

HYDROLOGY 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	Hydrology 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_SW	
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 hydrology 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 hydrology assessment was compiled to evaluate the existing and predicted future hydrological environments and surface water risks 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 study found that 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.

Five (5) hydrological response units (HRU) describe the drainage of the Project Site, specifically the drainage associated with the Horn and Ingagane Rivers.

Flood analysis was undertaken for the Horn and Ingagane rivers (refer to Section 5):

- ✚ The major rivers are prone to flooding due to the flatter topography. Drainage lines associated with valleys are less susceptible to cause flood inundation, and limited flooding is predicted and generally associated with the valleys. The entire Ballengeich operations are situated in the 1–100-year flood line and a GN704 exception in terms of the National Water Act (NWA) of 1998 (Act No. 36 of 1998).

A water and coupled salt balance was developed for the mine (refer to Section 6):

- ✚ The water balance was developed by calculating the volumes of water that flow in and out of each component at the Ballengeich Mine. A simulation of water movement within the mine was carried out. The water balances indicate 333 994 m³/yr of water into/onto the mine.
- ✚ An average of 1 22 859 kg/year 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. It was estimated that the semi-passive treatment system needs to remove about 515 440 kg/year to achieve the WQO <500 mg/l SO₄ for discharge into the Horn River. The reduced impact on the watercourse is estimated to be 41% if the semi-passive treatment system is implemented.

EC and pH stream profiles were completed on the Horn and Ingagane Rivers (refer to Section 4.4). 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. Surface water can be classified as water influenced by active ion exchange.

A hydrological risk assessment is available in Section 7, where site-specific and regional cumulative impacts have been assessed. The hydrological risks associated with the construction phase of the proposed Project range from moderate to high and reduced to low after mitigation is considered. The operational phase risks are marginal, and the proposed semi-passive treatment system aims to improve the environmental status of the Horn and Ingagane Rivers.

A moderate to low probability of erosion of the banks of the rivers/streams associated with the project area is anticipated. The 1:100-year flood line should be considered an avoidance area (buffer area). Proper flooding protocols and erosion prevention measures should be implemented.

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 D.
(b) Declaration that the specialist is independent in a form as may be specialities by the competent authority	Appendix D.
(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 9.
(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 6 & 9.
(k) Mitigation measures for inclusion in the EMPr	Section 9.2.
(l) Conditions for inclusion in the environmental authorisation	Refer to Section 9.
(m) Monitoring requirements for inclusion in the EMPr or environmental authorisation	Refer to Section 9.
(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 9.2
(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	5
CONTENTS PAGE	6
List of Figures	7
List of Tables	8
List of Appendices	9
DETAILS OF AUTHOR	10
CONFIDENTIALITY	10
COPYRIGHT OF ELEMENTAL WATER SERVICES Propriety Limited – ALL RIGHTS RESERVED	10
DECLARATION OF INDEPENDENCE	10
General List Of Acronyms	12
list of KEY Definitions	14
1 Introduction	15
1.1 Project Background	15
1.1.1 Treatment of Old UG Workings	16
1.1.2 Treatment of Effluent from West Decant Sump	16
1.1.3 Anoxic Limestone drain (ALD)	17
1.1.4 Successive Alkaline Producing System (SAPS)	19
1.1.5 Sedimentation/Oxidation Pond	19
1.1.6 Aerobic wetland	20
1.1.7 Predicted impact on water quality of the treatment system proposed	20
1.2 Objectives	23
1.3 Study relevance to the season in which it was undertaken	23
1.4 Scope of work	23
2 Methodology	24
2.1 Legal considerations	24
2.2 Hydrological overview	25
2.3 Water Users and Losses	25
2.3.1 Assessment of alien invasive plants	25
2.3.2 Ecological Water Reserve Determination	25
2.3.3 WARMS data analysis	25
2.4 Catchment description and delineation	26
2.5 Design rainfall and peak flows	26
2.6 Flood line modelling	27
2.7 Water and salt balance	27
2.8 Hydrological risk assessment	28
2.9 Surface water monitoring plan	30
3 Site overview and hydrology	32
3.1 Sub-catchments / hydrological response units	32
3.2 Local geology & soils	33
3.3 Hydrogeology and depth to groundwater	33
3.4 Climate	34
3.4.1 Temperature	34
3.4.2 Wind speed and direction	35
3.4.3 Rainfall and evaporation	36

3.4.4	Run-off	38
3.4.5	Climate change considerations	40
3.5	Wetland areas	42
3.6	Present ecological state (PES), ecological importance and sensitivity (EIS), Ecological Water Reserve (EWR) and recommended ecological category (REC)	44
3.7	Groundwater and surface water users in the project area	45
3.8	Overview of site hydrological cycle	45
4	Water quality	52
4.1	Groundwater levels	52
4.2	Groundwater water quality.....	53
4.3	Surface water quality	54
4.4	Stream EC and pH profiling	58
5	Flood hydrology assessment	62
5.1	Calculated flood peak flows	62
5.2	Post-development/farming peak flows.....	63
5.3	Flood line modelling	63
5.3.1	Software.....	63
5.3.2	Topography profile data	63
5.3.3	Manning's roughness coefficients.....	63
5.3.4	Inflow and boundary conditions.....	63
5.3.5	Hydraulic structures	63
5.3.6	Model conditions	63
5.4	Model results	64
5.5	Site-specific sensitivity & buffers (avoidance areas).....	64
5.6	Model assumptions	64
6	Water and salt balance.....	66
6.1	Model boundaries	66
6.2	Water and salt inflows and outflows	66
6.3	Water balance assumptions.....	68
6.4	Calibration.....	69
6.5	Process flow diagram	69
6.6	Water and salt balance results	71
7	Hydrological impact and risk assessment	76
7.1	Preparation phase	76
7.2	Operational Phase	77
7.3	Offsets and alternatives	78
7.4	Cumulative impacts and impacts on the hydrological cycle.....	78
8	Surface Water monitoring	81
9	Conclusions	81
9.1	Mitigation measures for inclusion in the EMPr	82
9.2	Identification of any areas that should be avoided.....	83
9.3	Reasoned opinion on whether EA/WULA should be considered	83
10	Bibliography	84

LIST OF FIGURES

Figure 1-1:	Passive treatment system proposed (Bhekhani Pty Ltd, 2023)	15
Figure 1-2:	Area with underground workings to receive full treatment train (Bhekhani Pty Ltd, 2023)	16
Figure 1-3:	West Decant Sump area to be treated with ALD and cut off Aerobic Wetland along Horn River boundary	17
Figure 1-4:	Typical section of Anoxic Limestone drainage system.....	18

Figure 1-5:	Site layout	22
Figure 2-1:	Monitoring Process	31
Figure 3-1:	Typical cross section of surface topography (30m DTM based)	32
Figure 3-2:	Average yearly temperatures (Meteoblue, 2025)	35
Figure 3-3:	Wind rose (Meteoblue, 2025)	35
Figure 3-4:	Average rainfall for Station 0370834W & WR2012 evaporation	37
Figure 3-5:	CHIRPS rainfall data for the site (2010 to 2024)	37
Figure 3-6:	CHIRPS daily data for the site (2010 to 2024)	38
Figure 3-7:	Simulated run-off distribution for V31G	39
Figure 3-8:	Simulated run-off distribution for V31F	39
Figure 3-9:	Simulated run-off distribution for V31K	40
Figure 3-10:	Yearly Temperature Change (Meteoblue, 2025)	41
Figure 3-11:	Yearly Precipitation Change (Meteoblue, 2025)	41
Figure 3-12:	Monthly Anomalies of Temperature and Precipitation (Meteoblue, 2025)	42
Figure 3-13:	Wetland areas identified by MENCO (2022)	43
Figure 3-14:	Groundwater baseflow concept	44
Figure 3-15:	Simplified overview of the hydrological cycle at the site (averages presented)	46
Figure 3-16:	Topography and drainage	47
Figure 3-17:	Land cover types (DFFE, 2024)	48
Figure 3-18:	Sub-catchments and slope rise %	49
Figure 3-19:	Regional surface geology	50
Figure 3-20:	WARMS users in the project area	51
Figure 4-1:	Ballengeich groundwater level graph	52
Figure 4-2:	Ballengeich groundwater pH graph	53
Figure 4-3:	Ballengeich groundwater sulphate graph	54
Figure 4-4:	Ballengeich surface water sulphate graph for the monthly monitoring points	55
Figure 4-5:	Ballengeich surface water pH graph for the quarterly monitoring points	57
Figure 4-6:	Ballengeich surface water sulphate graph for the quarterly monitoring points	57
Figure 4-7:	River profile upstream to downstream in the Horn River	58
Figure 4-8:	River profile upstream to downstream in the Ingagane Reiver, up to the confluence area downstream of the discard dump	59
Figure 4-9:	Groundwater and surface water monitoring network	60
Figure 4-10:	Stream profiles of the Ngagane and Horn Rivers	61
Figure 5-1:	Simulated 1-50 and 1-100-year flood areas	65
Figure 6-1:	Ballengeich PFD	70

LIST OF TABLES

Table 1-1:	Assimilated capacity for Ngagane River (MENCO, 2022)	21
Table 1-2:	Assimilated capacity for Horn River inclusive of decant (MENCO, 2022)	21
Table 2-1:	Summary of flood line peak flow methods (SANRAL, 2013)	27
Table 2-2:	Proposed Criteria and Rating Scales to be used in the Assessment of the Potential Impacts	29
Table 2-3:	Explanation of Assessment Criteria	30
Table 3-1:	Summary of HRU attributes	32
Table 3-2:	Summary of SCS soil type hydrological characteristics (Muthu, 2015)	33
Table 3-3:	Summary of MAP recorded at nearest rainfall stations	36
Table 3-4:	Summary of PES, EIS and EWR	44
Table 3-5:	Boreholes identified within a 5km radius of the site	45
Table 3-6:	Summary of WARMS users' allocations for the HRUs	45
Table 5-1:	Summary of design rainfall data used for peak flow estimates	62
Table 5-2:	Summary of design peak flows for the delineated sub-catchments (m ³ /s)	62
Table 6-1:	Water and salt inflows to process units at Ballengeich Mine	66

Table 6-2:	Water and salt outflows to process units at Ballengeich Mine.....	67
Table 6-3:	Water recharge characteristics for opencast mining	68
Table 6-4:	Estimated Sulphate Concentrations around the Ballengeich Mine	71
Table 6-5:	Average annual water balance	72
Table 6-6:	Average annual salt balance.....	74
Table 7-1:	Risk rating scale	76
Table 7-2:	Impacts during the preparation phase.....	79
Table 7-3:	Impacts during the closure operational & decommissioning phase	80

LIST OF APPENDICES

Appendix A: Peak Flow Calculations	86
HRU01	86
HRU02	89
HRU03	92
HRU04	95
HRU05	98
Appendix B: Laboratory Certificates	101
Appendix C: Disclaimer	106
Appendix D: CV of Specialist.....	107

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, 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.

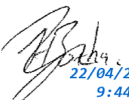
DECLARATION OF INDEPENDENCE

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.

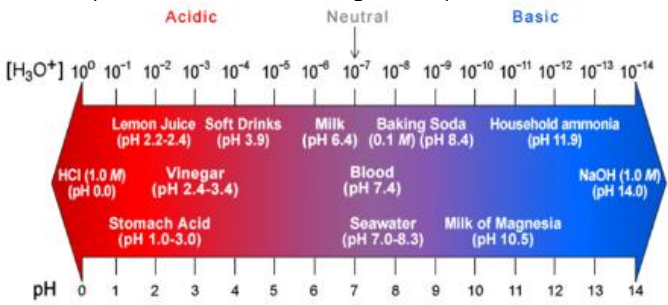


22/04/2025
9:44:26
Pr.Sci.Nat (400139/17)

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
Mm ³ /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 (Red): Lemon Juice (pH 2.2-2.4), Soft Drinks (pH 3.9), HCl (1.0 M) (pH 0.0), Vinegar (pH 2.4-3.4), Stomach Acid (pH 1.0-3.0). - Neutral (Blue): Milk (pH 6.4), Baking Soda (0.1 M) (pH 8.4), Blood (pH 7.4), Seawater (pH 7.0-8.3), Milk of Magnesia (pH 10.5). - Basic (Blue): 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 are expected to respond to weather and precipitation in a similar way.
PES	Ecological status is described in terms of Ecological Categories: A – near natural, B – largely natural, C – moderately modified, D – largely modified, E – seriously modified, and F - critically modified.
REC	a resource is a component of an ecosystem that maintains it, while the 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 hydrology 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.

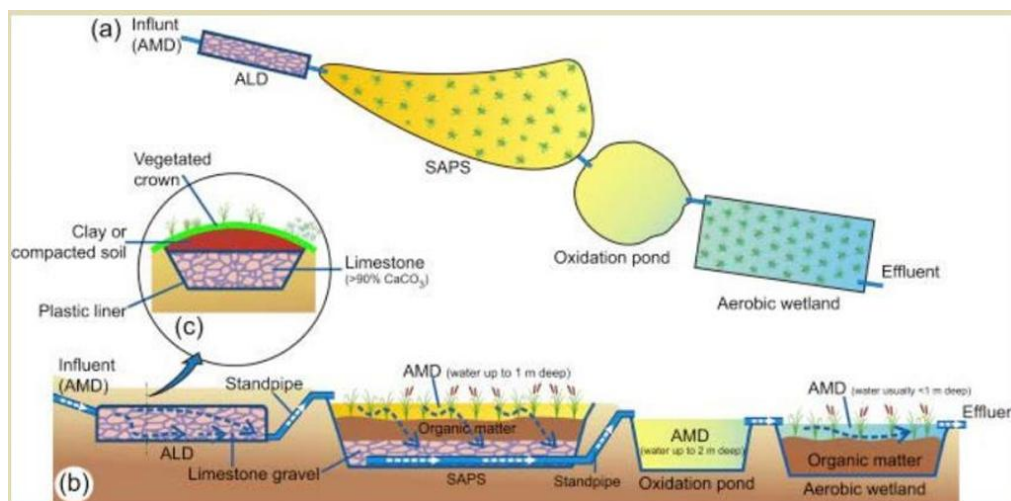


Figure 1-1: Passive treatment system proposed (Bhekhani Pty Ltd, 2023)

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.

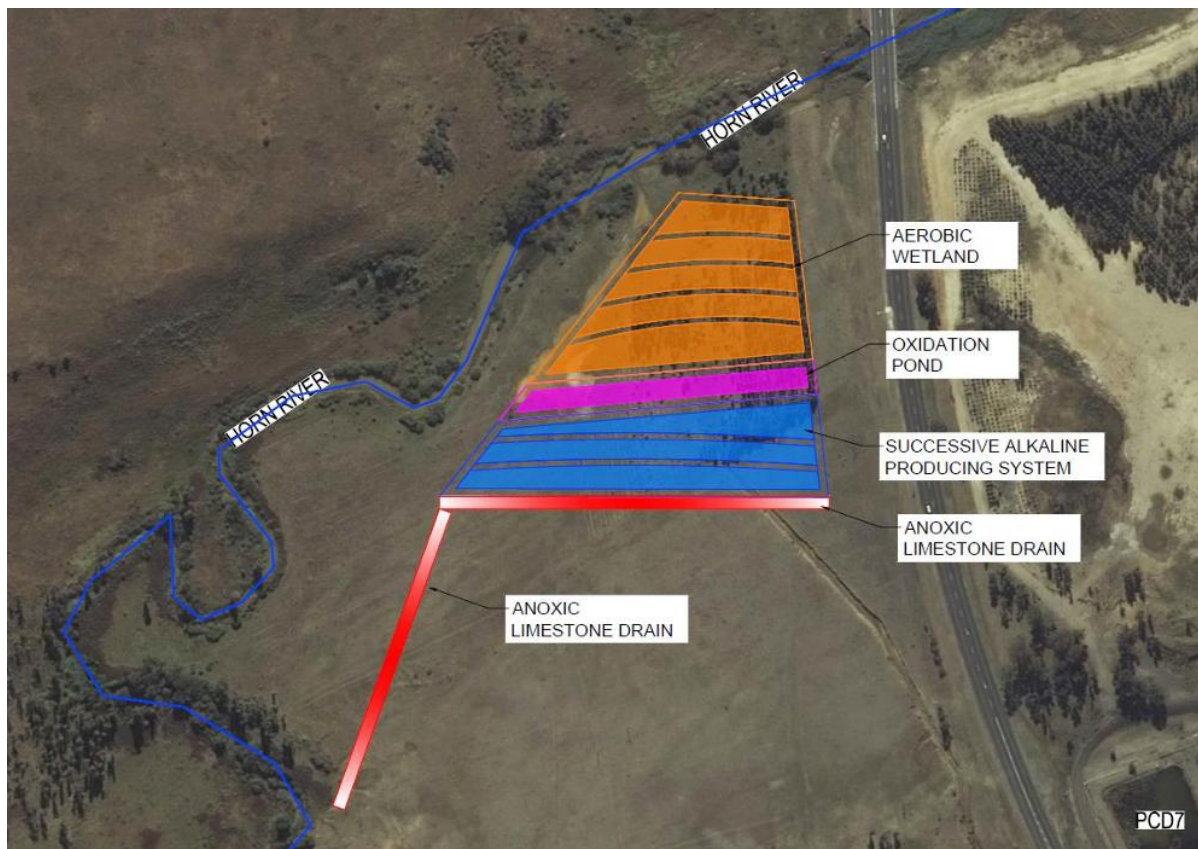


Figure 1-2: Area with underground workings to receive full treatment train (Bhekhani Pty Ltd, 2023)

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.

