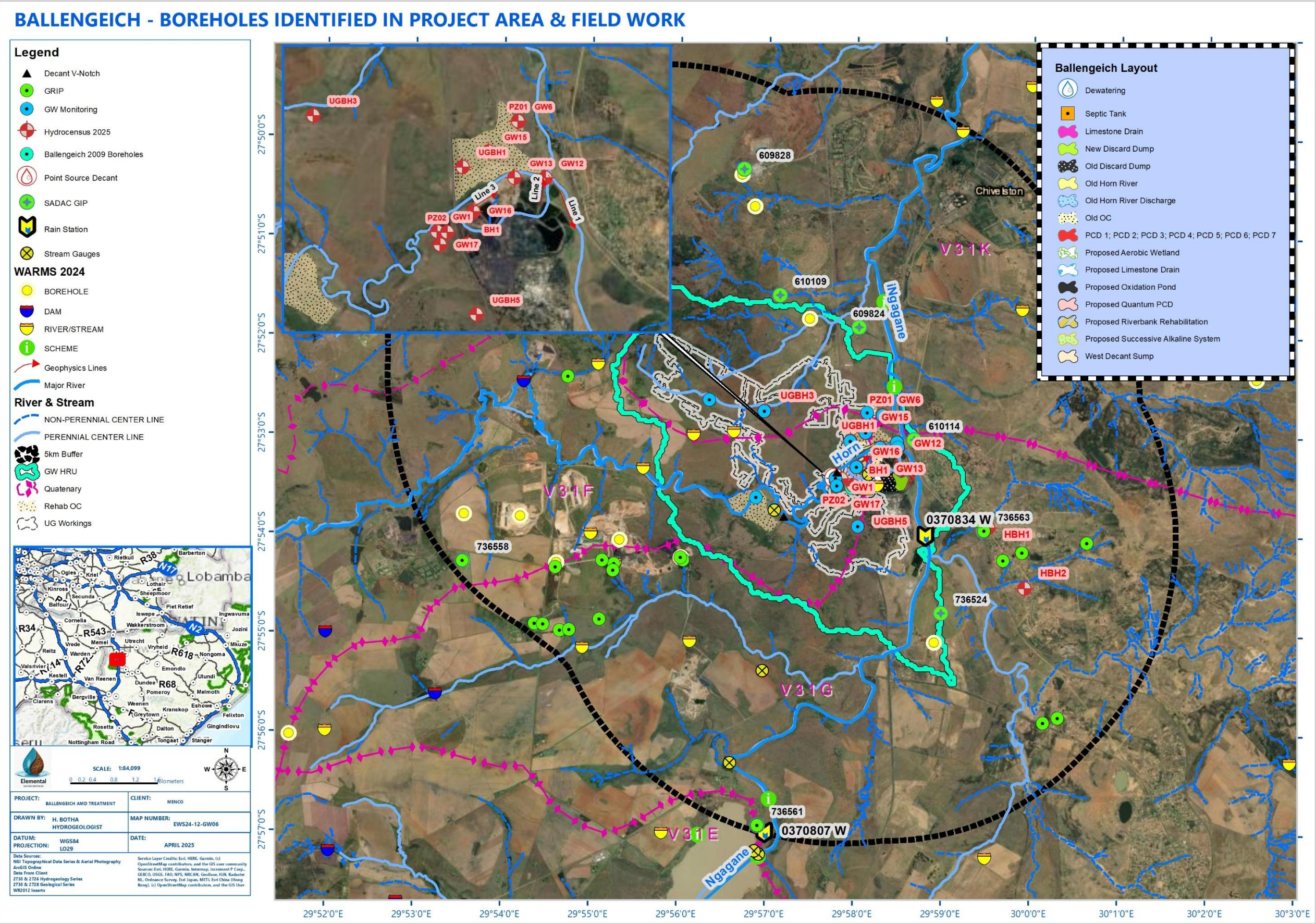


Figure 4-1: Fieldwork, proposed drilling positions and hydrocensus boreholes identified in the project area

4.6 Groundwater recharge calculations

Recharge is defined as the process by which water is added from outside to the zone of saturation of an aquifer, either directly into a formation or indirectly by way of another formation. The effective rainfall recharge is dependent on catchment geology, soil surface run-off and stream morphology. Seepage from onsite infrastructure, such as the return water dams and/or pollution control dams, may contribute a small proportion of recharge to the system.

Groundwater recharge was estimated from the literature and hydrogeology maps for the study area. The groundwater recharge (Re) for the local area was also calculated using the chloride method (Bredenkamp, et al., 1995) and is expressed as a percentage of the MAP. The method is based on the following equation:

$$R = \frac{\text{Chloride concentration in rainfall}}{\text{Chloride concentration in ground water}} \times 100 \quad \text{Equation 1}$$

The recharge to the aquifer was further refined and determined by running qualified guess analyses using the RECHARGE model developed by IGS (Van Tonder & Xu, 2000); (Vegter, 1995).

4.7 Groundwater quantity/availability assessment

An Intermediate Groundwater Reserve Determination (IGRD) (Parsons & Wentzel, 2007) was conducted for the study area to fulfil the requirements of the Water Use License concerning groundwater use in terms of Section 21a of the NWA. The IGRD aims to establish the groundwater reserve, thereby quantifying the safe aquifer yield, which is required to determine the impact of aquifer dewatering.

From a groundwater point of view, it is necessary to determine the groundwater quantity and the likely future impacts on quantity. Moreover, the groundwater balance gives an estimate of how much groundwater can safely be abstracted on a sub-catchment level (i.e., groundwater dewatering or wellfield dewatering).

The IGRD considers the following parameters:

- ✚ Effective recharge from rainfall and specific geological conditions.
- ✚ Basic human needs for the sub-catchment.
- ✚ Groundwater contribution to surface water (baseflow).
- ✚ Existing and proposed abstraction; and
- ✚ Surplus reserve.

The groundwater balance and the reserve determination on a sub-catchment scale are summarised below:

$$\text{GW}_{\text{available}} = (\text{Re}) - (\text{EU} + \text{BHN} + \text{BF} + \text{PU})$$

Where:

- ✚ $GW_{\text{available}}$ = Available groundwater for use.
- ✚ Re = Effective recharge to the aquifer.
- ✚ BF = Baseflow to surface water streams.
- ✚ EU = Existing groundwater abstraction/use (identified on sub-catchment, excluding applicant).
- ✚ PU = proposed use/likely dewatering use.
- ✚ BHN = Basic Human Needs.

4.8 Numerical model development

The modelling processes followed are indicated in Figure 4-2. The numerical model for the project was constructed using Visual Modflow 6.1 Pro, Build 7088.31257, a pre-and post-processing package for the modelling code MODFLOW. MODFLOW is a modular three-dimensional groundwater flow model developed by the United States Geological Survey (Harbaugh, et al., 2000). MODFLOW uses 3D finite-difference discretisation and flow codes to solve the governing equations of groundwater flow.

The numerical model used in this modelling study was based on the conceptual model developed from the findings of the desktop and the baseline investigations. The model simulates groundwater flow based on a three-dimensional cell-centred grid and may be described by the following partial differential equation:

$$\frac{\partial}{\partial x} \left(K_{xx} \frac{\partial h}{\partial x} \right) + \frac{\partial}{\partial y} \left(K_{yy} \frac{\partial h}{\partial y} \right) + \frac{\partial}{\partial z} \left(K_{zz} \frac{\partial h}{\partial z} \right) \pm W = S_s \frac{\partial h}{\partial t} \quad \text{Equation 2}$$

Where:

- ✚ ∂ - partial derivative.
- ✚ K_{xx} , K_{yy} , and K_{zz} are values of hydraulic conductivity along the x, y, and z coordinate axes, which are assumed to be parallel to the major axes of hydraulic conductivity (L/T).
- ✚ h is the potentiometric head (L).
- ✚ W is a volumetric flux per unit volume representing sources and/or sinks of water.

With:

- ✚ $W < 0.0$ for flow out of the ground-water system, and $W > 0.0$ for flow in (T-1).
- ✚ S_s is the specific storage of the porous material (L-1), and
- ✚ t is time (T).

Equation 2, when combined with boundary and initial conditions, describes transient three-dimensional groundwater flow in a heterogeneous and anisotropic medium, provided that the principal axes of hydraulic conductivity are aligned with the coordinate directions (Harbaugh, et al., 2000).

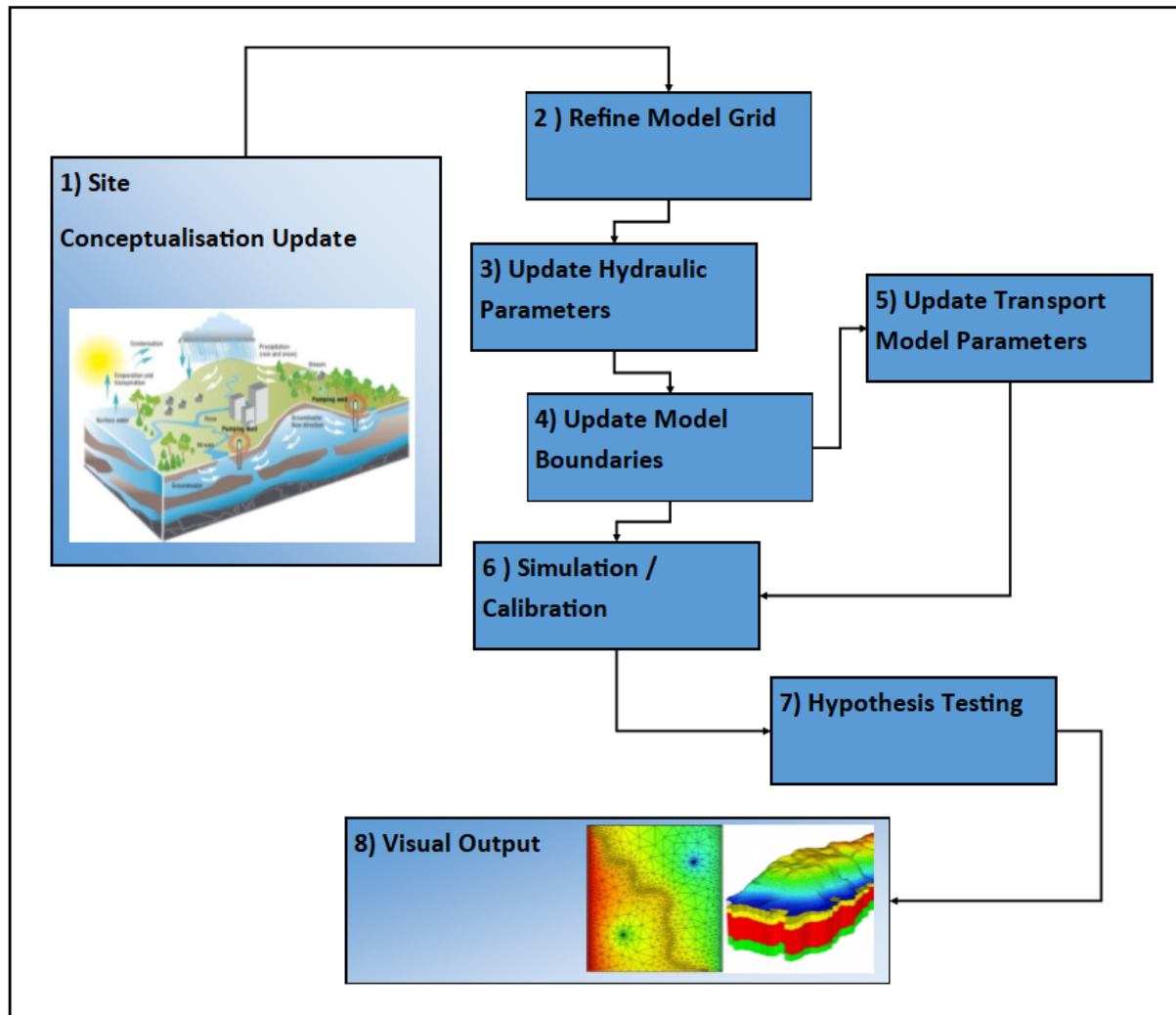


Figure 4-2: Numerical groundwater modelling process

4.9 Model confidence level classification

The Australian Groundwater Modelling Guidelines (Barnett, et al., 2012) refer to the following two principles that were considered in the numerical calibration process (refer to **Appendix D**):

Guiding Principle 2.3:

- A target model confidence level classification should be agreed upon and documented at an early stage of the project to help clarify expectations. The classification can be estimated from a semi-quantitative assessment of the available data on which the model is based (both for conceptualisation and calibration), the way the model is calibrated, and the predictions formulated.
- EWS aimed to construct a Class 2 flow and transport model. Class 2 models are founded on sufficient hydrogeological data (i.e., water level data and aquifer hydraulic parameters) and can be used to predict the future behaviour of a groundwater aquifer system.

Guiding Principle 2.4:

- The initial assessment of the confidence level classification should be revisited at later stages of the project, as many of the issues that influence the classification may not be known at the model planning stage.

4.10 Hydrogeological risk assessment

Due to the assessment forming part of a larger risk assessment for the study area, the potential impacts and the determination of impact significance were assessed. The process of assessing the potential impacts of the project includes the following four activities:

1. Identification and assessment of potential impacts.
2. Prediction of the nature, magnitude, extent, and duration of potentially significant impacts.
3. Identification of mitigation measures that could be implemented to reduce the severity or significance of the impacts of the activity.
4. Evaluation of the significance of the impact after the mitigation measures have been implemented, i.e., the significance of the residual impact.

As per the 2014 EIA Regulations (GN982 of 4 December 2014, as amended), the significance of potential impacts was assessed in terms of the following criteria:

- I. Cumulative impacts.
- II. Nature of the impact.

- III. The extent of the impact.
- IV. Probability of the impact occurring.
- V. The degree to which the impact can be reversed.
- VI. The degree to which the impact may cause irreplaceable loss of resources.
- VII. The degree to which the impact can be mitigated.

Table 4-7 provides a summary of the criteria used to assess the significance of the potential impacts identified. An explanation of these impact criteria is provided in Table 4-8.

The net consequence is established by the following equation:

$$\text{Consequence} = (\text{Duration} + \text{Extent} + \text{Irreplaceability of resource}) \times \text{Severity}$$

The environmental significance of an impact was determined by:

$$\text{Environmental Significance} = \text{Consequence} \times \text{Probability}$$

Table 4-7: Proposed Criteria and Rating Scales to be used in the Assessment of the Potential Impacts

Criteria	Rating Scales	Notes
Nature	Positive (+)	An evaluation of the effect of the impact related to the proposed development.
	Negative (-)	
Extent	Footprint (1)	The impact only affects the area in which the proposed activity will occur.
	Site (2)	The impact will affect only the development area.
	Local (3)	The impact affects the development area and adjacent properties.
	Regional (4)	The impact extends beyond municipal boundaries.
	National (5)	The impact extends beyond more than 2 regional/ provincial boundaries.
	International (6)	The impact extends beyond the country's borders.
Duration	Temporary (1)	The duration of the activity associated with the impact will last 0-6 months.
	Short-term (2)	The duration of the activity associated with the impact will last 6 -18 months.
	Medium-term (3)	The duration of the activity associated with the impact will last 18 months - 5 years.
	Long-term (4)	The duration of the activity associated with the impact will last more than 5 years.
Severity	Low (1)	Where the impact affects the environment in such a way that natural, cultural, and social functions and processes are minimally affected.
	Moderate (2)	Where the affected environment is altered but natural, cultural, and social functions and processes continue albeit in a modified way; and valued, important, sensitive, or vulnerable systems or communities are negatively affected.
	High (3)	Where natural, cultural, or social functions and processes are altered to the extent that the natural process will temporarily or permanently cease, and valued, important, sensitive, or vulnerable systems or communities are substantially affected.
Potential for impact on irreplaceable resources	No (0)	No irreplaceable resources will be impacted.
	Yes (1)	Irreplaceable resources will be impacted.
Consequence	Extremely detrimental (-25 to -33)	A combination of extent, duration, intensity, and the potential for impact on irreplaceable resources.
	Highly detrimental (-19 to -24)	

Criteria	Rating Scales	Notes
	Moderately detrimental (-13 to -18)	
	Slightly detrimental (-7 to -12)	
	Negligible (-6 to 0)	
	Slightly beneficial (0 to 6)	
	Moderately beneficial (13 to 18)	
	Highly beneficial (19 to 24)	
	Extremely beneficial (25 to 33)	
Probability (the likelihood of the impact occurring)	Improbable (0)	It is highly unlikely or less than 50% likely that an impact will occur.
	Probable (1)	It is between 50 and 70% certain that the impact will occur.
	Definite (2)	It is more than 75% certain that the impact will occur or the impact will occur.
Significance	Very high – negative (-49 to -66)	A function of Consequence and Probability.
	High – negative (-37 to -48)	
	Moderate – negative (-25 to -36)	
	Low – negative (-13 to -24)	
	Neutral - Very low (0 to -12)	
	Low-positive (0 to 12)	
	Moderate-positive (13 to 24)	
	High-positive (37 to 48)	
	Very high – positive (49 to 66)	

Table 4-8: Explanation of Assessment Criteria

Criteria	Explanation
Nature	This is an evaluation of the type of effect the construction, operation, and management of the proposed development would have on the affected environment. Will the impact of change on the environment be positive, negative, or neutral?
Extent or Scale	This refers to the spatial scale at which the impact will occur. The extent of the impact is described as footprint (affecting only the footprint of the development), site (limited to the site), and regional (limited to the immediate surroundings and closest towns to the site). The extent of scale refers to the actual physical footprint of the impact, not to the spatial significance. It is acknowledged that some impacts, even though they may be of a small extent, are of very high importance, e.g., impacts on species of very restricted range. To avoid "double counting, specialists have been requested to indicate spatial significance under "intensity" or "impact on irreplaceable resources" but not under "extent" as well.
Duration	The lifespan of the impact is indicated as temporary, short, medium, and long-term.
Severity	This is a relative evaluation within the context of all the activities and the other impacts within the framework of the project. Does the activity destroy the impacted environment, alter its functioning, or render it slightly altered?
Impact on irreplaceable resources	This refers to the potential for an environmental resource to be replaced should it be impacted. A resource could be replaced by natural processes (e.g., by natural colonization from surrounding areas), through artificial means (e.g., by reseeding disturbed areas or replanting rescued species) or by providing a substitute resource, in certain cases. In natural systems, providing substitute resources is usually not possible, but in social systems, substitutes are often possible (e.g., by constructing new social facilities for those who are lost). Should it not be possible to replace a resource, the resource is essentially irreplaceable, e.g., red data species that are restricted to a particular site or habitat to a very limited extent.
Consequence	The consequence of the potential impacts is a summation of the above criteria, namely the extent, duration, intensity, and impact on irreplaceable resources.
Probability of occurrence	The probability of the impact occurring is based on the professional experience of the specialist with environments of a similar nature to the site and/or with similar projects. It is important to distinguish between the probability of the impact occurring and the probability that the activity causing a potential impact will occur. Probability is defined as the probability of the impact occurring, not as the probability of the activities that may result in the impact.
Significance	Impact significance is defined as a combination of the consequence (as described below) and the probability of the impact occurring. The relationship between consequence and probability highlights that the risk (or impact significance) must be evaluated in terms of the seriousness (consequence) of the impact, weighted by the probability of the impact occurring. In simple terms, if the consequence and probability of an impact are high, then the impact will have a high significance. The significance defines the level to which the impact will

Criteria	Explanation
	influence the proposed development and/or environment. It determines whether mitigation measures need to be identified and implemented and whether the impact is important for decision-making.
Degree of confidence in predictions	Specialists and the EIR team were required to indicate the degree of confidence (low, medium, or high) in the predictions made for each impact based on the available information and their level of knowledge and expertise. The degree of confidence is not taken into account in the determination of consequence or probability.
Mitigation measures	Mitigation measures are designed to reduce the consequence or probability of an impact or to reduce both consequence and probability. The significance of impacts has been assessed both with mitigation and without mitigation.

4.11 Water monitoring improvement plan & audit

The monitoring network is based on the principles of a monitoring network design as described by the DWAF “Best Practice Guidelines: G3 Monitoring” (DWAF, 2007). The methodological approach that the monitoring plan follows is represented in Figure 4-3.

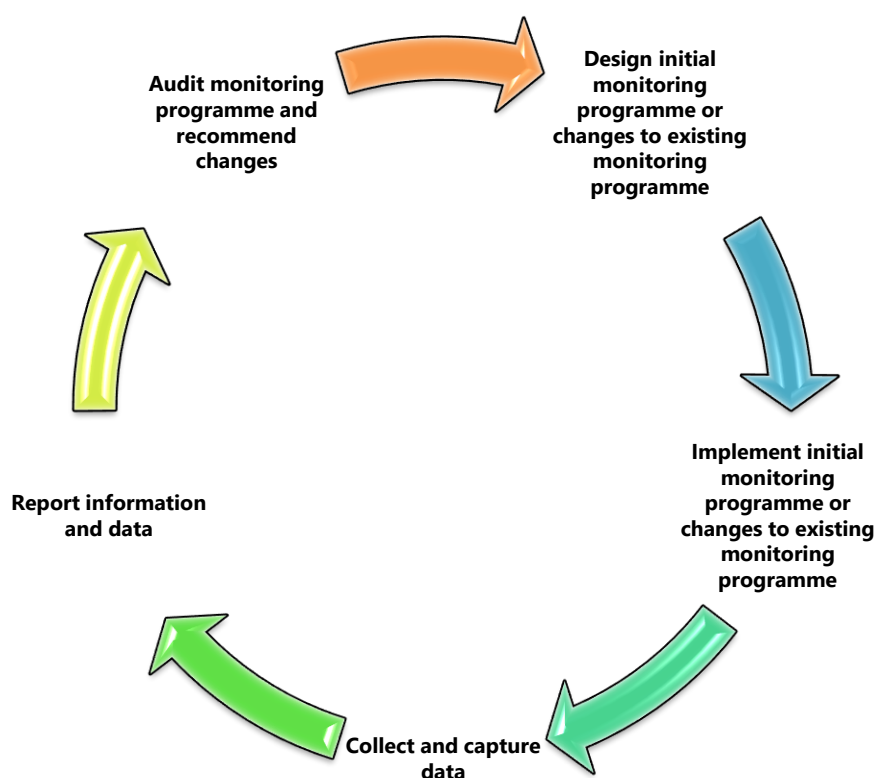


Figure 4-3: Monitoring Process

The existing groundwater monitoring network was reviewed, and a gap assessment was undertaken. A groundwater monitoring improvement, or full monitoring plan, was developed based on available site information and risks identified.

5 PREVAILING GROUNDWATER CONDITIONS

The following section supplies an overview of the prevailing hydrogeological conditions encountered in the Project Area. The data were derived from available literature sources, and fieldwork was completed.

5.1 Local geology & soils

The regional geology of the area is dominated by a succession of near-horizontal sedimentary rocks of the Vryheid Formation (Pv) of the Ecca Group of the Karoo Supergroup (DMEA, 1998g). These sediments comprise a cyclic succession of sandstones, shales, mudstones, carbonaceous shales and coal seams, underlain by older basement granitic and granitoid rocks, refer to Figure 5-2. Intrusive dolerite (Jd) sills and dykes are known to occur in the project area.

According to the Land Types of South Africa databases (ARC, 2006), the soils in the area fall within the Bb land types. Soils associated with these groups typically entail:

- ✚ Bb - Red and yellow, dystrophic/mesotrophic, apedal soils with plinthic subsoils (plinthic soils comprise >10% of land type, red soils comprise <33% of land type).

According to Soil Conservation Service (SCS) data for the project area, the soils are divided into "Type A/B" soils. SCS curve number is a function of the ability of soils to allow infiltration of water, land use and the antecedent soil moisture condition. Table 5-1 provides a summary of the hydrological characteristics of the different SCS soil types. The soils have a moderate erosion potential.

Table 5-1: Summary of SCS soil type hydrological characteristics (Muthu, 2015)

Hydrological Soil	Type of Soil	Runoff Potential	Final Infiltration Rate (mm/hr)	Remarks
Group A	Deep, well-drained sands and gravel	Low	>7.5	High rate of water transmission
Group B	Moderately deep, well-drained with moderately fine to coarse textures	Moderate	3.8 – 7.5	Moderate rate of water transmission
Group C	Clay loams, shallow sandy loam, soils with moderately fine to fine textures	Moderately high	1.3 – 3.8	Moderate rate of water transmission
Group D	Clay soils that swell significantly when wet, heavy plastic and soils with a permanent high-water table	High	<1.3	Low rate of water transmission

5.2 Structural geology

Several Karoo dolerite (Jd) sills and dykes exist in the area. The older, more persistent sills are generally concordant, while the younger ones are typically erratic and dyke-like. Hilltops towards the northwest are generally capped with 10m to >100m thick dolerite sills.

5.3 Geochemical overview

In the absence of site-specific geochemical data, EWS presents geochemical data from nearby coal mines mining (Hlobane, Aviemore, Roy Point, Kilbarchan, Magdalena and Coalfields in the Newcastle and Dundee areas) that have mined the same coal seams (Alfred, Dundas and Gus) to present an overview of the acid potential of the waste residues (i.e. the discard dump). Data was provided by Kangra Coal.

From available geochemical data and EWS experience, the following is anticipated:

- ✚ During the removal of the dump, sulfide-bearing minerals associated with the discarded material will be exposed to oxygen and rainwater infiltration.
- ✚ Seepage from the discard dump material will be prone to cause acid mine drainage (low pH, High TDS, High pH) and

The discard dump and decanting underground workings can be seen as the point source at the Site (from a geochemical perspective), and it is anticipated that removing the dump may improve the impact of the mine residue associated with the area. Furthermore, treatment of the decant discharge will decrease the impact on the surface water.

Based on a sample taken during this study from GW1 situated in the decanting underground working, the pH of the AMD is <3, $\text{SO}_4 > 2800 \text{ mg/l}$ and $\text{Fe} > 262 \text{ mg/l}$.

5.4 Hydrogeology and aquifer units

Based on available data, the aquifers occurring in the study area can be divided into two (2) distinct zones:

1. Unconfined quaternary alluvium zones:

- ✚ In several areas associated with the study area (i.e. along the Ngagane River and the Horn River, as well as the old Horn River flow path that was diverted at Ballengeich), consolidated alluvium occurs. These occurrences can be classified as unconfined aquifer zones.
- ✚ The recharge to these aquifer zones is estimated to vary from 10% to 20% of the MAP and have a greater permeability and porosity than the underlying and surrounding weathered aquifer zones.

2. Shallow weathered aquifer zone (unconfined to semi-confined):

- ✚ The weathered aquifer is an unconfined system located in the weathered sandstone formation of the Eccu Group. In the Eccu group, multi-layered aquifers are common. It is, however, conceptualised as a single unit with interconnectivity between layers as a best-case scenario.
- ✚ This aquifer is recharged by rainfall. Recharge is estimated to range from 4 to 6 % of the MAP.

- ✚ These aquifer types generally have moderate primary hydraulic conductivity and medium to low porosity values due to the secondary nature of the aquifer (King *et al.*, 1998).
- ✚ On a catchment scale, the average weathered thickness is estimated to be in the order of 28 m (King *et al.*, 1998).

3. Intergranular and fractured aquifer zone (semi-confined to confined):

- ✚ The fractured aquifer zone is characterised by the older Karoo Rock of the Ecca Group and normally has a very low permeability due to its secondary aquifer characteristics. The aquifer can be referred to as being intergranular and fractured.
- ✚ These aquifer types generally have low primary hydraulic conductivity and medium to low porosity values due to the secondary nature of the aquifer (King *et al.*, 1998).
- ✚ Recharge to this aquifer unit is in the form of percolation from the overlying weathered zone. The percentage recharge to this aquifer is estimated to be in the order of 1 – 3% of the annual rainfall, based on work by Kirchner *et al.* (1991) and Bredenkamp (1987) in other parts of the country.
- ✚ The saturated fractured aquifer thickness for the general area is estimated to be in the order of 100 - 108 m (King *et al.*, 1998; Lourens, 2013).
- ✚ In terms of water quality, the fractured Karoo aquifer contains higher salt loads than the upper-weathered aquifer. These higher concentrations are attributed to the longer contact time between the water and the rock. The occasional high chloride and sodium levels are attributed to boreholes in the vicinity of areas where salts naturally accumulate on the surface, such as pans or springs.

4. Mine hydrogeological units:

- ✚ Historical underground workings have likely led to the formation of a hydrogeological unit in the mines that have undergone coal extraction. Significantly higher hydraulic conductivity and storage values are expected for the aquifer due to the presence of mine voids or backfilled material with higher permeability than surrounding sediment/rock.

5.5 Preferential flow paths

Dolerite intrusions in the form of dykes and sills are common in the Karoo Supergroup and are often encountered in the study area. These intrusions can serve as both aquifers and aquifuges¹.

¹ Aquifuge: An impermeable body of rock which contains no interconnected openings or interstices and therefore neither absorbs nor transmits water.

Thick un-weathered dykes will inhibit the flow of water, while the baked and cracked contact zones can be highly conductive. These conductive zones effectively interconnect the strata of the Ecca sediments both vertically and horizontally into a single but highly heterogeneous and anisotropic zone on the scale of typical mining activity.

Several likely geological structures were identified as part of this investigation, and the presence of these structures and water-bearing capabilities should be confirmed via the drilling of several monitoring boreholes.

5.6 Primary groundwater occurrence

The hydrogeology is mainly controlled by the movement of water via weathered zones (i.e. upper weathered Ecca) and secondary structures such as faulting and dykes. According to available literature for the region (King *et al.*, 1998), groundwater is typically encountered in/along:

- ✚ Dolerite dyke and sill contacts with the host rock.
- ✚ Contact zones between lithologies or unconformities.
- ✚ Faults and associated fracture zones.