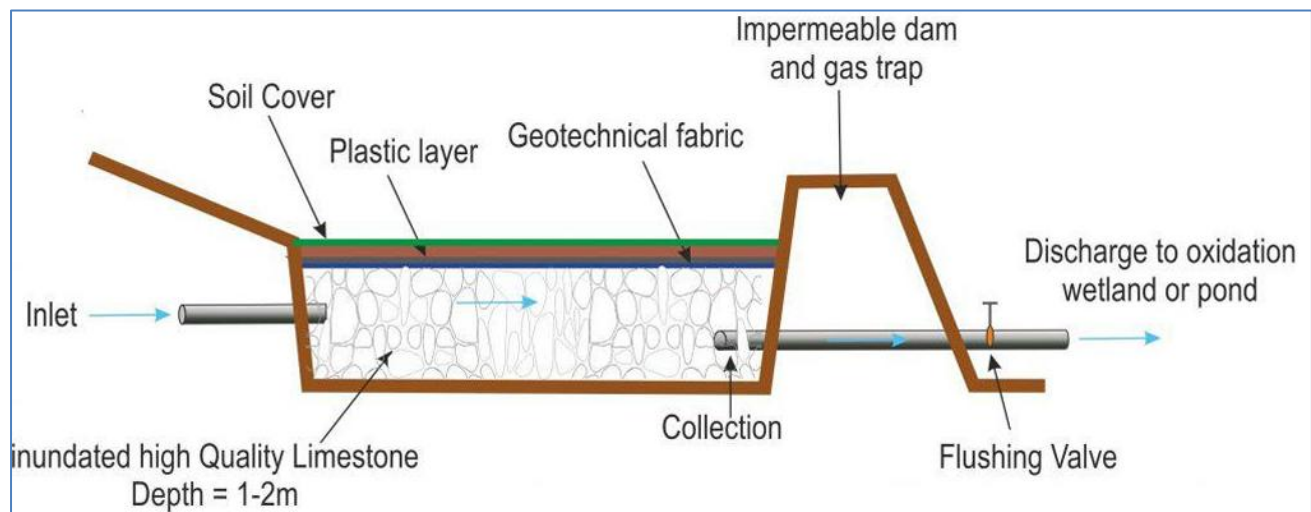


Figure 1-4: Typical section of Anoxic Limestone drainage system

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	

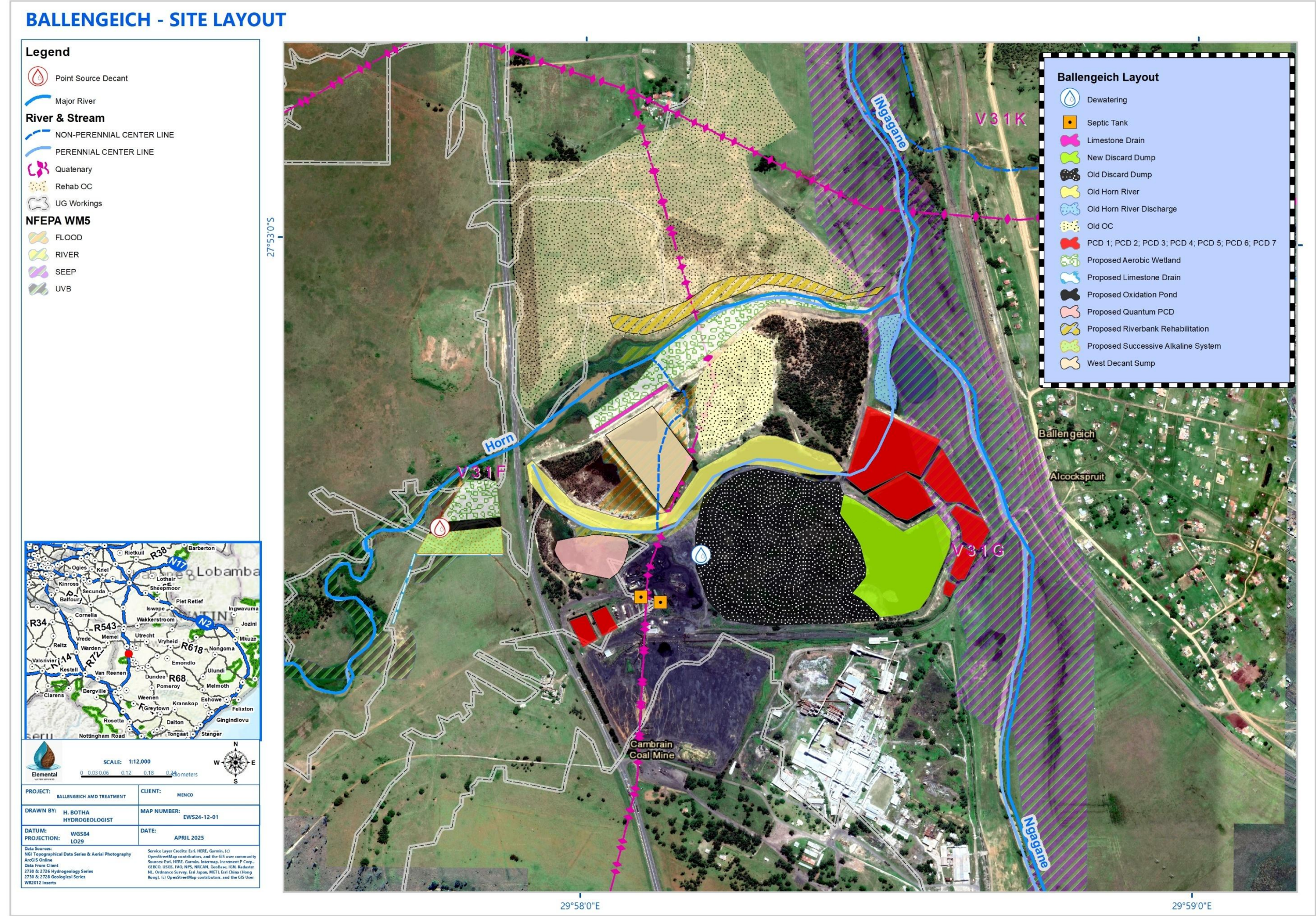


Figure 1-5: Site layout

1.2 Objectives

This hydrology assessment was compiled to evaluate the existing and predicted future hydrological environments and surface water risks 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:

- ✚ Identify natural and man-made drainage lines on a desktop level.
- ✚ Evaluate the site's hydrological setting (i.e., climate, rainfall, drainage, etc.).
- ✚ Determine the 1:10, 1:20, 1:50, and 1:100-year peak flows for the major rivers and drainage streams associated with the project area.
- ✚ Model the 1-50- and 1-100-year flood lines in HEC-RAS to illustrate flood inundation areas.
- ✚ Undertake a water balance assessment and coupled salt balance for the Ballengeich Mine.
- ✚ Undertake a hydrological risk assessment and compile mitigation measures.
- ✚ Compile a surface water monitoring plan to monitor the impact on the receiving environment.

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 hydrological data that was extracted from available monitoring reports.

1.4 Scope of work

The scope of work completed was as follows:

1. Baseline Hydrology Review:

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

2. Site walkover assessment:

- a. A site walkover assessment was completed, and a stream EC and pH profile was conducted on the Hron and Ingagane Rivers.

- b. The aim was to establish if there are any groundwater pollution plumes entering the rivers, as well as to determine the impact associated with the decant into the Horn River.

3. Peak flows & flood line modelling:

- a. Peak flood volume calculation for the 1:10, 1:20, 1:50, and 1:100-year recurring events.
- b. Flood line modelling using HEC-RAS hydraulic software – 1:50 and 1:100-year flood lines were presented, and
- c. Analysis of the modelling results.

4. Water and salt balance:

- a. A process flow diagram for the water distribution at the Ballengeich Mine was developed.
- b. A water balance and salt balance were developed based on available water reticulation and hydrochemistry data for the mine.
- c. The water and salt balance aligns with DWAF requirements for salt and water balances.

5. Risk assessment:

- a. A hydrological risk assessment was undertaken to contextualise the Project's potential surface water risk.

6. Surface Water Monitoring Plan:

- a. A surface water monitoring plan was developed.

7. Reporting.

2 METHODOLOGY

The methodological approach for the study is described in the sub-sections below.

2.1 Legal considerations

The National Water Act (Act 36 of 1998) (NWA) governs the use of water and protection of water resources in South Africa. The following legislation applies:

- 🚦 Government Notice No. 704, 4 June 1999, National Water Act, 1998 (No. 36 of 1998): Regulations on the use of water for mining and related activities aimed at the protection of water resources (GN704).
- 🚦 Government Notice No. 1352, 12 November 1999, National Water Act, 1998 (No. 36 of 1998): Regulations requiring that water use be registered.
- 🚦 GNR.810 of 17 September 2010: Regulations for the Establishment of a Water Resource Classification System (Government Gazette No. 33541).

- ✚ GN R. 1036 of 31 October 2007: Regulations on financial assistance to resource-poor farmers (Government Gazette No. 30427).
- ✚ GNR.131 of 17 February 2017: Regulations requiring that the taking of water for irrigation purposes be measured, recorded, and reported (Government Gazette No. 40621).
- ✚ GNR. 267 of 24 March 2017: Regulations regarding the procedural requirements for water use licence applications and appeals (Government Gazette No. 40713).

2.2 Hydrological overview

Hydrometeorological data for the study area were 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.

2.3 Water Users and Losses

2.3.1 *Assessment of alien invasive plants*

Land and water use data were obtained from the WR2012 South African Water Resources study (Bailey & Pitman, 2015), in which information on the percentage of the catchment that is covered by Alien Invasive Plants (AIPs) is provided. This was checked against Google Earth Imagery to determine the presence of AIP within the sub-catchments of the dam.

2.3.2 *Ecological Water Reserve Determination*

The calculation of the EWR was conducted per the stipulations from the National Water Act (Act No. 36 of 1998). Catchment classification and the physical characteristics of the dam sub-catchment were used to determine the Ecological Reserve Category. The long-term mean instream flow requirement (IFR) for quaternary catchments W41, W42, W43, W44 and W45 were obtained from the Hughes Desktop Model (Hughes & Hannart, 2003). This was then used to calculate the EWR for sub-catchment. EWR/IFR was further refined by available surface water reserve studies for the study area.

2.3.3 *WARMS data analysis*

The Water Allocation Management System (WARMS) database for KZN (DWS, 2024) was analysed for the quaternary catchment to determine the total legal water use.

2.4 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 hydraulic model for flood line modelling, water balance modelling or stormwater modelling. The ALOS DTM was further refined by applying 5 m contour or SRTM 1-Arc degree topography elevation (depending on resolution quality) in areas where drainage channels did not correspond to satellite imagery or actual field-recorded positions.

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.

2.5 Design rainfall and peak flows

The Design Rainfall Estimation Software (Meteoblue, 2025) data from the rainfall stations surrounding the study site were used to calculate the 24-hour design rainfall depths for various return periods. Critical storm durations for Rational Methods Alternative 3 were calculated using the Modified Hershfield Equation (Adamson, 1981).

The streams/drainage sections that were modelled applying the three widely used methods were used to calculate 1:10, 1:20, 1:50, and 1:100-year peak flows. These are the Rational Method, Midgley and Pitman (MIPI), and the Standard Design Flood (SDF) methods. A brief description of each of the peak flow methods can be seen in Table 2 1.

Methodologies for using the applied peak flow models are explained broadly in the South African Drainage Manual (SANRAL, 2013). The calibration of the run-off coefficients for the drainage areas was guided by the manual, as well as the understanding of the runoff-generating processes and land cover attributes. The resulting peak flows calculated using the selected methods were evaluated, and conservative values were provided as inputs into the 1D HEC-RAS flood line model.

Table 2-1: Summary of flood line peak flow methods (SANRAL, 2013)**Rational Method**

The rational method was developed in the mid-19th century and is one of the most widely used methods for the calculation of peak flows for small catchments (< 15 km²). The formula indicates that $Q = CIA$, where I is the rainfall intensity, A is the upstream run-off area, and C is the run-off coefficient. Q is the peak flow. There are 3 alternatives to the Rational Method, which differ in the methodology used to calculate rainfall intensities. The first alternative (RM1) uses the depth-duration frequency relationships approach, the second uses the modified Hershfield equation, and the third alternative uses the Design Rainfall software for South Africa (SANRAL, 2013).

Midgley and Pitman

The Midgley and Pitman (MIPI) method is an empirical method that relates peak discharge to catchment size, Slope, and distance from the drainage point to the centroid of the catchment (Campbell, 1986). The MIPI method uses 10-unit hydrographs for 10 zones in South Africa. The method does not consider overland flow as a component separate from streamflow but considers only the total longest flow path (Campbell, 1986).

Standard Design Flood Method

The Standard Design Flood (SDF) method was developed specifically to address the uncertainty in flood prediction under South African conditions (Alexander, 2002). The run-off coefficient (C) is replaced by a calibrated value based on the subdivision of the country into 26 regions or Water Management Areas (WMAs). The design methodology is slightly different and looks at the probability of a peak flood event occurring at any one of a series of similarly sized catchments in a wider region, while other methods focus on point probabilities (SANRAL, 2013).

2.6 Flood line modelling

A 30 m ALOS digital terrain model (DTM) (JAXA, 2025) was used to derive the hydraulic and river geometry parameters. River/stream cross-sections and flow paths were prepared using RAS Mapper software and provided input into a 1D HEC-RAS (US Army Corps of Engineers, 2016) flood model. Visual assessment of riverbanks from the Google Earth Imagery and land cover types (DFFE, 2024) was used to estimate Manning's 'n' coefficients along the river/streamlines. The 1:50 and 1:100-year flood lines were generated and mapped in Global Mapper and ArcGIS (ESRI, 2024).

2.7 Water and salt balance

A schematic presentation of the water process flow diagram (PFD) for the development was drafted using the information obtained from the client regarding the components that need to be licensed. The PFD represented the operational phases of the project. The PFD schematically presents the sources of water, storage, and linkages to different uses and losses from the proposed development system.

The client provided the estimates of the daily water requirements for the operational phases of the proposed development activities (if any). The provided estimates of water requirements were used together with the finalised PFDs to calculate average annual water balances. In the case where there was a lack of information in terms of water requirements, reasonable assumptions were made to determine the water balance. Data was further extracted from available specialist reports pertaining to the proposed projects. The water balance is based on techniques as described by Best Practice Guideline G2: Water and Salt Balances (DWAf, 2006).

The salt balance is based on techniques as described by Best Practice Guideline G2: Water and Salt Balances (DWAF, 2006).

The salt balance assumes conservation of mass across the flow system, and the following equation was used to estimate the salt loads (kg/unit of time) (DWAF, 2006):

$$\text{Salt load (kg/unit of time)} = \text{Flow (m}^3\text{/unit of time)} \times 0.001 \times \text{Salt concentration (mg/l)}$$

2.8 Hydrological 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 encompasses 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.

Per GNR 982 of the EIA Regulations (2014), the significance of potential impacts was assessed in terms of the following criteria:

1. Cumulative impacts.
2. Nature of the impact.
3. The extent of the impact.
4. Probability of the impact occurring.
5. The degree to which the impact can be reversed.
6. The degree to which the impact may cause irreplaceable loss of resources and
7. The degree to which the impact can be mitigated.

Table 2-2 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 2-3.

$$[\text{Consequence} = (\text{Duration} + \text{Extent} + \text{Irreplaceability of resource}) \times \text{Severity}] \text{ Equation 1}$$

The environmental significance of an impact was determined by multiplying the consequence by probability.

$$[\text{Environmental Significance} = (\text{Consequence} \times (\text{Probability} + \text{Reversibility}))] \text{ Equation 2}$$

Table 2-2: 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, 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)	
	Moderately detrimental (-13 to -18)	
	Slightly detrimental (-7 to -12)	
	Negligible (-6 to 0)	
	Slightly beneficial (0 to 6)	
	Moderately beneficial (7 to 18)	
	Highly beneficial (19 to 24)	
Probability (the likelihood of the impact occurring)	Extremely beneficial (25 to 33)	
	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 (24 to 48)	
	Very high – positive (49 to 66)	

Table 2-3: 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 colonisation 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 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 considered 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.

2.9 Surface water monitoring plan

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 2-1.

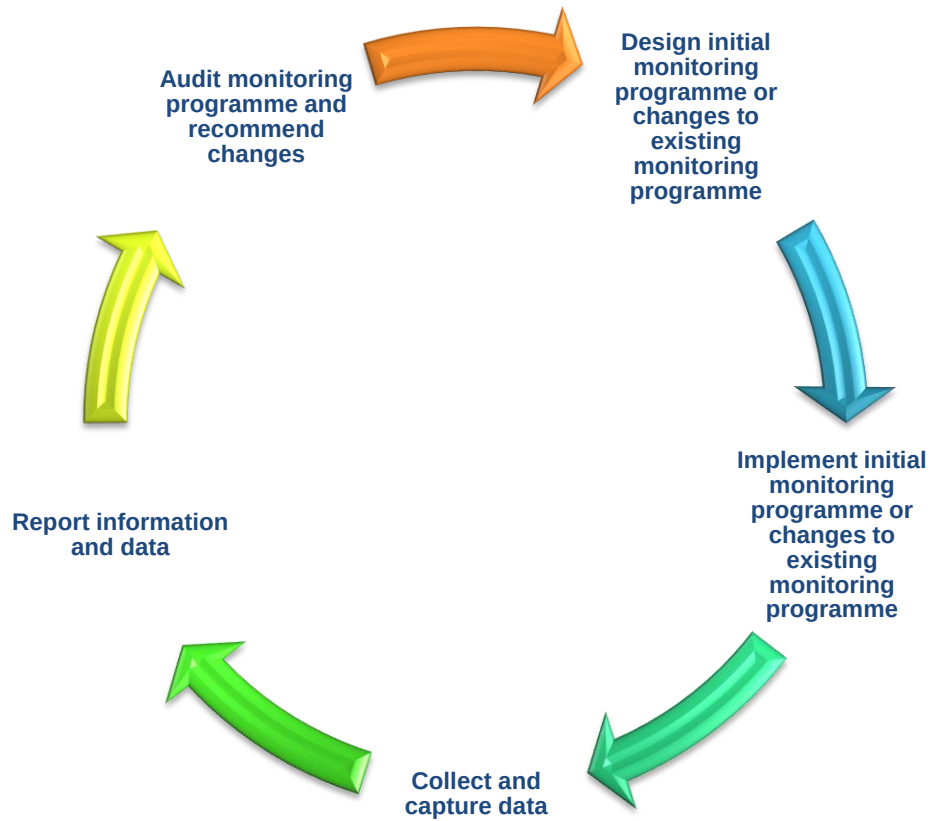


Figure 2-1: Monitoring Process

A surface water and stormwater monitoring plan (where required) was drafted and is based on the hydrological risks identified for the Site.

3 SITE OVERVIEW AND HYDROLOGY

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.

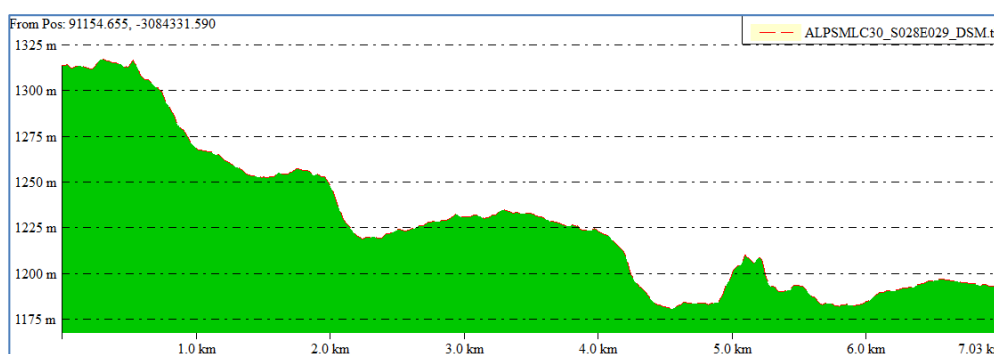


Figure 3-1: Typical cross section of surface topography (30m DTM based)

3.1 Sub-catchments / hydrological response units

Five (5) hydrological response units (HRU) describe the drainage of the Project Site, specifically the drainage associated with the Horn and Ingagane Rivers – refer to Figure 3-16. The land cover types associated with the HRUs are shown in Figure 3-17, and the topography slope rise % is shown in Figure 3-18. Table 3-1 provides a summary of the physical attributes associated with the HRUs.

Table 3-1: Summary of HRU attributes

Sub-Catchment		HRU01	HRU02	HRU03	HRU04	HRU05
Area (km ²)		880.210	198.590	155.61	1.97	173.08
Longest Drainage Line (km)		47.90	6.41	17.48	2.32	23.54
Average Slope (%)		0.20%	0.18%	0.60%	0.04%	0.03%
Slope (%)	<3	22.57%	21.23%	21.33%	29.66%	29.01%
	3-10	46.77%	65.62%	48.00%	62.38%	56.91%
	10-30	20.07%	12.61%	22.12%	7.65%	13.09%
	>30	10.58%	0.53%	8.55%	0.30%	1.00%
Land Cover	Thick bush & plantation	11.38%	1.24%	22.88%	0.16%	1.58%
	Light bush & farm-lands	24.60%	21.46%	24.98%	26.50%	16.76%
	Grasslands	59.55%	70.56%	49.24%	23.67%	74.69%
	No Vegetation	4.46%	6.73%	2.90%	49.67%	6.97%

3.2 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 3-19. 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 3-2 provides a summary of the hydrological characteristics of the different SCS soil types. The soils have a moderate erosion potential.