5.7 Groundwater recharge

Recharge to the underlying weathered aquifer is estimated to range from 4 to 6 % of the MAP, and that of deeper aquifer zones is estimated to be <3% (DWAF, 2006). The recharge to the aquifer was further refined and determined by running qualified guess analyses using the RECHARGE model developed by IGS, as summarised in Table 5-2. A recharge of 34.7 mm/yr corresponding to 5.1 % was determined for the overall combined aquifer, and as further estimated per surface geology unit in the project area (i.e. alluvium recharge is > sedimentary rock > intrusive solid rock). Recharge applied to the numerical model.

Table 5-2: RECHARGE Program (Van Tonder & Yongxin Xu, 2000)

Method	mm/a	% of rainfall	Certainty (Very High=5 ; Low=1)
CI	56.3	7.6	4
Qualified Guesses :			
Soil	50.8	6.9	3
Geology	25.2	3.4	3
Vegter	32.0	4.3	3
Acru	30.0	4.1	3
Base Flow (minimum Re)	20.0	2.7	2
Groundwater Flow Model	37.7	5.1	5
Average recharge	37.7	5.1	
Recharge =	37.7	5.1	= 1.05541

5.8 Aquifer yield & hydraulic conductivity

The aquifer is considered a low to moderate-yielding aquifer and has a reported yield in the order of 0.5 l/s to 2 l/s – Type d 3 aquifer (King, et al., 1998). Several boreholes have been slug-tested and pump-tested at Ballengeich, as well as neighbouring mines. The hydraulic permeability and transmissivity for the Eccu sediments, dolerite contacts and alluvium associated with the Project area are listed in Table 5-3 and Table 5-4.

Table 5-3: Summary of slug test data for Ballengeich

Borehole	Comment	Geology	K (m/day)
GW12	Only a small seepage of water was found at 6m.	Pv SND	0.3491
GW13	The blow yield was 2.80 l/s at 12m	Alluvium/OC	13.9
GW16	The blow yield was 0.83 l/s at 12m	Alluvium/OC	15.58
BH1		Alluvium	5.183
GW17	Drilled through the underground workings at 21m.	VOID	4.823
UGBH5		Jd Contact	2.424
Average			11.55

Table 5-4: Summary of other boreholes tested at neighbouring mines

Borehole ID	Tested By	Borehole Depth (mbgl)	Rest Water Level (mbgl)	Pump Rate (l/sec)	Pump/Recovery Time (min)	Slug Test Duration (min)	Test Type	Calculated Transmissivity (T = m ² /day)	Hydraulic Conductivity (K - m/day)
BH1	Jones & Wagner (2017a)	55	6.78	0.5	10		Constant	0.21	0.01
				-	230		Recovery	0.60	0.12
				-	-		Average	0.41	0.07
BH4	Jones & Wagner (2017a)	40	8.72	0.85	240		Constant	1.59	0.05
				-	240		Recovery	2.04	0.07
				-	-		Average	1.82	0.06
BH3	Jones & Wagner (2017a)	30	15.88	0.5	0.5		Constant	-	-
				-	370		Recovery	0.15	0.01
				-	-		Average	0.15	0.01
BH1a	GCS (2013)	60	11.66	0.5	60		Constant	1.26	0.06
BH6a	GCS (2013)	50	12.27	1.3	180		Constant	14.22	0.71
BH7a	GCS (2013)	60	4.00	1.3	9		Constant	0.51	0.03
BHD4(6)	GCS (2013)	30	6.70	1.3	7		Constant	0.79	0.04
PRBH2a	GCS (2019)	28	26.22			60	Slug Test	0.01	0.00
PRBH3a	GCS (2019)	28	20.65			60	Slug Test	0.01	0.00

PRBH6a	GCS (2019)	30	20.12			60	Slug Test	0.00	0.01
PRBH5a	GCS (2019)	36	17.21			60	Slug Test	0.16	0.01
Geometric Mean								0.21	0.02

5.9 Aquifer storage/storativity

According to King et al. (1998) and DWAF (2006), the aquifer storage/storage coefficient is in the order of magnitude of $< 3.1 \times 10^{-3}$ (unitless) – supported by available pump test data. The porosity of the aquifer is expected to range from 15 to 20 %. Literature data suggest that aquifer storage coefficients range from 5 to 10%.

5.10 Groundwater levels

Available hydrocensus and monitoring data for the Site suggest the following:

- ✚ Groundwater levels for the catchment range from 5 to 25 mbgl.
- ✚ The groundwater levels for the Ballengeich colliery range from artesian (decant area) to an average of 5.7 metres below ground level (mbgl).

Figure 5-1 plots the groundwater elevation vs topographic elevation for groundwater monitoring boreholes situated in and adjacent to the site catchment. There is a good linear relationship ($R \approx 97\%$) between topographic and groundwater elevations. The data suggest that the groundwater table mimics the topography.

Bayesian extrapolation was applied to available data to conceptualise the groundwater elevation and flow directions for the project area. The groundwater elevations and flow directions can be seen in Figure 5-4. Groundwater flow is towards the northeast and closely related to surface water runoff directions.

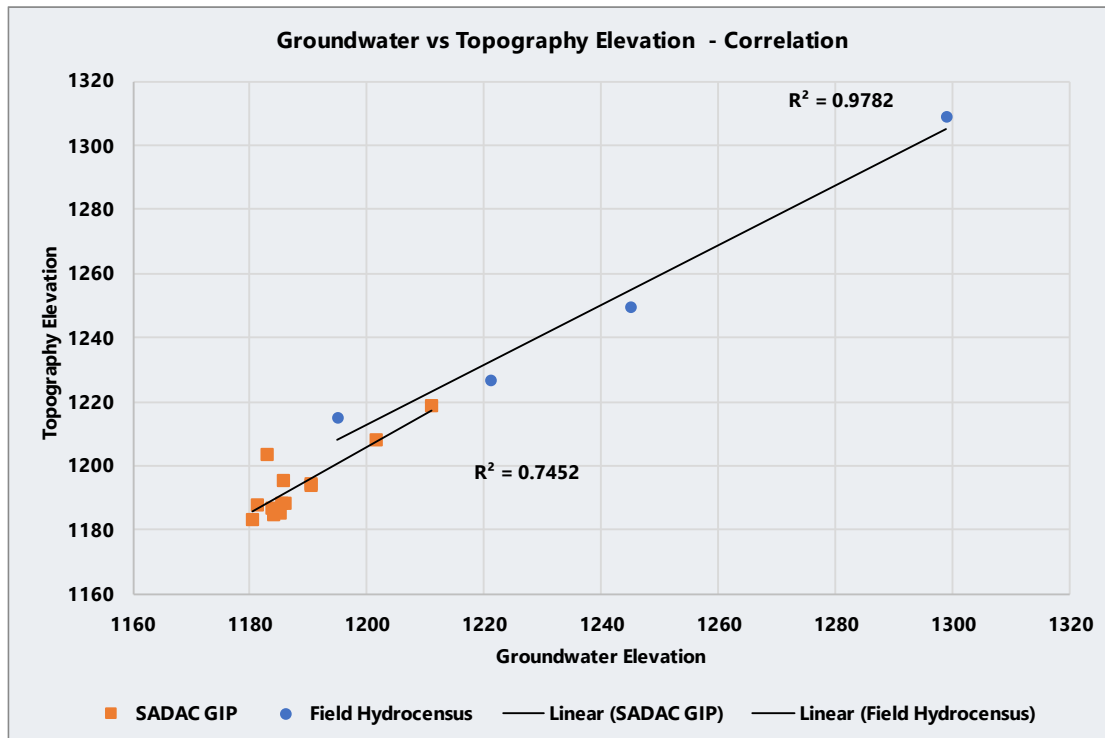


Table 5-5: Hydraulic gradient calculation

Component	BH1 to GW16	GW15 to GW13	GW13 to GW12
h1 (mamsl)	1186.0679	1185.6617	1181.2502
h2 (mamsl)	1184.1309	1181.2502	1180.5695
h1-h2 (m)	1.937	4.4115	0.6807
L (m)	350	394	332
i	0.006	0.011	0.002
K (m/day)	1.57	1.57	1.57
n	0.2	0.2	0.2

Table 5-6: Flow velocity calculation

Flow Rate	BH1 to GW16	GW15 to GW13	GW13 to GW12	Average
m/day	0.0435	0.0881	0.0161	0.0493
m/year	15.8912	32.1503	5.8873	17.9763

Groundwater flow generally follows the topographical characteristics of the area and flows from upstream to downstream within the weathered zone. It can be more complex in the fractured zone (depending on interconnectivity and piezometric pressure heads – complex and difficult to map).

5.12 Aquifer classification

The weathered/fractured aquifer that underlies the site may be classified as a minor aquifer (Parsons, 1995) due to the general yields of less than 2.0 l/s. The Minor Aquifer System is defined as “fractured or potentially fractured rocks which do not have high primary permeability or other formations of variable permeability. Aquifer extent may be limited, and water quality may be variable. Although these aquifers seldom produce large quantities of water, they are important both for local supplies and in supplying base flow to rivers.”

5.13 Aquifer contextualization and extent

As groundwater flow behaviour is aligned to surface water flow conditions in the weathered zone and for the upper saturated aquifer zone, it was assumed that the aquifer extent for the work conducted by EWS coincides with the surface water catchment boundaries. Local topographical boundaries are considered real-life flow boundaries for the upper aquifer zones that could potentially be impacted. Deeper aquifer zones could be subjected to transboundary systems. However, limited information is available to accurately quantify transboundary aquifer movement in the fractured aquifer systems. The potential sphere of influence (i.e. the total area that can likely be subjected to groundwater impacts or the so-called domain) associated with the proposed activities for this investigation is called the sphere of influence (SOIf) and was fixed at a 2.5km radius around the GW HRU.



Figure 5-2: Local surface geology



Figure 5-3: Local hydrogeological setting

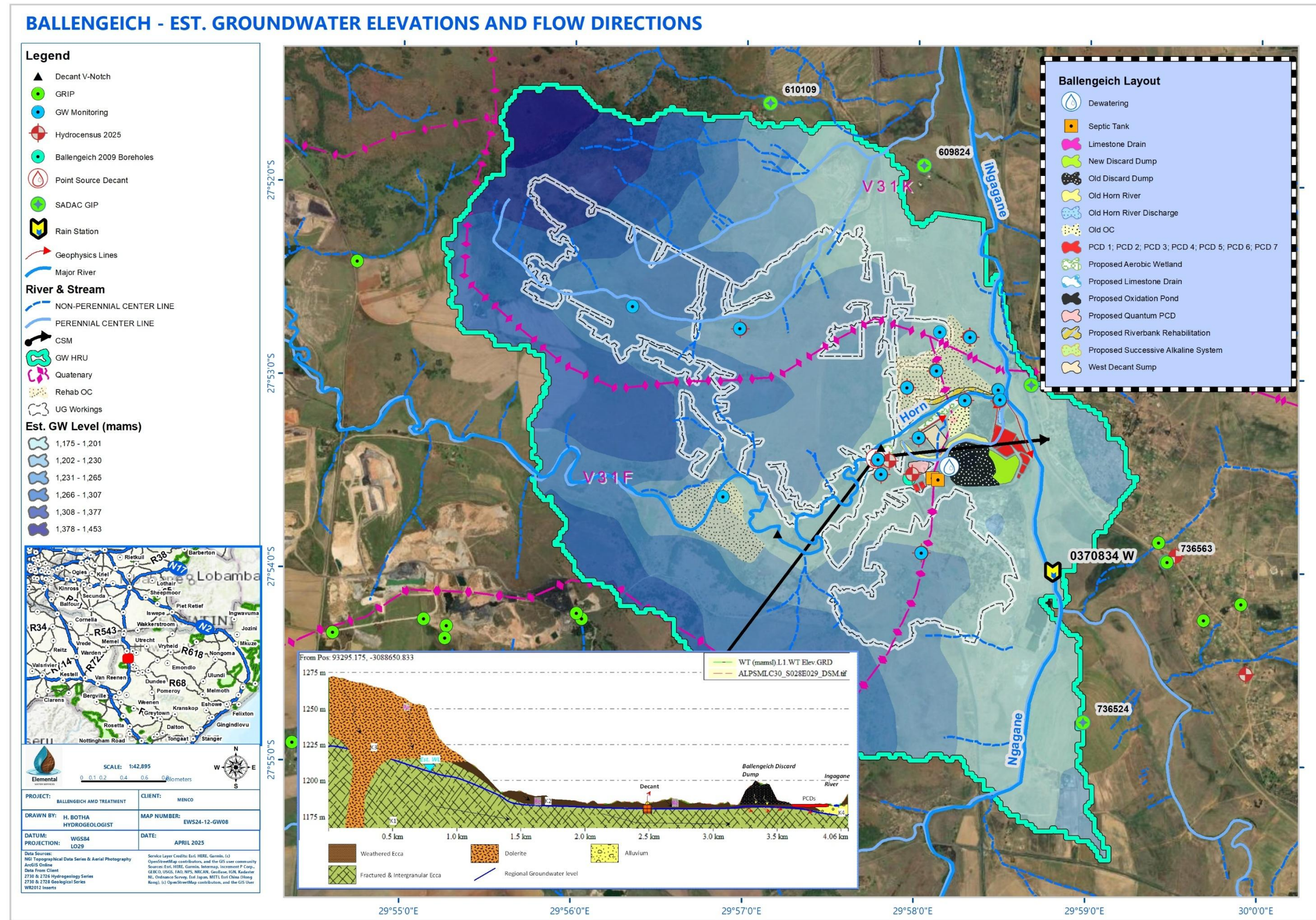


Figure 5-4: Bayesian estimation of groundwater table, groundwater sphere of influence and CSM

5.14 Wetland areas

Based on available National Wetland Freshwater Ecosystem Priority Areas (NFEPA) (Van Deventer, 2018), sections of the Horn River and the old Horn River have been classified as unchanneled valley bottom (UVB) wetlands, and the flood plain of the Ingagane River has been classified as seepage slope (Seep) wetland areas – refer to Figure 1-5. The presence of the wetland units mentioned was confirmed by (MENCO, 2022) – refer to Figure 5-5.

MENCO (2022) determined that the present ecological state and environmental importance and significance of the wetland is Class C (moderately modified and important).

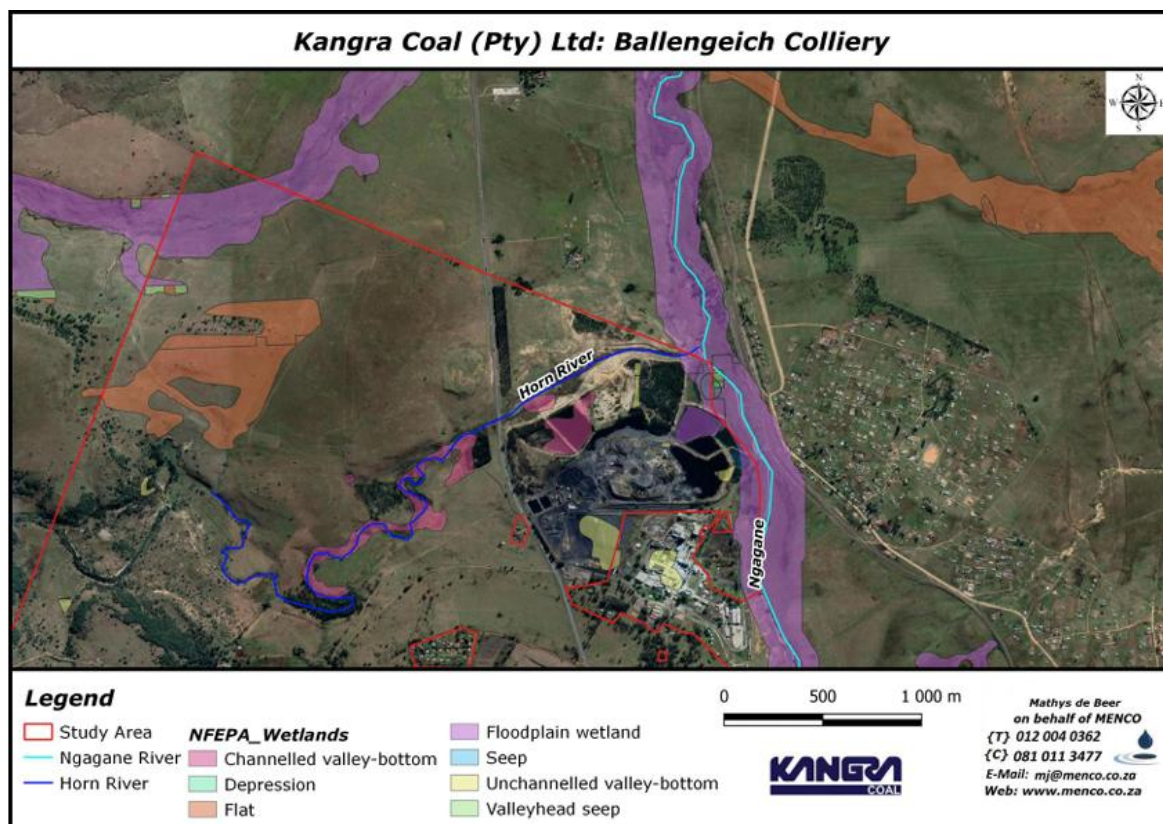


Figure 5-5: Wetland areas identified by MENCO (2022)

In terms of wetland hydrogeology, baseflow is considered the most important contributor to wetland health. Baseflow (refer to Figure 5-6) is a non-process-related term that signifies low amplitude high-frequency flow in a river during dry or fair-weather periods. Baseflow is not a measure of the volume of groundwater discharged into a river or wetland, but it is recognised that groundwater contributes to the baseflow component of a river or wetland flow.

Available literature (WRC, 2015; DWAF, 2006) suggests that groundwater contribution to baseflow ranges from 7 mm/yr (PITMAN MODEL) to 37 mm/yr (HUGHES MODEL). This relates to approximately 0.9% to 4.4% of rainfall. Indications from the water monitoring of the Ngagane River suggest little impact relating to the Ballengeich operations, and therefore, it is believed that the Ngagane River is a losing river system (i.e. limited groundwater baseflow into the river takes place).

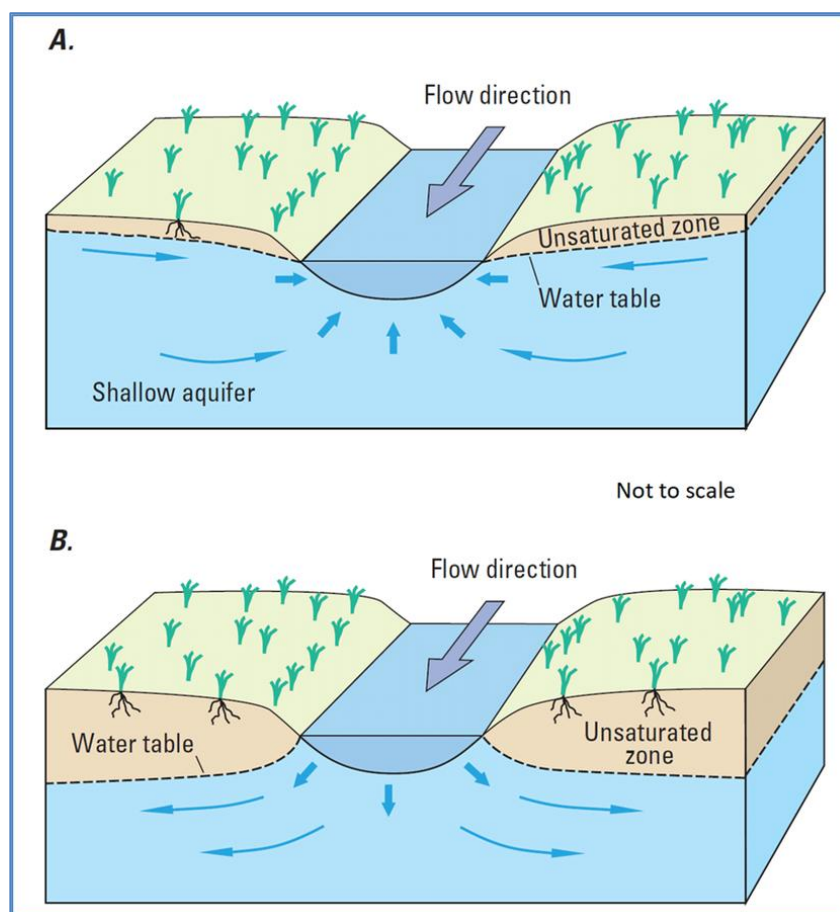


Figure 5-6: Groundwater baseflow concept

5.15 Present ecological state (PES), ecological importance and sensitivity (EIS), Ecological Water Reserve (EWR) and recommended ecological category (REC)

Table 5-7 provides a summary of the PES, EIS, REC and EWR (as a percentage of the MAR / Instream Rating Curves (IRF)) for the quaternary catchments associated with the project area. The same conditions are inferred to apply to delineated sub-catchments. It was decided that EWR could be simplified and represented as a percentage of Normal Dry Weather Flow (NDWF). The total releases for EWR were accounted for in the yield estimate.

Table 5-7: Summary of PES, EIS and EWR

Quat	PES	EIS	REC	Total Flow EWR (% nMAR)	Source
V31K – V31G	C	Moderately High	C/D	19.44 %	DWS Proposed Reserve Determination for Water Resources of the

					Thukela Catchments in the Pongola-Mtamvuna Water Management Area (DWS, 2024)
--	--	--	--	--	--

5.16 Groundwater quantity assessment

Data from relevant hydrogeological databases was obtained from Water Resources of South Africa Report 2012 (WR2005 and WR2012) and Groundwater Resource Assessment Ver. 2 datasets (DWAF, GRAII, 2006). As stated previously, the mining operations fall within quaternary catchments V31G, V31F and V31K, as tabulated by Table 5-8.

The groundwater reserve and existing allocations as per the DWS National Integrated Water Information System (DWS, 2025) are summarised in Figure 5-7 to Figure 5-9. The quaternary catchment has a surplus reserve available for groundwater abstraction. There is a surplus of groundwater available for both the GRA2 and GWR models.

Table 5-8: Summarised Quaternary Catchment Information

Quaternary Catchment	Total Area (km ²)	Recharge (%)	Rainfall (mm/a)	Baseflow (mm/a)	Population
V31G	254.79	5.3	739	7	Unknown
V31F	155.62	6	739	8.8	Unknown
V31K	226.71	5.4	739	7.48	Unknown

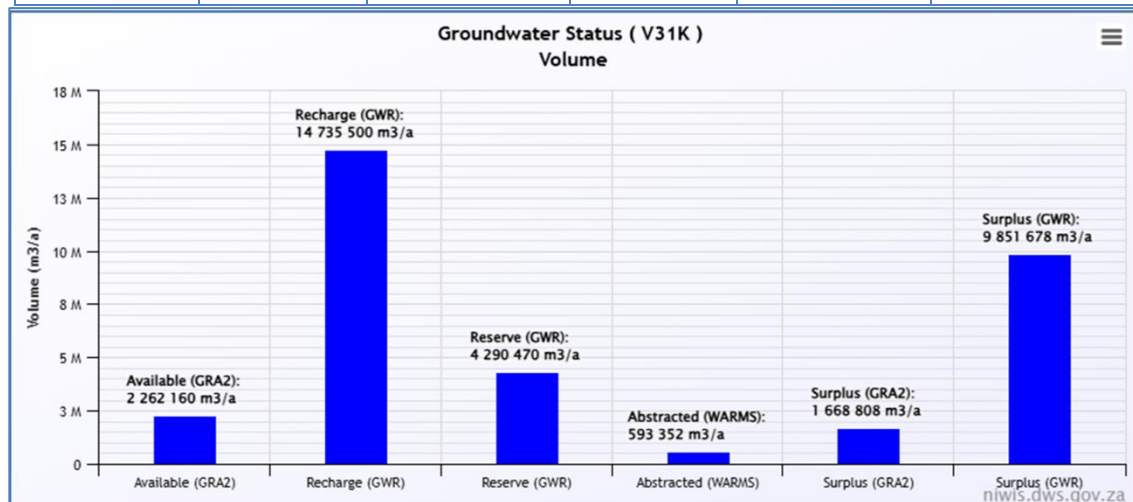


Figure 5-7: Groundwater reserve overview (DWS, 2025) – V31K

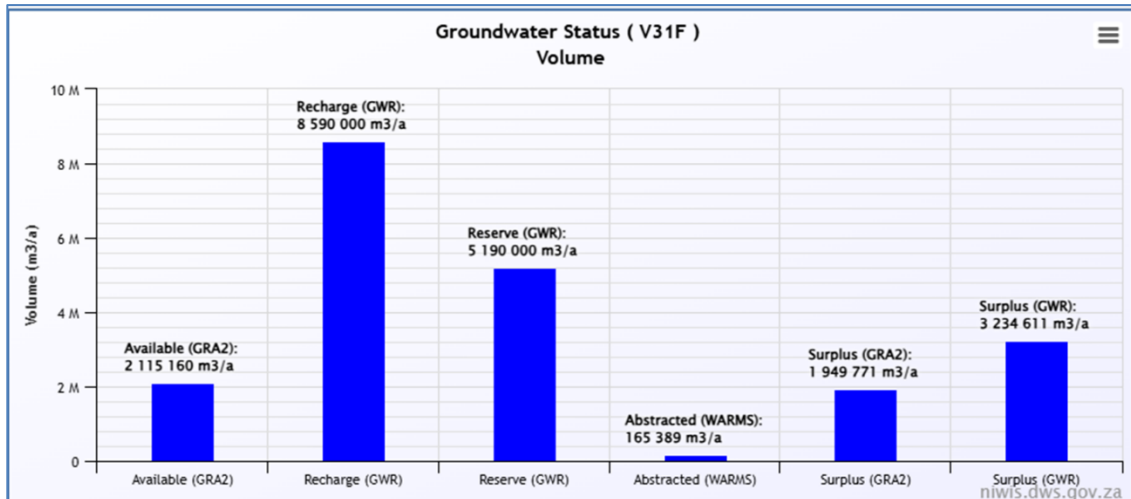


Figure 5-8: Groundwater reserve overview (DWS, 2025) – V31F

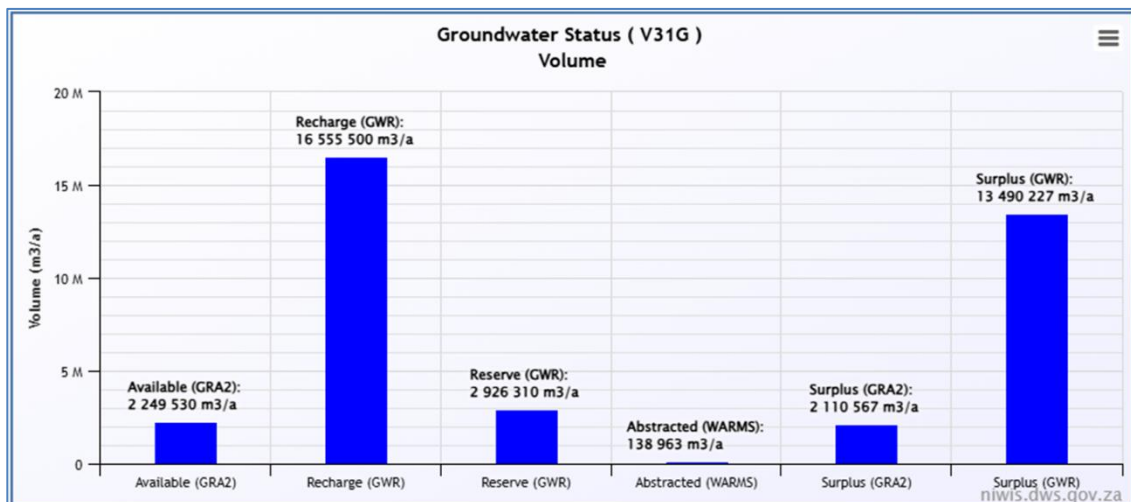


Figure 5-9: Groundwater reserve overview (DWS, 2025) – V31G

5.16.1 Groundwater balance

The groundwater reserve calculation for the sub-catchment is summarised in Table 5-9. The water balance calculation is based on the following assumptions:

- There are several WARMS (2024) groundwater users within the GW HRU. The total daily allocation to existing use (EU) is 68.49 m³/day.
- Rainfall, groundwater recharge and baseflow were determined from the literature (DWAF, 2006).
- There are no groundwater abstraction activities associated with the Project. Decant abstraction is also not considered as part of the reserve, as the water quality has been compromised.
- Based on 2022 National Land Cover data for the sub-catchment, the sub-catchment consists predominantly of agricultural land and mines (DFFE, 2024). The sub-catchments are largely natural, and hence, groundwater recharge suppression is considered marginal.

The groundwater balance indicates a surplus value of approx. $\pm 0.81 \text{ Mm}^3/\text{yr}$ is available for abstraction on a sub-catchment scale.

Table 5-9: Groundwater reserve determination

GW HRU		
Area	28.00	km ²
Rainfall	739.19	mm/yr
BF	7.86	mm/yr
Aquifer Recharge		
Re	37.70	mm/yr
Re to Aquifer	1055378.73	m ³ /yr
Re	5.10	%
Existing Use (EU)		
WARMS 2024	68.49	m ³ /day
Total EU Day	68.49	m ³ /day
Total EU Year	25000.00	m ³ /yr
Basic Human Needs		
BHN	0.00	m ³ /day
BHN	0.00	m ³ /yr
Base Flow		
BF	219947.38	m ³ /yr
Available	810431.35	m ³ /yr
Proposed Use (PU)		
None		m ³ /day
		m ³ /day
Total PU Day	0.00	m ³ /day
Total PU Year	0.00	m ³ /yr
Nett Balance	810431.35	m ³ /yr

5.17 Hydrochemistry

The following section supplies an overview of the groundwater and surface water quality associated with the Project area.

5.17.1 Hydrocensus sample data

Table 5-10 summarises the catchment scale groundwater and surface water quality as observed from the hydrocensus sampling. Sample sites are shown in Figure 5-17. The results are compared with DWAF's (1996) Ideal Target Water Quality Ranges (TWQR) for Domestic Water Use to contextualise the water quality data. Laboratory certificates are available in **Appendix C**. From the hydrochemistry data obtained, the following is observed:

Surface water

- ✚ Surface water sample sites in both the Ngagane and Horn rivers are pH neutral.
- ✚ The electrical conductivity (EC) for all sample sites is well within TWQR. However, Al, Fe, suspended solids and turbidity are observed to be high compared to TWQR.
- ✚ There is a definite increase in SO₄ and Fe content in the Horn River nearing the discard dump. This is obviously related to the active decant inflow into the river.

Groundwater

- ✚ All boreholes exhibit neutral pH conditions, except for GW12 and GW1, drilled into the decanting underground workings with a pH of 2.8 (acidic).
- ✚ The (EC) for UGBH5 and GW6 is well within TWQR. However, Fe and Mn are high for these boreholes.
- ✚ Borehole GW1, GW12 and GW16 exhibit very high EC and subsequently high Ca, Mg, Na, SO₄, Al, Fe, and Mn. These boreholes have been impacted by acid mine drainage.
- ✚ Figure 5-10 shows a piper plot of the hydrocensus borehole samples. From the Piper plot, the following is noted:
 - Groundwater samples plot from the left to the right middle of the left ternary diagram and towards the top corner of the right ternary diagram. Only borehole UGBH5 plots towards the middle left of the left and right ternary diagrams. The groundwater is dominated by Ca, Mg and Na cations and by SO₄ anions.
 - Groundwater samples plot towards the right and top right of the centre rhombus. The groundwater at the Ballengeich Mine can be classified as Na-Cl (GW16), Ca-HCO₃ (UGBH5) and Ca-SO₄ (GW12, GW6, GW1). These are typical attributes of fresh shallow groundwater, deep ancient groundwaters, and groundwater impacted by mine drainage.
 - Surface water samples are spread from the middle to the lower left of the left ternary diagram and towards the left of the right ternary diagram. Surface water samples are dominated by Na and Ca cations and HCO₃ anions.
 - Surface water samples plot towards the middle of the Rhombus and, therefore, can be classified as water influenced by active ion exchange.

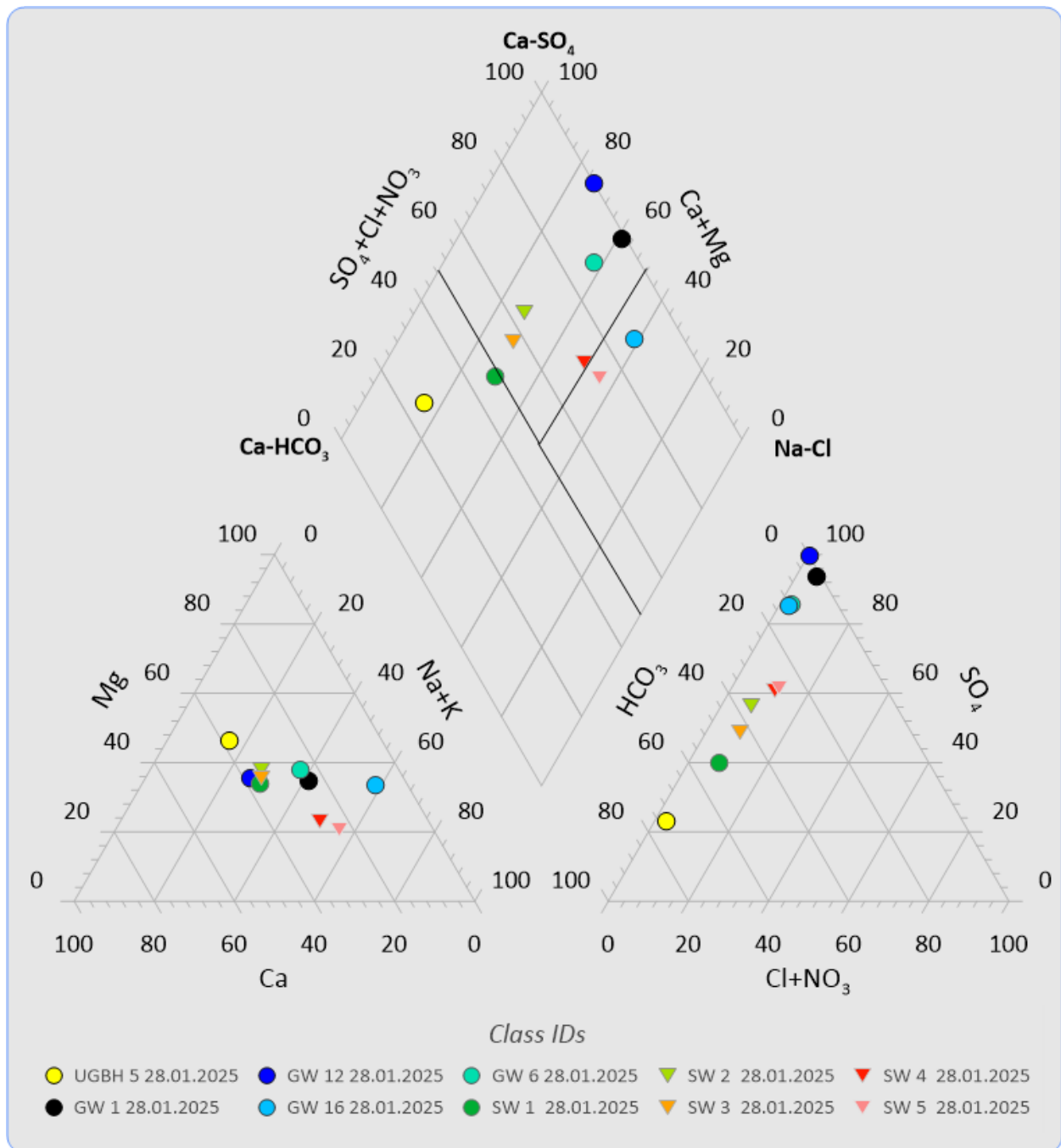


Figure 5-10: Field hydrochemistry – Piper plot

Table 5-10: Summary of field hydrocensus water quality data

Constituent	Unit	GW 1 28.01.2025	GW 6 28.01.2025	GW 12 28.01.2025	GW 16 28.01.2025	UGBH 5 28.01.2025	SW 1 28.01.2025	SW 2 28.01.2025	SW 3 28.01.2025	SW 4 28.01.2025	SW 5 28.01.2025	DWAF 1996 Domestic Use – TWQR
pH in water at 25°C	-	5.9	6	2.8	6.7	6.9	7.3	7	7	7.2	7.2	4 - 9
Conductivity in mS/m @ 25°C	mS/m	672	39	476	224	30	14	19	16	39	38	0 - 70
TDS	mg/l	6780	196	4924	1614	208	110	147	113	288	298	<450
Bicarbonate Alkalinity as HCO ₃	mg/l	57	15	pH <4.5, No Alkalinity detected	168	104						ns
Bicarbonate as CaCO ₃	mg/l	57	15	pH <4.5, No Alkalinity detected	168	104						ns
Total Alkalinity as CaCO ₃	mg/l	57	15.5	pH <4.5, No Alkalinity detected	168	104	38	34	36	52	47	ns
Calcium	mg/l	478	9.86	315	37	22	10	12.6	11.3	21	16.9	0 - 32
Magnesium	mg/l	416	9.26	177	94	16.1	5.55	8.42	6.89	10.8	8.99	0 - 30
Potassium	mg/l	30	4.06	26	12.6	2.66	2.73	2.81	2.37	3.58	3.52	0 - 50
Sodium	mg/l	915	14.9	234	306	8.73	7.57	9.96	9.26	42	44	0 - 100
Chloride	mg/l	146	<2.5	6.12	18.3	<2.5	3.33	4.09	4.12	11.8	12	0 - 100
Fluoride	mg/l	<0.06	<0.06	<0.06	<0.06	0.1	0.06	0.09	0.08	0.13	0.11	0 - 1
Nitrate	mg/l	<0.25	<0.25	<0.25	0.58	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	0 - 6
Sulphate	mg/l	3640	91.6	2984	910	25.6	22.7	42	32	88.6	85.5	0 - 200
Aluminium	µg Al/l	27	10	6174	<10	10.8	127	112	50	18	72	<15
Iron	µg Fe/l	79140	103	262354	21	13	313	466	133	20	52	<100
Manganese	µg Mn/l	4349	286	32532	72	13.6	<10	<10	<10	<10	<10	<50
Suspended Solids	mg/l						18	37	34	172	96	ns
Turbidity	NTU						42	55	35	216	123	<1
Sodium Adsorption Ratio (SAR)	Calculated	7.41	0.82	2.63	6.09	0.35	0.48	0.54	0.54	1.87	2.16	>8

ns = No Quality Range in Reference Guideline, Orange = Above DWAF (1996) Ideal Water Quality Ranges

5.17.2 Monitoring network hydrochemistry

GCS undertook quarterly monitoring of the Ballengeich site in July 2024 (GCS, 2024). This area consists of twelve (12) surface water points and twelve (12) groundwater points. Sample sites are shown in Figure 5-17. From the quarterly monitoring undertaken, the following is noted:

5.17.2.1 Groundwater levels

Shallow groundwater levels (<12.0 mbgl) are observed in the Ballengeich area (refer to Figure 5-11). Therefore, the boreholes are likely to be influenced by the upper weathered zone/ weathered aquifer, except for GW1.

- ✚ Borehole GW1 is an artesian borehole that constantly discharges groundwater from the Ballengeich underground workings.
- ✚ Recent data for the remaining boreholes indicate seasonal fluctuations, with water levels predominantly remaining in their respective historical ranges. Borehole GW6 is characterized by fluctuating water levels.
 - The most significant decrease was observed at GW6 (decrease of 1.16 m) and at
 - GWO3 (decrease of 0.65 m). All other sites displayed a <0.44 m change in July 2024.

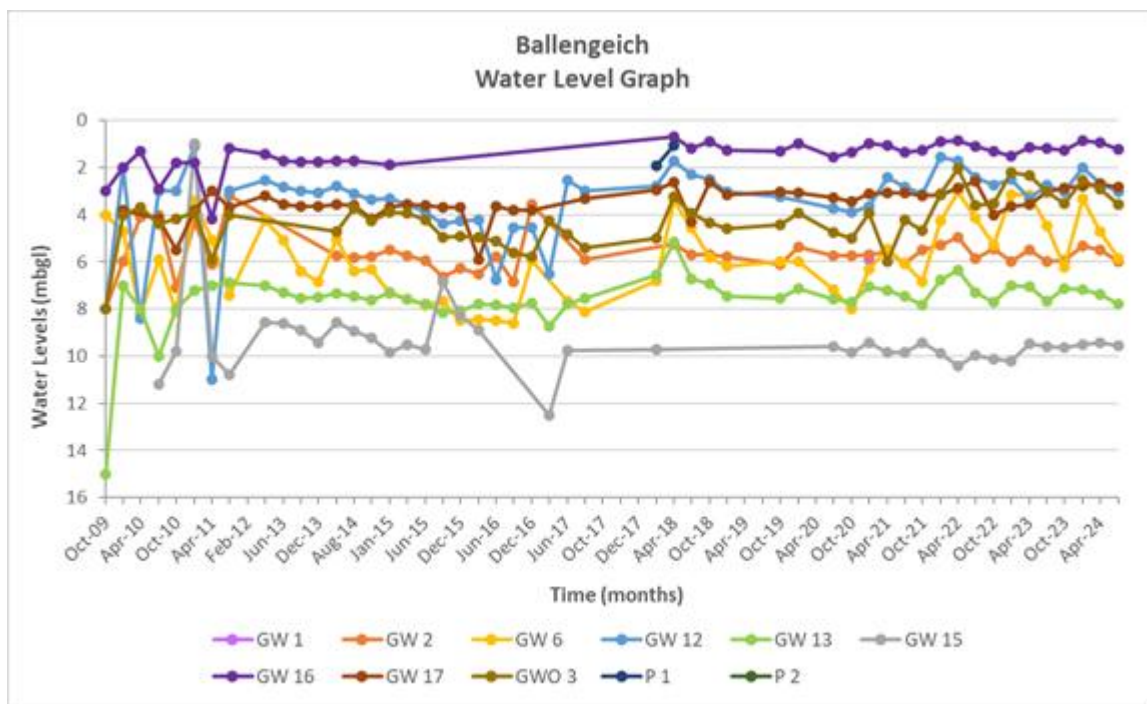


Figure 5-11: Ballengeich groundwater level graph

5.17.2.2 Groundwater water quality

Boreholes GW6 and GW17 indicated a slight impact from the site in July 2024.

- ✚ pH levels were neutral, ranging between 6.4 and 6.7; refer to Figure 5-12.
- ✚ Suspended solids (SS) were in exceedance at GW6 (1 200 mg/l) in July 2024

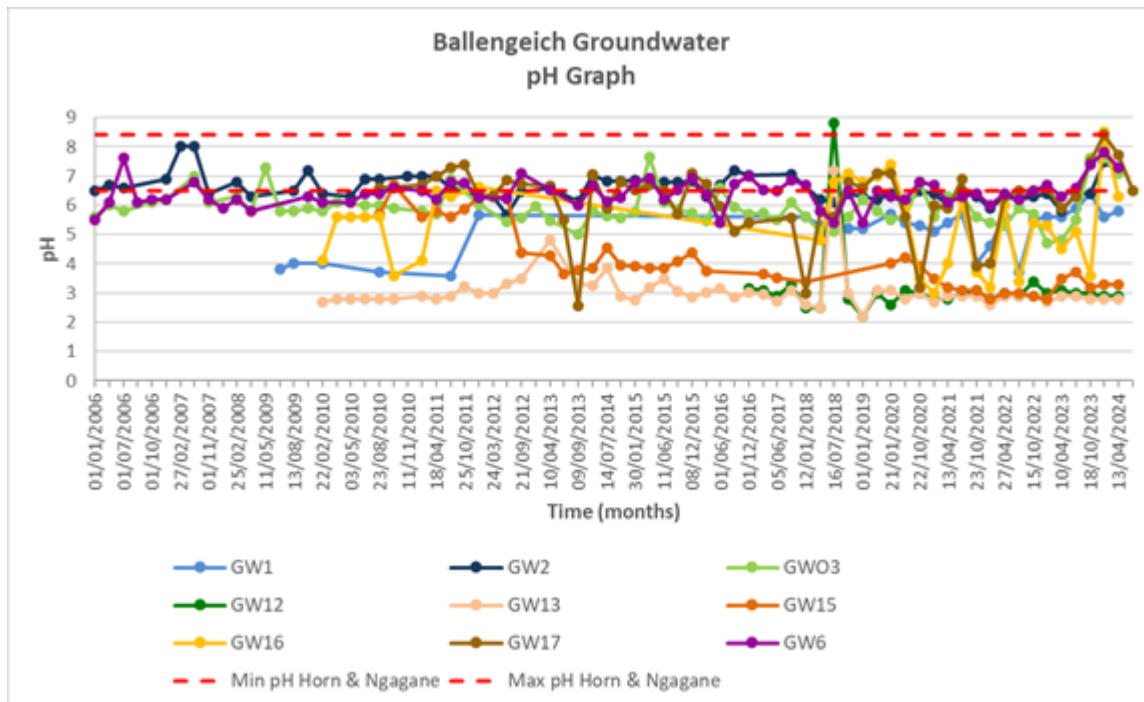


Figure 5-12: Ballengeich groundwater pH graph

The hydrochemical results for boreholes GWO3, GW1, GW2, GW12, GW13, GW15 and GW16 are indicative of impacted water quality.

✚ pH levels varied at the site; refer to Figure 4-15.

- Acidic to slightly acidic pH was recorded at GWO3, GW1, GW12, GW13, GW15 and GW16, ranging between 2.9 and 5.8.
- Neutral pH was recorded at GW2 (6.4).

✚ EC, TDS, calcium, magnesium and sulphate concentrations significantly exceeded the Horn and Ngagane Quality Objectives at all boreholes. Sodium, potassium, chloride, fluoride, ammonia and SS were also high at several points.

- Historically, GWO3 has displayed relatively stable sulphate concentrations, which are high above the Horn and Ngagane Quality limit but are <700 mg/l. Sulphate was recorded as 580 mg/l in July 2024.
- The remaining six boreholes are characterized by fluctuating sulphate trends.

These six boreholes displayed significantly high sulphate concentrations, which exceeded the stipulated objective, ranging between 310 mg/l (at GW2) and 5 100 mg/l (at GW13) in July 2024; refer to Figure 5-13. The results indicate acid mine drainage conditions, with GWO3 likely located at the edge of the ZOI

✚ Metal concentrations (aluminium, iron and manganese) were high at several points. However, there are no specified limits for these in the Horn and Ngagane limits.

The impacted water quality at GW1 is likely a result of discharge from the underground workings, whilst GW12, GW13, GW15, GW16, and GW17 have likely been impacted by cumulative seepage from underground workings, opencast workings, discard dump and PCD.

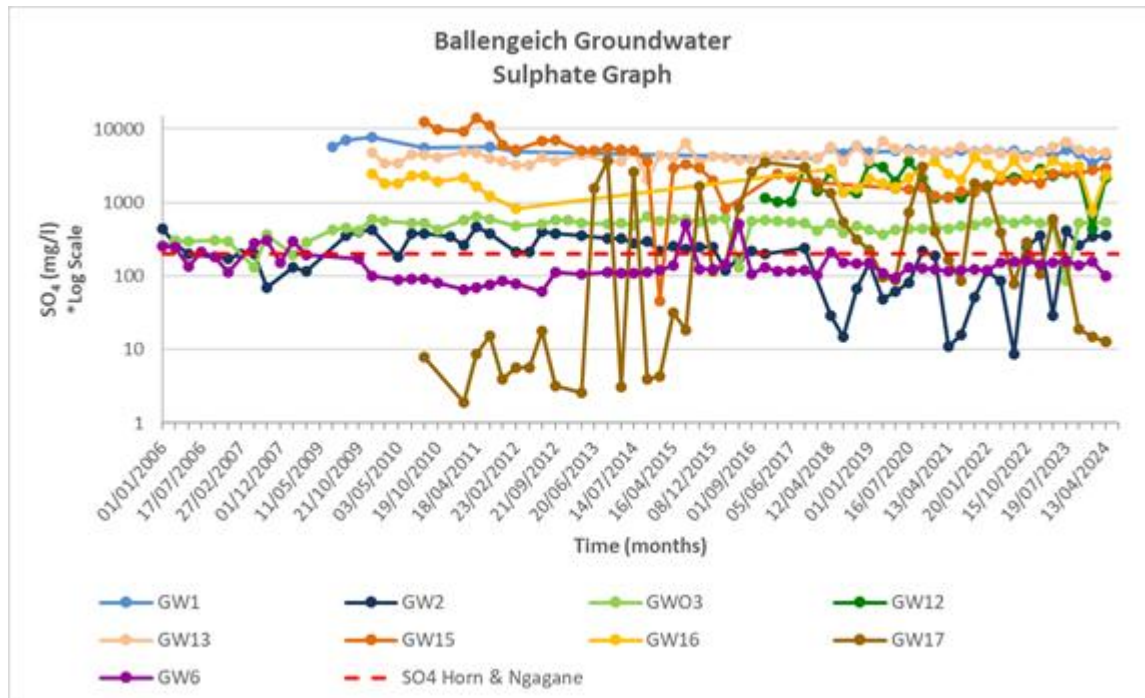


Figure 5-13: Ballengeich groundwater sulphate graph

5.17.2.3 Surface water quality

Five surface water points (SW1, SW4, SW6, SW9 and SW10) are monitored every month, whilst the remaining surface water points (SW 2, SW 3, SW 3(1), SW 5, VN 11, VN 3 and SW 7) are monitored quarterly. Two new points, namely Ingagane US and Ingagane DS, were added to the monitoring network in March 2022 to better monitor the Ngagane River. An additional point was added to the monitoring network in July 2022, namely VN5. The hydrochemical results for the seven monthly surface water points indicated varying water quality in the second quarter of 2024, with the greatest impact observed at SW4, SW6 and Ingagane DS.

- ✚ Neutral to slightly alkaline pH levels were recorded at all points (ranging between 6.8 and 8.2).
- ✚ EC, TDS, calcium, magnesium and SS concentrations intermittently exceeded the Horn and Ngagane Quality Objectives at most points during the second quarter.
 - TDS ranged between 270 (at Ingagane DS) and 780 mg/l (at SW6).
- ✚ Sulphate concentrations were high at SW6 (520 mg/l) in July 2024. SW4 and SW6, which monitor the Horn River and Ingagane DS, are characterized by similarly fluctuating sulphate trends. The remaining points indicated fairly low sulphate concentrations (<194 mg/l); refer to Figure 5-14.

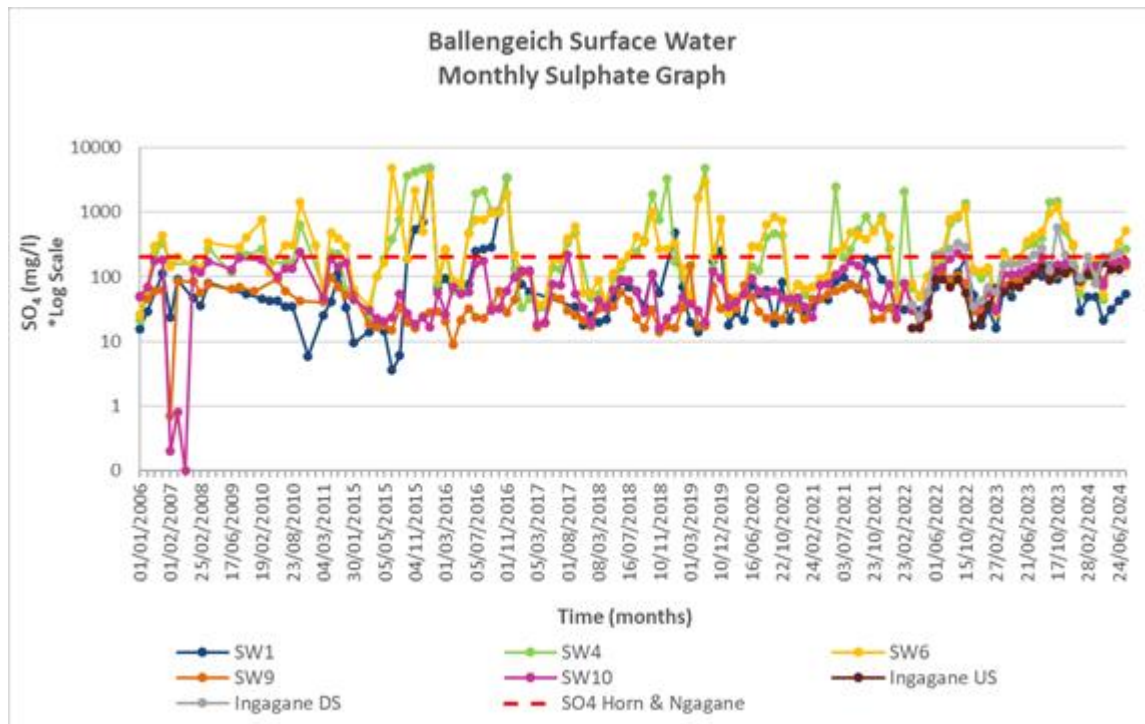


Figure 5-14: *Ballengeich surface water sulphate graph for the monthly monitoring points*

Ammonia concentrations were also intermittently in exceedance at SW4, SW6, SW9, SW10, Ingagane US and Ingagane DS (<1.5).

The water quality at SW6, SW9 and SW10 indicates an impact on the Horn River, whilst Ingagane DS indicates an impact on the Ngagane River. The hydrochemical results for the quarterly surface water points indicated varying water quality.

- ✚ Surface water points SW2, SW5 and VN 11 indicated acceptable water quality in July 2024, exceeding the Horn and Ngagane WQOs.
 - Neutral pH conditions were recorded, ranging between 6.3 and 7.6.
- ✚ Surface water points SW3, SW3(1), SW5, SW7, VN3 and VN5 indicated impacted water quality.
 - Acidic pH conditions were recorded at SW3(1), SW5, SW7 and VN3 (ranging between 2.4 and 3.5), whilst slightly alkaline pH conditions were recorded at SW3 (8.3); refer to Figure 5-15.
 - EC, TDS, calcium, magnesium, sodium and sulphate concentration values predominantly exceeded the Horn and Ngagane Quality Objectives at all points during the second quarter. Additionally, chloride and potassium concentrations exceeded VN3, whilst SS concentrations exceeded SW3(1) and SW7.

- ✚ Surface water points SW3, SW3(1), SW5, SW7, VN3 and VN5 are characterized by fluctuating sulphate concentrations, which consistently exceed the Horn and Ngagane Quality Objectives, ranging between 430 and 8 800 mg/l in July 2024. The data indicates acid mine drainage conditions; refer to Figure 5-16.
- Ammonia concentrations also exceeded all surface water points (ranging between 0.03 and 7.5 mg/l).
- Metal concentrations (aluminium, iron and manganese) were high at several points, particularly SW3(1), SW5 and SW7. However, there are no specified limits for these in the Horn and Ngagane quality objectives.
- ✚ The trend data for VN11 and SW2 indicates a slight impact on the water quality in the vicinity of the western old opencast mine.
- ✚ SW3(1) and SW7 monitor PCDs and are, therefore, expected to have poor water quality.

The dams should be lined up to create a closed system and prevent seepage of the contaminated water into the environment.

- ✚ The water quality at VN3 is likely influenced by decant from the underground workings.
- ✚ The water quality at VN5 indicates an impact on the Horn River.