Table 3-2: 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

3.3 Hydrogeology and depth to groundwater

Available hydrogeology data suggests that three (3) aquifers exist in the area (refer to EWS Hydrogeology Assessment, 2025):

- ✚ 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.

The weathered zone for the area is estimated to be 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. 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 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.

3.4 Climate

Climate, amongst other factors, influences soil-water processes, run-off, and peak flows. The most influential climatic parameter is rainfall. Rainfall intensity, duration, evaporative demand, and run-off were considered in this study to indicate rainfall partitioning within the project area.

3.4.1 Temperature

The average yearly temperature (refer to Figure 3-2) 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).

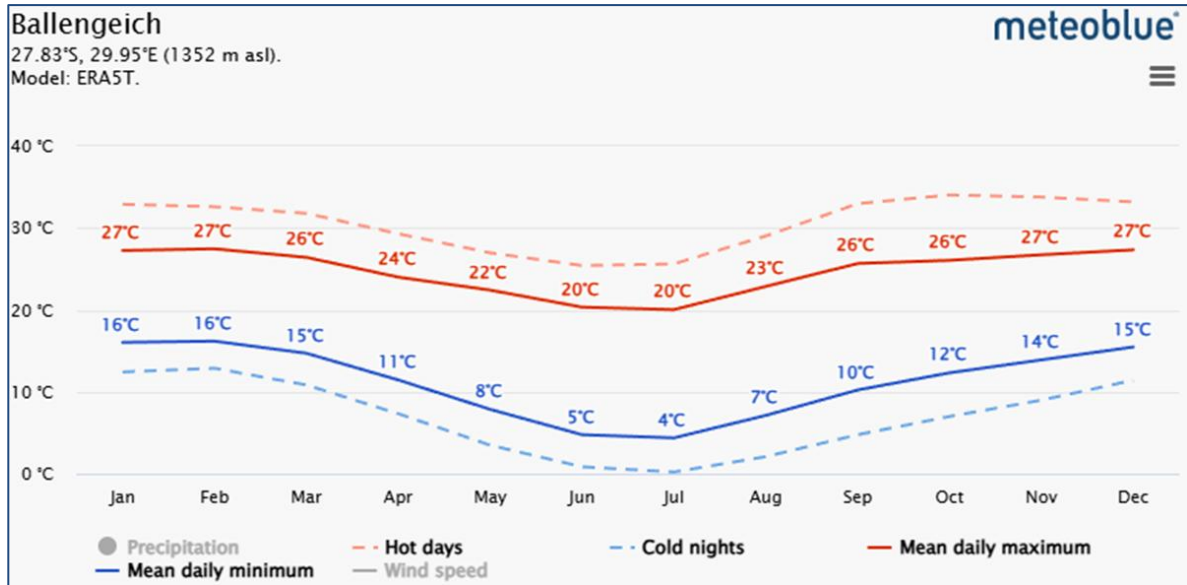


Figure 3-2: Average yearly temperatures (Meteoblue, 2025)

3.4.2 Wind speed and direction

Figure 3-3 shows the modelled wind rose for the project area (Ballengeich used as reference) and presents the number of hours per year the wind blows from the indicated direction.

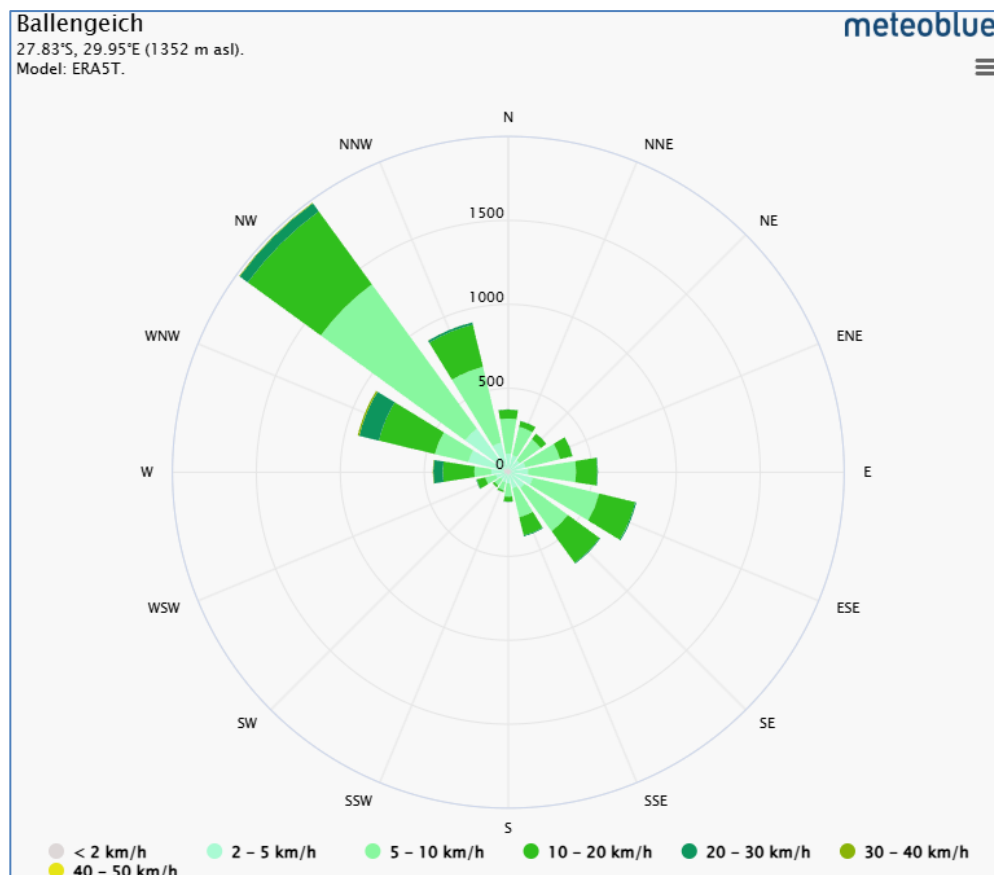


Figure 3-3: Wind rose (Meteoblue, 2025)

3.4.3 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 3-3 (WRC, 2015). The MAP for several sites is within the same order of magnitude.

Table 3-3: 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 3-4. 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 3-5, and the daily average rainfall is shown in Figure 3-6. 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 3-4.

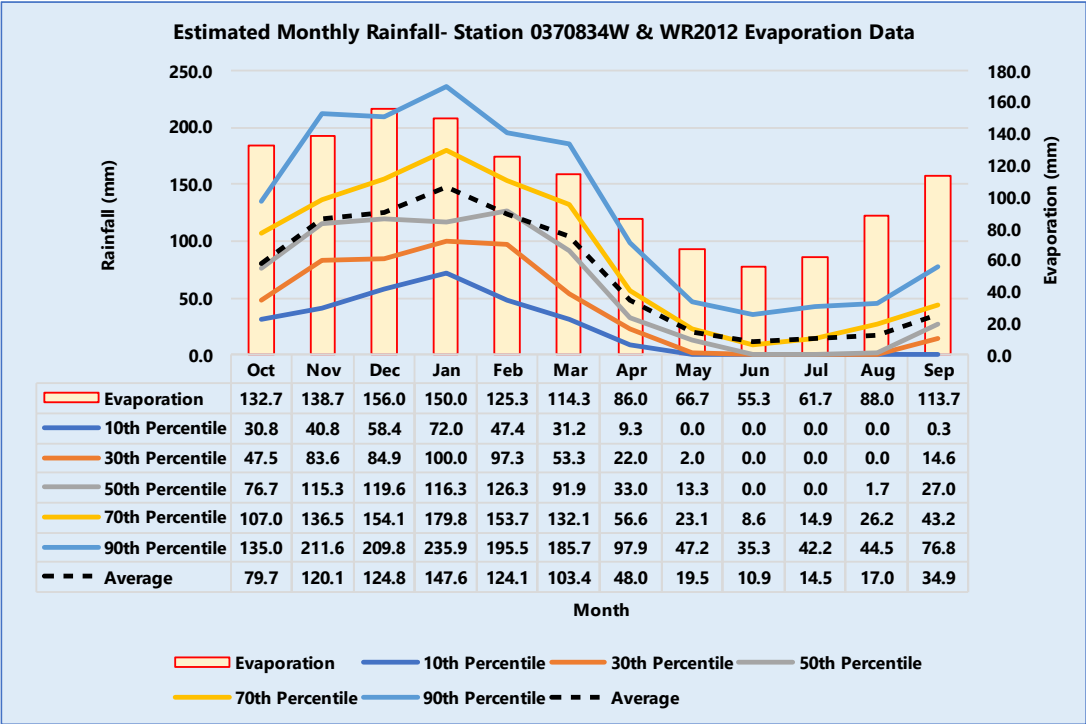


Figure 3-4: Average rainfall for Station 0370834W & WR2012 evaporation

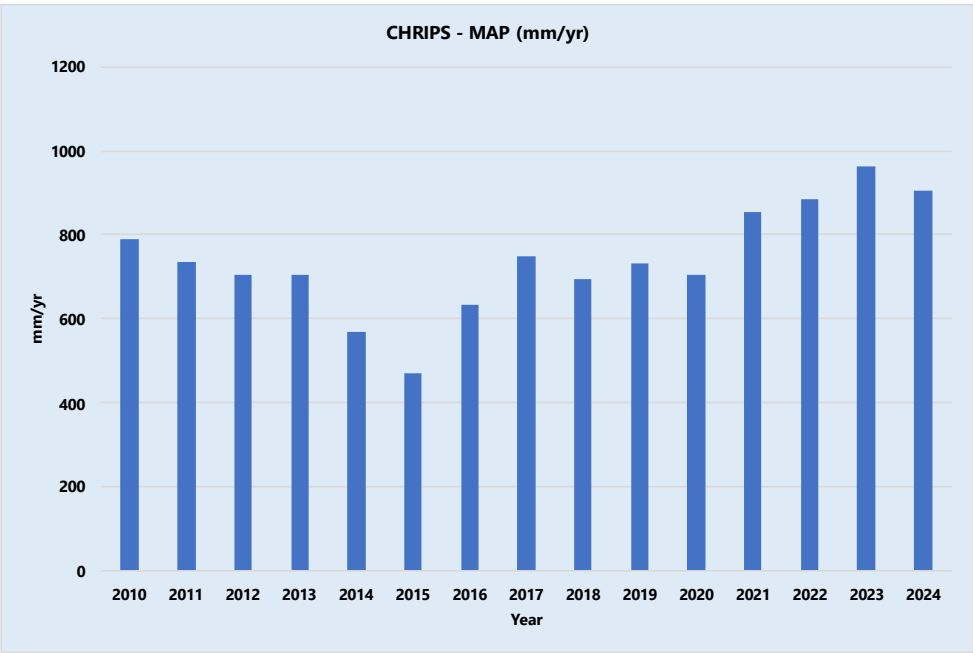


Figure 3-5: CHIRPS rainfall data for the site (2010 to 2024)

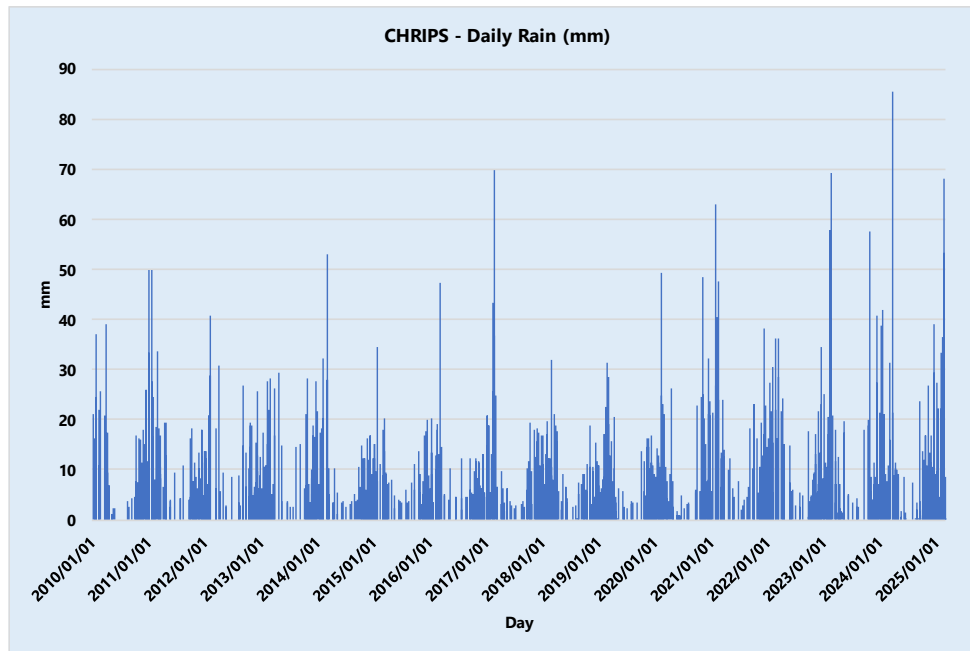


Figure 3-6: CHIRPS daily data for the site (2010 to 2024)

3.4.4 Run-off

Run-off from natural (unmodified) catchments for the quaternary, as simulated in WR2000/WR2012 models (WRC, 2015), is (refer to Figure 3-7 to Figure 3-9):

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

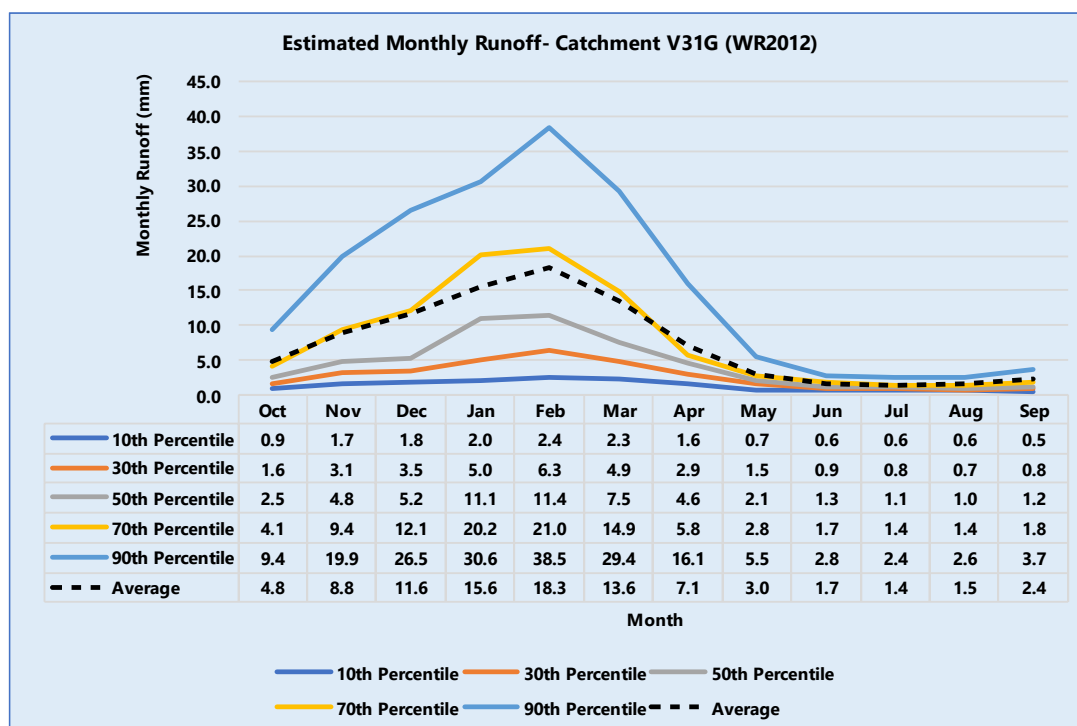


Figure 3-7: Simulated run-off distribution for V31G

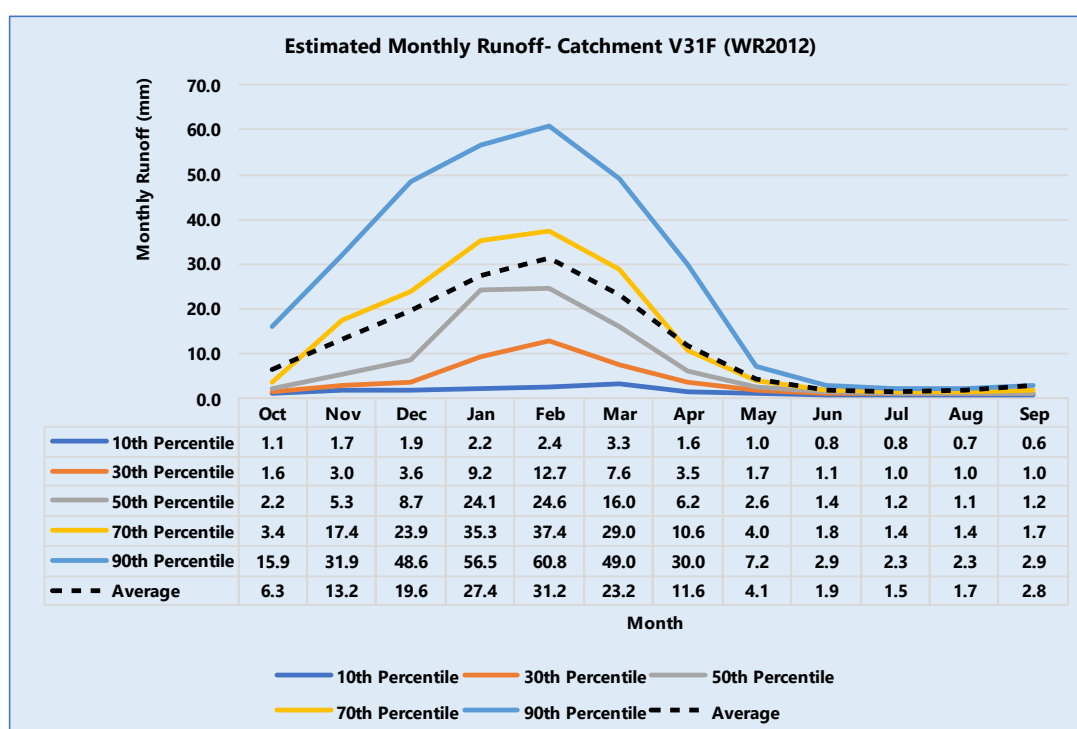


Figure 3-8: Simulated run-off distribution for V31F

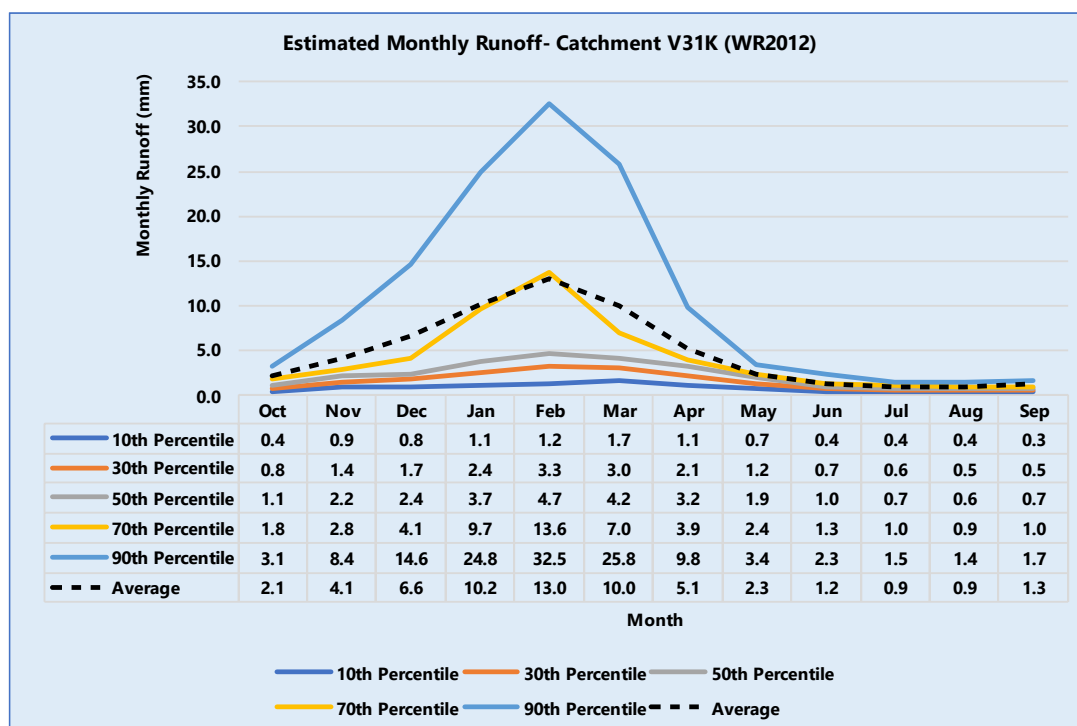


Figure 3-9: Simulated run-off distribution for V31K

3.4.5 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 3-2 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.