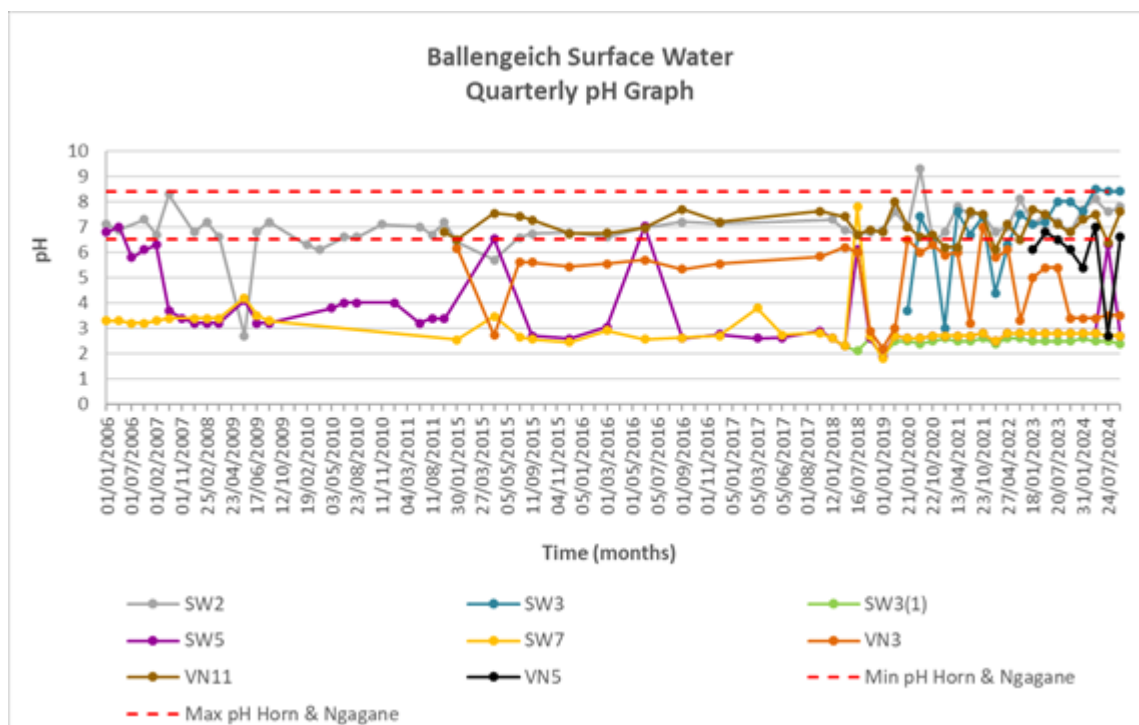


Figure 5-15: Ballengeich surface water pH graph for the quarterly monitoring points

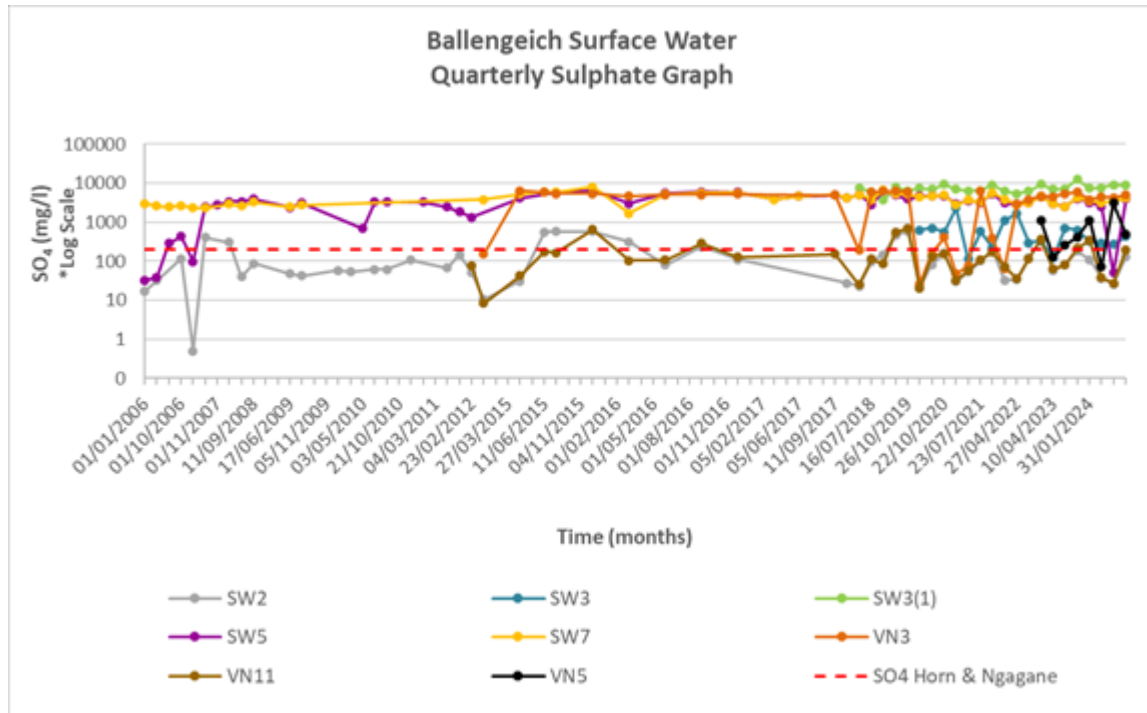


Figure 5-16: Ballengeich surface water sulphate graph for the quarterly monitoring points

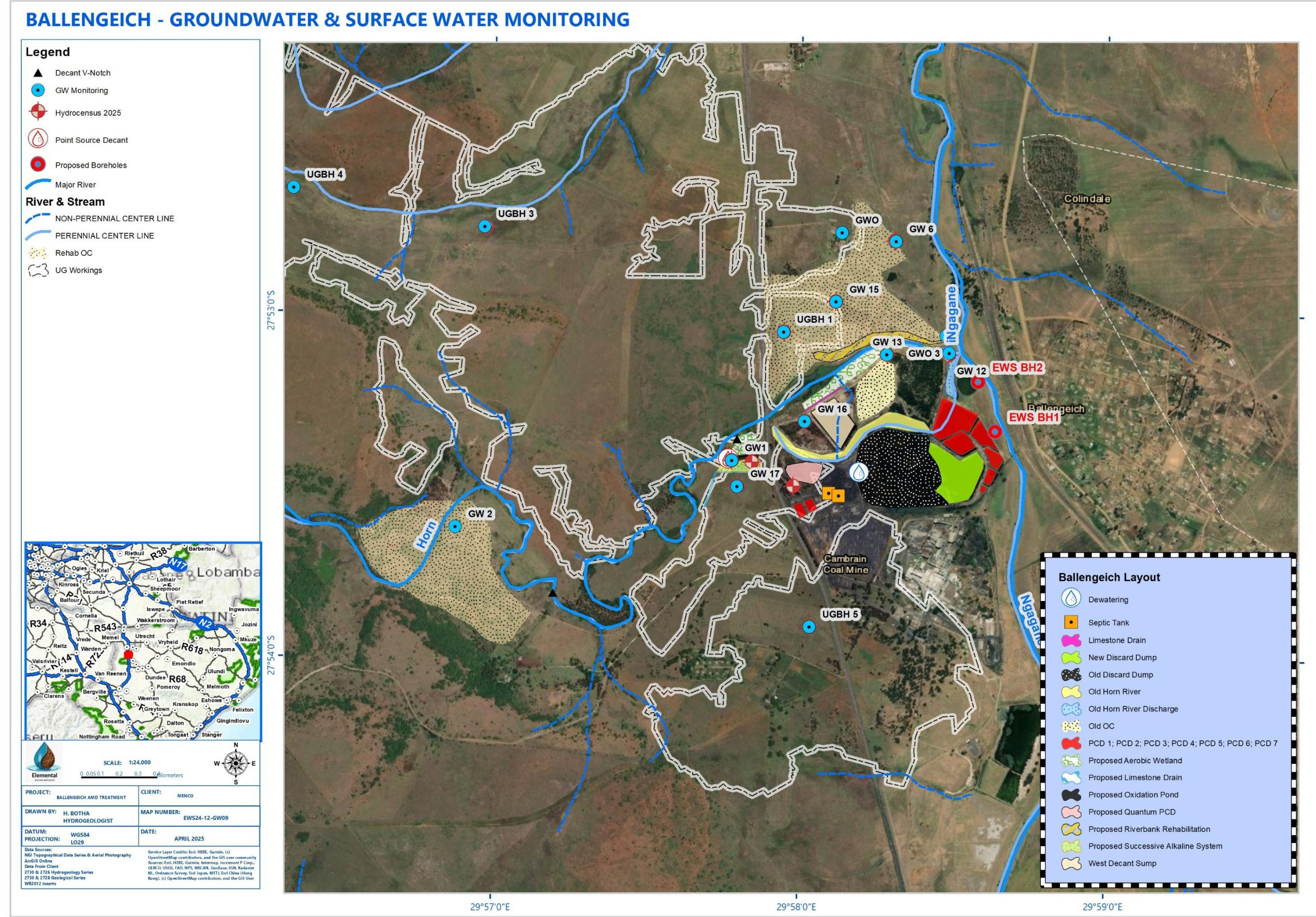


Figure 5-17: Groundwater and surface water monitoring network

6 CONCEPTUAL HYDROGEOLOGICAL MODEL

A conceptual model was developed for the groundwater sub-catchment based on information from available literature and the field investigation data. A conceptual hydrogeological cross-section is presented in Figure 6-1.

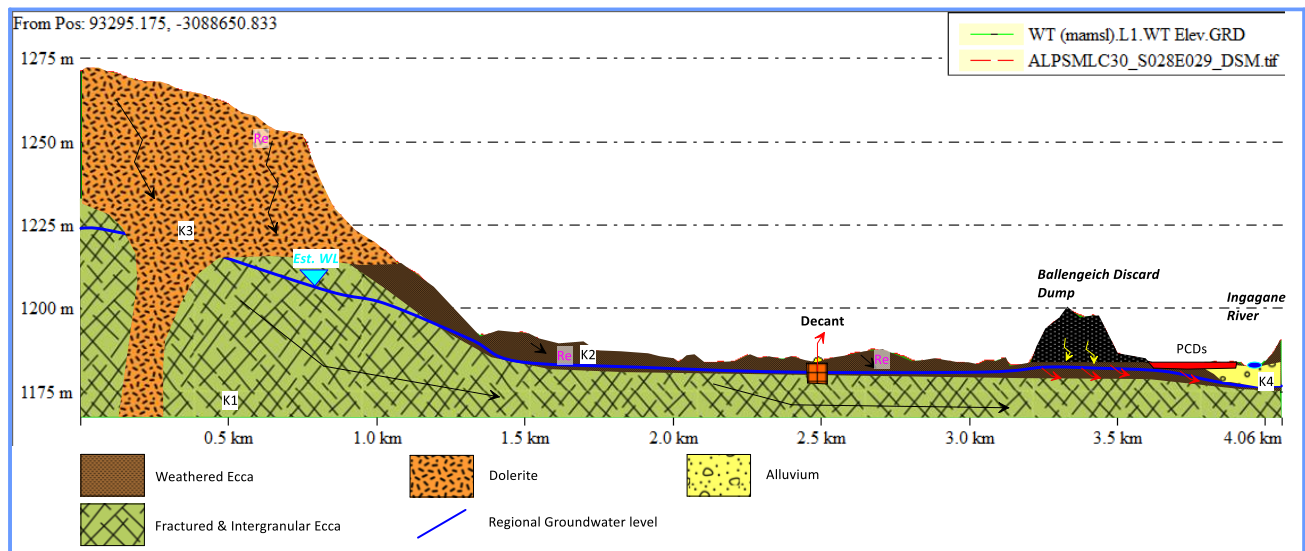


Figure 6-1: Conceptual hydrogeology cross-section

Available hydrogeology data suggests that three (3) aquifers exist in the area:

- ✚ An unconfined aquifer associated with the unconsolidated sands along the Horn River & Ingagane River, particularly in floodplain areas.
- ✚ A shallower aquifer system is associated with weathered to partly consolidated sedimentary rock as well as moderately to partially weathered sandstone and shale of the Eccla Group.
- ✚ A deeper confined fractured aquifer network associated with the Dwyka Group Tillite of the Karoo Sequence.

Historical underground workings have likely led to the formation of a hydrogeological unit in the mines that have undergone coal extraction. Significantly higher hydraulic conductivity and storage values are expected for the aquifer due to the presence of mine voids or backfilled material with higher permeability than surrounding sediment/rock. The flooded underground workings are believed to be in a pseudo-steady state and decanting near the Horn River.

From available literature data, the weathered zone for the area is estimated to be in the order of 5 - 28 m thick, followed by a subsequent thicker intergranular & fractured aquifer zone. The groundwater levels for the Ballengeich colliery range from artesian (decant area) to an average of 5.7 metres below ground level (mbgl). Groundwater is found within mined-out voids (underground workings beneath the regional water table), the weathered zone (perched), as well as fractures and bedrock contacts, contacts between lithologies or at unconformities and dolerite/diabase dyke contacts. The groundwater table mimics the topography, and groundwater flows from high-lying areas (water divides) to low-lying areas (refer to Figure 5-4).

The main source of groundwater recharge is rainfall. The rainfall infiltrates into the ground to become groundwater through the Vadose Zone. The water then moves both vertically and horizontally in the weathered zone. Greater interflow is expected in a horizontal direction within the weathered zone matrix. Water flowing horizontally in the soil and the weathered zone may enter the surface water streams/rivers if hydraulically connected (i.e. gaining rivers/streams). Available data does suggest that the portion of the Ingagane and Horn Rivers bordering the site may be a losing river. Water that makes it through the weathered zone slowly percolates and recharges the deeper intergranular and fractured aquifers, with much lower permeabilities and storage potential.

The groundwater at the Ballengeich Mine can be classified as Na-Cl (GW16), Ca-HCO₃ (UGBH5) and Ca-SO₄ (GW12, GW6, GW1). These are typical attributes of fresh shallow groundwater, deep ancient groundwaters, and groundwater impacted by mine drainage. Surface water can be classified as water influenced by active ion exchange.

6.1 Receivers in the local area

There are no recognised groundwater users downstream of the Ballengeich operations. However, the regional groundwater table and the Horn and Ingagane Rivers are the local receivers of groundwater and surface water pollution.

7 NUMERICAL GROUNDWATER MODEL

The groundwater flow and transport models were developed to:

- ✚ Characterize the groundwater flow systems more fully (i.e. aquifer flow velocities, heads, water levels, groundwater inflow rates, etc.).
- ✚ Determine groundwater flow rates and water budgets.
- ✚ Determine preferential flow paths.
- ✚ Calibrate and present the 2025 sulphate pollution plume for the Ballengeich operations in the determination of the zone of impact (ZOIp).

7.1 Model uncertainties and limitations

There are **uncertainties** in the groundwater flow field simulated by a numerical model. The model uncertainties are as follows:

- ✚ Artificial recharge or reduced recharge as a result of land use was not incorporated into the model.
- ✚ Literature recharge characteristics govern water recharge for opencast mining (Hodgson & Krantz, 1998). Typical ranges applied in the water balance are presented in Table 7-1.
- ✚ Groundwater-specific yield and specific storage values were derived from reported ranges for the rock types encountered in the study area.
- ✚ The model grid was constructed based on the regional geology map for the area and refined in areas where drilling log data and/or geophysical data are available.
- ✚ Groundwater-specific yield and specific storage values were derived from reported ranges for the rock types encountered in the study area.
- ✚ All proposed lined/bunded facilities are assumed to have a net zero recharge and seepage potential.

Table 7-1: Water recharge characteristics for opencast mining

Sources which contribute water	Water sources into opencast pits	Suggested average values
Rain onto ramps and voids	20 - 100% of rainfall	70% of rainfall
Rain onto unrehabilitated spoils (run-off and seepage)	30 - 80% of rainfall	60% of rainfall
Rain onto levelled spoils (run-off)	3 - 7% of rainfall	5% of rainfall
Rain onto levelled spoils (seepage)	15 - 30% of rainfall	20% of rainfall
Rain onto rehabilitated spoils (run-off)	5 - 15% of rainfall	10% of rainfall
Rain onto rehabilitated spoils (seepage)	5 - 10% of rainfall	8% of rainfall
Surface run-off from pit surroundings into pits	5 - 15% of total pit water	6% of total pit water
Groundwater seepage	2 - 15% of total pit water	10% of total pit water

The numerical groundwater model has the following **limitations**:

- ✚ Conductance for river and stream drainage cells was derived from the literature and built-in stream conductance models in Visual Modflow. It is assumed that conductance in the model domain is like literature values.
- ✚ The model does not consider kinetic mineral reactions (i.e. oxidation of minerals within the waste storage facilities or seepage thereof).
- ✚ Source terms were defined based on available data for the site and traced based on available borehole SO₄ data and Google imagery of the site.
- ✚ The model does not consider climate change.

7.2 Model time

The model ran from 2010 to 2210 and has a total simulation time of 73,000 days. The model simulation time aims to describe the LOM and 50Y impacts associated with the Project, and they were formulated as such. The model time is summarised in Table 7-2.

Table 7-2: Numerical model time

Year	Diff	Mod (d)	
1950	0	0	The fully mechanized Ballengeich section of Natal Cambrian Colliery opened in 1950. This section, owned by JCI, was the first of its kind in Natal
1960	10	3650	
1970	20	7300	
1980	30	10950	
1990	40	14600	
2000	50	18250	
2010	60	21900	
2020	70	25550	
2021	71	25915	
2022	72	26280	
2023	73	26645	
2024	74	27010	
2025	75	27375	Cal
2026	76	27740	
2027	77	28105	
2028	78	28470	
2029	79	28835	
2030	80	29200	5Y
2045	95	34675	20Y
2075	125	45625	50Y
2225	275	100375	200Y

7.3 Model conceptualisation

The groundwater model grid and boundary condition visualisation are shown in Figure 7-1 and Figure 7-2. The model describes the groundwater flow field within the sphere of influence mentioned earlier in the report. Both hydrocensus, monitoring, NGA and SADAC GIP data for the model domain were applied to calibrate and illustrate the groundwater flow system for the project area. Table 7-3 summarises the initial conditions and model constructs.

Table 7-3: Numerical modal constructs and initial conditions

Component	Model Conditions
Model Flow Engine	Modflow NWT Solver Rewetting Disabled
Transport Model Engine	MTS3D
Model Grid and Layers	Grid of 2.5 to 5 m, and >30m moving further away from the site. 3 Layers represent the alluvium, weathered and fractured aquifer systems.
Boundary Conditions	Stream drains and river boundaries are assigned to all identified streams and rivers.

Component	Model Conditions																														
	The Ingagane and Horn Rivers consist of river boundaries. The conductance was estimated at 8mbgl x surface area of the drainage zone x 6-8m riverbed thickness. Initial recharge assigned: <table><tr><td>Material Zone</td><td>Re (mm/yr)</td></tr><tr><td>Pv</td><td>37.7</td></tr><tr><td>Jd</td><td>22.2</td></tr><tr><td>Oc</td><td>147.8</td></tr><tr><td>Al</td><td>73.9</td></tr></table>	Material Zone	Re (mm/yr)	Pv	37.7	Jd	22.2	Oc	147.8	Al	73.9																				
Material Zone	Re (mm/yr)																														
Pv	37.7																														
Jd	22.2																														
Oc	147.8																														
Al	73.9																														
Initial Heads	The depth to water level ranged between 0.1 to 23 mbgl.																														
Conductivity	<table><tr><th>Zone</th><th>K_x [m/d]</th><th>K_y [m/d]</th><th>K_z [m/d]</th></tr><tr><td>1</td><td>0.05</td><td>0.01756674</td><td>0.001560477</td></tr><tr><td>2</td><td>0.1</td><td>0.01</td><td>0.001</td></tr><tr><td>3</td><td>5</td><td>8</td><td>0.8</td></tr><tr><td>4</td><td>3</td><td>2</td><td>0.3</td></tr><tr><td>5</td><td>0.002689644</td><td>0.0001</td><td>0.0005</td></tr></table>	Zone	K _x [m/d]	K _y [m/d]	K _z [m/d]	1	0.05	0.01756674	0.001560477	2	0.1	0.01	0.001	3	5	8	0.8	4	3	2	0.3	5	0.002689644	0.0001	0.0005						
Zone	K _x [m/d]	K _y [m/d]	K _z [m/d]																												
1	0.05	0.01756674	0.001560477																												
2	0.1	0.01	0.001																												
3	5	8	0.8																												
4	3	2	0.3																												
5	0.002689644	0.0001	0.0005																												
Storage	<table><tr><th>Zone</th><th>S_s [1/m]</th><th>S_y []</th><th>Eff. Por. []</th><th>Tot. Por. []</th></tr><tr><td>1</td><td>8.015698E-6</td><td>0.2</td><td>0.2</td><td>0.3</td></tr><tr><td>2</td><td>8.015698E-6</td><td>0.04293855</td><td>0.18</td><td>0.3</td></tr><tr><td>3</td><td>8.015698E-6</td><td>0.22</td><td>0.25</td><td>0.3</td></tr><tr><td>4</td><td>8.015698E-6</td><td>0.22</td><td>0.25</td><td>0.3</td></tr><tr><td>5</td><td>8.015698E-6</td><td>0.1</td><td>0.1</td><td>0.2</td></tr></table>	Zone	S _s [1/m]	S _y []	Eff. Por. []	Tot. Por. []	1	8.015698E-6	0.2	0.2	0.3	2	8.015698E-6	0.04293855	0.18	0.3	3	8.015698E-6	0.22	0.25	0.3	4	8.015698E-6	0.22	0.25	0.3	5	8.015698E-6	0.1	0.1	0.2
Zone	S _s [1/m]	S _y []	Eff. Por. []	Tot. Por. []																											
1	8.015698E-6	0.2	0.2	0.3																											
2	8.015698E-6	0.04293855	0.18	0.3																											
3	8.015698E-6	0.22	0.25	0.3																											
4	8.015698E-6	0.22	0.25	0.3																											
5	8.015698E-6	0.1	0.1	0.2																											
Dispersity	<table><tr><th>Zone</th><th>Dl [m]</th></tr><tr><td>1</td><td>20</td></tr><tr><td>2</td><td>10</td></tr><tr><td>3</td><td>50</td></tr><tr><td>4</td><td>80</td></tr><tr><td>5</td><td>5</td></tr></table>	Zone	Dl [m]	1	20	2	10	3	50	4	80	5	5																		
Zone	Dl [m]																														
1	20																														
2	10																														
3	50																														
4	80																														
5	5																														
Model Calibration Points	18 Head Boreholes 5 concentration boreholes																														

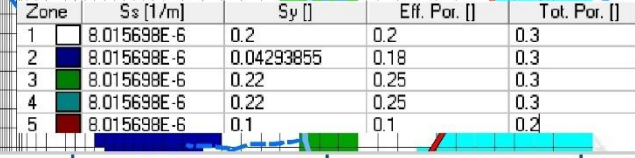


Figure 7-1: Model grid & property zones

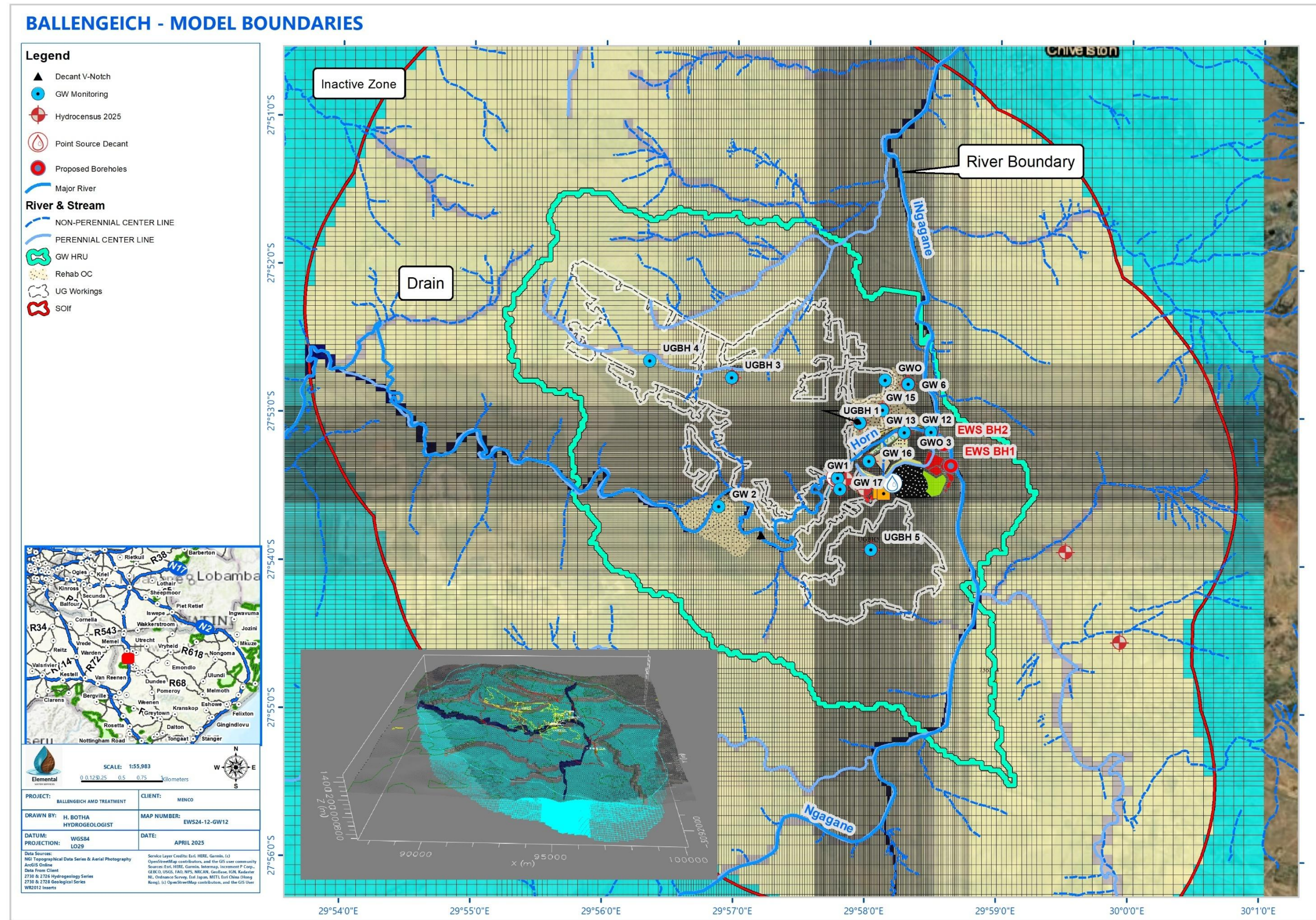


Figure 7-2: Model boundary conditions

7.4 Model sensitivity

A sensitivity analysis was carried out on the calibrated steady-state model using zones to assess the influence on groundwater level and flow dimensions by running the model in the PEST and sensitivity mode.

It can be seen from Figure 7-3 that the calibrated residuals (calculated heads vs observed heads) are slightly skewed towards the right. However, most of the data plots are within 5-10% of the normalised distribution of the dataset used for calibration.

The following summarises the sensitivity analyses:

- ✚ The flow model is very sensitive to changes in aquifer recharge (Par001 – Par004). Higher recharge to the model was simulated.
- ✚ The flow model is sensitive to changes in horizontal hydraulic conductivity (Kx and Ky) in the 1st layer (top weathered aquifer) and 2nd layer (transition to fractured zone) and
- ✚ The flow model is less sensitive to changes in storage and vertical hydraulic conductivity (Ss, Sy and Kz).
- ✚ The final parameters applied to the model, as determined by PEST, were as follows:

kx_1	5.000000E-02	par001	1.10000
ky_1	1.756674E-02	par002	1.10000
kz_1	1.560477E-03	par003	1.10000
kx_2	0.100000	par004	1.10000
ky_2	1.000000E-02		
kz_2	1.000000E-03	ss_1	8.015698E-06
kx_3	5.00000	ss_2	8.015698E-06
ky_3	8.00000	ss_3	8.015698E-06
kz_3	0.800000	ss_4	8.015698E-06
kx_4	3.00000	ss_5	8.015698E-06
ky_4	2.00000		
kz_4	0.300000	sy_1	0.200000
kx_5	2.689644E-0	sy_2	4.293855E-02
ky_5	1.000000E-04	sy_3	0.220000
kz_5	5.000000E-04	sy_4	0.220000
		sy_5	0.100000

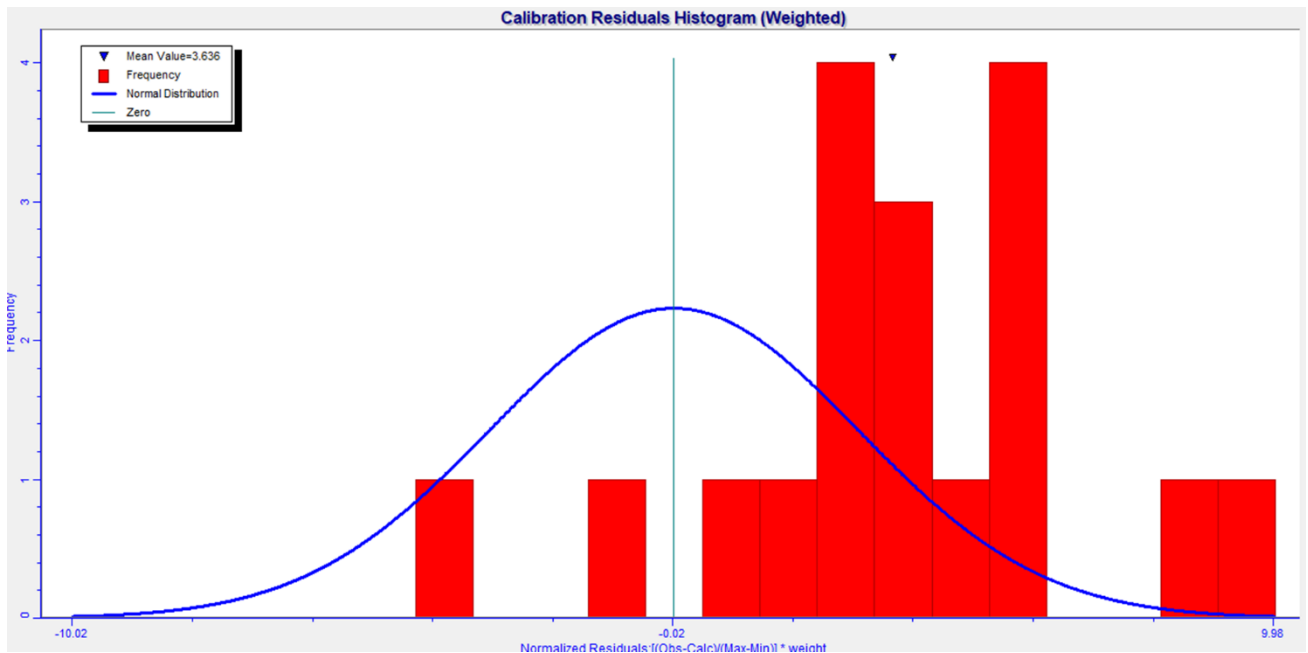


Figure 7-3: PEST run simulation histogram

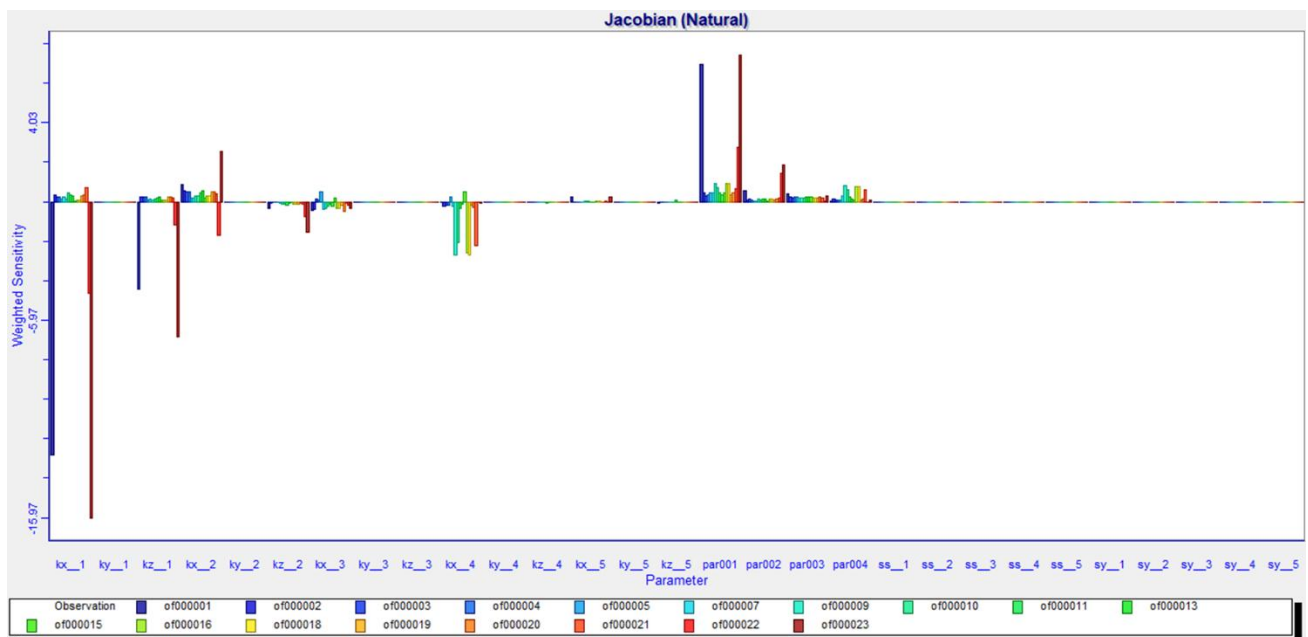


Figure 7-4: Model sensitivity (Jacobian matrix)

7.5 Model calibration

Aquifer parameters used in the model were obtained from field measurements and model calibration using measured groundwater levels. Figure 7-5 illustrates the calibration graph for the calculated versus observed heads for the steady-state model. A scaled absolute mean value (RMS) below < 20 % is generally regarded as acceptable for a local/regional model (Hill & Tiedeman, 2005).

The initial calibration was done under steady-state conditions. An RMS in the order of 13.7 % was achieved for the steady-state flow model ($R^2 \sim 93\%$). When calibrated, the model was used as an input to a transient state model to predict future scenarios. Adopting this approach, the flow model was calibrated with data for the year 2025, and an RMS in the order of 16.5% ($R^2 \sim 85\%$) was achieved (refer to Figure 7-3).

The transport model was calibrated with SO_4 for groundwater monitoring boreholes at Ballengeich. An RMS of 5% was achieved. The groundwater flow and transport models are considered representative of the groundwater flow system and existing ZOIp.

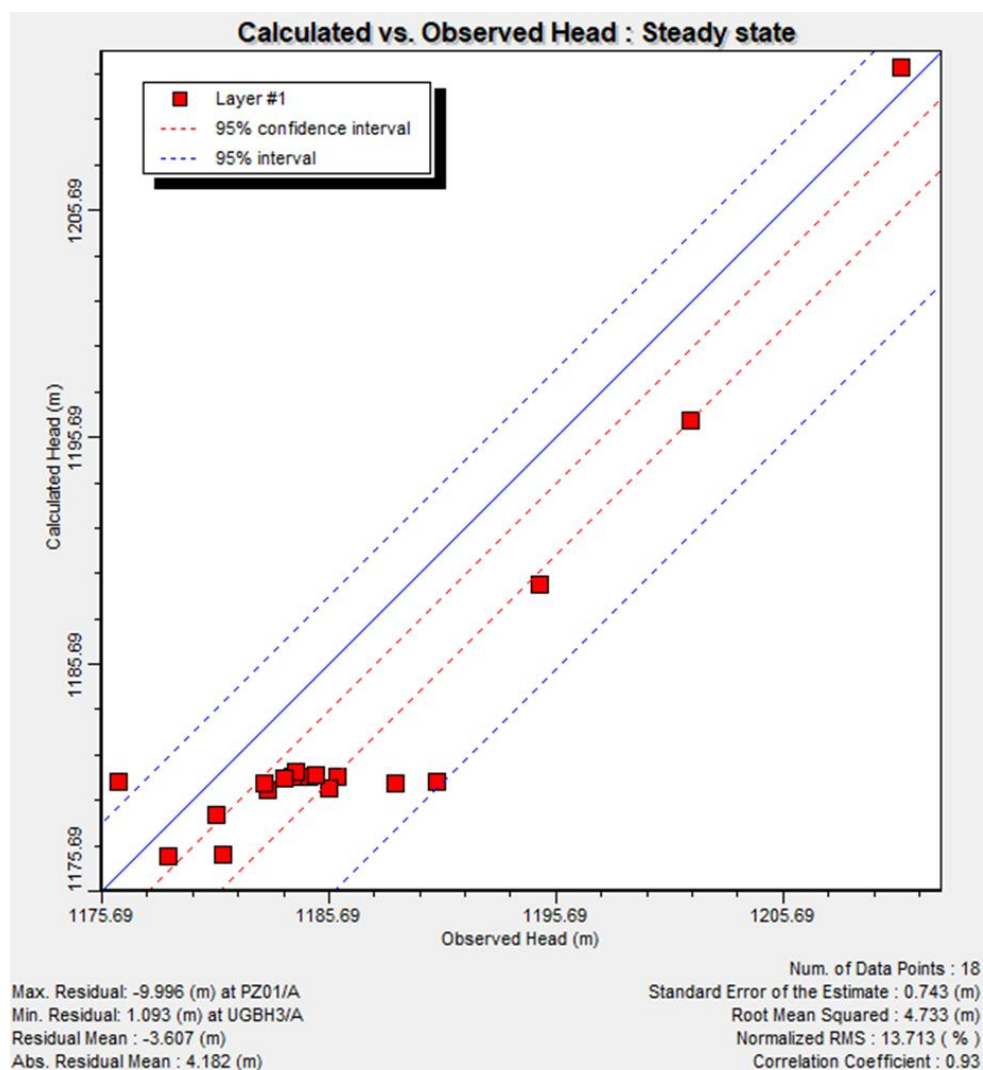


Figure 7-5: Calibrated steady-state model

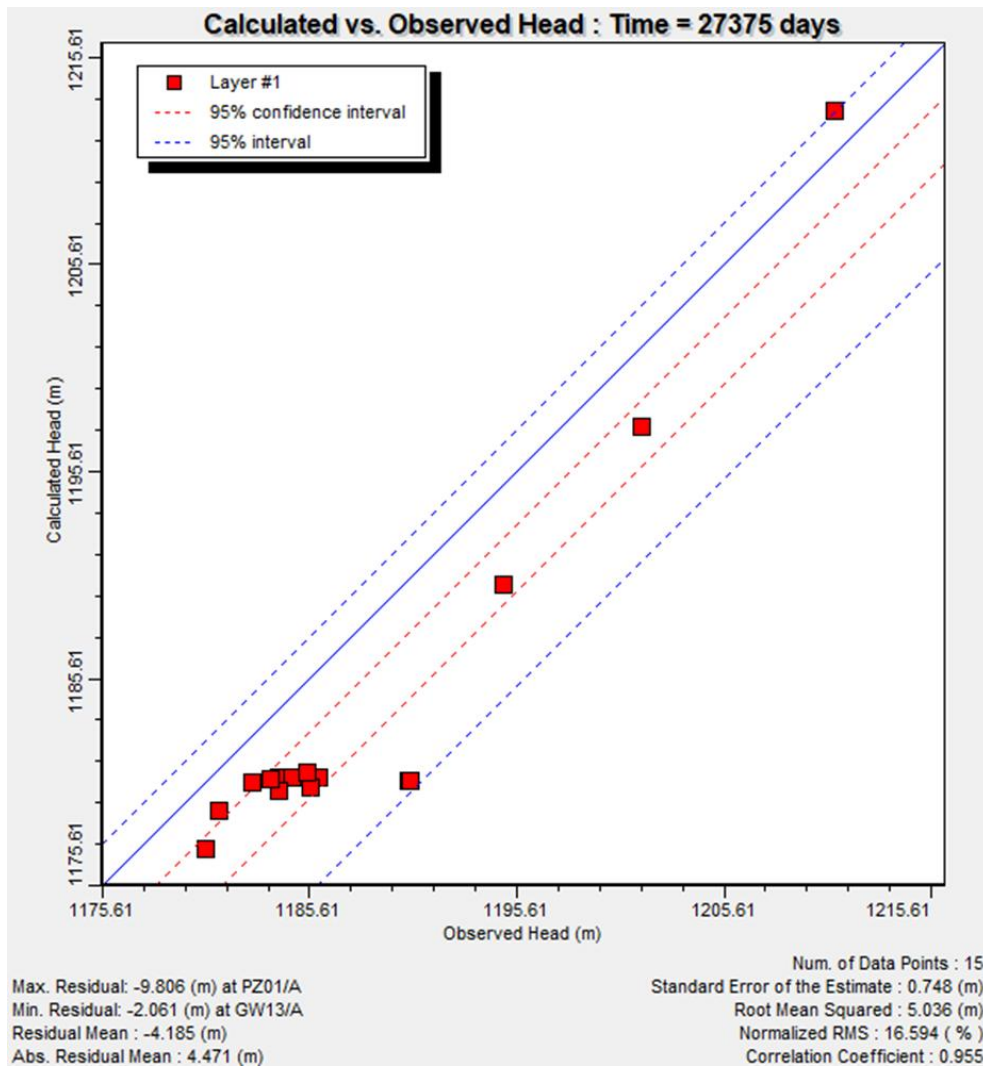


Figure 7-6: Calibrated transient-state model (the year 2025)

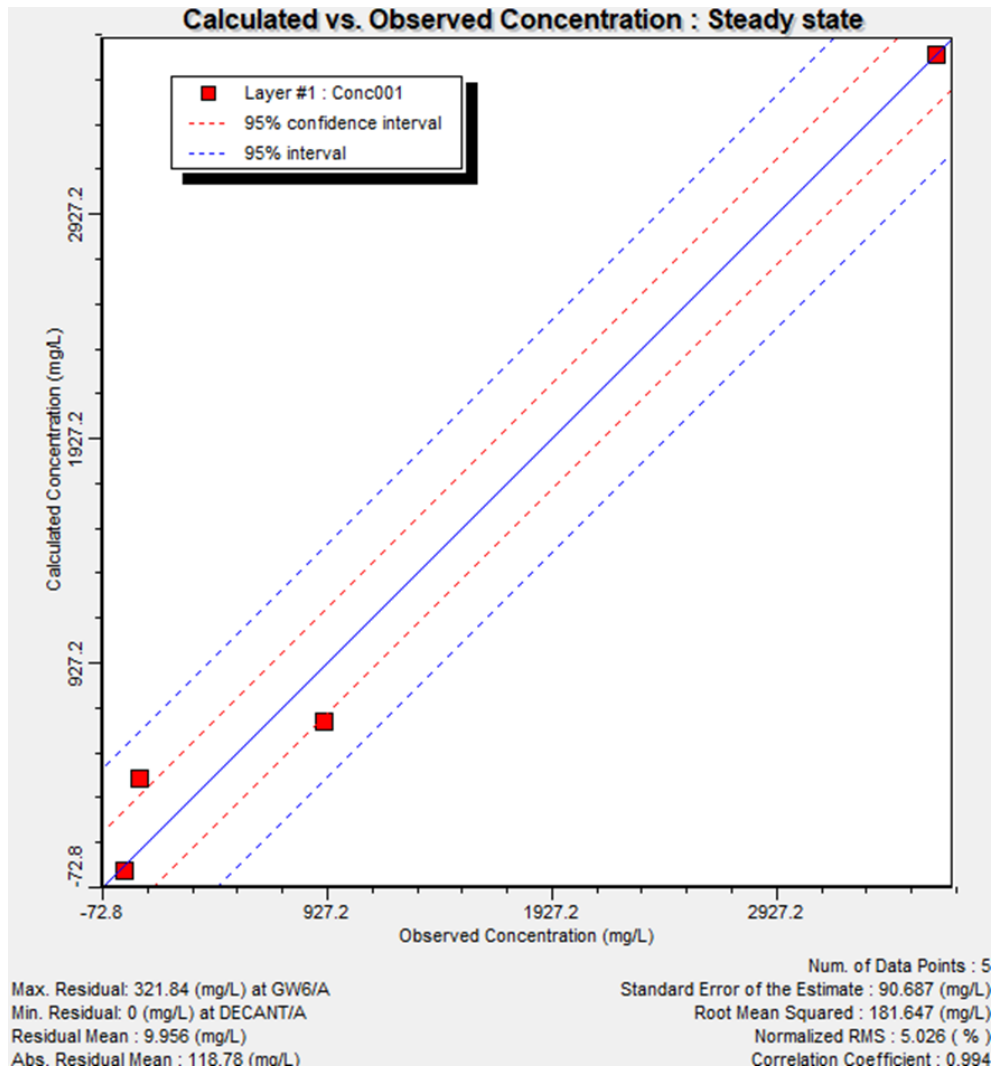


Figure 7-7: Calibrated transport model (2025)

7.6 Model outputs

7.6.1 Calibrated flow model 2025

The calibrated flow model with simulated groundwater elevations is shown in Figure 7-10. The following is noted when evaluating the flow model:

- ✚ The groundwater table mimics the topography.
 - ✚ Groundwater flow is towards the south and west, towards the perennial river systems/topography lows.
 - ✚ The flow model indicates groundwater flow velocities ranging from 0.001 (min) to 0.38 (max) m/day.
- The above suggests that groundwater is very slow-moving in the study area.

Groundwater movement in the weathered zone is greater than that of the deeper aquifer zones, and several orders are greater in the alluvium and underground zones when compared to the host rock. The model confidence level was evaluated and assigned a Class 2 rating – refer to **Appendix D**.

7.6.2 Simulated 2025 sulphate plume and ZOIp

The calibrated SO₄ plume for the Ballengeich operations is shown in Figure 7-7. The model suggests that the plumes remain in close proximity to the point sources at the site, with a concentration gradient from 4000 mg/l to 50mg/l towards the Ingagane River and a higher SO₄ concentration gradient towards the Horn River ranging from 4000 to 1000 mg/l.

As mentioned earlier, the Horn and Ingagane Rivers exhibit attributes relating to losing rivers. This means that the groundwater plumes are likely going underneath the river systems, and the baseflow to the rivers is marginal. If baseflow had been higher, an immediate impact on surface water quality would have been observed.

Two (2) stream profiles were completed for the Horn and Ingagane Rivers and are shown in Figure 7-8 and Figure 7-9. A definite increase in EC and decrease in pH is observed at NH12 to NH7 (at the N11 bridge), which are downstream of the known decant area. The remainder of the Horn River shows little impact, with a decrease in EC as a result of the artificial wetland and phytoremediation. The pH and EC for the Ingagane River show marginal changes from upstream to downstream relative to the discard dump. A marginal impact is observed. The spatial orientation of the profiles is shown in Figure 7-9.

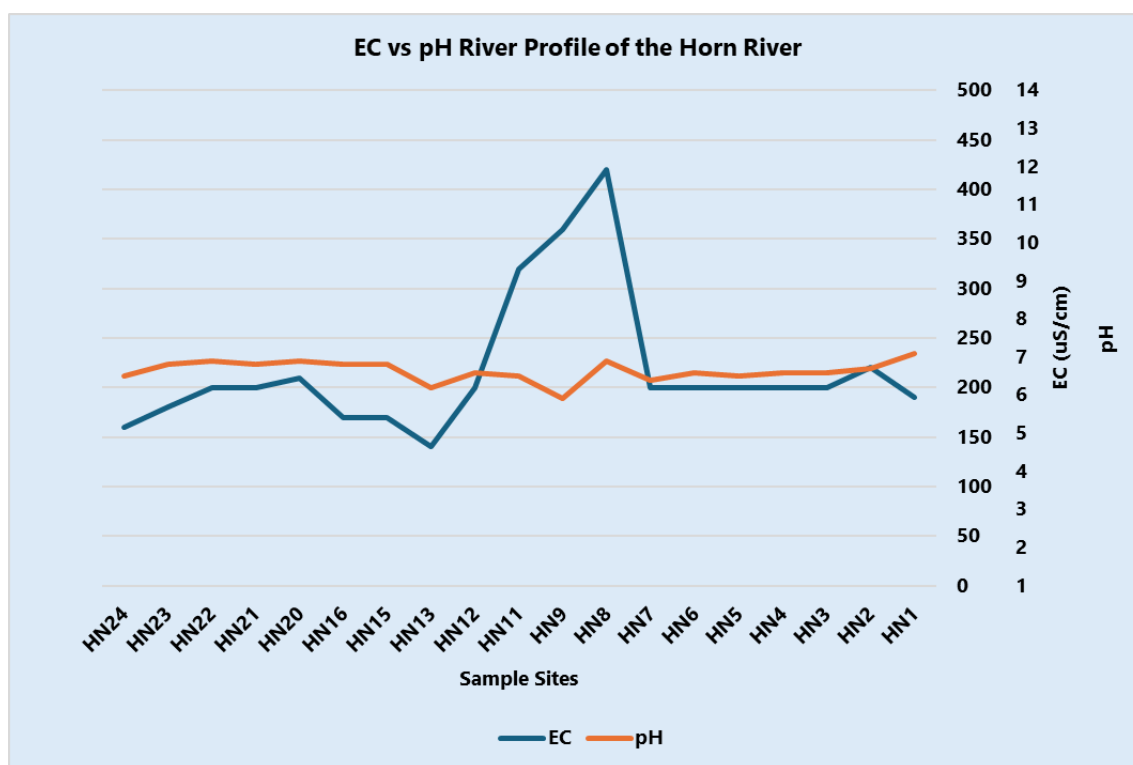


Figure 7-8: River profile upstream to downstream in the Horn River

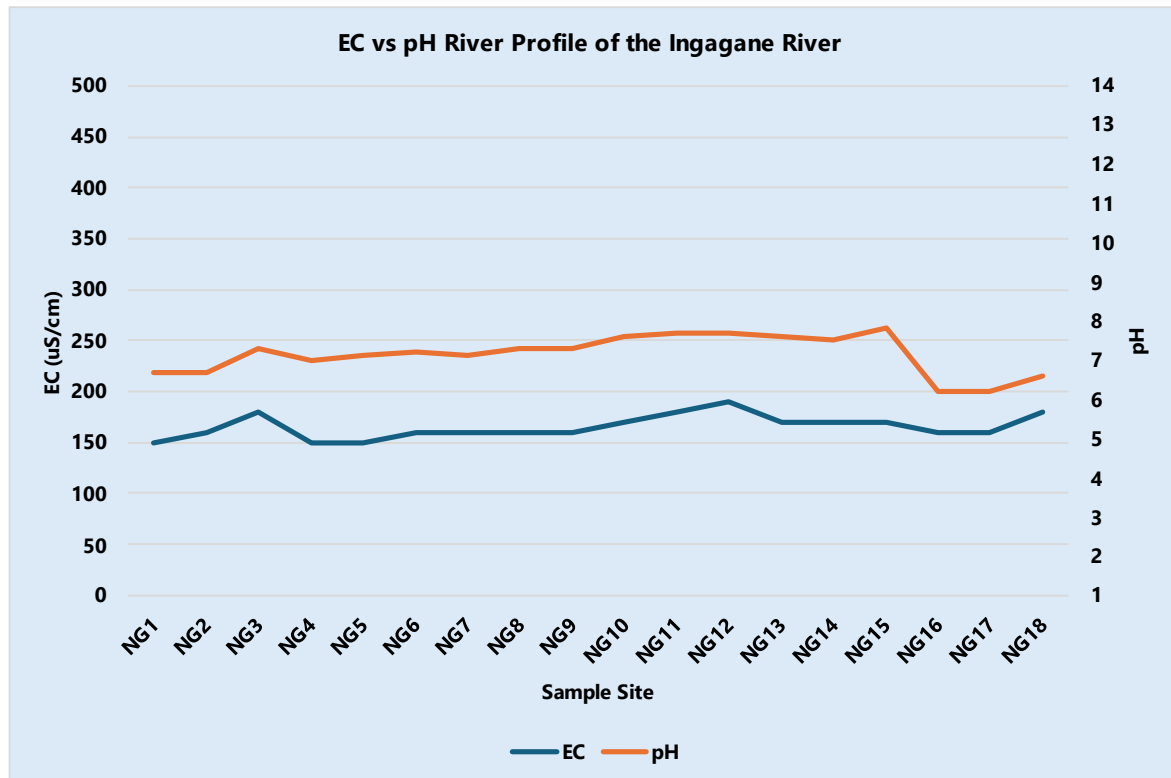


Figure 7-9: River profile upstream to downstream in the Ingagane Reiver, up to the confluence area downstream of the discard dump

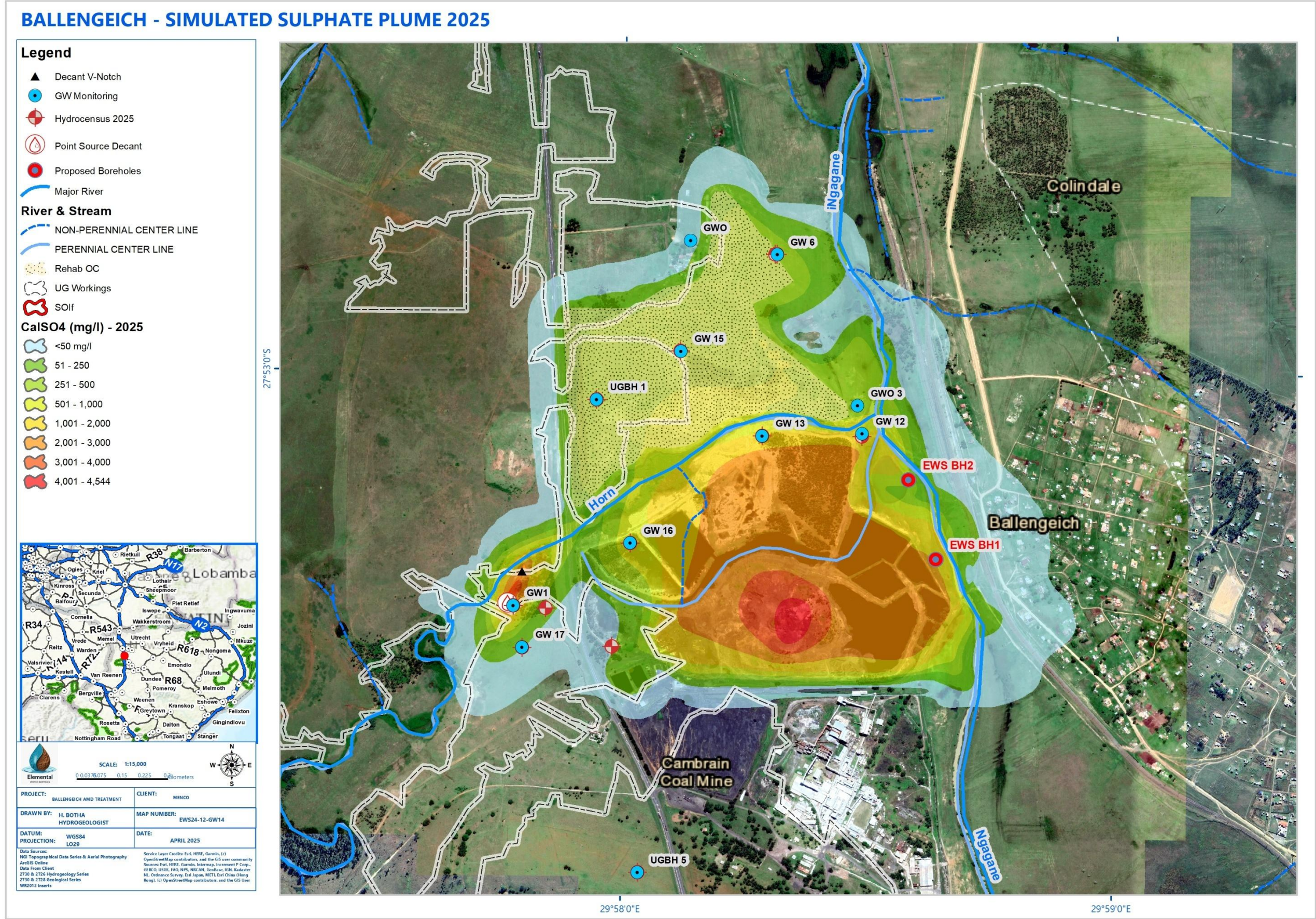


Figure 7-11: Simulated sulphate plume as of 2025

BALLENGEICH - RIVER EC PROFILE

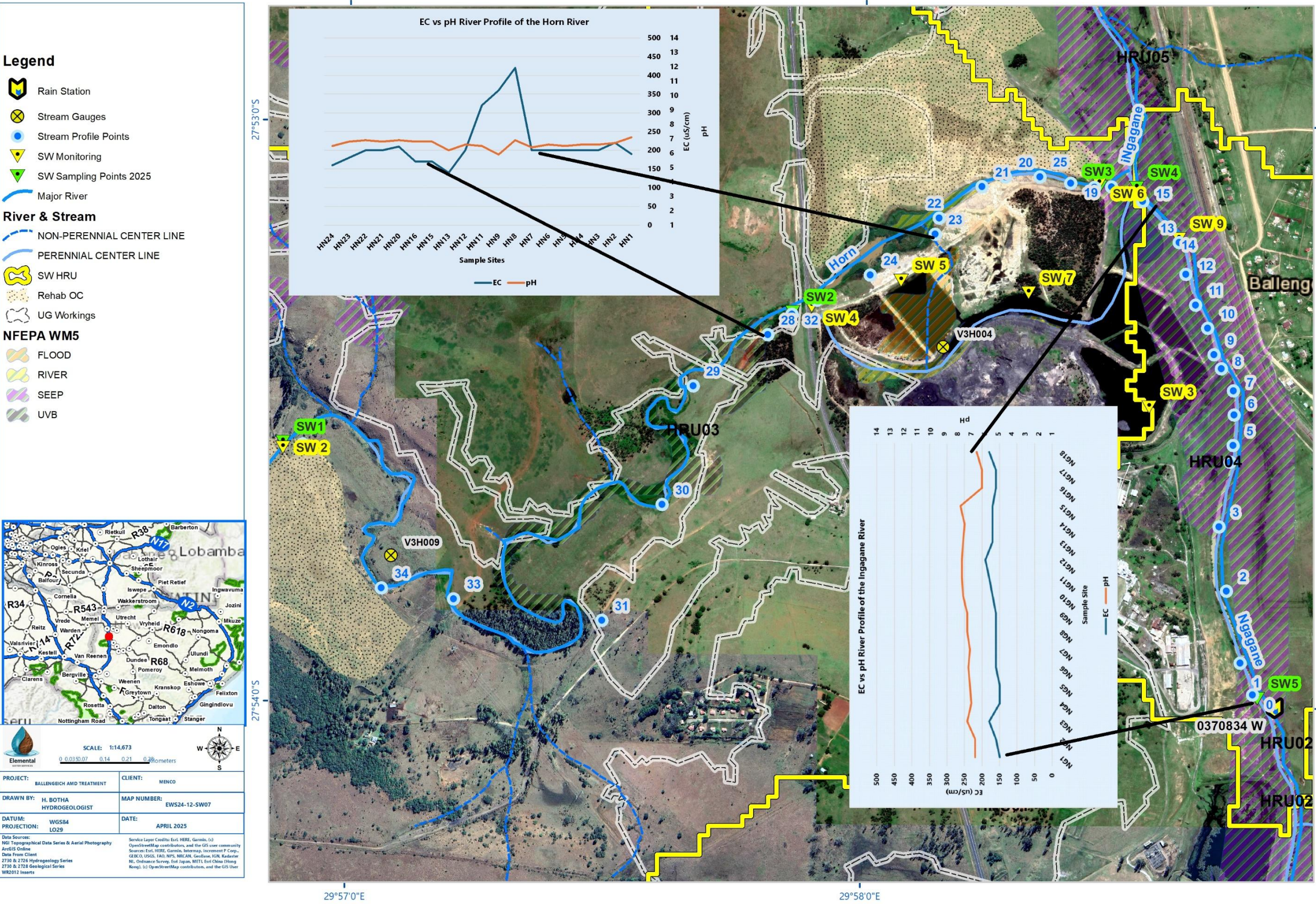


Figure 7-12: Stream profiles for the Ingagane and Horn Rivers

8 HYDROGEOLOGICAL IMPACT ASSESSMENT

For the Ballengeich Mine, there are existing impacts due to decant and poor-quality seepage into the groundwater table and directly into the Horn River. The activities proposed aim to improve the environmental status and reduce the impacts relating to the decant and poor-quality seepage.

There may be some construction phase risk for the development of the artificial wetland, limestone drains, ALD and SAPS. The operational phase of the treatment proposed will have positive environmental impacts.

Risk assessment entails understanding the generation of a hazard, the probability that the hazard will occur, and the consequences if it should occur. The net consequence is established by the following equation:

$$\text{Consequence} = \text{Duration} + \text{Extent} + (\text{Irreplaceability of resource}) \times \text{Severity}$$

And

$$\text{Environmental Significance (SP)} = \text{Consequence} \times \text{Probability}$$

The risk significance rating is summarised in Table 8-1

Table 8-1: Risk rating scale

Criteria	Rating Scales
Environmental Significance (SP)	Very high – negative (-49 to -66)
	High – negative (-37 to -48)
	Moderate – negative (-25 to -36)
	Low – negative (-13 to -24)
	Neutral - Very low (0 to -12)
	Low-positive (0 to 12)
	Moderate-positive (13 to 24)
	High-positive (37 to 48)
	Very high – positive (49 to 66)

The anticipated hydrogeological impacts for the preparation, operational and closure phases impacts are summarised in Table 8-4 to Table 8-5. The risks were evaluated in the context of the hydrogeological setting, as well as existing impacts and predicted impacts.

8.1 Preparation phase

The following activities are anticipated during the preparation phase of the project:

- ✚ Typical earthworks are required to clear the areas.
- ✚ Construction of access roads.
- ✚ Establish service platforms, material handling areas, and other temporary infrastructure.
- ✚ Dust suppression of access roads.
- ✚ Construction of the wetlands, ponds, dams and associated drains.

- ✚ Placing of topsoil in designated areas; and
- ✚ Constructing laydown areas and temporary stormwater systems and berms.

The identified possible hydrology impacts for the preparation phase include (refer to Table 8-4):

- ✚ The destruction of the vadose zone sediments by clearing activities. This impact is permanent and is therefore not included in the impact table, as no mitigation measures can be recommended. This could lead to sediment runoff and surface water contamination.
- ✚ Secondary seepage from the decant area as a result of diversion and temporary management of the decant is needed to construct the required semi-passive treatment system.
- ✚ Clearing topsoil from footprint areas will influence the rate of infiltration of water to the shallow groundwater system and/or baseflow component to shallow streams.
- ✚ Transporting material can cause various types of spills (i.e. hydrocarbons or dosing chemicals), which can infiltrate and contaminate the soils and groundwater system.
- ✚ Oil and fuel spills and leakages at vehicle park areas and in the project areas may cause poor-quality seepage and soil contamination.

Overall, the predicted impact is low and may decrease to marginal if mitigation measures are implemented – refer to the tables below. Ongoing quarterly groundwater and surface water monitoring will help to establish new impacts, and weekly site inspections will be keen to determine issues that could lead to environmental incidents.

8.2 Operational Phase

The operational phase will be indefinite, as decant and AMD will be treated indefinitely. The predicted impacts are as follows (refer to Table 8-5):

- ✚ Ongoing passive treatment of AMD.
- ✚ Improvement of the environmental status of the Horn River and Ingagane River, as well as reduced salt loads into the watercourses.
- ✚ The groundwater impact will remain mostly unchanged until the Ballengeich discard dump is rehabilitated, as well as pollution control dams.