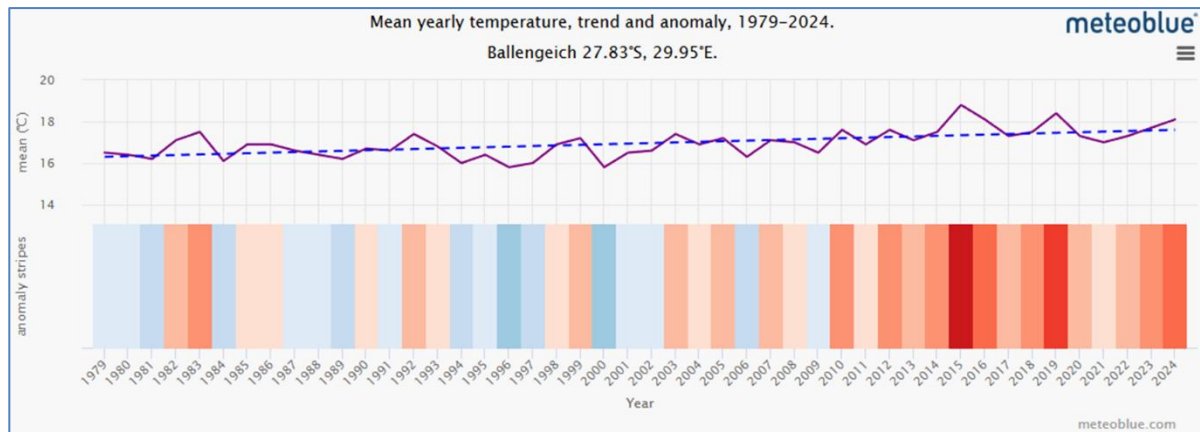


Figure 3-10: Yearly Temperature Change (Meteoblue, 2025)

Figure 3-11 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.

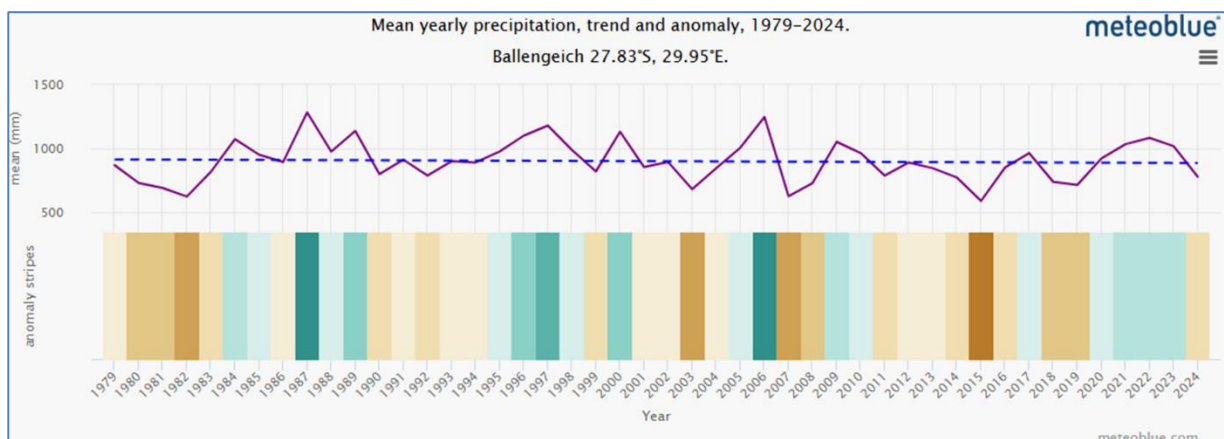


Figure 3-11: Yearly Precipitation Change (Meteoblue, 2025)

Figure 3-12 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 3-12. 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.

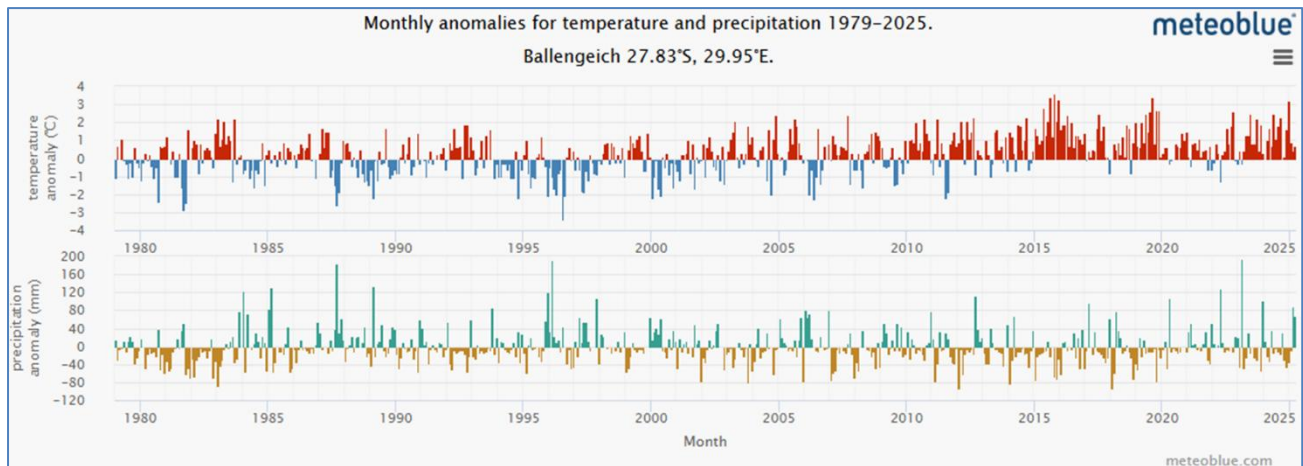


Figure 3-12: Monthly Anomalies of Temperature and Precipitation (Meteoblue, 2025)

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.

3.5 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 3-16. The presence of the wetland units mentioned was confirmed by (MENCO, 2022) – refer to Figure 3-13.

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

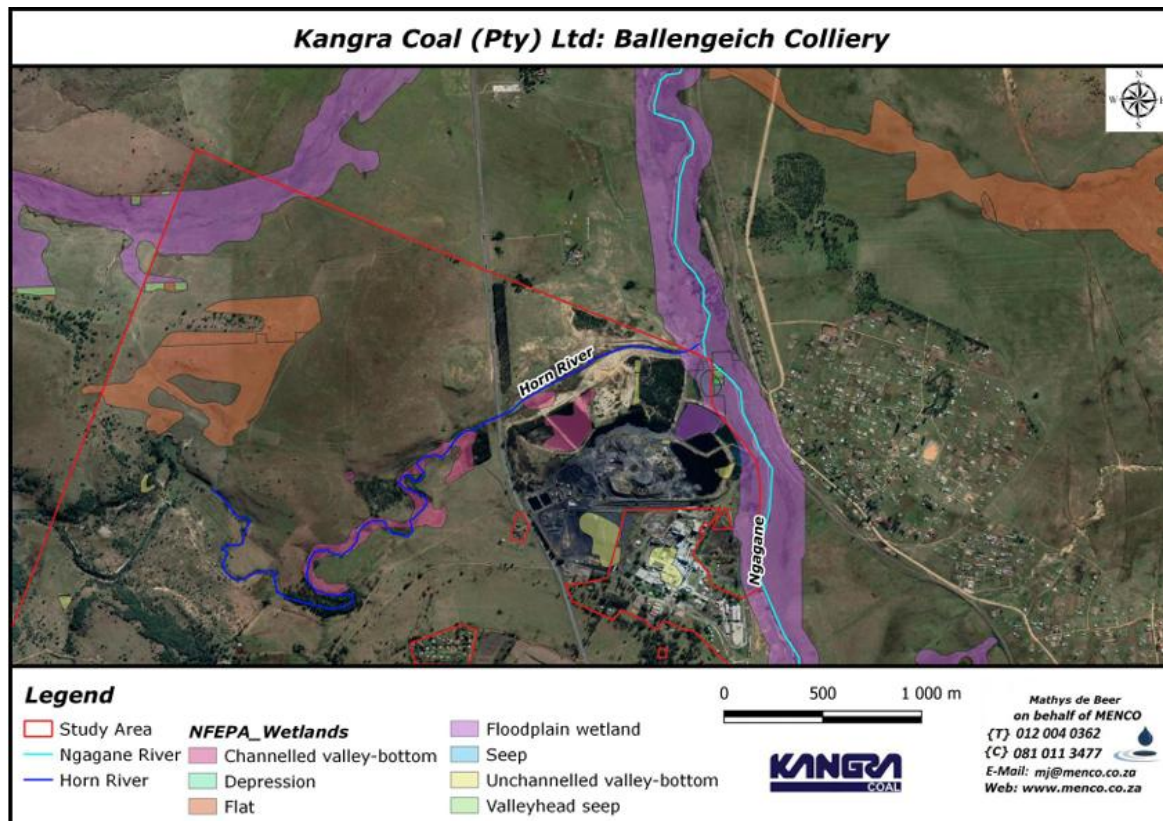


Figure 3-13: Wetland areas identified by Menco (2022)

In terms of wetland hydrogeology, baseflow is considered the most important contributor to wetland health. Baseflow (refer to Figure 3-14) 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).

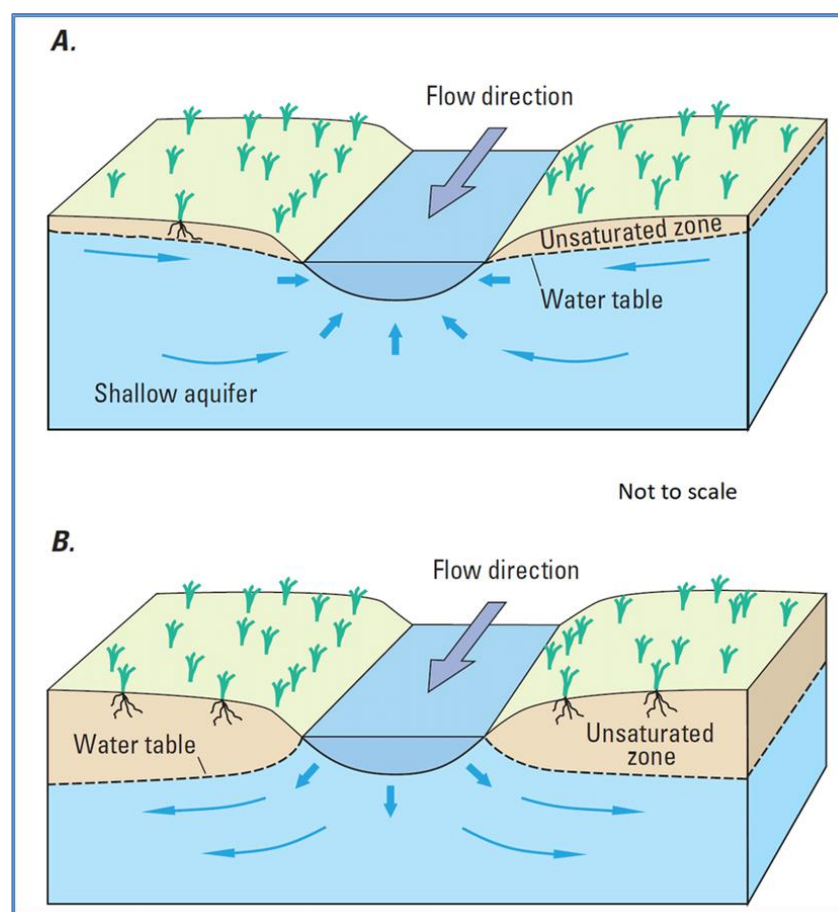


Figure 3-14: Groundwater baseflow concept

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

Table 3-4 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 3-4: 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)

3.7 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 3-5, and their positions are shown in Figure 3-20. There are numerous other WARMS users (groundwater, surface water, dams, springs, and water supply schemes) associated with the HRUs. The spatial distribution is indicated in Figure 3-20, and the total water use allocations are summarised in Table 3-6.

Table 3-5: 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 3-6: Summary of WARMS users' allocations for the HRUs

WARMS User	The sum of Registered Volume (m ³ /yr.)
BOREHOLE	780813
DAM	5678247
RIVER/STREAM	5692457
SCHEME	59834351
SPRING/EYE	5548
Grand Total	71991416

3.8 Overview of site hydrological cycle

Based on the information attained for the study area (as presented in this section), existing groundwater and surface water users, climate, run-off and estimated baseflow to wetland/river areas, a sub-catchment-specific hydrological cycle was developed (refer to Figure 3-15). *The impact of the proposed/existing activities at the site on the cycle was considered in the hydrological impact assessment.* With regards to the hydrological cycle for the combined sub-catchment area, the following are estimated:

- ✚ Average rainfall accounts for a volume in the order of 1041 Mm³/yr.
- ✚ Average run-off accounts for a volume in the order of 215 Mm³/yr.
- ✚ The average groundwater contribution to baseflow to rivers/wetlands/streams is in the order of 11 Mm³/yr.
- ✚ Evaporation, soil retention and evapotranspiration account for a volume in the order of 648 Mm³/yr.
- ✚ EWR is estimated in the order of 41.8 Mm³/yr.
- ✚ WARMS (2024) groundwater use is estimated in the order of 0.78 Mm³/yr.
- ✚ WARMS (2024) surface water use is in the order of 71.2 Mm³/yr.

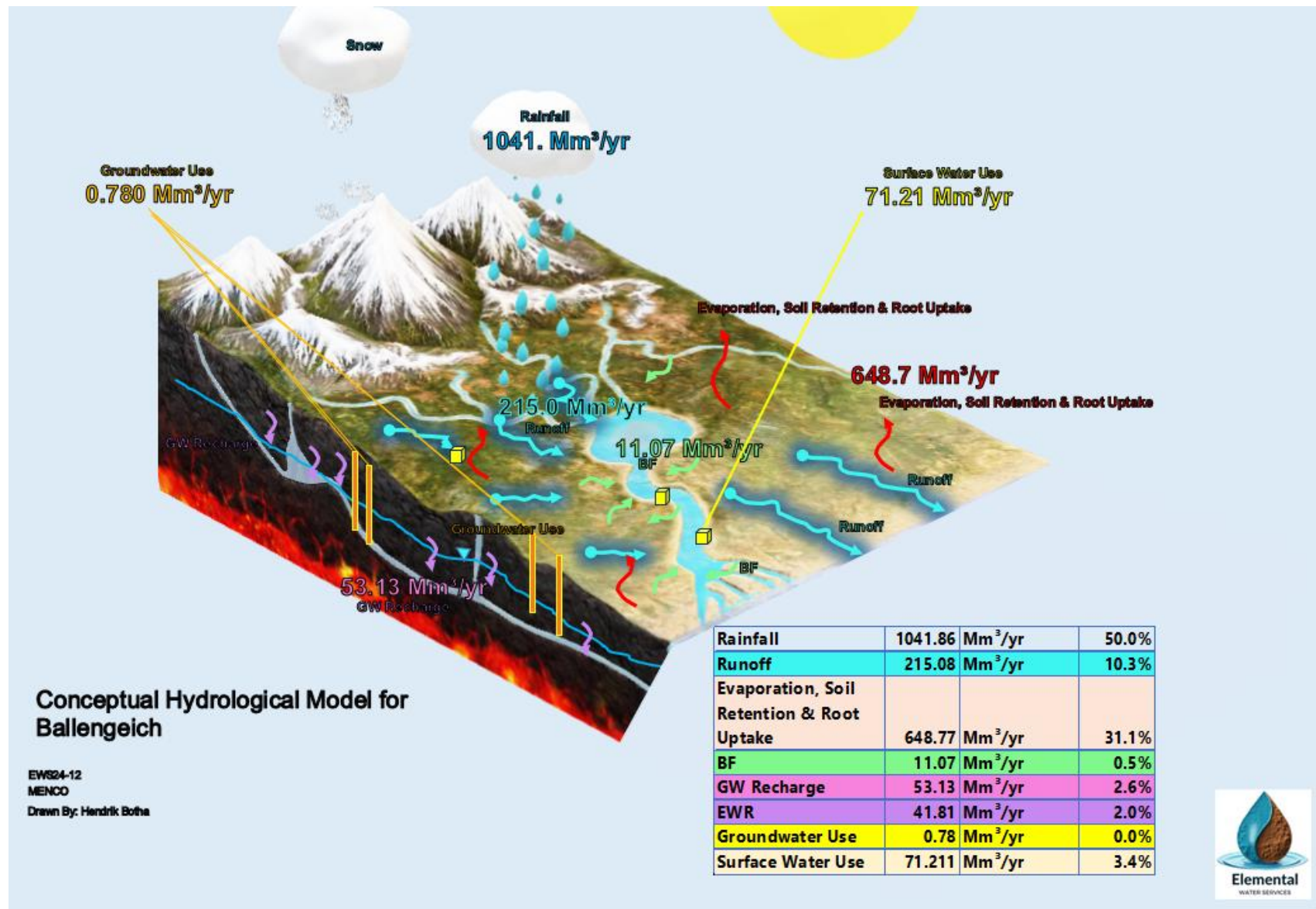
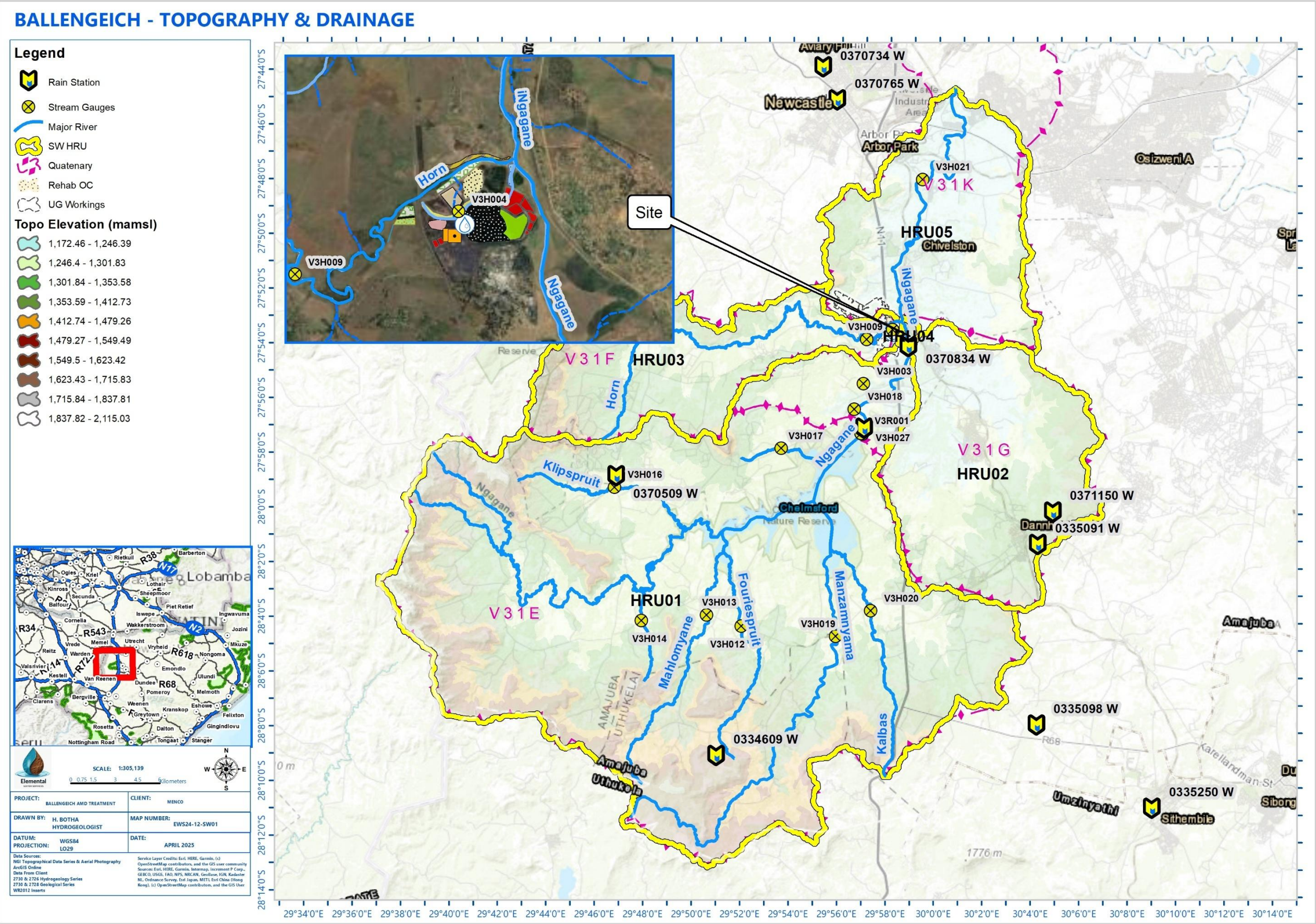