8.3 Offsets and alternatives

No alternatives are available, and the proposed treatment system must be placed in the pre-defined areas in order to ensure optimum efficiency of the treatment of AMD. No hydrogeological buffers or offsets were identified.

8.4 Cumulative impacts on the groundwater reserve

The tables presented below consider cumulative impacts. The largest cumulative impact is notable due to the potential combined regional scale impact on groundwater quantity and quality. However, considering the risk assessment and predicted flow and transport modelling outcomes, the cumulative impact can be considered marginal. T

No groundwater abstraction has been proposed, and the treatment of AMD is not viewed as having a quantitative impact on the groundwater reserve. The scale of groundwater abstraction and the stress of the aquifer units are considered small – refer to the section below. There are no predicted groundwater impacts in terms of groundwater quantity.

8.4.1 Scale of abstraction

The scale of abstraction for the aquifer unit is summarised in Table 8-2. Based on available information, groundwater abstraction is considered a small scale of the GW HRU.

Table 8-2: The estimated scale of abstraction

Scale	
Component	GW HRU
Re (m ³ /yr)	1055378.73
Use (m ³ /yr)	244947.38
Abs. Scale	0.23
Class	Small Scale

8.4.2 Water quantity stress index

The predicted aquifer stress or stress on the groundwater reserve is summarised in Table 8-3. Based on available information, the GW HRU is considered unstressed.

Table 8-3: Level of the stress of proposed abstraction

Water Stress	
Component	GW HRU
Proposed Abstraction	0.00
Re - BF	835431.35
Stress Index	0.00
Class	A

Table 8-4: Impacts during the preparation phase

Component Being Impacted On	Activity Which May Cause the Impact	Activity	Pre- Mitigation							Recommended Mitigation Measures	Post Mitigation						
			Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance		Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance
Vadose zone soils and subsequent aquifer (groundwater table)	Disturbing vadose zone during soil excavations/construction activities.	The net result of the installation of the treatment system	Medium Term (3)	Site (2)	Yes (1)	High (-3)	Highly detrimental (-19 to -24) (-18)	Probable - definite(1.5)	Moderate – negative (-25 to -36) (-27)	- Only excavated areas apply to the project area. - Cover excavated soils with a temporary liner to prevent contamination (if required and for higher-risk wastes/materials). - Retain as much indigenous vegetation as possible. - Exposed soils are to be protected using a suitable covering or revegetating. - Keep wastes and material stockpiles apart (i.e. don't mix different materials).	Medium Term (3)	Site (2)	Yes (1)	Moderate (-2)	Slightly detrimental (-7 to -12) (-12)	Definite (2)	Low – negative (-13 to -24) (-24)
	Poor quality seepage from machinery used to excavate soils. Oil, grease, and fuel leaks could lead to hydrocarbon contamination of the vadose zone - which could percolate into the shallow aquifer.	The net result of the installation of the treatment system	Medium Term (3)	Site (2)	Yes (1)	High (-3)	Highly detrimental (-19 to -24) (-18)	Probable - definite(1.5)	Moderate – negative (-25 to -36) (-27)	- Park heavy machinery in lined areas and place drip trays under vehicles at the site. - Visual soil assessments for signs of contamination during construction (monthly)	Medium Term (3)	Site (2)	Yes (1)	Moderate (-2)	Slightly detrimental (-7 to -12) (-12)	Definite (2)	Low – negative (-13 to -24) (-24)
Primary Surface Water Receivers Horn River Wetland units	Erosion and sedimentation runoff may enter the stream (worst case). To date, no sedimentation has taken place (i.e. no evidence observed during the site walkover assessment).	The net result of the installation of the treatment system	Medium Term (3)	Site (2)	Yes (1)	High (-3)	Highly detrimental (-19 to -24) (-18)	Probable - definite(1.5)	Moderate – negative (-25 to -36) (-27)	- Use temporary or permanent stormwater systems (as per this report) to prevent erosion and manage sediment runoff. - Visual inspections of all vehicles entering and operating at the site. - Use silt traps or fences where required to manage runoff and areas prone to cause erosion. This will decrease sedimentation risk.	Medium Term (3)	Site (2)	Yes (1)	Moderate (-2)	Slightly detrimental (-7 to -12) (-12)	Definite (2)	Low – negative (-13 to -24) (-24)
	Decant from the underground workings into the Horn River and flow into the Ingagane River.	Decant	Long Term (4)	Site (2)	Yes (1)	High (-3)	Extremely detrimental (-25 to -33) (-28)	Definite(2)	Very high – negative (-49 to -66) (-56)	- Temporary diversion methods are used to manage the runoff of AMD into the Horn River during the construction of the lime drains and treatment ponds. - Ensure that AMD water is kept within already impacted drainage servitudes.	Long Term (4)	Site (2)	Yes (1)	High (-3)	Extremely detrimental (-25 to -33) (-28)	Probable - definite(1.5)	High – negative (-37 to -48) (-42)

Component Being Impacted On	Activity Which May Cause the Impact	Activity	Pre- Mitigation							Recommended Mitigation Measures	Post Mitigation						
			Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance		Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance
Regional water table	Poor quality seepage from machinery used to excavate soils. Oil, grease, and fuel leaks could lead to hydrocarbon contamination of the vadose zone - which could percolate into the shallow aquifer.	The net result of the installation of the treatment system	Medium Term (3)	Site (2)	Yes (1)	High (-3)	Highly detrimental (-19 to -24) (-18)	Probable - definite(1.5)	Moderate – negative (-25 to -36) (-27)	➤ Park heavy machinery in lined areas and place drip trays under vehicles at the site. ➤ Have fuel and oil spill cleanup kits on site and clean up these areas immediately. ➤ Visual soil assessments for signs of contamination during construction (monthly)	Medium Term (3)	Site (2)	Yes (1)	Moderate (-2)	Slightly detrimental (-7 to -12) (-12)	Definite (2)	Low – negative (-13 to -24) (-24)
	Poor quality seepage percolation into the groundwater table	Seepage from existing infrastructure at Ballengeich Mine	Long Term (4)	Site (2)	Yes (1)	High (-3)	Extremely detrimental (-25 to -33) (-28)	Definite(2)	Very high – negative (-49 to -66) (-56)	➤ Rehabilitate the discard dump at the site's closure. ➤ Ensure that PCDs are rehabilitated or re-purposed at closure. ➤ Ensure that the plants and stockpiles are rehabilitated. ➤ Continue with groundwater and surface water monitoring up to 5 years after the closure of the mine to confirm closure trends and mitigation measures that will be required.	Medium Term (3)	Site (2)	Yes (1)	Moderate (-2)	Slightly detrimental (-7 to -12) (-12)	Definite (2)	Low – negative (-13 to -24) (-24)

Table 8-5: Impacts during the closure operational & decommissioning phase

Component Being Impacted On	Activity Which May Cause the Impact	Activity	Pre- Mitigation							Recommended Mitigation Measures	Post Mitigation						
			Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance		Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance
Primary Surface Water Receivers ➤ Horn River ➤ Wetland units	Decant from the underground workings into the Horn River and flow into the Ingagane River. The AMD will be treated via the proposed semi-passive treatment system.	Decant	Long Term (4)	Site (2)	Yes (1)	High Positive (+3)	Extremely beneficial (25 to 33) (28)	Definite (2)	Very high – positive (49 to 66) (56)	➤ Continue with groundwater monitoring and surface water monitoring up to 5 years after the system is installed. Re-evaluate the requirement for monitoring based on quality trends thereafter.							
Regional water table	Poor quality seepage percolation into the groundwater table	Seepage from existing infrastructure at Ballengeich Mine	Long Term (4)	Site (2)	Yes (1)	High (-3)	Extremely detrimental (-25 to -33) (-28)	Definite(2)	Very high – negative (-49 to -66) (-56)	➤ Rehabilitate the discard dump at the site's closure. ➤ Ensure that PCDs are rehabilitated or re-purposed at closure. ➤ Ensure that the plants and stockpiles are rehabilitated. ➤ Continue with groundwater and surface water monitoring up to 5 years after the closure of the mine to confirm closure trends and mitigation measures that will be required.	Medium Term (3)	Site (2)	Yes (1)	Moderate (-2)	Slightly detrimental (-7 to -12) (-12)	Definite (2)	Low – negative (-13 to -24) (-24)

9 GROUNDWATER MANAGEMENT

To restrict the local groundwater and surface water impact, the following actions are proposed:

- ✚ Reduce the recharge potential through stockpiles and the discard dump by capping or covering the material with a geomembrane. Ongoing rehabilitation through implementation and maintenance of the above-mentioned will reduce the impact on the groundwater.
- ✚ Re-use of groundwater seepage collected in soak ways, stormwater trenches, cut-off trenches, underground and opencast workings and adequately sized pollution control facilities.
- ✚ Keep dirty areas like workshops and oil and diesel storage areas as small as possible.
- ✚ Contain poor quality runoff from dirty areas and divert this water to PCDs for re-use.
- ✚ Have oil/diesel spill kits on site.
- ✚ Confirm groundwater and surface water monitoring protocol and plans during the operational and pre-closure phase, as well as the groundwater risk and potential water liabilities.

9.1 Monitoring

To restrict the local groundwater and surface water impact, the following actions are proposed:

- ✚ Cap or line overburden dumps with a geomembrane or clay liner to reduce infiltration into the dumps. Hence, this will reduce poor-quality seepage percolation into the groundwater aquifer.
- ✚ Plan for closure and consider stabilising the existing discard dump before the new proposed discard dump is constructed on the same footprint.
- ✚ Install the proposed additional groundwater boreholes upstream of the Ingagane River.
- ✚ Multiple-level monitoring wells must be constructed to monitor base-flow quality within the identified sensitive zones and to monitor groundwater level behaviour in the open cast pits. Use the results of the monitoring programme to confirm/validate the predicted impacts on groundwater availability and quality after closure.
- ✚ Update existing predictive tools to verify long-term impacts on groundwater, if required.
- ✚ Continue with groundwater quality and groundwater level monitoring for a period of 5 years after Ballengeich is decommissioned to establish post-closure groundwater level and quality trends. The monitoring information must be used to update, verify and recalibrate the predictive tools used during the study to increase confidence in the closure objectives and management plans.

9.2 Groundwater closure objectives

The following actions are proposed:

- ✚ Update existing predictive tools to verify long-term impacts on groundwater, if required.
- ✚ Present the results to the competent authority on an annual basis to determine compliance with the closure objectives set during the Decommissioning Phase.
- ✚ Negotiate and get groundwater closure objectives approved by the competent authority during the decommissioning phase of the project (i.e. if wetlands for closure is anticipated, then this should be trailed and tested and communicated to the DWS as well as other treatment technologies), based on the results of the monitoring information obtained during the construction and operational phases of the project, and through verification of the numerical model constructed for the project.
- ✚ Continue with groundwater quality and groundwater level monitoring for up to 5 years after closure or as specified by DWS to confirm post-closure impact trends.
- ✚ Present results of the monitoring programme to the competent authority on an annual basis. The post-closure monitoring programme will be re-evaluated on an annual basis in consultation with the competent authority.
- ✚ Negotiate closure with competent authority based on the results of the groundwater monitoring undertaken after the two to four-year post-closure monitoring periods.

10 GROUNDWATER MONITORING

There are existing groundwater monitoring boreholes and surface water monitoring points at Ballengeich, and quarterly water monitoring takes place by contractors as appointed by Kangra Coal (Pty) Ltd. From this investigation undertaken, there is a gap in the groundwater monitoring network, and the boreholes as listed below are proposed to fill the gaps. Positions are shown in Figure 10-1.

Table 10-1: Proposed additional groundwater boreholes

Site	Type	Latitude	Longitude	Proposed Depth
EWS BH1	Proposed Groundwater	-27.888936	29.977264	30m
EWS BH2	Proposed Groundwater	-27.886541	29.976321	30m

The following is proposed in terms of monitoring of these boreholes:

- ✚ **Quarterly** water level monitoring of the abstraction borehole should take place.
- ✚ **A quarterly** hydrochemical sampling of these boreholes is proposed.

- ✚ The monitoring network should be audited annually to verify gaps and to expand the groundwater monitoring network as required.
- ✚ Monitoring up to closure and up to 5 years after closure is recommended.
- ✚ Monitoring should look at the following parameters (at minimum) or as specified in the WULA:

Groundwater and surface water sample analyses

- ✚ Sum of Anion Milliequivalents
- ✚ Sum of Cation Milliequivalents
- ✚ Anion-Cation Balance
- ✚ Bicarbonate Alkalinity as CaCO_3
- ✚ Carbonate Alkalinity as CaCO_3
- ✚ Total Alkalinity as CaCO_3
- ✚ Conductivity in mS/m @ 25°C
- ✚ TDS ($0.7\mu\text{m}$) @ 105°C
- ✚ Aluminium
- ✚ Calcium
- ✚ Copper
- ✚ Iron
- ✚ Potassium
- ✚ Magnesium
- ✚ Manganese
- ✚ Sodium
- ✚ Zinc
- ✚ Chloride
- ✚ Fluoride
- ✚ Nitrate
- ✚ Nitrate as N
- ✚ Sulphate
- ✚ pH in water at 25°C

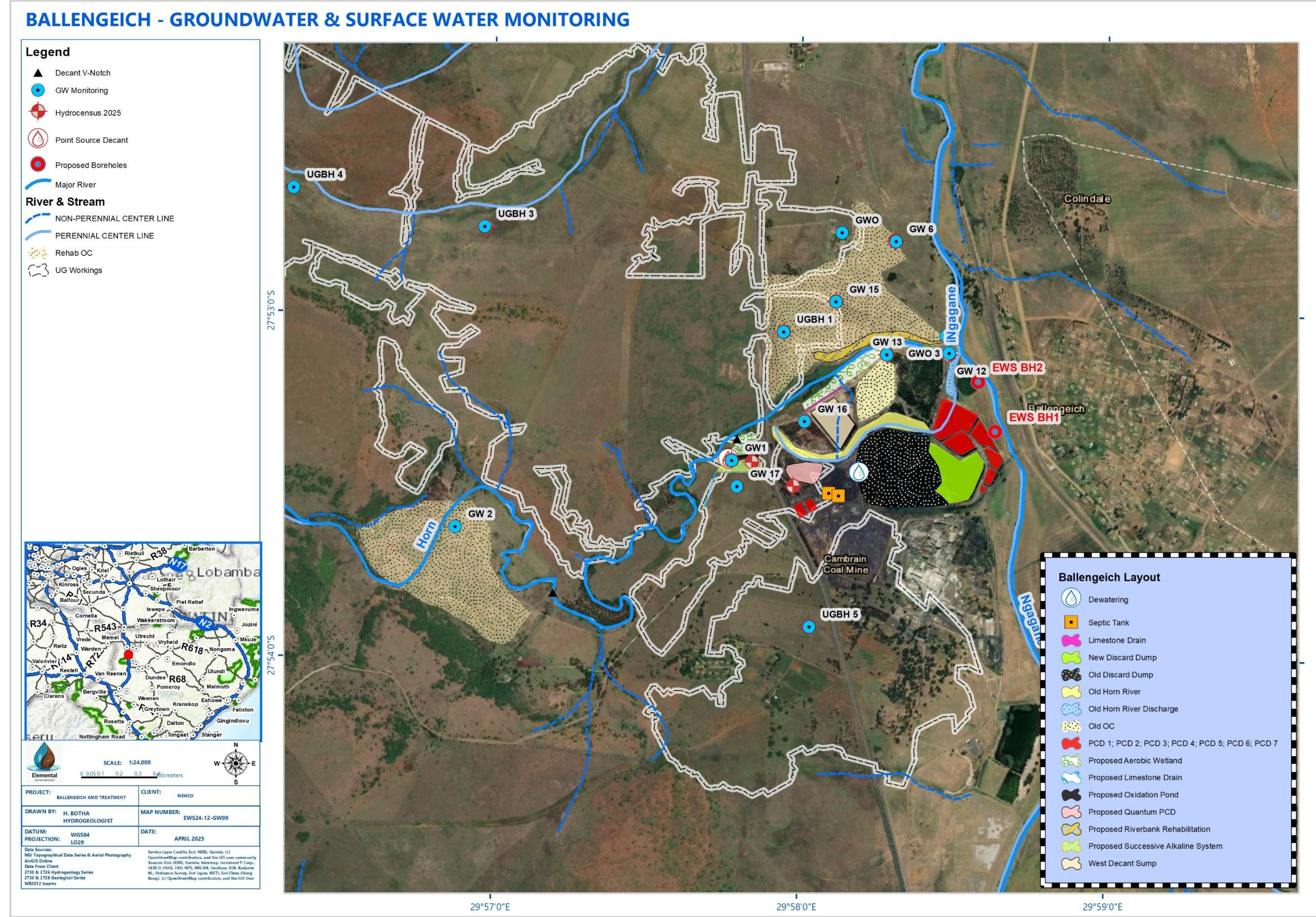


Figure 10-1: Proposed additional groundwater monitoring points

11 CONCLUSIONS

Based on the investigation undertaken, the following conclusions are made:

- ✚ The Ballengeich Colliery is situated on the southern side of the Horn River and the western side of the Ingagane River, at the confluence of the two (2) rivers, about 12km South of the Town of Newcastle, in the KwaZulu-Natal Province. The Ballengeich surface operations are situated within quaternary catchment W31G, with the old underground workings extending into V31F and V31K of the Mtamvuna-Pongola Water Management Area. The MAP of the site is in the order of 739 mm/yr, MAE is in the order of 1200 mm/yr, and MAR is in the order of 104 mm/yr.
- ✚ 15 boreholes were identified during the field hydrocensus, of which 2 are used for domestic water supply, 1 is used for the decant management at Ballengeich, and the remaining are used for groundwater monitoring. The water level was observed to vary from artesian (decant area) to an average of 5.7 metres below ground level (mbgl).
- ✚ Available hydrogeology data suggests that three (3) aquifers exist in the area:
 - An unconfined aquifer associated with the unconsolidated sands along the Horn River & Ingagane River, particularly in floodplain areas.
 - A shallower aquifer system is associated with weathered to partly consolidated sedimentary rock as well as moderately to partially weathered sandstone and shale of the Ecca Group.
 - A deeper confined fractured aquifer network associated with the Dwyka Group Tillite of the Karoo Sequence.
- ✚ Historical underground workings have likely led to the formation of a hydrogeological unit in the mines that have undergone coal extraction. Significantly higher hydraulic conductivity and storage values are expected for the aquifer due to the presence of mine voids or backfilled material with higher permeability than surrounding sediment/rock. The flooded underground workings are believed to be in a pseudo-steady state and decanting near the Horn River.
- ✚ From available literature data, the weathered zone for the area is estimated to be in the order of 5 - 28 m thick, followed by a subsequent thicker intergranular & fractured aquifer zone. The groundwater levels for the Ballengeich colliery range from artesian (decant area) to an average of 5.7 metres below ground level (mbgl). Groundwater is found within mined-out voids (underground workings beneath the regional water table), the weathered zone (perched), as well as fractures and bedrock contacts, contacts between lithologies or at unconformities and dolerite/diabase dyke contacts. The groundwater table mimics the topography, and groundwater flows from high-lying areas (water divides) to low-lying areas.

- ✚ The main source of groundwater recharge is rainfall. The rainfall infiltrates into the ground to become groundwater through the Vadose Zone. The water then moves both vertically and horizontally in the weathered zone. Greater interflow is expected in a horizontal direction within the weathered zone matrix. Water flowing horizontally in the soil and the weathered zone may enter the surface water streams/rivers if hydraulically connected (i.e. gaining rivers/streams). Available data does suggest that the portion of the Ingagane and Horn Rivers bordering the site may be a losing river. Water that makes it through the weathered zone slowly percolates and recharges the deeper intergranular and fractured aquifers, with much lower permeabilities and storage potential.
- ✚ The groundwater at the Ballengeich Mine can be classified as Na-Cl (GW16), Ca-HCO₃ (UGBH5) and Ca-SO₄ (GW12, GW6, GW1). These are typical attributes of fresh shallow groundwater, deep ancient groundwaters, and groundwater impacted by mine drainage. Surface water can be classified as water influenced by active ion exchange.
- ✚ A groundwater flow and transport model was developed for the Site.
 - The flow model suggests that the groundwater table mimics the topography. Groundwater flow is towards the south and west, towards the perennial river systems/topography lows. The flow model indicates groundwater flow velocities ranging from 0.001 (min) to 0.38 (max) m/day. The above suggests that groundwater is very slow-moving in the study area.
 - The transport model suggests that the plumes remain in close proximity to the point sources at the site, with a concentration gradient from 4000 mg/l to 50mg/l towards the Ingagane River and higher SO₄ concentration gradient towards the Horn River ranging from 4000 to 1000 mg/l.
- ✚ The Horn and Ingagane Rivers exhibit attributes relating to losing rivers. This means that the groundwater plumes are likely going underneath the river systems, and the baseflow to the rivers is marginal. If baseflow had been higher, an immediate impact on surface water quality would have been observed.
- ✚ Two (2) stream profiles were completed for the Horn and Ingagane Rivers and are discussed in Section 7.6.2. A definite increase in EC and decrease in pH is observed at NH12 to NH7 (at the N11 bridge), which are downstream of the known decant area. The remainder of the Horn River shows little impact, with a decrease in EC as a result of the artificial wetland and phytoremediation. The pH and EC for the Ingagane River show marginal changes from upstream to downstream relative to the discard dump. A marginal impact is observed.

- ✚ A hydrogeological risk assessment is available in Section 8, where site-specific and regional cumulative impacts have been assessed. Groundwater management and monitoring aspects have been addressed and are available in Sections 9 and 10.

11.1 Recommendations

The following recommendations are made:

- ✚ Ensure that the groundwater mitigation measures, as mentioned in Section 8, are considered during the operation and closure phases of the Project.
- ✚ Update the numerical groundwater flow and transport model annually to:
 - Track the sulphate plume movement into the surrounding aquifer.
 - Track preferential flow paths and changes to groundwater flow.
 - Ensure no monitoring network gaps exist (i.e. check if the monitoring network is representative of the site).
 - Update the numerical groundwater model annually.
- ✚ Continue with quarterly groundwater quality and groundwater level up to 5 years after closure to confirm water quality trends and closure objectives.
 - The monitoring information must be used to update, verify, and re-calibrate the predictive tools used during the study to increase confidence in the closure objectives and management plans.
 - The numerical model platforms can be updated on an annual basis to confirm groundwater and pollution transport movement into the environment.
 - Once the model is updated, the groundwater monitoring plan and mine water treatment plans can be updated.

11.2 Identification of any areas that should be avoided

No alternatives are available, and the proposed treatment system must be placed in the pre-defined areas in order to ensure optimum efficiency of the treatment of AMD. No hydrogeological buffers or offsets were identified.

11.3 Reasoned opinion on whether EA/WULA should be considered

Based on the findings of this assessment, EWS believes that the proposed activities are to benefit the receiving groundwater and surface water environments. The approval of the activity should be considered to enable Kangra to mitigate the impacts associated with the Legacy Ballengeich Mine.

12 BIBLIOGRAPHY

- ARC, 2006. *Lan Types of South Africa*, s.l.: Pretoria: Agricultural Reserach Council.
- Bailey, A. & Pitman, W., 2015. *Water Resources of South Africa 2012 Study (WR2012): Executive Summary Version 1*. WRC Report No. K5/2143/1, Gezina, South Africa: Water Research Commission Report.
- Barnett, B. et al., 2012. *Australian groundwater modelling guidelines*. ISBN- 978-1-921853-91-3, s.l.: s.n.
- Bhekhani Pty Ltd, 2023. *BALLENGEICH COLLIERY PRELIMINARY CIVIL DESIGN REPORT FOR ACID MINE DRAINAGE PASSIVE TREATMENT DESIGN*, s.l.: s.n.
- Bredenkamp, D., Botha, L., Van Tonder, G. & Van Rensburg, H., 1995. *Manual on Quantitave Estimation of Groundwater Recharge and Aquifer Storativity.*, South Africa: WRC Report No TT 73/95.
- ClimateSERV 2.0, 2025. *CHIRPS RAINFALL DATA*, s.l.: <https://climateserv.servirglobal.net/>.
- DFFE, 2024. *South African National Land Cover (SANLC) 2022 data*, s.l.: s.n.
- DMEA, 1998. *1:250 000 Geological Series - 2728 Frankfort*. s.l.:s.n.
- DMEA, 1998g. *1:250 000 Geological Series - 2730 Vryheid*, s.l.: s.n.
- DWA, 2012. *Aquifer Classification of South Africa map*, s.l.: Hydrological Services - Groundwater Information..
- DWAF, 2006. *Groundwater Resource Assessment II*, s.l.: s.n.
- DWAF, 2007. *Best Practice Guidelines – G3: Water Monitoring Systems*, s.l.: DWS.
- DWAF, 2008. *Best Practice Guidelines: Impact Prediction (G4)*, s.l.: DWS.
- DWS, 2016. *New Water Management Areas*, South Africa: Government Gazette No. 40279.
- DWS, 2024. *DWS Proposed Reserve Determination for Water Resources of the Thukela Catchments in the Pongola-Mtamvuna Water Management Area*, s.l.: s.n.
- DWS, 2025. *DWS National Integrated Water Information System*, s.l.: s.n.
- Eyring, V. B. S. M. G. A. S. C. A. S. B. S. R. J. a. T. K. E., 2016. *Overview of the Coupled Model Intercomparison Project Phase 6 (CMIP6) experimental design and organization*, *Geosci. Model Dev.*, 9, 1937-1958, doi:10.5194/gmd-9-1937-2016. s.l.:<https://greenbook.co.za/>.
- GCS, 2016. *Hydrological Assessment of Ballengeich Mine* , s.l.: s.n.
- GCS, 2024. *Water Quality Monitoring Report for the Kangra Coal KwaZulu-Natal Operations: Second Quarter, 2024 Monitoring Period*, s.l.: s.n.
- GRIP, 2016. *Groundwater Resource Information Project* , s.l.: s.n.
- Harbaugh, A., B. E., Hill, M. & McDonald, M., 2000. *Modflow-200, the U.S. Geological Survey Modular Ground-Water Model - User Guide to Modularization Concepts and the Ground-Water Flow Process*. Open-File Report 00-92, s.l.: s.n.
- Hill, M. & Tiedeman, C., 2005. *Effective Groundwater Model Calibration: With analysis of Data, Sensitivities, and Uncertainty*. Wiley Press. ISBN-13: 978-0-471-77636-9, s.l.: s.n.
- King, G., Maritz, E. & and Jonck, F., 1998. *2730 Vryheid - 1:500 000 Hydrogeological map series of the Republic of South Africa.*, s.l.: s.n.
- King, G., Maritz, E. & Jonck, F., 1998. *2726 Kroonstad - 1:500 000 Hydrological Map Series of the Republic of South Africa*, s.l.: s.n.
- Kottek, M. et al., 2006. *World Map of the Köppen-Geiger climate classification updated*. *Meteorol. Z.*15, 259-263. doi:10.1127/0941-2948/2006/0130. s.l.:s.n.
- Lourens, P., 2013. *The relationship between South African geology and geohydrology*, s.l.: IGS, University of the Free State, Bloemfontein. Masters Dissertation..
- Lynch, S., 2004. *Development of a Raster Database of Annual, Monthly and Daily Rainfall for Southern Africa*, WRC Report No. 1156/1/04, Pretoria: Water Research Commission.
- MENCO, 2022. *Kangra Coal (Pty) Ltd: Ballengeich Colliery Determination of the Assimilative Capacity of V30 Catchment* , s.l.: s.n.
- MENCO, 2022. *Wetland delineation assessment for Kangra Coal (Pty) Ltd Ballengeich Colliery*, s.l.: s.n.
- MENCO, 2022. *Wetland Delineation Assessment For Kangra Coal (Pty) Ltd: Ballengeich Colliery* , s.l.: s.n.
- Meteoblue, 2025. *Climate Data*. s.l.:<https://www.meteoblue.com>.
- Muthu, A. & S. M., 2015. *Estimation of Surface Runoff Potential using SCS-CN Method Integrated with GIS.* , s.l.: Indian Journal of Science and Technology. 8. 10.17485/ijst/2015/v8i28/83324. .
- NGA, 2022. *National Groundwater Archive*. [Online]
Available at: <https://www3.dwa.gov.za/NGANet/Security/WebLoginForm.aspx>
- NGA, 2025. *National Groundwater Archive*. [Online]
Available at: <https://www3.dwa.gov.za/NGANet/Security/WebLoginForm.aspx>
- Parsons, R., 1995. *A South African Aquifer System Management Classification*, s.l.: Water Research Commission Report No. KV 7795.
- Parsons, R. & Wentzel, J., 2007. *Groundwater Resource Directed Measures Manual*, WRC Report No TT 299/07, s.l.: DWAF.
- SADAC GIP, 2025. *SADC Groundwater Information Portal*, s.l.: s.n.

Schulze, R., 1997. *South African Atlas of Agrohydrology and Climatology*. WRC Report No. TT85/96, Pretoria: Water Research Commission.

SERVIR, 2025. *SERVIR Project - CHIRPS, eMODIS NDVI, and NMME seasonal observation and forecast data*, s.l.: <https://climateserv.servirglobal.net/map>.

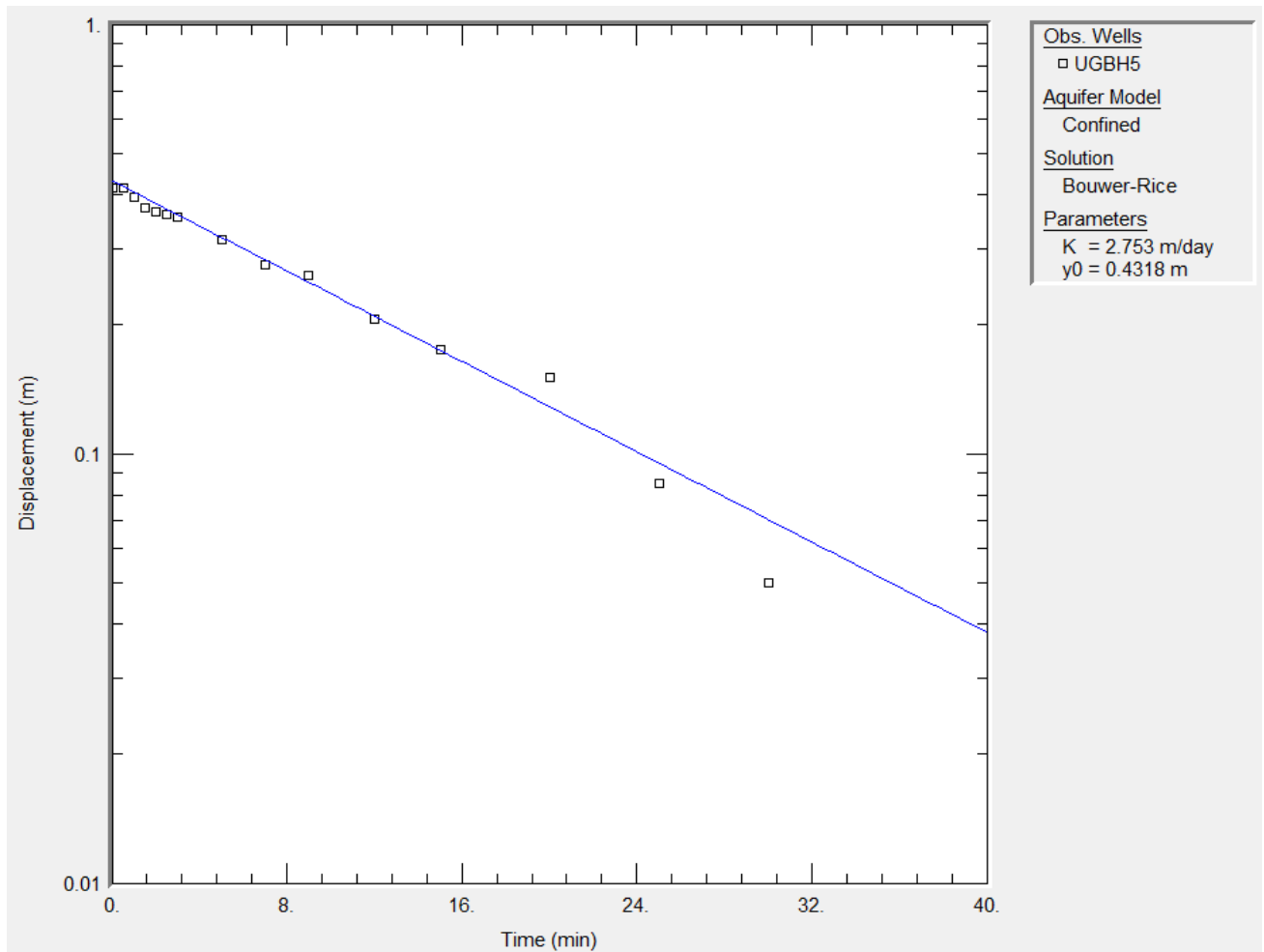
Van Deventer, H. S.-A. L. M. N. P. C. S. A. C. N. G. M. J. N. L. M. O. D. S. P. S. E. & S. K., 2018. *NBA2018 National Wetland Map 5*. s.l.:s.n.

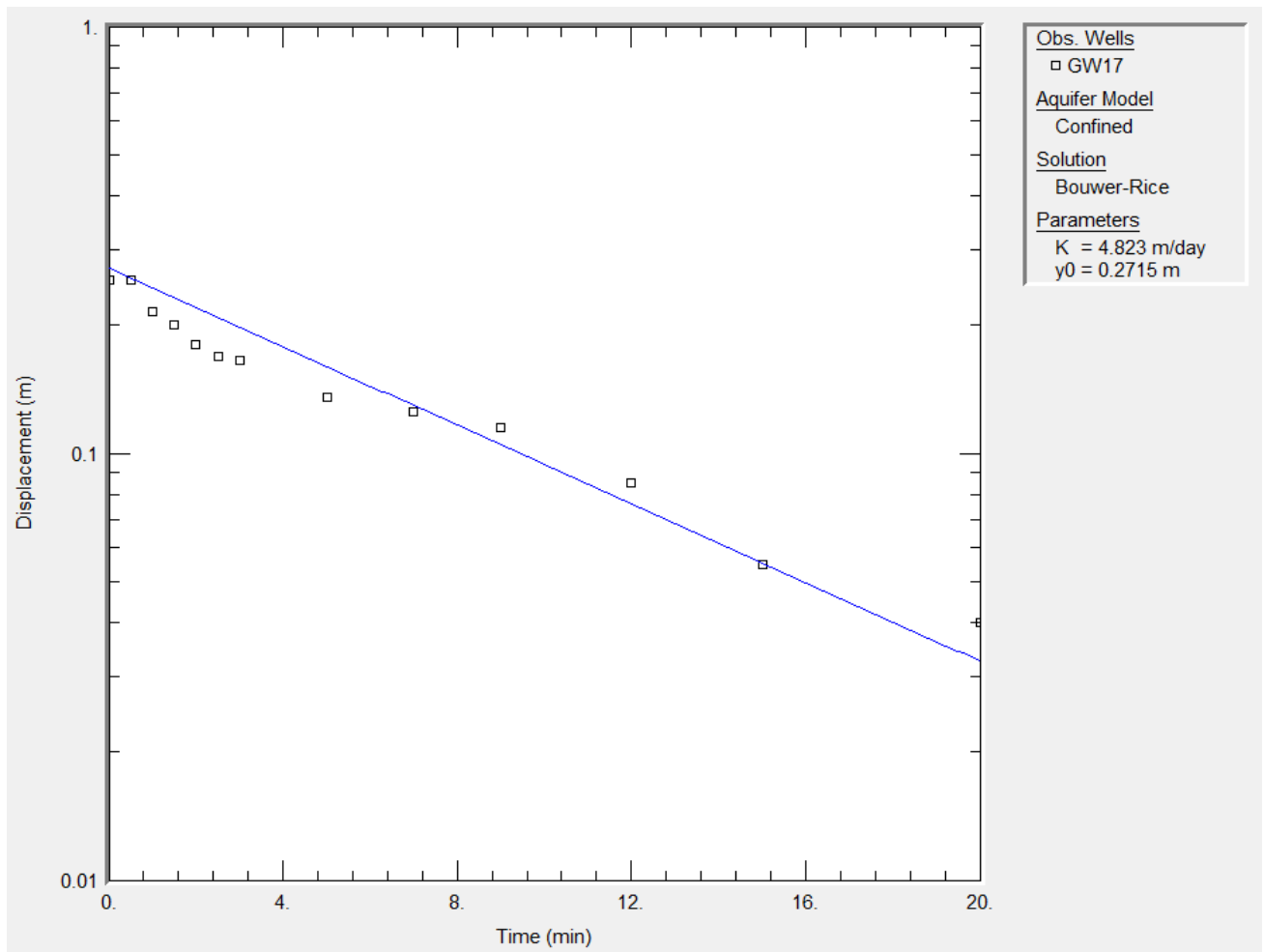
Van Tonder, G. & Xu, Y., 2000. *A guide for the estimation of groundwater recharge in South Africa*. *Water South Africa*. 27(3): 341 - 343 p., s.l.: s.n.

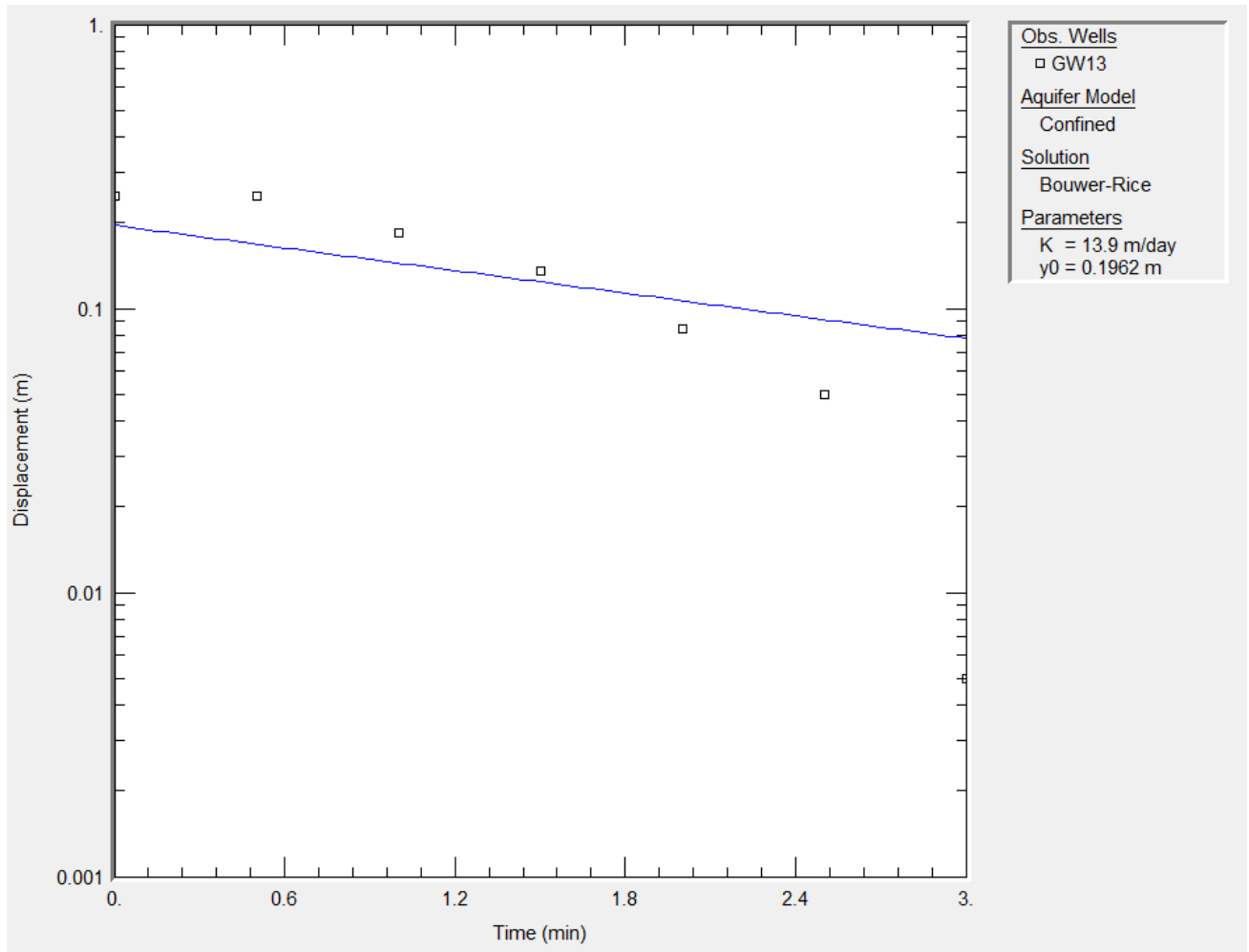
Vegter, 1995. *Groundwater Recharge Map of South Africa*, s.l.: s.n.

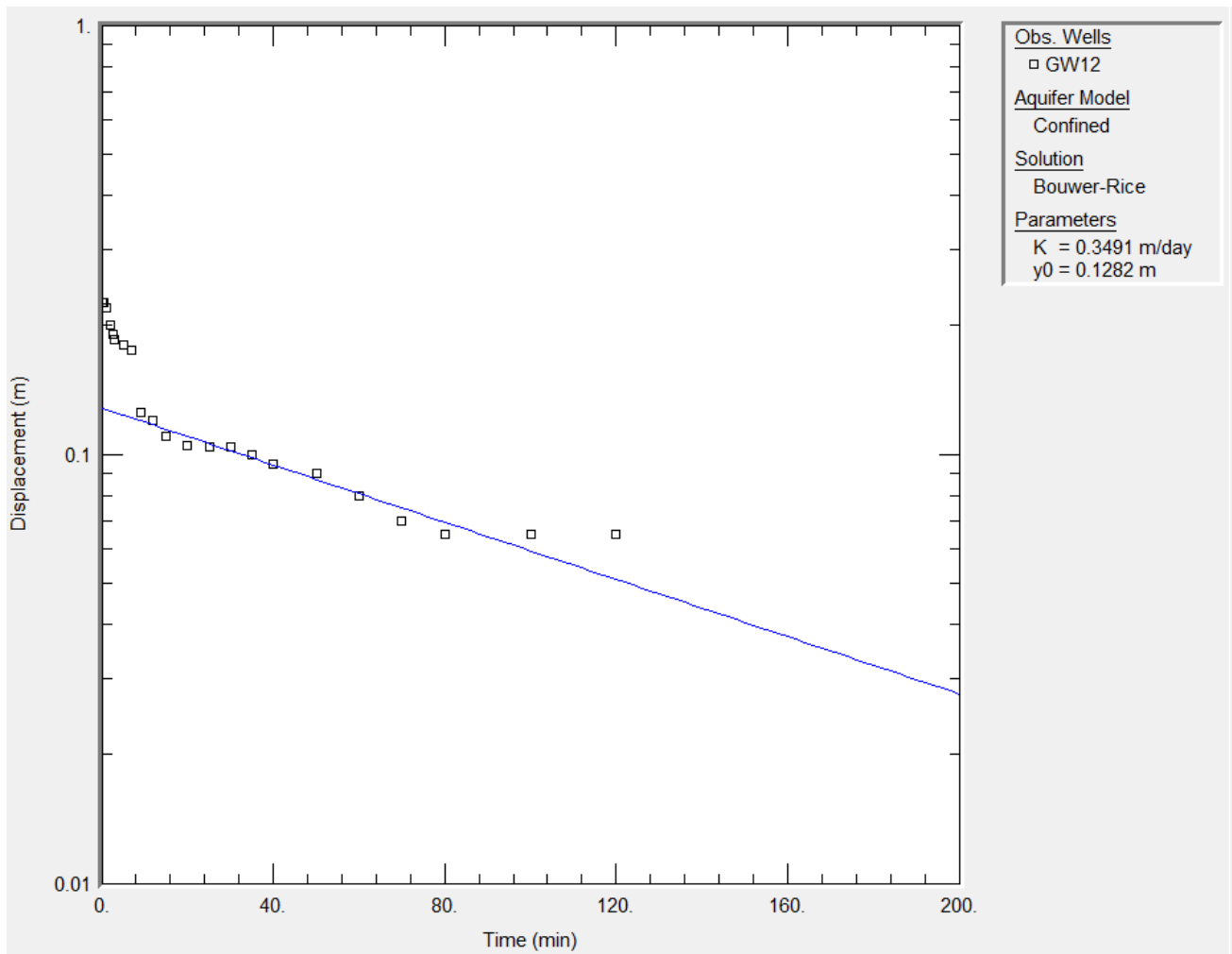
WRC, 2015. <http://www.waterresourceswr2012.co.za/resource-centre/>. [Online].

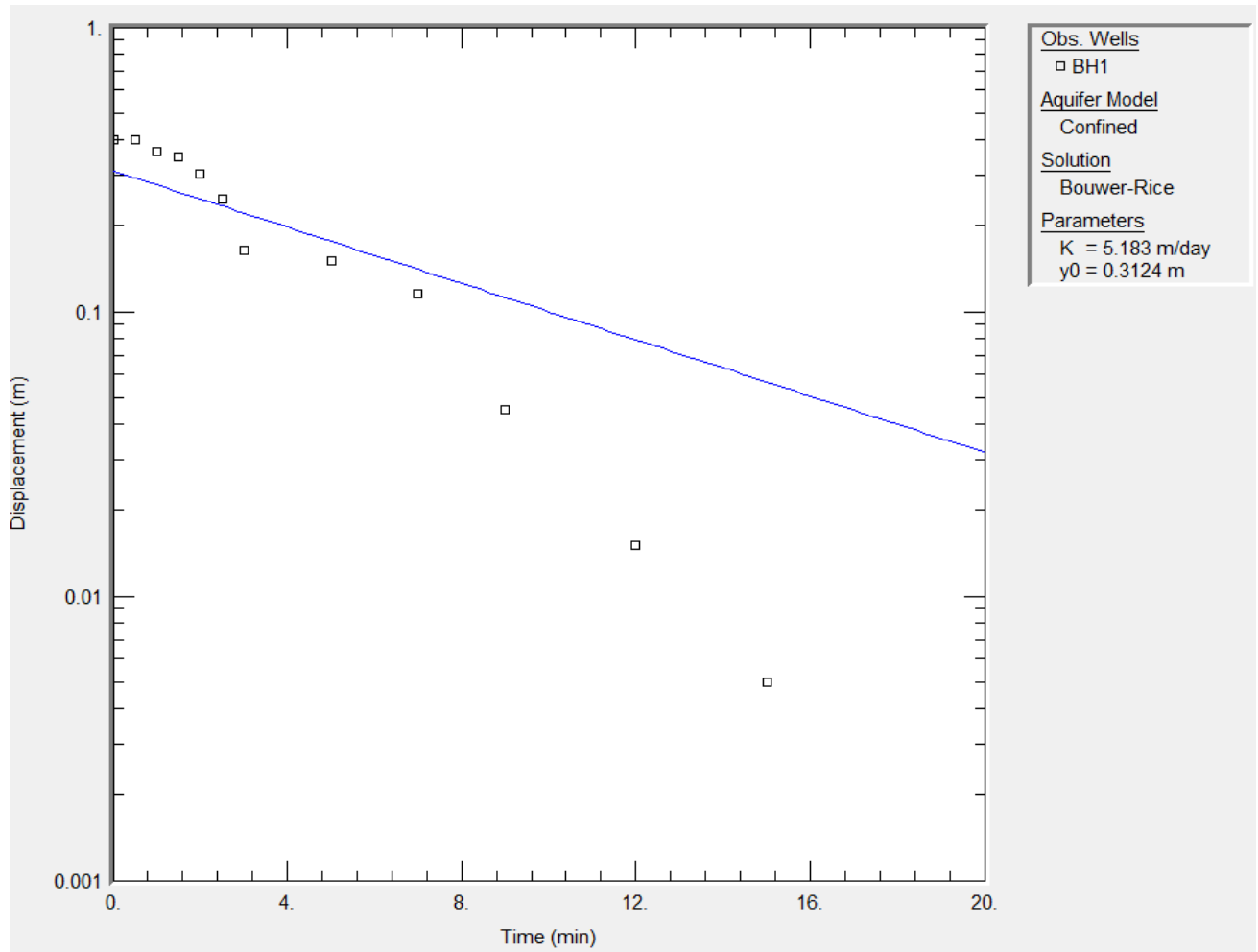
APPENDIX A: SLUG TEST DATA

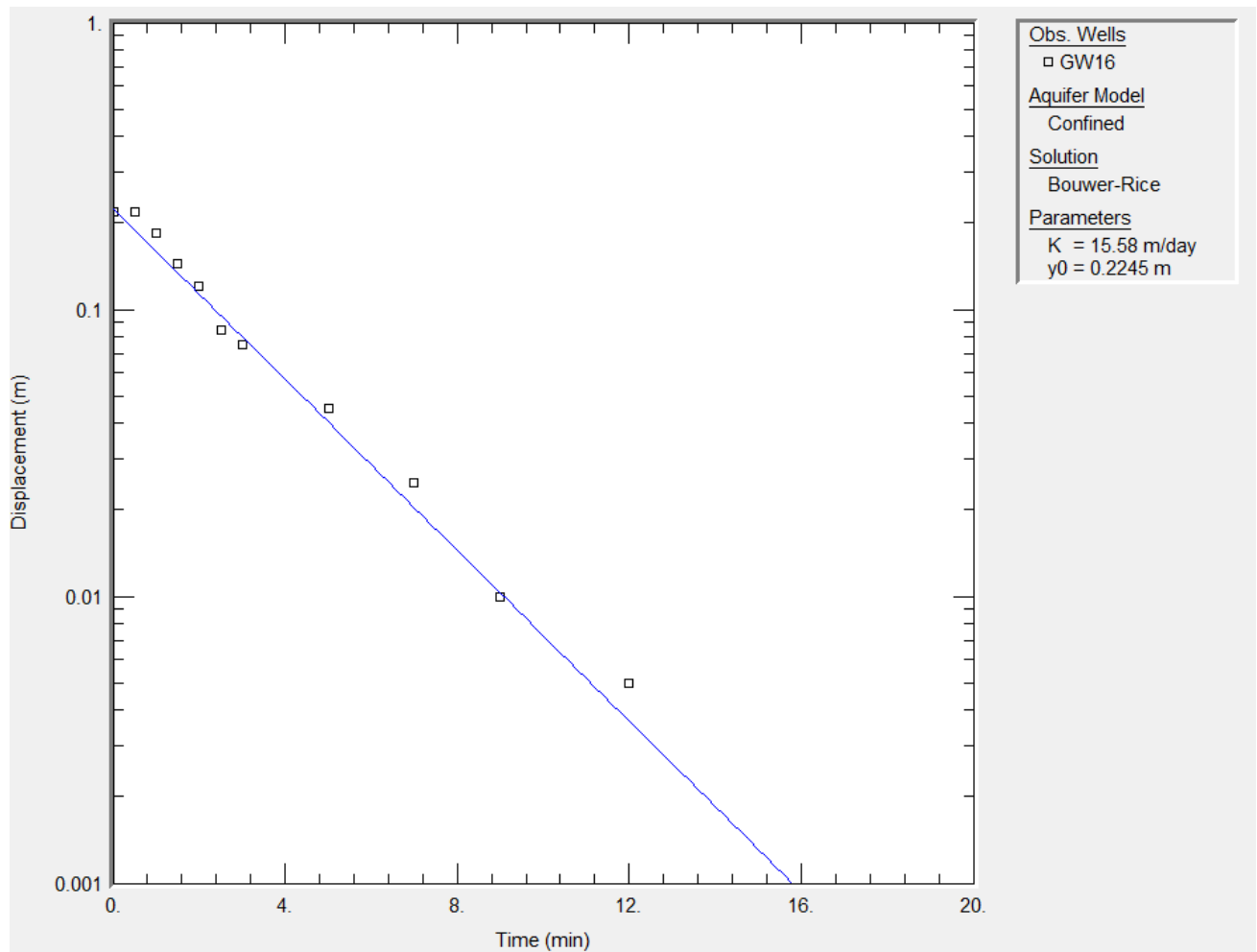












APPENDIX B: GEOPHYSICAL INVESTIGATION DATA

MAGNETIC INVESTIGATION METHODOLOGY

The geophysical system used in this investigation was a Geonics G5-proton precession magnetometer (Mag). The aim was to identify if there are dolerite intrusive rock or contact areas in the area, extrapolate the likely spatial spread of these structures, and site future monitoring boreholes.

The presence of magnetic minerals in rocks causes deviations in the earth's magnetic field. The proton precision magnetometer measures the remnant magnetic field strength of these rocks. The instrument measures the magnetic field strength in Nano Tesla (nT). Rock associated with magmatic intrusions, such as dolerite sills and dykes, have more magnetic minerals than the surrounding sedimentary rocks or metamorphic rocks. The zone between the intruding rocks is known as the baked zone (a zone that is weathered and cracked due to intruding magmatic rock heat and pressure) and is known to be associated with preferential flow paths of groundwater. It is these structures that are primarily targeted in Karoo aquifer systems for groundwater development and as potential pollution transmitters/boundaries. Hence, the purpose of the survey was to identify structures that may/may not promote groundwater flow.

ELECTRICAL RESISTIVITY TOMOGRAPHY METHODOLOGY

The geoelectrical technique known as Electrical Resistivity Tomography (ERT) which uses a series of electrodes along a straight line attached to a multi-core cable was employed during this assessment. During the ERT survey, a DC or slowly varying AC is artificially injected into the Earth through a series of grounded current electrodes, and the resulting potential measurements are made at several grounded potential electrode pairs. This information (injected current and the measured potential) is then used to identify apparent subsurface resistivities. The distances between the electrodes (two out current electrodes and two inner potential electrodes) are varied based on various four-electrode array configurations e.g., Wenner, Schlumberger, Dipole-Dipole, etc. The concept is illustrated in Figure A

These array configurations can all be used to characterize subsurface material properties associated with groundwater mobilization. However, the standard Wenner (Wenner α) and the hybrid Wenner-Schlumberger arrays are the most popular arrays and can be used interchangeably depending on the geological conditions (as per the geological description) and other related technical conditions (as per the site conditions).

Wenner-Schlumberger array has a slightly better horizontal coverage compared to the Wenner array; however, its signal strength is lower in areas where electrode grounding is partial and electromagnetic background noise is imminent; therefore, it is usually deployed in suitable areas where electrode grounding is substantial and electromagnetic background noise is reduced. Due to a small geometric factor, a high signal-to-noise ratio, and a smaller first fitting variance, Wenner leads to a strong signal and less noisy data even in areas with electromagnetic background noise.

In the Wenner array, the vertical resolution of the subsurface resistivities is achieved by increasing the common distance between the electrodes while maintaining the location of the centre point of the array. The horizontal resolution is achieved by moving the electrodes laterally across the surface while maintaining a constant electrode separation. The ultimate result is a 2D collection of the raw resistivity measurements at different depths along a given survey traverse. The inversion of this 2D survey data results in a resistivity model which is then interpreted in terms of the subsurface properties associated with possible exploitable aquifer conditions (e.g., dykes, saturated zone, dykes, weathered zones, etc) along the surveyed line.