Figure 3-15: Simplified overview of the hydrological cycle at the site (averages presented)



BALLENGEICH - LAND COVER (DFFE, 2024)

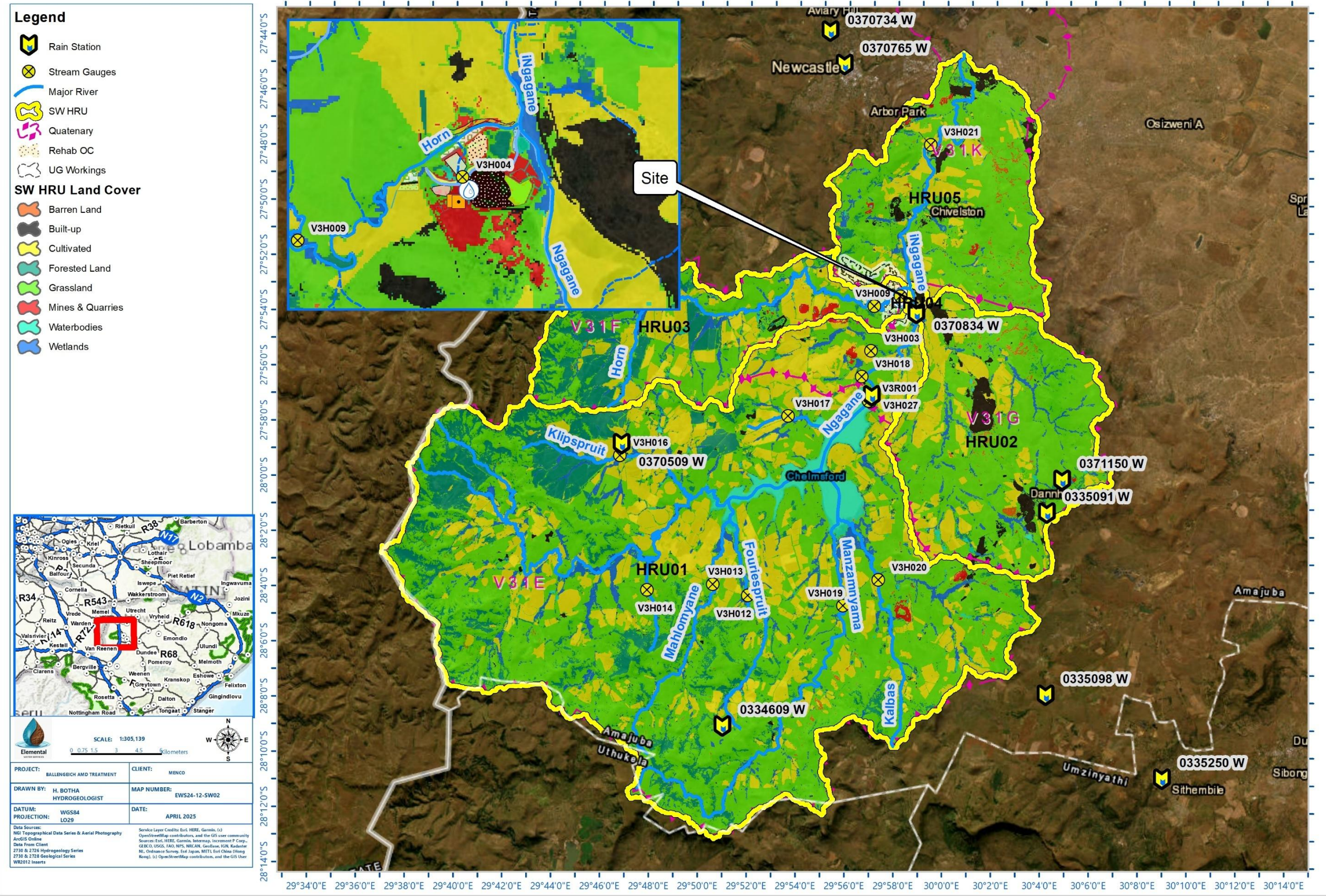


Figure 3-17: Land cover types (DFFE, 2024)

BALLENGEICH - SUB-CATCHMENTS & SLOPE RISE %

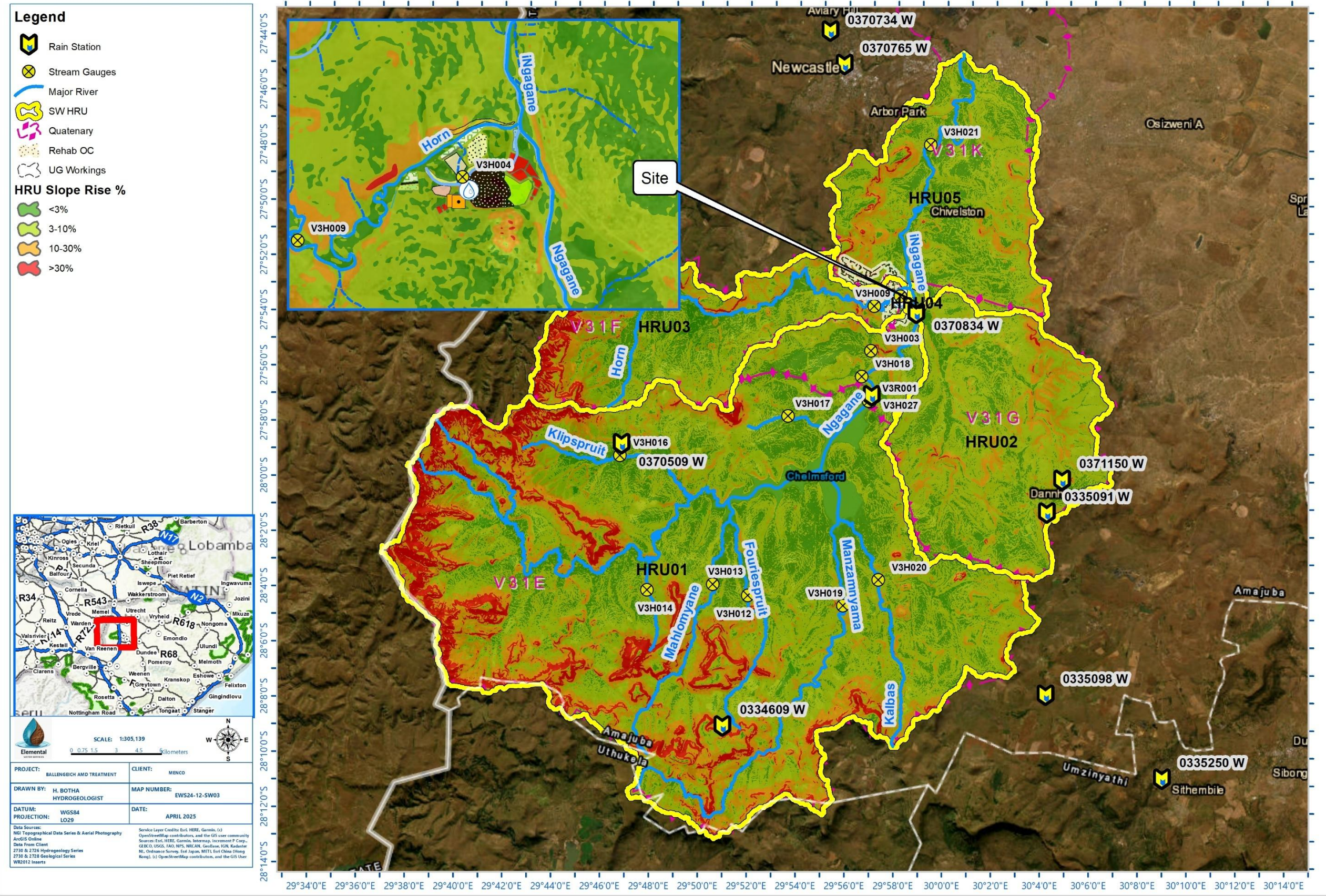


Figure 3-18: Sub-catchments and slope rise %

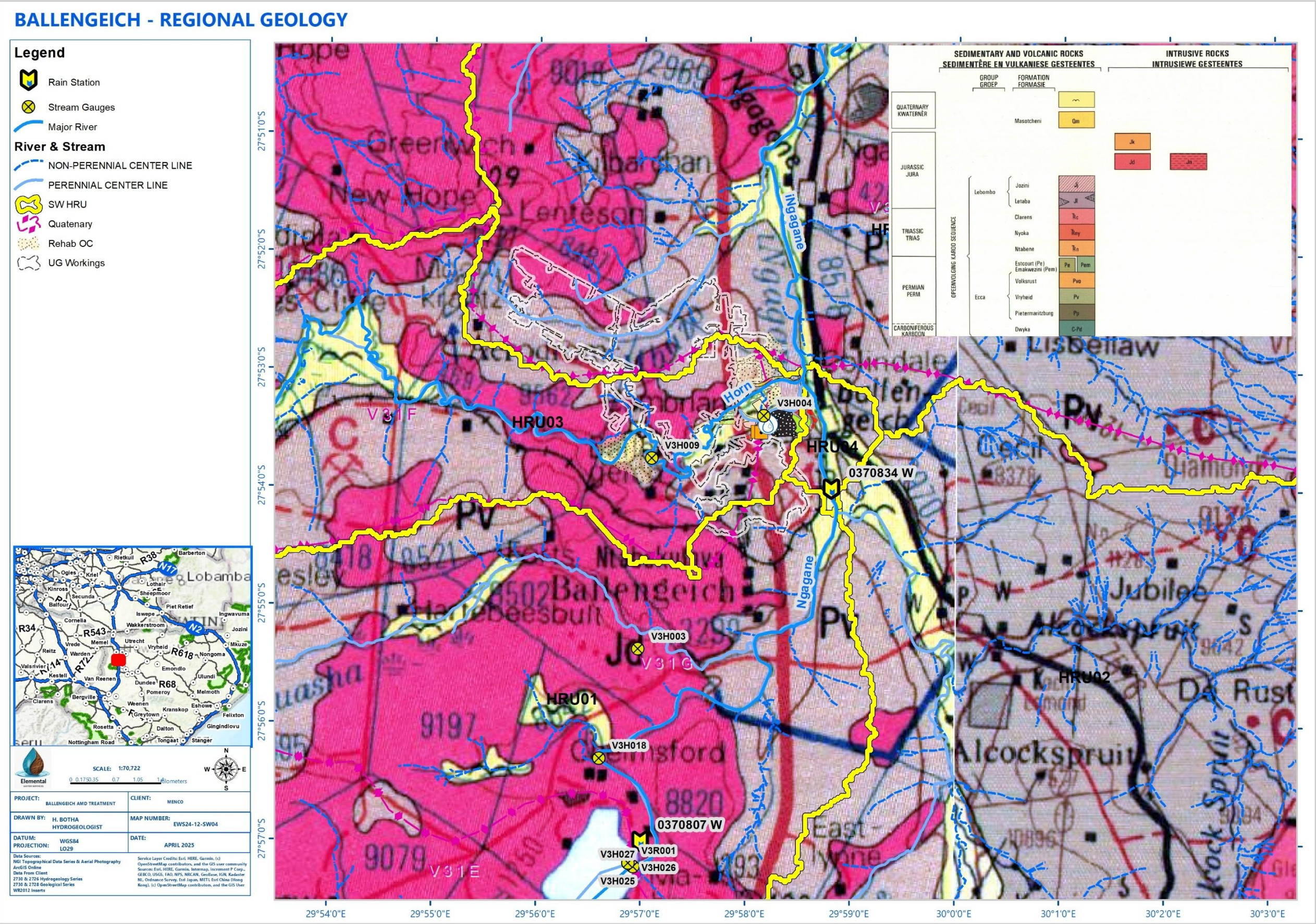


Figure 3-19: Regional surface geology

BALLENGEICH - WARMS USERS

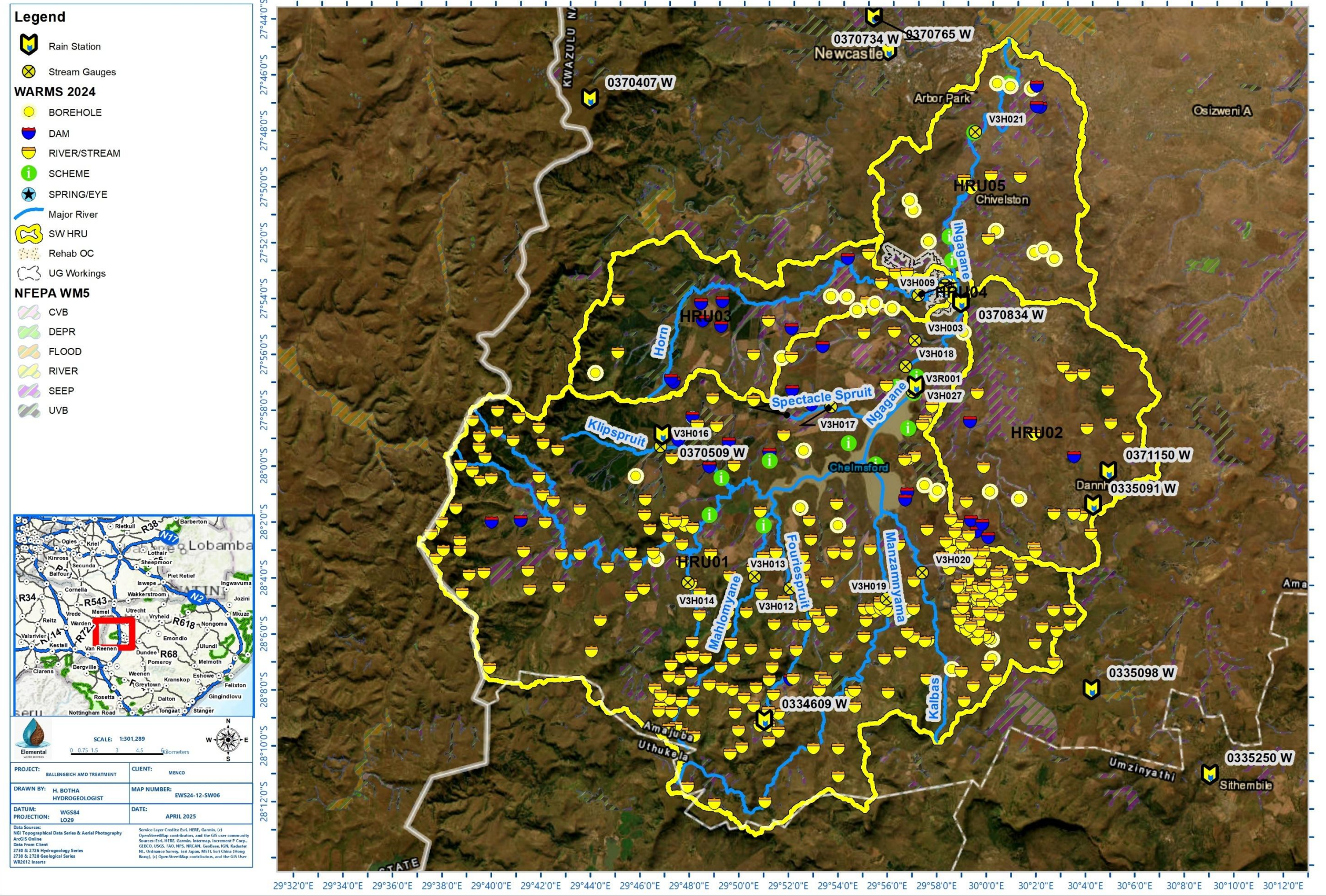


Figure 3-20: WARMS users in the project area

4 WATER QUALITY

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 4-9. From the quarterly monitoring undertaken, the following is noted.

4.1 Groundwater levels

Shallow groundwater levels (<12.0 mbgl) are observed in the Ballengeich area (refer to Figure 4-1). 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.

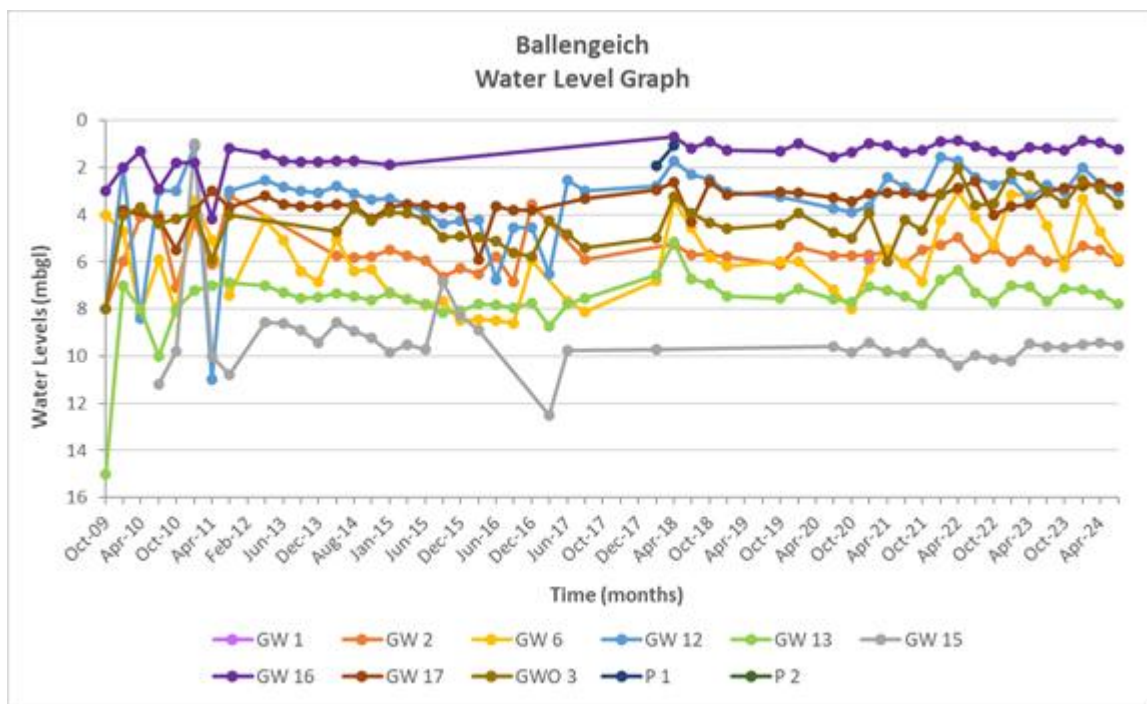


Figure 4-1: Ballengeich groundwater level graph

4.2 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 4-2.
- ✚ Suspended solids (SS) were in exceedance at GW6 (1 200 mg/l) in July 2024

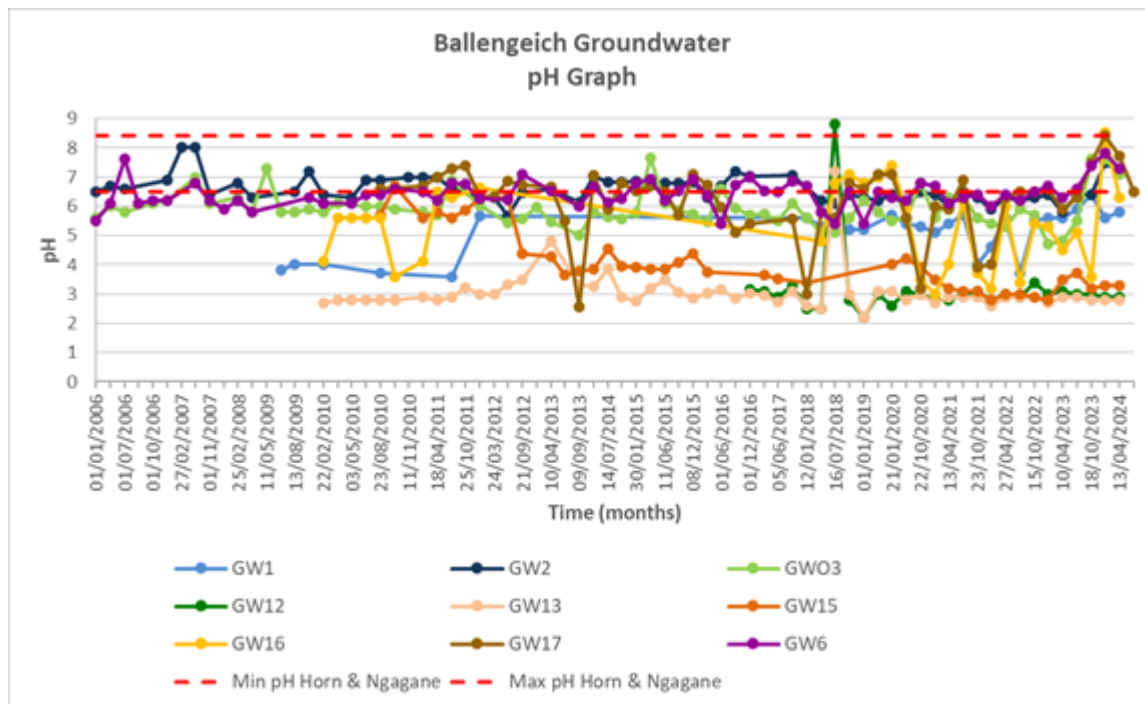


Figure 4-2: Ballengeich groundwater pH graph

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 4-3. 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.

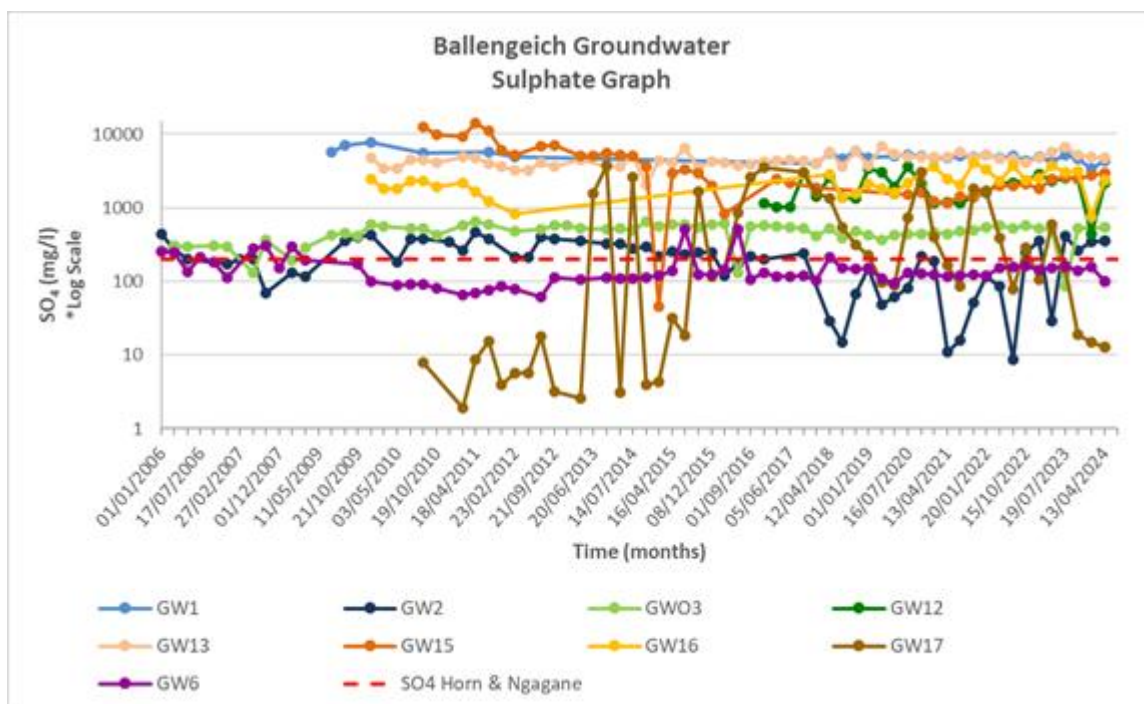


Figure 4-3: Ballengeich groundwater sulphate graph

4.3 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 4-4.

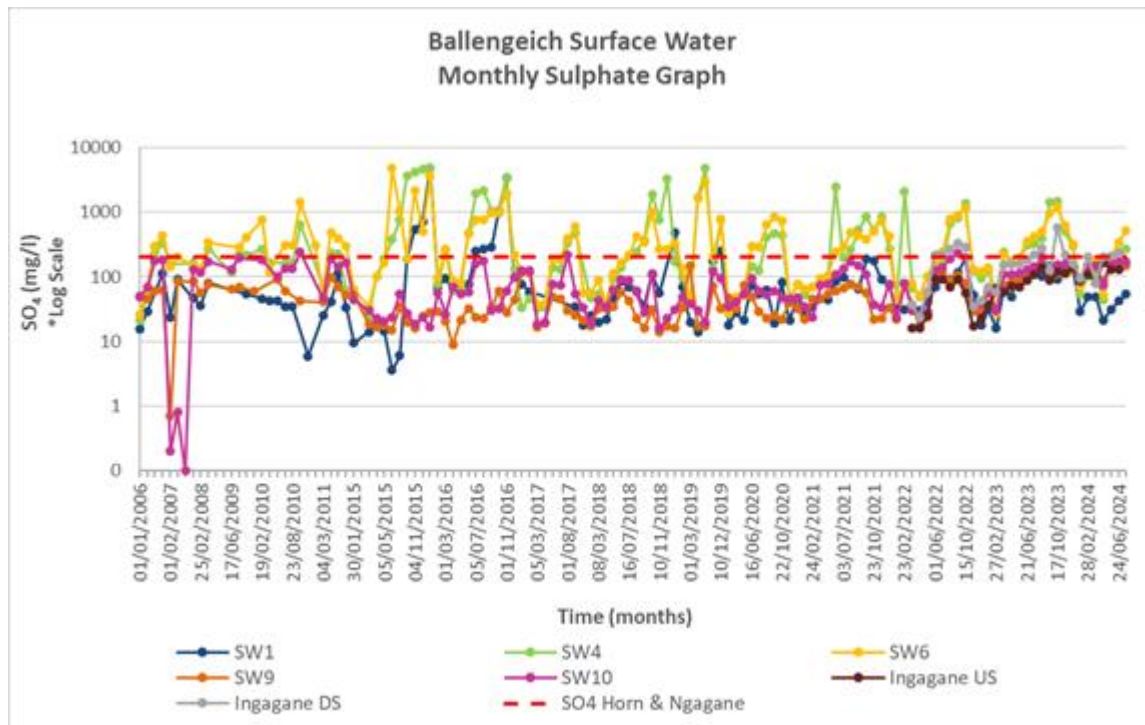


Figure 4-4: Ballengeich surface water sulphate graph for the monthly monitoring points

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 4-5.

- 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 4-6.
 - 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.

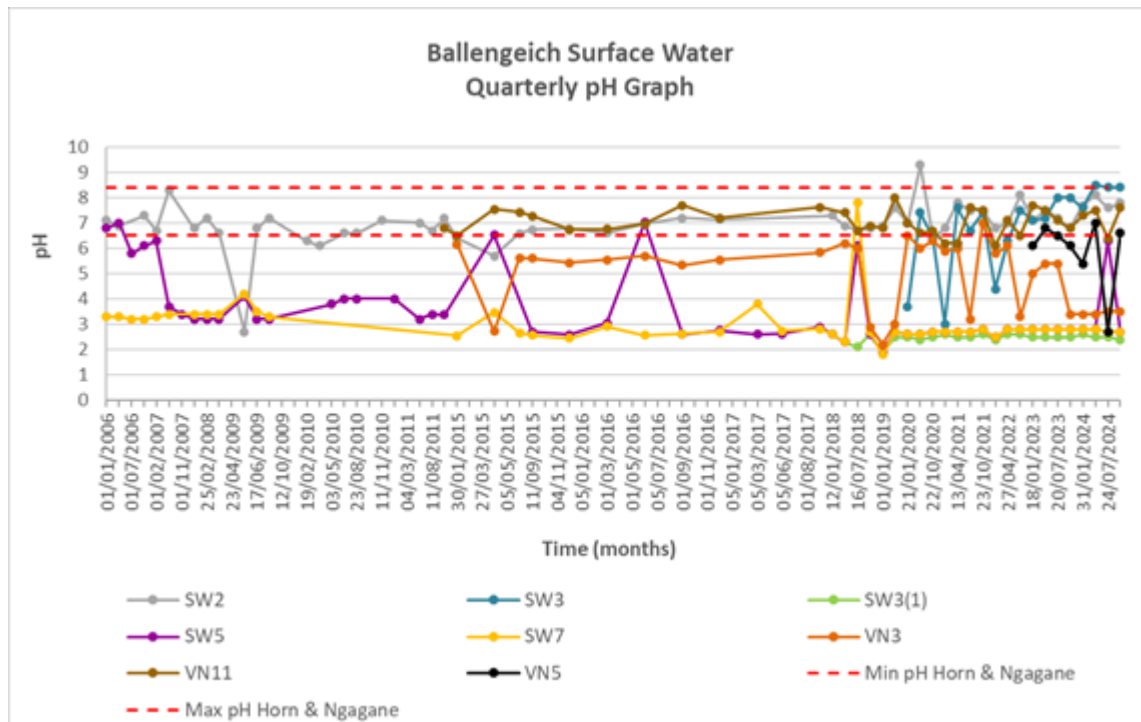


Figure 4-5: Ballengeich surface water pH graph for the quarterly monitoring points

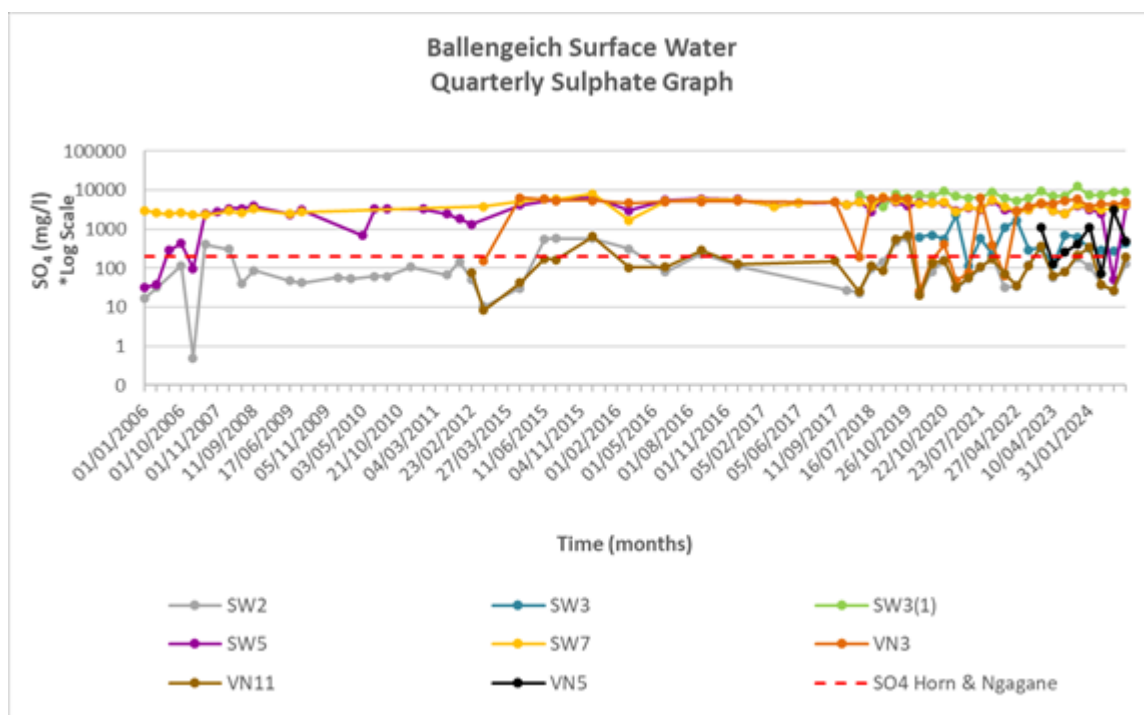


Figure 4-6: Ballengeich surface water sulphate graph for the quarterly monitoring points

4.4 Stream EC and pH profiling

Two (2) stream profiles were completed for the Horn and Ingagane Rivers and are shown in Figure 4-7 and Figure 4-8. 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 4-10.

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.

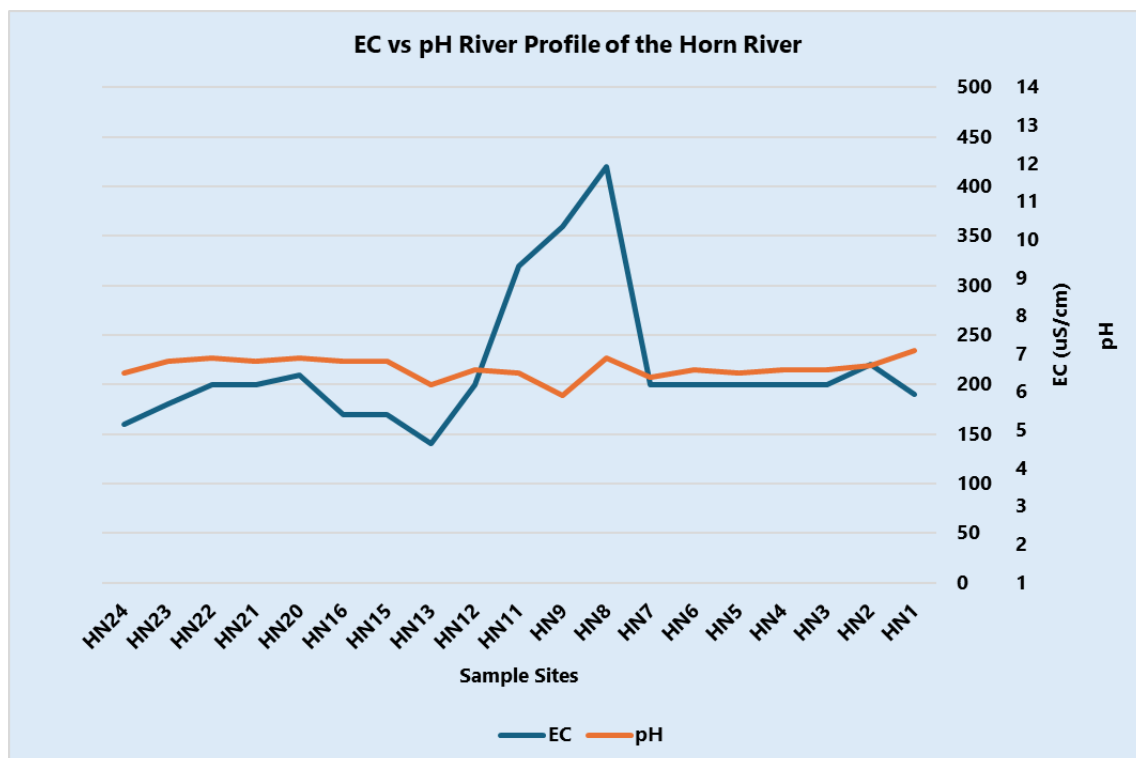


Figure 4-7: River profile upstream to downstream in the Horn River

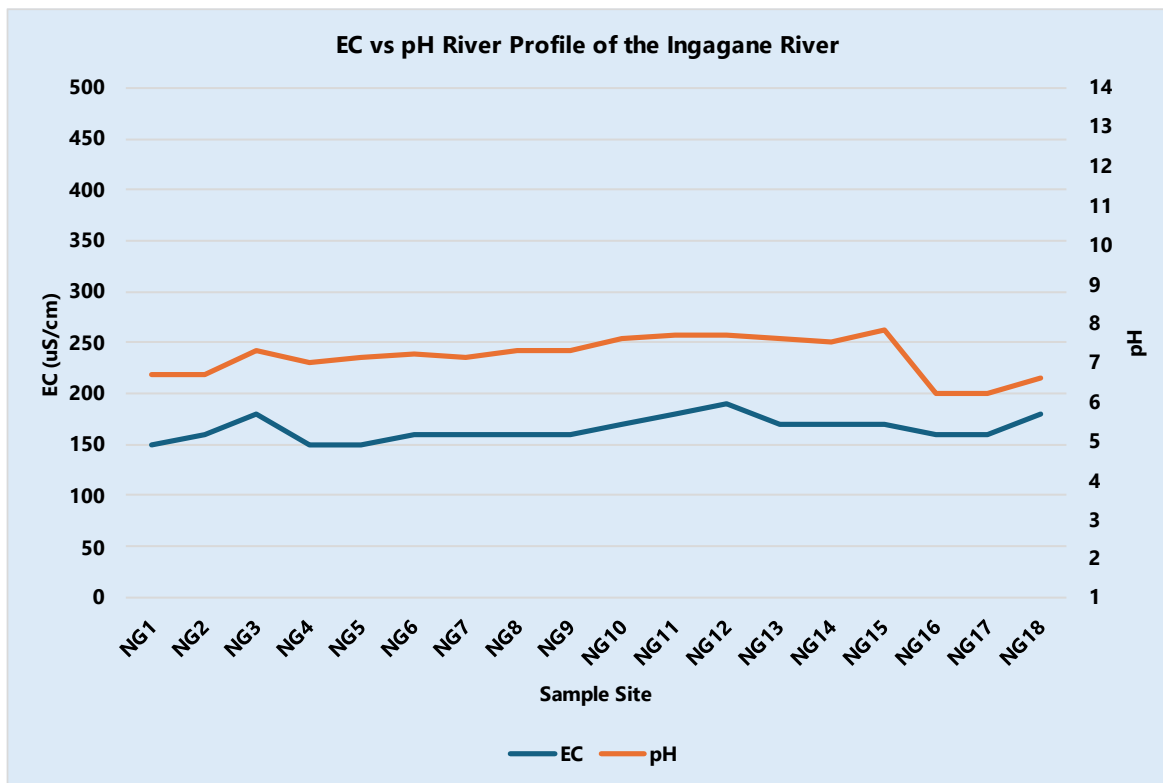


Figure 4-8: River profile upstream to downstream in the Ingagane Reiver, up to the confluence area downstream of the discard dump