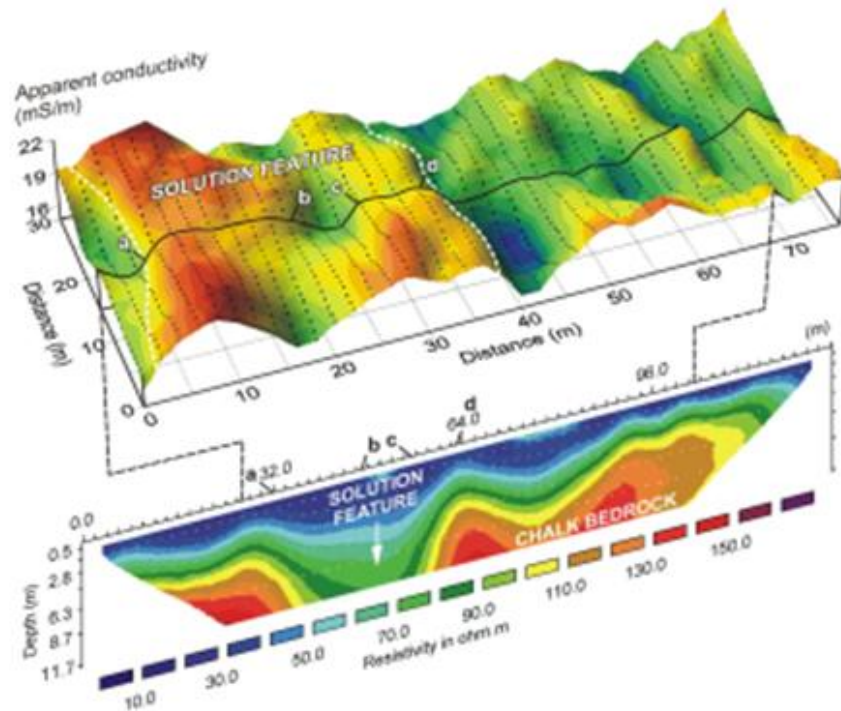


Figure A: ERT concept

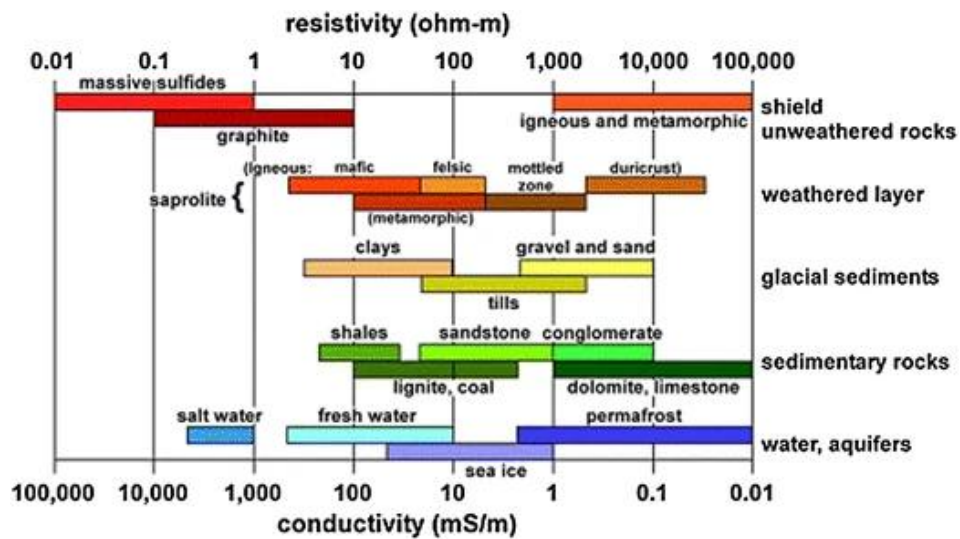


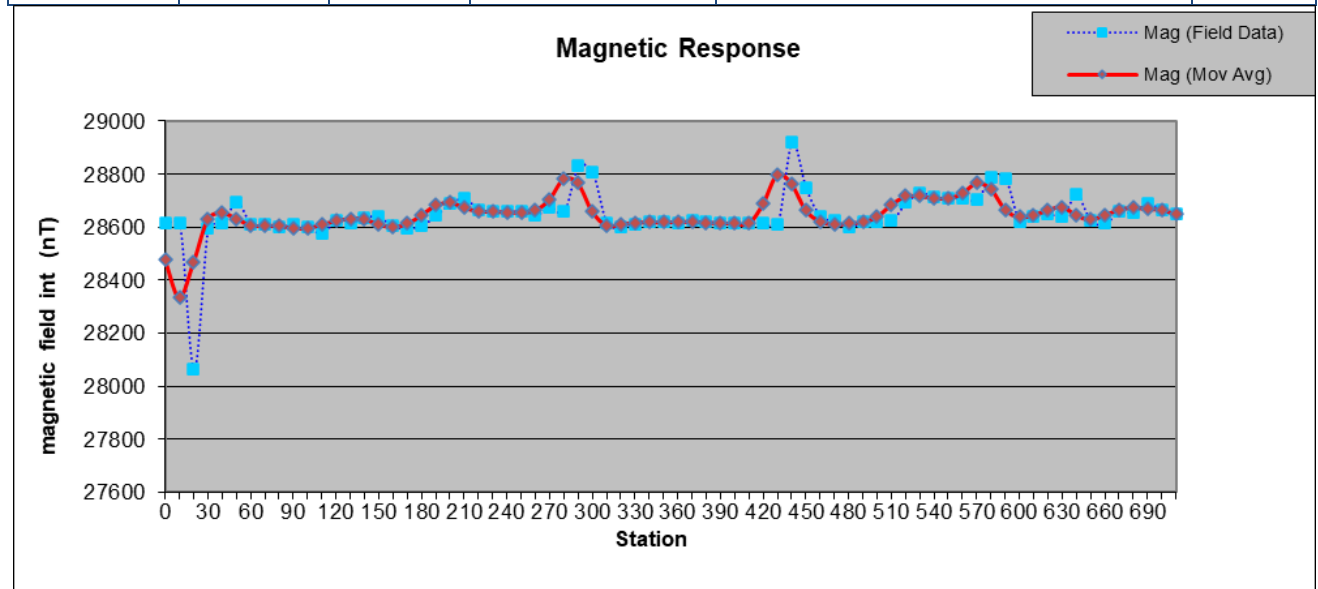
Figure B: Typical ranges of electrical resistivity of earth materials (Palacky, 1988)

MAG LINE 1

Project:	Ballengeich WULA	Traverse Number:	T1
Project Number:	EWS24-12	Traverse Direction:	South-east - Northwest
Survey Area:	Ballengeich	Station Spacing:	10 meters
Date of Survey:	01 February 2025	Operator:	Siphe

Station	Station Coordinates		Mag		Comments
Station	Latitude (y)	Longitude (x)	Mag	Mag (Mov Average)	
0	-27.8850	29.9750	28613.9	28476.325	
10	-27.8851	29.9751	28614.3	28334.55	
20	-27.8851	29.9751	28062.8	28468.25	
30	-27.8852	29.9752	28598.3	28630.375	
40	-27.8852	29.9752	28613.6	28654.575	
50	-27.8853	29.9753	28696	28633	
60	-27.8853	29.9754	28612.7	28608.325	
70	-27.8854	29.9754	28610.6	28605.275	
80	-27.8855	29.9755	28599.4	28605.775	
90	-27.8855	29.9755	28611.7	28597.3	
100	-27.8856	29.9756	28600.3	28595.275	
110	-27.8857	29.9756	28576.9	28611.575	
120	-27.8857	29.9757	28627	28623.9	
130	-27.8858	29.9758	28615.4	28632.8	
140	-27.8859	29.9758	28637.8	28630.45	
150	-27.8860	29.9759	28640.2	28611.025	
160	-27.8860	29.9759	28603.6	28600.675	
170	-27.8861	29.9760	28596.7	28613.4	
180	-27.8862	29.9760	28605.7	28646.025	
190	-27.8862	29.9761	28645.5	28682.825	
200	-27.8863	29.9761	28687.4	28693.6	
210	-27.8864	29.9762	28711	28674.7	
220	-27.8865	29.9763	28665	28660.475	
230	-27.8865	29.9763	28657.8	28660.2	
240	-27.8866	29.9763	28661.3	28656.775	
250	-27.8867	29.9764	28660.4	28656.575	
260	-27.8868	29.9764	28645	28663.8	
270	-27.8868	29.9764	28675.9	28706.025	
280	-27.8868	29.9764	28658.4	28782.525	
290	-27.8869	29.9765	28831.4	28765.975	
300	-27.8870	29.9765	28808.9	28659.975	
310	-27.8871	29.9765	28614.7	28606.975	
320	-27.8871	29.9766	28601.6	28610.65	
330	-27.8872	29.9766	28610	28618.25	
340	-27.8873	29.9766	28621	28619.125	
350	-27.8874	29.9766	28621	28618.325	
360	-27.8875	29.9767	28613.5	28621.7	
370	-27.8876	29.9767	28625.3	28622	
380	-27.8876	29.9767	28622.7	28617.925	
390	-27.8877	29.9768	28617.3	28615.25	
400	-27.8878	29.9768	28614.4	28614.825	
410	-27.88787	29.97684333	28614.9	28613.825	
420	-27.88796167	29.97686667	28615.1	28688.9	
430	-27.888035	29.97690167	28610.2	28799.2	
440	-27.88811667	29.97694	28920.1	28763.75	
450	-27.88821167	29.976965	28746.4	28664	
460	-27.88824667	29.97701833	28642.1	28623	
470	-27.888335	29.97701667	28625.4	28610.925	
480	-27.88842167	29.97702667	28599.1	28614.45	
490	-27.88850833	29.97706833	28620.1	28620.125	
500	-27.888595	29.97709833	28618.5	28639.45	
510	-27.888595	29.97709833	28623.4	28684.65	

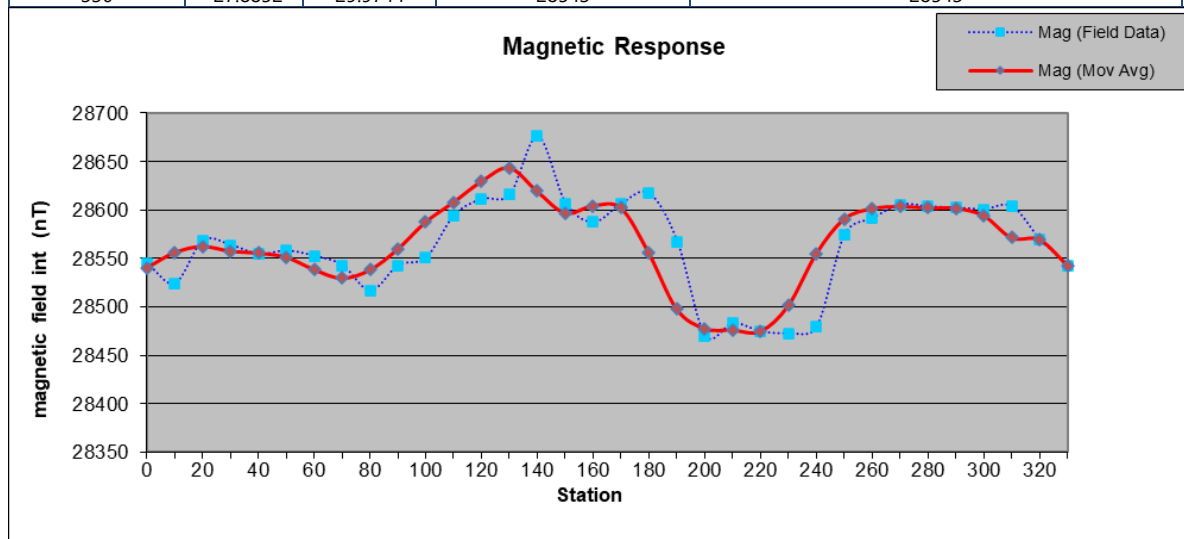
520	-27.88866833	29.97715167	28692.5	28716.825	
530	-27.88875	29.97715	28730.2	28717.25	
540	-27.88882667	29.97718833	28714.4	28711.375	
550	-27.88890167	29.97722667	28710	28709.4	
560	-27.88897167	29.97725667	28711.1	28728.1	
570	-27.88905667	29.97730333	28705.4	28767.5	
580	-27.889125	29.977345	28790.5	28745	
590	-27.88920167	29.97738667	28783.6	28667.175	
600	-27.88928167	29.97742	28622.3	28638.9	
610	-27.88935333	29.97745667	28640.5	28646.7	
620	-27.88942833	29.977475	28652.3	28664.45	
630	-27.88952	29.97750833	28641.7	28677.275	
640	-27.88961333	29.97756333	28722.1	28645.8	
650	-27.88969	29.97759833	28623.2	28628.2	
660	-27.88975333	29.97763833	28614.7	28647.375	
670	-27.88982167	29.97767667	28660.2	28665.225	
680	-27.8899	29.97773667	28654.4	28676.075	
690	-27.88996833	29.97777	28691.9	28668.125	
700	-27.89003	29.97782	28666.1	28666.1	
710	-27.89010167	29.97785	28648.4	28648.4	



MAG LINE 2

Project:	Ballengeich WULA	Traverse Number:	T1
Project Number:	EWS24-12	Traverse Direction:	South-east - Northwest
Survey Area:	Ballengeich	Station Spacing:	10 meters
Date of Survey:	01 February 2025	Operator:	Siphe

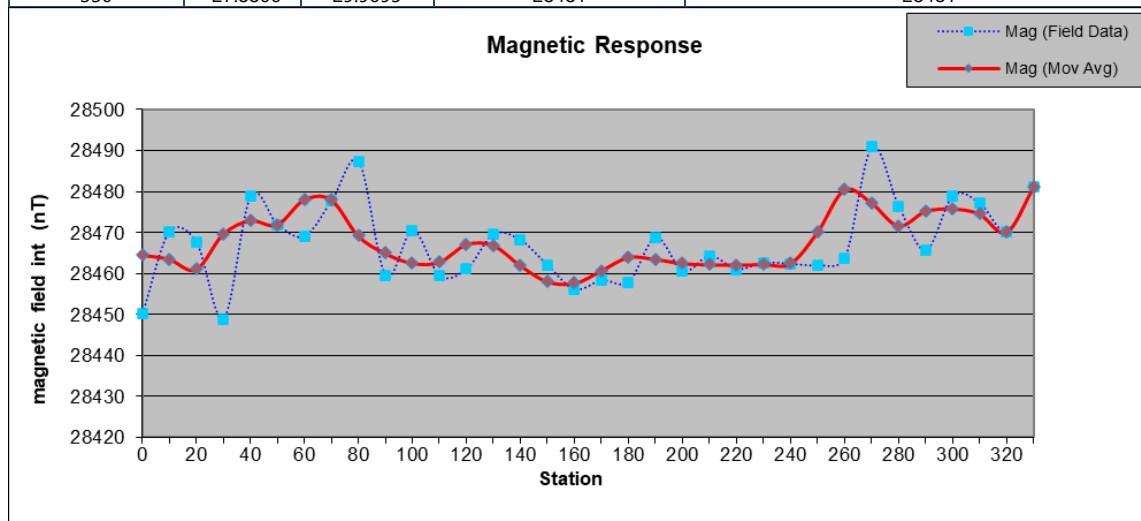
Station	Station Coordinates		Mag		Comments
Station	Latitude (y)	Longitude (x)	Mag	Mag (Mov Average)	
0	-27.8880	29.9741	28544.7	28540.3	
10	-27.8879	29.9742	28524.1	28556.1	
20	-27.8878	29.9742	28568.3	28562.525	
30	-27.8877	29.9742	28563.7	28557.6	
40	-27.8876	29.9742	28554.4	28555.65	
50	-27.8875	29.9742	28557.9	28551.4	
60	-27.8875	29.9742	28552.4	28538.675	
70	-27.8874	29.9743	28542.9	28529.675	
80	-27.8873	29.9743	28516.5	28538.2	
90	-27.8872	29.9743	28542.8	28559.65	
100	-27.8871	29.9743	28550.7	28587.7	
110	-27.8871	29.9743	28594.4	28608.2	
120	-27.8870	29.9743	28611.3	28629.75	
130	-27.8869	29.9744	28615.8	28643.75	
140	-27.8868	29.9744	28676.1	28619.375	
150	-27.8867	29.9744	28607	28597.15	
160	-27.8866	29.9744	28587.4	28604.55	
170	-27.8866	29.9744	28606.8	28602.175	
180	-27.8865	29.9744	28617.2	28555.55	
190	-27.8864	29.9744	28567.5	28497.625	
200	-27.8863	29.9744	28470	28477.575	
210	-27.8862	29.9744	28483	28476.05	
220	-27.8861	29.9745	28474.3	28474.675	
230	-27.8860	29.9745	28472.6	28501.475	
240	-27.8860	29.9745	28479.2	28555.1	
250	-27.8859	29.9745	28574.9	28590.825	
260	-27.8858	29.9745	28591.4	28601.55	
270	-27.8857	29.9745	28605.6	28603.8	
280	-27.8856	29.9745	28603.6	28602.275	
290	-27.8855	29.9745	28602.4	28601.875	
300	-27.8855	29.9745	28600.7	28594.4	
310	-27.8854	29.9745	28603.7	28571.425	
320	-27.8853	29.9744	28569.5	28569.5	
330	-27.8852	29.9744	28543	28543	



MAG LINE 3

Project:	Ballengeich WULA	Traverse Number:	T3
Project Number:	EWS24-12	Traverse Direction:	South-east - Northwest
Survey Area:	Ballengeich	Station Spacing:	10 meters
Date of Survey:	01 February 2025	Operator:	Siphe

Station	Station Coordinates		Mag		Comments
Station	Latitude (y)	Longitude (x)	Mag	Mag (Mov Average)	
0	-27.8881	29.9669	28450.2	28464.575	
10	-27.8880	29.9669	28470.3	28463.55	
20	-27.8880	29.9670	28467.5	28461.05	
30	-27.8879	29.9671	28448.9	28469.65	
40	-27.8879	29.9672	28478.9	28472.95	
50	-27.8878	29.9672	28471.9	28471.975	
60	-27.8878	29.9673	28469.1	28478.025	
70	-27.8877	29.9674	28477.8	28478.025	
80	-27.8877	29.9675	28487.4	28469.225	
90	-27.8876	29.9675	28459.5	28464.975	
100	-27.8876	29.9676	28470.5	28462.6	
110	-27.8876	29.9677	28459.4	28462.8	
120	-27.8875	29.9678	28461.1	28467.1	
130	-27.8874	29.9679	28469.6	28466.925	
140	-27.8874	29.9679	28468.1	28462	
150	-27.8874	29.9680	28461.9	28458.1	
160	-27.8873	29.9681	28456.1	28457.65	
170	-27.8873	29.9682	28458.3	28460.725	
180	-27.8872	29.9683	28457.9	28464	
190	-27.8872	29.9683	28468.8	28463.525	
200	-27.8871	29.9684	28460.5	28462.525	
210	-27.8871	29.9685	28464.3	28462.225	
220	-27.8871	29.9686	28461	28462.125	
230	-27.8870	29.9687	28462.6	28462.3	
240	-27.8870	29.9688	28462.3	28462.5	
250	-27.8869	29.9689	28462	28470.075	
260	-27.8869	29.9689	28463.7	28480.45	
270	-27.8868	29.9691	28490.9	28477.3	
280	-27.8868	29.9691	28476.3	28471.675	
290	-27.8867	29.9692	28465.7	28475.2	
300	-27.8867	29.9693	28479	28475.825	
310	-27.8866	29.9694	28477.1	28474.575	
320	-27.8866	29.9694	28470.1	28470.1	
330	-27.8866	29.9695	28481	28481	



APPENDIX C: LABORATORY CERTIFICATES



[001533/25], [2025/02/21]

Certificate of Analysis

Project details

Customer Details

Invoice Category	400.004
Customer reference:	BALLENGEICH - EWS24-12
Order number:	EWS24-12
Company name:	ELEMENTAL WATER SERVICES
Contact address:	460A THE WISHBONE NORTH, LYNNWOOD, GAUTENG, 0081
Contact person:	HENRI BOTHA
Additional customer information:	003212/25,003213/25,003214/25,003215/25,003216/25,003217/25,003208/25,003209/25,003210/25,003211/25 - CLIENT: Menco

Sampling Details

Sampled by:	CUSTOMER
Sampled date:	2025/01/28

Sample Details

Sample type(s):	GROUNDWATER SAMPLES, SURFACE WATER SAMPLES
Date received:	2025/01/31
Delivered by:	CUSTOMER - GILLITTS DEPOT
Temperature at sample receipt (°C):	22.6

Report Details

Testing commenced:	2025/01/31
Testing completed:	2025/02/20
Report date:	2025/02/21
Our reference:	001533/25

Talbot Laboratories (Pty) Ltd Reg: 2016/334237/07
P.O Box 22598 Pietermaritzburg 3203 South Africa
+27 (0) 33 346 1444 www.talbot.co.za

Page 1 of 5

Talbot Laboratories (Pty) Ltd

Analytical Results

Methods	Determinands	Units	003208/25	003209/25
			GW 1 28.01.2025	GW 6 28.01.2025
Chemical				
233	Dissolved Calcium	mg Ca/l	478	9.86
233	Dissolved Potassium	mg K/l	30	4.06
233	Dissolved Magnesium	mg Mg/l	416	9.26
233	Sodium	mg Na/l	915	14.9
94	Dissolved Aluminium	µg Al/l	27	10.0
94	Dissolved Iron	µg Fe/l	79140	103
94	Dissolved Manganese	µg Mn/l	4349	286
10G	Total Alkalinity	mg CaCO ₃ /l	57	15.5
Calc.	Bicarbonate Alkalinity	mg CaCO ₃ /l	57	15
16G	Chloride	mg Cl/l	146	<2.5
2B	Electrical Conductivity at 25°C	mS/m	672	39
18G	Fluoride	mg F/l	<0.06	<0.06
65Gc	Nitrate	mg N/l	<0.25	<0.25
1B	pH at 25°C	pH units	5.9	6.0
67G	Sulphate	mg SO ₄ /l	3640	91.6
41	Total Dissolved Solids at 180°C	mg/l	6780	196
Methods	Determinands	Units	003210/25	003211/25
			GW 12 28.01.2025	GW 16 28.01.2025
Chemical				
233	Dissolved Calcium	mg Ca/l	315	37
233	Dissolved Potassium	mg K/l	26	12.6
233	Dissolved Magnesium	mg Mg/l	177	94
233	Sodium	mg Na/l	234	306
94	Dissolved Aluminium	µg Al/l	6174	<10
94	Dissolved Iron	µg Fe/l	262354	21
94	Dissolved Manganese	µg Mn/l	32532	72
10G	Total Alkalinity	mg CaCO ₃ /l	pH <4.5, No Alkalinity detected	168
Calc.	Bicarbonate Alkalinity	mg CaCO ₃ /l	pH <4.5, No Alkalinity detected	168
16G	Chloride	mg Cl/l	6.12	18.3
2B	Electrical Conductivity at 25°C	mS/m	476	224
18G	Fluoride	mg F/l	<0.06	<0.06
65Gc	Nitrate	mg N/l	<0.25	0.58
1B	pH at 25°C	pH units	2.8	6.7
67G	Sulphate	mg SO ₄ /l	2984	910

Talbot Laboratories (Pty) Ltd

Reference: [001533/25]

Page 2 of 5

Talbot Laboratories (Pty) Ltd

Methods	Determinands	Units	003210/25	003211/25
			GW 12 28.01.2025	GW 16 28.01.2025
41	Total Dissolved Solids at 180°C	mg/t	4924	1614
Methods	Determinands	Units	003212/25	003213/25
			GBH 5 28.01.2025	SW 1 28.01.2025
Chemical				
233	Dissolved Calcium	mg Ca/t	22	10.0
233	Dissolved Potassium	mg K/t	2.66	2.73
233	Dissolved Magnesium	mg Mg/t	16.1	5.55
233	Sodium	mg Na/t	8.73	7.57
94	Dissolved Aluminium	µg Al/t	10.8	127
94	Dissolved Iron	µg Fe/t	13.0	313
94	Dissolved Manganese	µg Mn/t	13.6	<10
10G	Total Alkalinity	mg CaCO ₃ /t	104	38
Calc.	Bicarbonate Alkalinity	mg CaCO ₃ /t	104	NR
16G	Chloride	mg Cl/t	<2.5	3.33
2B	Electrical Conductivity at 25°C	mS/m	30	14
18G	Fluoride	mg F/t	0.10	0.06
65Gc	Nitrate	mg N/t	<0.25	<0.25
4	Turbidity	NTU	NR	42
1B	pH at 25°C	pH units	6.9	7.3
67G	Sulphate	mg SO ₄ /t	25.6	22.7
5	Suspended Solids at 105°C	mg/t	NR	18
41	Total Dissolved Solids at 180°C	mg/t	208	110
Methods	Determinands	Units	003214/25	003215/25
			SW 2 28.01.2025	SW 3 28.01.2025
Chemical				
233	Dissolved Calcium	mg Ca/t	12.6	11.3
233	Dissolved Potassium	mg K/t	2.81	2.37
233	Dissolved Magnesium	mg Mg/t	8.42	6.89
233	Sodium	mg Na/t	9.96	9.26
94	Dissolved Aluminium	µg Al/t	112	50
94	Dissolved Iron	µg Fe/t	466	133
94	Dissolved Manganese	µg Mn/t	<10	<10
10G	Total Alkalinity	mg CaCO ₃ /t	34	36
16G	Chloride	mg Cl/t	4.09	4.12
2B	Electrical Conductivity at 25°C	mS/m	19	16
18G	Fluoride	mg F/t	0.09	0.08
65Gc	Nitrate	mg N/t	<0.25	<0.25
4	Turbidity	NTU	55	35

Talbot Laboratories (Pty) Ltd

Reference: [001533/25]

Page 3 of 5

Talbot Laboratories (Pty) Ltd

Methods	Determinands	Units	003214/25	003215/25
			SW 2 28.01.2025	SW 3 28.01.2025
1B	pH at 25°C	pH units	7.0	7.0
67G	Sulphate	mg SO ₄ /l	42.0	32.0
5	Suspended Solids at 105°C	mg/l	37	34
41	Total Dissolved Solids at 180°C	mg/l	147	113
Methods	Determinands	Units	003216/25	003217/25
			SW 4 28.01.2025	SW 5 28.01.2025
Chemical				
233	Dissolved Calcium	mg Ca/l	21	16.9
233	Dissolved Potassium	mg K/l	3.58	3.52
233	Dissolved Magnesium	mg Mg/l	10.8	8.99
233	Sodium	mg Na/l	42	44
94	Dissolved Aluminium	µg Al/l	18.0	72
94	Dissolved Iron	µg Fe/l	20	52
94	Dissolved Manganese	µg Mn/l	<10	<10
10G	Total Alkalinity	mg CaCO ₃ /l	52	47
16G	Chloride	mg Cl/l	11.8	12.0
2B	Electrical Conductivity at 25°C	mS/m	39	38
18G	Fluoride	mg F/l	0.13	0.11
65Gc	Nitrate	mg N/l	<0.25	<0.25
4	Turbidity	NTU	216	123
1B	pH at 25°C	pH units	7.2	7.2
67G	Sulphate	mg SO ₄ /l	88.6	85.5
5	Suspended Solids at 105°C	mg/l	172	96
41	Total Dissolved Solids at 180°C	mg/l	288	298

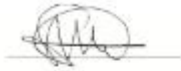
Refer to the "Notes" section at the end of this report for further explanations.

Specific Observations

None

Quality Assurance

Technical signatories



Inorganic Chemistry: Siphiso Mgabhi

Notes to this report

Limitations

This report shall not be reproduced except in full without prior written approval of the laboratory. Results in this report relate only to the samples as taken, and the condition received by the laboratory. Any opinions and interpretations expressed herein are outside the scope of SANAS accreditation. The decision rule applicable to this laboratory is available on request. Sample preparation may require filtration, dilution, digestion or similar. Final results are reported accordingly. Where the laboratory has undertaken the sampling, the location of sampling and sampling plan are available on request. Talbot is guided by the National Standards SANS 5667-1:2008 Part 1 Guidance on the Design of Sampling Programmes and Sampling Techniques and SANS 5667-3:2008 Part 3 Guidance on the Preservation and Handling of Water Samples.

Customers to contact Talbot Laboratories for further information.

Uncertainty of measurement

Talbot Laboratories' Uncertainty of Measurement (UoM) values are:

- Identified for relevant tests.
- Calculated as a percentage of the respective results.
- Applicable to total, dissolved and acid soluble metals for ICP element analyses.
- Available upon request.

Analysis explanatory notes

Tests may be marked as follows:

^	Tests conducted at our Pretoria satellite laboratory (1 Sydney Brenner St, Lynwood, Pretoria, 0087).
*	Tests not included in our Schedule of Accreditation and therefore that are not SANAS accredited.
#	Tests that have been sub-contracted to a peer laboratory.
NR	Not required -shown, for example, where the schedule of analysis varied between samples.
σ	ISO 9001 Certified testing.
α	Testing has deviated from Method.

*****End of Report*****

APPENDIX D: NUMERICAL GROUNDWATER FLOW AND TRANSPORT MODEL CONFIDENCE

In the development of the numerical model, a detailed data review was conducted. Data confidence and data availability dictate model confidence. A summary of the required data versus the data available is outlined below; 3: indicates sufficient data availability, 2: indicates moderate availability, and 1: indicates limited or no availability.

As indicated in the table below, critical data required for the development of a medium-high confidence model is available. Based on the model, key data gaps will be identified. These data gaps will be required to be filled before updating the model and producing a higher confidence model suitable for defensible predictive modelling.

Data types	Confidence
Spatial and temporal distribution of groundwater head observations are required to adequately define groundwater behaviour, especially in areas of greatest interest and where outcomes are to be reported.	3
Spatial distribution of bore logs and associated stratigraphic interpretations clearly define aquifer geometry.	2
Reliable metered groundwater extraction and injection data is available.	1
Rainfall and evaporation data is available.	3
Aquifer-testing data to define key parameters.	2
Streamflow and stage measurements are available with reliable base flow estimates at a number of points.	1
Reliable land-use and soil mapping data available.	2
Good quality and adequate spatial coverage of digital elevation model to define ground surface elevation.	3
Geometry of the existing opencast workings.	3
Geometry and temporal plan of future mine workings.	2
Geometry of existing mine residue disposal/storage areas	2
Transport model calibration points and confidence of constant sampling data	2
Aquifer dewatering rates / verified estimates	1
Model Data Confidence Rating	Class 2

Class 1: Low Confidence Model	Score < 16 (40%)
Class 2: Intermediate Confidence Model	Score 16 - 31 (41-80%)
Class 3: High Confidence Model	Score > 31 (80 - 100%)

APPENDIX E: DISCLAIMER

The opinions expressed in this Report have been based on site /project information supplied to Elemental Water Services Proprietary Limited (EWS) and are based on public domain data and data supplied to EWS by the client. EWS has acted and undertaken this assessment objectively and independently.

EWS has exercised all due care in reviewing the supplied information. Whilst EWS has compared key supplied data with expected values, the accuracy of the results and conclusions are entirely reliant on the accuracy and completeness of the supplied data. EWS does not accept responsibility for any errors or omissions in the supplied information and does not accept any consequential liability arising from commercial decisions or actions resulting from them.

Opinions presented in this Report apply to the site conditions and features as they existed at the time of EWS investigations, as well as those reasonably foreseeable. These opinions do not necessarily apply to conditions and features that may arise after the date of this Report, about which EWS had no prior knowledge nor had the opportunity to evaluate.

APPENDIX F: CV OF SPECIALIST



Hendrik Botha Principal Hydrogeologist & Director



CORE SKILLS

- ✦ Project management
- ✦ Analytical and numerical groundwater modelling
- ✦ Geochemical assessments and geochemical modelling
- ✦ Hydrogeology and soil pollution assessments
- ✦ Hydrology, floodline modelling, yield modelling, storm water management
- ✦ Groundwater vulnerability, impact, and risk assessments
- ✦ Technical report writing
- ✦ GIS and mapping

DETAILS

Qualifications

- ✦ BSc Chemistry and Geology (Environmental Sciences) (2012)
- ✦ BSc Hons Hydrology (Environmental Sciences) (2013)
- ✦ MSc Geohydrology and Hydrology (Environmental Sciences) (2014-2016)

Membership

- ✦ Groundwater Division of GSSA
- ✦ Groundwater Association of KwaZulu Natal Member
- ✦ International Mine Water Association (IMWA)

Languages

- ✦ Afrikaans – Speak, read, write.
- ✦ English – Speak, read, write.

Projects undertaken in

- ✦ South Africa
- ✦ Nigeria
- ✦ Namibia
- ✦ Liberia
- ✦ Malawi
- ✦ Botswana

PROFILE

Hendrik (Henri) Botha is a Principal Hydrogeologist. He holds an MSc in Environmental Science in Geohydrology & Geochemistry and a BSc Hons. Degree in Hydrology. He is registered as a SACNASP Professional Natural Scientist in the Earth Science Field. Groundwater, geochemistry and surface hydrology, as well as knowledge of water chemistry together with GIS and analytical and numerical modelling skills, are some of his sought-after expertise. General and applied logical knowledge are his key elements in problem-solving.

Professional Affiliations:

SACNASP Professional Natural Scientist (400139/17)

Areas of Expertise:

- ✦ Project Management of water and environmental projects for mining, industrial and agriculture sectors.
- ✦ Integrated Water Investigations
- ✦ Waste Classification and Impact Assessments
- ✦ Aquifer vulnerability assessments
- ✦ Geochemical sampling, data interpretation and modelling
- ✦ Groundwater impact and risk assessments
- ✦ Numerical and Conceptual Visual Modelling (Visual Modflow, ModflowFLEX, Voxler, RockWorks, Surfer and Excel)
- ✦ Hydrogeology (Hydrological Soil Types) & Soils Assessments
- ✦ Floodline Modelling (HEC-RAS)
- ✦ Conceptual Stormwater Management Assessments and EPA SWMM modelling
- ✦ Surface Water Yield Assessments
- ✦ Water and Salt Balance