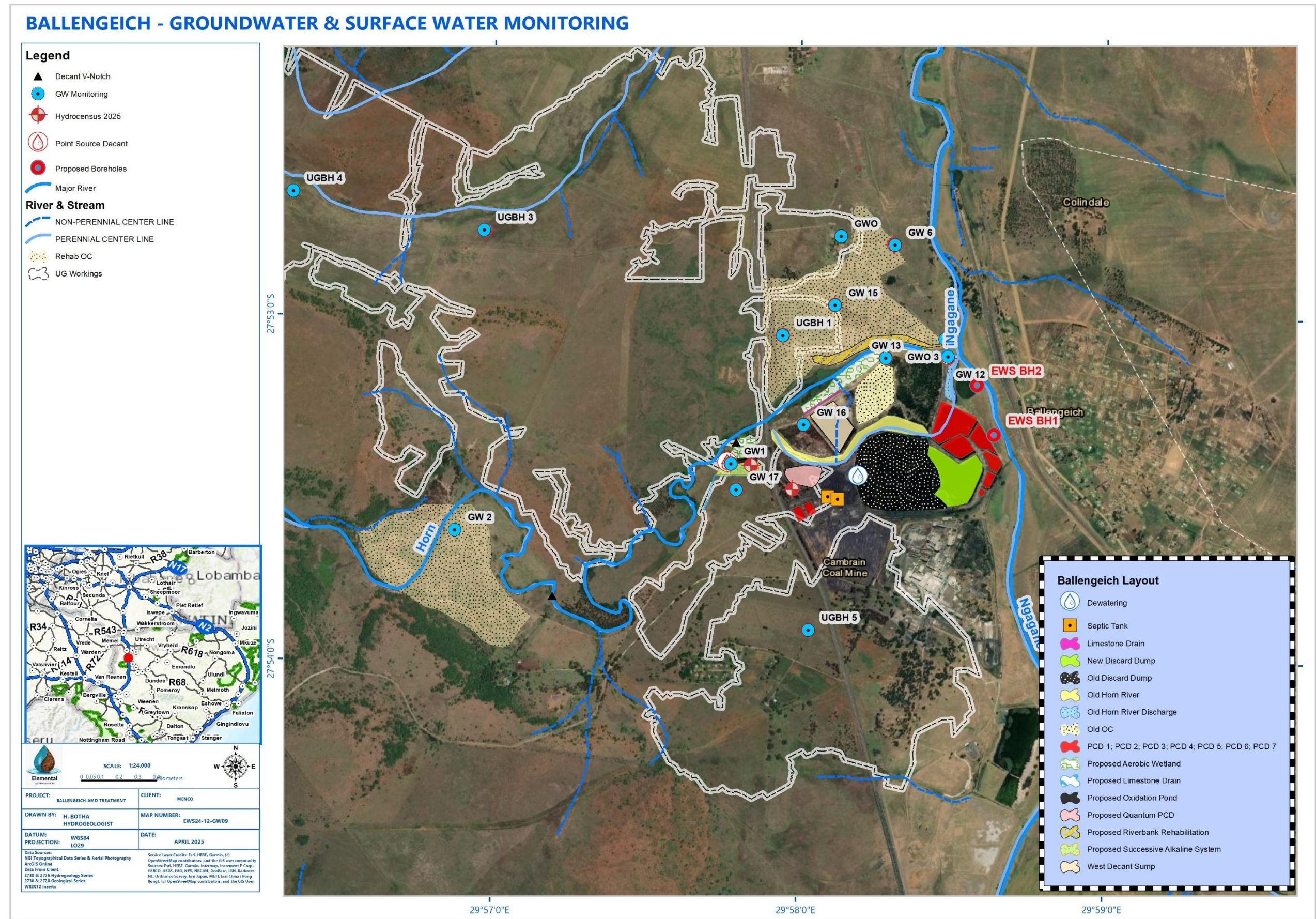


Figure 4-9: Groundwater and surface water monitoring network

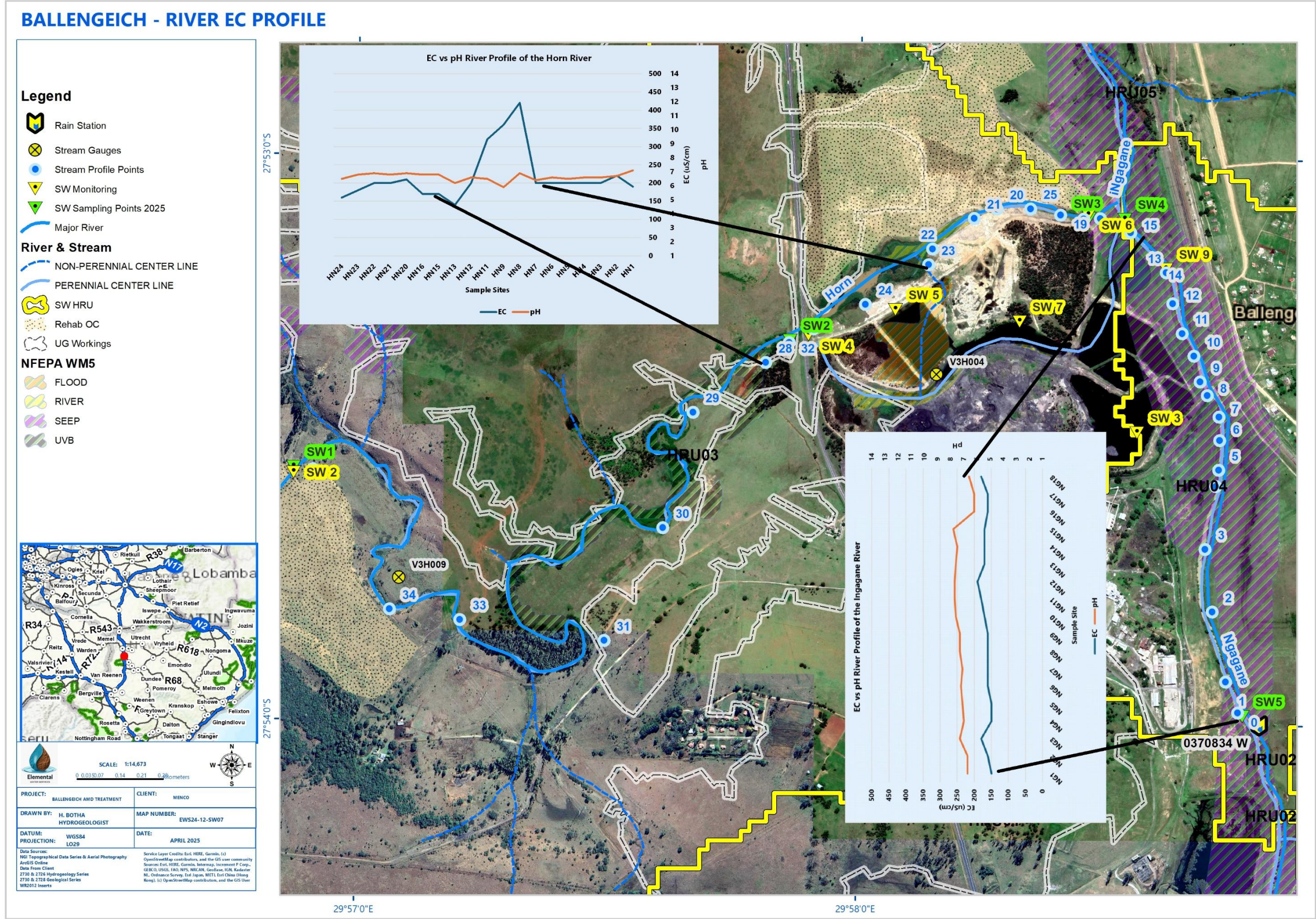


Figure 4-10: Stream profiles of the Ngagane and Horn Rivers

5 FLOOD HYDROLOGY ASSESSMENT

Flood peak flows for the delineated sub-catchments were calculated using the Rational Method (RM3), Midgley and Pitman (MIPI) and the SDF methods (refer to **Appendix A**). Design rainfall was retrieved from the site coordinates, gridded to the nearest station (ID – 0240185W) and used to calculate peak flow volumes. Table 5-1 provides a summary of the design rainfall data used to calculate peak flows. The upper “U” rainfall intensity values were used, and catchment-based time concentration estimates were used in the estimation of the return period peak flows.

Table 5-1: Summary of design rainfall data used for peak flow estimates

Duration	Return Period (years)						
	2	5	10	20	50	100	200
5 min	18.2	24.4	28.6	32.8	38.5	43	47.7
10 min	22.8	30.4	35.7	41	48.2	53.7	59.6
15 min	25.9	34.7	40.7	46.7	54.9	61.2	67.9
30 min	32.7	43.7	51.3	58.8	69.2	77.1	85.5
45 min	37.4	50	58.7	67.3	79.2	88.3	97.9
1 hr	41.2	55	64.6	74.1	87.1	97.1	107.7
1.5 hr	47.1	63	74	84.8	99.7	111.2	123.3
2 hr	51.9	69.3	81.4	93.3	109.8	122.4	135.7
4 hr	61.1	81.6	95.8	109.9	129.2	144.1	159.8
6 hr	67.2	89.8	105.4	120.9	142.2	158.5	175.8
8 hr	71.9	96.1	112.8	129.3	152.1	169.6	188.1
10 hr	75.8	101.3	118.9	136.3	160.4	178.8	198.3
12 hr	79.1	105.7	124.1	142.3	167.4	186.6	207
16 hr	84.7	113.1	132.8	152.3	179.1	199.7	221.5
20 hr	89.2	119.2	140	160.5	188.8	210.5	233.5
24 hr	93.2	124.5	146.2	167.5	197.1	219.7	243.7
1 day	79	105.6	124	142.1	167.2	186.4	206.7
2 days	93.4	124.8	146.5	167.9	197.5	220.2	244.3
3 days	103	137.6	161.5	185.1	217.8	242.8	269.3
4 days	114	152.3	178.8	205	241.1	268.8	298.1
5 days	123.3	164.8	193.5	221.8	260.9	290.9	322.6
6 days	131.5	175.7	206.3	236.5	278.2	310.2	344.1
7 days	138.9	185.6	217.9	249.8	293.8	327.6	363.3

5.1 Calculated flood peak flows

Calculated peak flows are summarised in Table 5-1. The flood line assessment is aimed at providing a worst-case inundation scenario to evaluate potential flooding risks associated with recognised rivers and streams associated with the study area. The geometric mean was applied in the HEC-RAS model.

Table 5-2: Summary of design peak flows for the delineated sub-catchments (m³/s)

Catchment	Area km ²	Tc min	Method											
			RM (3) - (m ³ /s)			SDF - (m ³ /s)			MIPI - (m ³ /s)			Geometric Mean - (m ³ /s)		
			1:20yr	1:50yr	1:100yr	1:20yr	1:50yr	1:100yr	1:20yr	1:50yr	1:100yr	1:20yr	1:50yr	1:100yr
HRU01	880.21	856.7	436	636	854	628	909	1 143	880	1 151	1 354	<u>622</u>	<u>873</u>	<u>1 097</u>
HRU02	198.59	189.6	363	529	711	500	723	910	470	615	724	<u>440</u>	<u>617</u>	<u>776</u>
HRU03	155.61	258.2	211	307	413	316	457	575	323	422	496	<u>278</u>	<u>390</u>	<u>490</u>
HRU04	1.97	154.7	5	8	11	7	11	13	19	25	30	<u>9</u>	<u>13</u>	<u>16</u>
HRU05	173.08	1029.1	82	119	160	118	171	215	291	380	447	<u>141</u>	<u>198</u>	<u>249</u>

5.2 Post-development/farming peak flows

The flood lines generated are based on the existing land use, and no increases or decreases are anticipated.

5.3 Flood line modelling

5.3.1 Software

HEC-RAS 6.6 was used to model the flood elevation profile for the 1:50 and 1:100-year flood events. HEC-RAS is a hydraulic programme designed to perform one-dimensional hydraulic calculations for a range of applications, from a single watercourse to a full network of natural or constructed channels. The software is used worldwide and has consequently been thoroughly tested through numerous case studies.

5.3.2 Topography profile data

A triangulated irregular network (TIN) from the 30 m DTM (JAXA, 2025) formed the foundation for the HEC-RAS model and was used to extract elevation data for the river profile together with the river cross-sections. Furthermore, the TIN was used to determine placement positions for the cross-sections along with the river profile so that the watercourse could be accurately modelled to the resolution of the provided topographical data. The positions of the river sections were further refined by evaluating Google Earth Imagery and its correlation to the DTM elevations (i.e., does the actual position of a river/stream correlate to the sub-catchment drainage line generated).

5.3.3 Manning's roughness coefficients

Manning's roughness factor (n) is used to describe the channel and adjacent floodplain's resistance to flow. A Manning factor of 0.03 to 0.05 best represents the frictional characteristics of the sub-catchment drainage areas, streams, and riverbank areas. This is due to isolated flow paths noted in the field, with a mixture of dense shrubs and bushels.

5.3.4 Inflow and boundary conditions

Several HEC-RAS rivers were defined, consisting of both critical depth (upstream) and normal depth slope boundary conditions. The normal depth slope was determined based on the DTM slope rise for the given sub-catchment drainage line.

5.3.5 Hydraulic structures

Hydraulic structures were not incorporated into the HEC-RAS model to determine a worst-case scenario flood (i.e. where there is hydraulic congestion in installed stormwater and water conveying systems).

5.3.6 Model conditions

In line with the development of the flood lines, the following assumptions were made:

- ✚ The topographic data provided was of sufficient accuracy and coverage to enable hydraulic modelling at a suitable level of detail.
- ✚ The Manning's 'n' values used are considered suitable for use in the flooding events modelled, representing all the channels and floodplains.
- ✚ No abstractions or discharges into the stream sections were considered during the modelling.
- ✚ Hydraulic structures, other than the water storage dams, were not included in the model due to the resolution of available topography data.
- ✚ Steady-state hydraulic modelling was undertaken, which assumes the flow is continuous at the peak rate.
- ✚ A mixed flow regime that is tailored to both subcritical and supercritical flows was selected for running the steady-state model.

5.4 Model results

The 1:50 and 1:100-year flood areas are shown in Figure 5-1. The major rivers are prone to flooding due to the flatter topography. Drainage lines associated with valleys are less susceptible to cause flood inundation, and limited flooding is predicted and generally associated with the valleys. The entire Ballengeich operations are situated in the 1–100-year flood line and a GN704 exception in terms of the National Water Act (NWA) of 1998 (Act No. 36 of 1998).

5.5 Site-specific sensitivity & buffers (avoidance areas)

A moderate-low probability of erosion of the banks of the rivers/streams associated with the project area is anticipated. The 1:100-year flood line should be considered an avoidance area (buffer area). Proper flooding protocols and erosion prevention measures should be implemented.

5.6 Model assumptions

Steady-state flood modelling was undertaken, which is a conservative approach as it ignores the effect of storage within the system and, therefore, produces higher flood levels than would be expected to occur. A steady-state model will result in worst-case (conservative) estimates of flooding, and resultant flood levels and floodplain extents would decrease if unsteady state modelling were undertaken using an inflow hydrograph as opposed to continuous peak flow.

Despite the above-mentioned and Manning's 'n' coefficients for the vegetation observed and the medium-low resolution topography data (limited to the 30m ALOS DTM), the flood risk to the surface infrastructure has been adequately assessed for the project area.

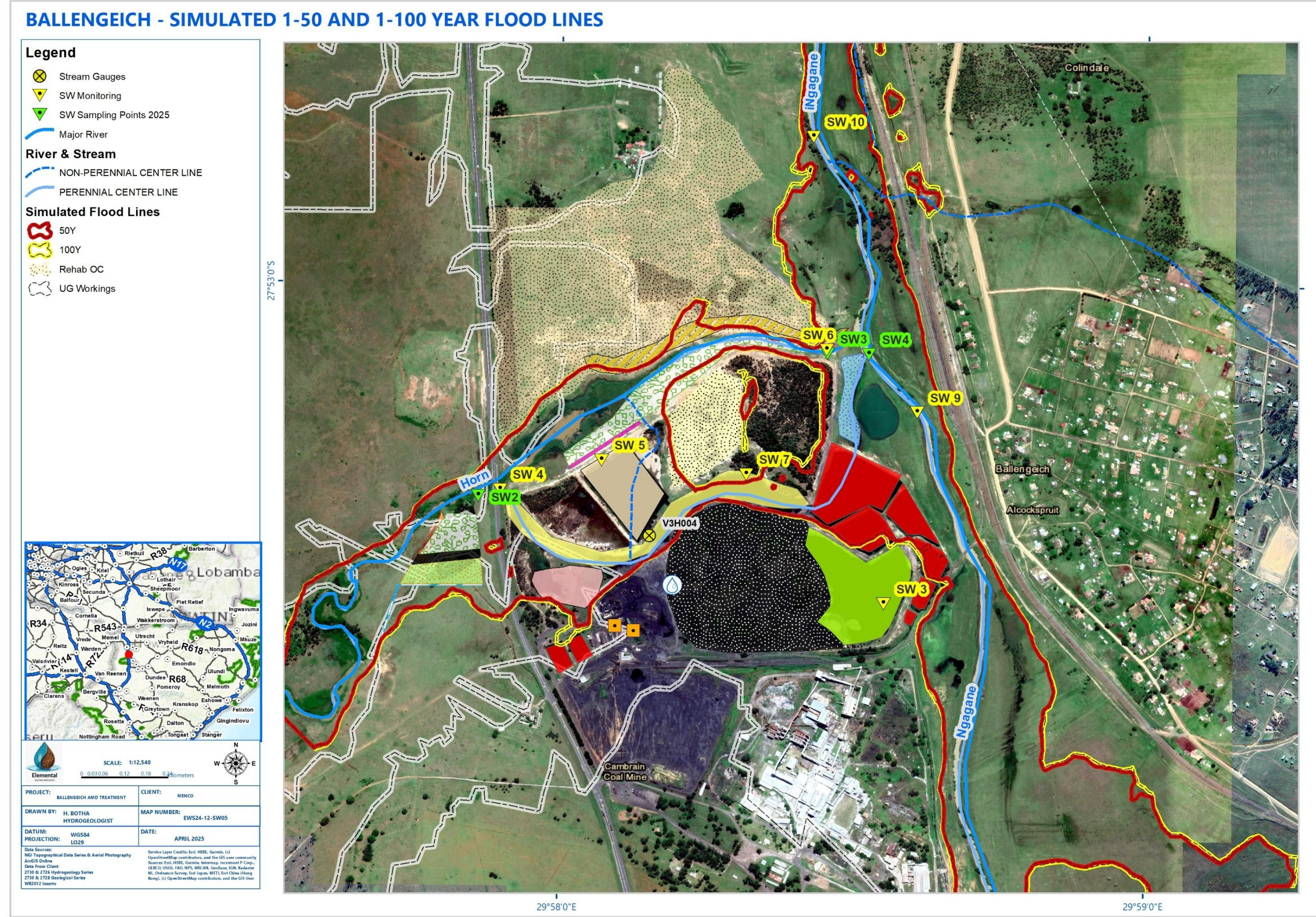


Figure 5-1: Simulated 1-50 and 1-100-year flood areas

6 WATER AND SALT BALANCE

The Water Balance modelling process commenced by utilising the hydro-meteorological assessment results to provide the hydrological inputs. Average volumes were calculated. Salt Balance calculations were undertaken by utilising surface water quality results and hydrological data from the hydro-meteorological investigation section.

6.1 Model boundaries

The model boundaries consist of sources and sinks and are summarised as follows:

- ✚ The Horn and Ingagane Rivers, as well as runoff into surface water dams, are the main input of new (clean) water into the water distribution system - source.
- ✚ Decant from the old underground workings – source.
- ✚ Evaporation – sink.
- ✚ Dust suppression – sink.
- ✚ Treatment and retention of water in the proposed treatment system – sink.
- ✚ Estimated runoff to the stormwater systems to various PCDs (sources) and runoff to the environment (i.e. uncaptured runoff) - sinks.

6.2 Water and salt inflows and outflows

Water and salt inflows and outflows for Ballengeich Mine are described in Table 6-1 and Table 6-2. The intention is to phase out the west decant sump as the semi-passive treatment system is developed and the treatment volumes increase over time.

Table 6-1: Water and salt inflows to process units at Ballengeich Mine

Process Units	Inflows
Discard Dump Area	From: Rainfall
Discard Dump Pit	From: Rainfall
	From: Discard Dump Pit
PCD 7	From: Shanduka Siding
	From: Rainfall
PCD 8	From: Shanduka Siding
	From: Rainfall
PCD 4a	From: Discard Dump Area
	From: Rainfall
PCD 4b	From: PCD 4a
	From: Rainfall
PCD 3	From: PCD 3
	From: Rainfall
PCD 2	From: PCD3
	From: Rainfall
PCD 1	From: PCD 6
	From: Rainfall
PCD 5	From: Discard Dump Area

Process Units	Inflows
	From: PCD 1
PCD 6	From: Discard Dump Area
	From: Rainfall
West Decant Sump (will be phased out as treatment system is rolled out)	From: Decant from old OC and UG Workings
	From: Rainfall
	From: PCD 5
Semi-Passive Treatment System	From: Rainfall
	From: Decant from old OC and UG Workings

Table 6-2: Water and salt outflows to process units at Ballengeich Mine

Process Units	Outflows
	To: Discard Dump Pit
Discard Dump Area	To: PCD 4a
	To: PCD 5
	To: PCD 6
Discard Dump Pit	To: Evaporation / Storage
PCD 7	To: Dust Suppression
	To: Evaporation / Storage
PCD 8	To: Dust Suppression
	To: Evaporation / Storage
PCD 4a	To: PCD 4b
	To: Evaporation / Storage
PCD 4b	To: PCD 3
	To: Evaporation / Storage
PCD 3	To: PCD 2
	To: Evaporation / Storage
PCD 2	To: PCD 1
	To: Evaporation / Storage
PCD 1	To: PCD 5
	To: Evaporation / Storage
	To: Ngagane River
PCD 5	To: West Decant Sump
	To: Evaporation
PCD 6	To: PCD 1
	To: Evaporation
West Decant Sump (will be phased out as treatment system is rolled out)	To: Horn River
	To: Transpiration / Storage
Semi-Passive Treatment System	To: Horn River

6.3 Water balance assumptions

The water balance calculations (i.e. recharge, infiltration, rainfall-runoff, and evaporation factors) are based on literature recharge characteristics which govern water recharge for opencast mining (Hodgson & Krantz, 1998).

Typical ranges applied in the water balance are presented in

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

Table 6-3.

The following additional assumptions pertain to the water balance calculations:

- ✚ Decant flow is estimated at ~200 l/min as input into the water balance. It is assumed that the semi-passive treatment system will be able to handle the full decant volume after it is established.
- ✚ It is assumed that the treated decant will conform to RQO Class III water quality, where SO_4 will be reduced to <500 mg/l – refer to (Bhekhani Pty Ltd, 2023).
- ✚ Rainfall-runoff from open areas is assumed to be 100% of the annual rainfall.
- ✚ Evaporation from various surfaces, dams and open-pit areas was calibrated to be fixed at 60% of the MAE. This is due to the lack of reliable on-site evaporation measurements (A-Pan or S-Pan).
- ✚ Surface runoff is assumed to be in the order of 95% of the annual rainfall (runoff coefficient of 0.95), and for larger catchments where no mining has taken place, in the order of 85%.

Table 6-3: 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

6.4 Calibration

There is no calibration data available for the Ballengeich Mine as there is currently no water reticulation data available. Generally, a calibration target of -10% to 10% is considered a well-calibrated water balance, and the inputs and outputs were balanced to achieve an error of <10%. The water balance does, however, remain conceptual due to the absence of calibration data.

6.5 Process flow diagram

Identified water use facilities and their associated inflows and outflows were incorporated into a process flow diagram (PFD). The PFD can be seen in Figure 6-1.

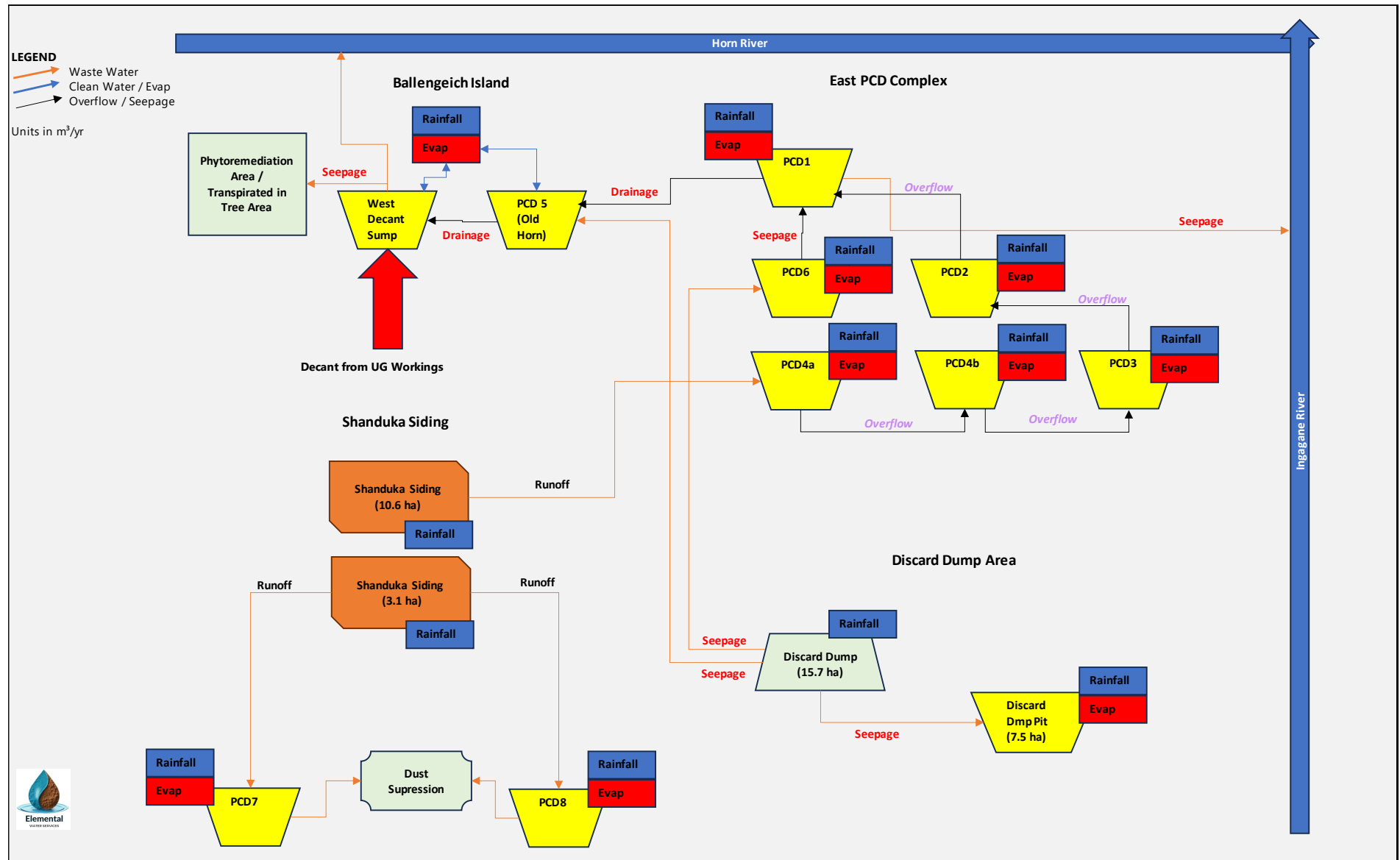


Figure 6-1: Ballengeich PFD

6.6 Water and salt balance results

The water balance is presented in Table 6-5, and the annual average salt balance is presented in Table 6-6. The water balance was developed by calculating the volumes of water that flow in and out of each component at the Ballengeich Mine. A simulation of water movement within the mine was carried out. The water balances indicate 333 994 m³/yr of water into/onto the mine.

The salt balance calculations commenced by utilizing average water balance results calculated in the water balance together with the results from the water quality assessment. Sulphate (SO₄) concentrations observed from the water monitoring points were adopted and used to represent salt content around the Ballengeich Mine. Sulphate concentrations were selected because this is a conservative salt and a good indicator of the impact of a coal mine and the impact of decant inflows on water quality. Sulphate concentrations applied to the salt balance are shown in Table 8-3.

An average of 1 22 859 kg/year 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. It was estimated that the semi-passive treatment system needs to remove about 515 440 kg/year to achieve the WQO <500 mg/l SO₄ for discharge into the Horn River. The reduced impact on the watercourse is estimated to be 41% if the semi-passive treatment system is implemented.

Table 6-4: Estimated Sulphate Concentrations around the Ballengeich Mine

Location	SO ₄ (mg/l)
Runoff/Seepage from Discard Dump	2500
Decant from Old Opencast Working	2800
Decant from Old Underground Workings	3640
Runoff from Shanduka Area	1200
Rainfall	2.5

Table 6-5: Average annual water balance

Facility Name	Water Circuit/stream	Quantity (m³/a) - IN	Water Circuit/stream	Quantity (m³/a) - OUT	Balance
Discard Dump	From: Rainfall & Runoff	52,705	To: PCD6	23,812	
	From: Discard Dump Area	6,547	To: Evaporation & Storage in Discard Dump	35,440	
	Total	59,252	Total	59,252	0
PCD7	From: Runoff from Shanduka Siding (3.1ha)	2,714	To: Evaporation	3,545	
	From: Rainfall	3,569	To: Dust Suppression	2,738	
	Total	6,283	Total	6,283	0
PCD8	From: Runoff from Shanduka Siding (3.1ha)	2,714	To: Evaporation	2,383	
	From: Rainfall	2,407	To: Dust Suppression	2,738	
	Total	5,121	Total	5,121	0
PCD4a	From: Runoff from Shanduka Siding (10.6 ha)	18,559	To: Overflow to PCD4b	22,204	
	From: Discard Dump Area	4,382	Evaporation/storage in PCD4a	1,650	
	From: Rainfall	913			
	Total	23,854	Total	23,854	0
PCD4b	From: Rainfall	3,154	To: Evaporation / Storage in PCD 4b	5,700	
	From: PCD4a	22,204	To: Overflow to PCD 3	19,658	
	Total	25,358	Total	25,358	0
PCD3	From: Rainfall	4,150	To: Evaporation / Storage in PCD 3	7,500	
	From: PCD 4b	19,658	To: Overflow to PCD2	16,308	
	Total	23,808	Total	23,808	0
PCD2	From: PCD 3	16,308	To: Evaporation / Storage in PCD 2	14,700	
	From: Rainfall	8,134	To: Overflow to PCD1	9,742	
	Total	24,442	Total	24,442	0
PCD1	From: PCD2	9,742	To: Seepage to Ngagane	0	
	From: Seepage from PCD6	39,627	To: Evaporation / Storage in PCD 1	14,355	
	From: Rainfall	8,134	To: Overflow to PCD5	43,148	
	Total	57,503	Total	57,503	0
PCD5	From: PCD1 Overflow	43,148	To: Evaporation / Storage in PCD 5	21,000	
	From: Discard Dump Area	9,854	To: West Decant Sump	43,622	
	From: Rainfall	11,620			

Facility Name	Water Circuit/stream	Quantity (m³/a) - IN	Water Circuit/stream	Quantity (m³/a) - OUT	Balance
	Total	64,622	Total	64,622	0
PCD6	From: Rainfall	10,375	To: Evaporation / Storage in PCD 1	39,627	
	From: Discard Dump Pit	35,440	To: Evaporation / Storage in PCD 6	6,188	
	Total	45,815	Total	45,815	0
West Decant Sump	From: PCD5	21,000	To: Transpiration and Seepage / Storage and Seepage in West Decant Sump	45,450	
	From: Rainfall	52,705	To: Transpiration and Seepage / Storage and Seepage in West Decant Sump	28,255	
	From: Decant from old OC & UG Workings	0			
	Total	73,705	Total	73,705	0
	From: Decant	164,153	To: Horn River	164,153	
Semi-Passive Treatment System					
	Total	164,153	Total	164,153	0
RED = Estimated, BLUE = Available Data	Total IN	573,916	Total Out	573,916	0
Per cent Error					0.00%

Table 6-6: Average annual salt balance

Facility Name	Water Circuit/stream	Annual sulphate salt load (kg/year)	Water Circuit/stream	Annual sulphate salt load (kg/year)	Balance
Discard Dump	From: Rainfall & Runoff	132	To: PCD6	7,988	
	From: Discard Dump Area	7,856	To: Evaporation & Storage in Discard Dump	0	
	Total	7,988	Total	7,988	0
PCD7	From: Runoff from Shanduka Siding (3.1ha)	3,257	To: Evaporation	0	
	From: Rainfall	9	To: Dust Suppression	3,266	
	Total	3,266	Total	3,266	0
PCD8	From: Runoff from Shanduka Siding (3.1ha)	3,257	To: Evaporation	0	
	From: Rainfall	6	To: Dust Suppression	3,263	
	Total	3,263	Total	3,263	0
PCD4a	From: Runoff from Shanduka Siding (10.6 ha)	22,271	To: Overflow to PCD4b	29,103	
	From: Discard Dump Area	10,955	Evaporation/storage in PCD4a	4,125	
	From: Rainfall	2			
	Total	33,228	Total	33,228	0
PCD4b	From: Rainfall	8	To: Evaporation / Storage in PCD 4b	6,373	
	From: PCD4a	55,510	To: Overflow to PCD 3	49,145	
	Total	55,518	Total	55,518	0
PCD3	From: Rainfall	10	To: Evaporation / Storage in PCD 3	8,385	
	From: PCD 4b	49,145	To: Overflow to PCD2	40,770	
	Total	49,155	Total	49,155	0
PCD2	From: PCD 3	61,085	To: Evaporation / Storage in PCD 2	36,750	
	From: Rainfall	20	To: Overflow to PCD1	24,355	
	Total	61,105	Total	61,105	0
PCD1	From: PCD2	24,355	To: Seepage to Ngagane	0	
	From: Seepage from PCD6	119,382	To: Evaporation / Storage in PCD 1	35,888	
	From: Rainfall	20	To: Overflow to PCD5	107,870	
	Total	143,758	Total	143,758	0
PCD5	From: PCD1 Overflow	107,870	To: Evaporation / Storage in PCD 5	52,500	
	From: Discard Dump Area	24,635	To: West Decant Sump	80,034	

Facility Name	Water Circuit/stream	Annual sulphate salt load (kg/year)	Water Circuit/stream	Annual sulphate salt load (kg/year)	Balance
	From: Rainfall	29			
	Total	132,534	Total	132,534	0
PCD6	From: Rainfall	26	To: Evaporation / Storage in PCD 1	39,627	
	From: Discard Dump Pit	88,600	To: Evaporation / Storage in PCD 6	48,999	
	Total	88,626	Total	88,626	0
West Decant Sump	From: PCD5	52,500	To: Transpiration and Seepage / Storage and Seepage in West Decant Sump	24,377	
	From: Rainfall	132	To: Transpiration and Seepage / Storage and Seepage in West Decant Sump	28,255	
	From: Decant from old OC & UG Workings	0			
	Total	52,632	Total	52,632	0
Semi-Passive Treatment System	From: Decant	597,517	To: Horn River	82,077	
	Total	597,517	Total	82,077	515,440
RED = Estimated, BLUE = Available Data	Total IN	1,228,589	Total Out	713,149	515,440
Per cent Error					41.95%

7 HYDROLOGICAL IMPACT AND RISK 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 7-1

Table 7-1: 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 7-2 to Table 7-3. The risks were evaluated in the context of the hydrological setting, as well as existing impacts and predicted impacts.

7.1 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 7-2):

- ✚ 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.

7.2 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 7-3):

- ✚ 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.

7.3 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. The flood modelling suggests that the Ballengeich Mine is situated within a 1–100-year flood area. Therefore, proper flooding protocols and erosion prevention measures should be implemented.

7.4 Cumulative impacts and impacts on the hydrological cycle

There is an existing groundwater impact and surface water impact associated with the Ballengeich Mine. The status is predicted to improve after rolling out of the treatment system. Thus far, and based on surface water quality and quantity data for the existing setting, the impact on the hydrological cycle appears to be marginal.

Limited operational phases exist, and the impact on the hydrological cycle will be marginal due to the Project Type. The tables below consider the mentioned cumulative impacts in the impact rating.

Table 7-2: 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 7-3: 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)

8 SURFACE WATER MONITORING

There are surface water monitoring points at Ballengeich, and quarterly water monitoring takes place by contractors as appointed by Kangra Coal (Pty) Ltd. No surface water monitoring gaps were identified, and the existing monitoring network is considered adequate.

No further improvements for the already established surface water monitoring system are proposed. The water monitoring should continue for at least 5 years after the closure of the Ballengeich Mine to confirm closure water quality trends and closure objectives.

9 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.
- ✚ Flood analysis was undertaken for the Horn and Ingagane rivers (refer to Section 5):
 - The major rivers are prone to flooding due to the flatter topography. Drainage lines associated with valleys are less susceptible to cause flood inundation, and limited flooding is predicted and generally associated with the valleys. The entire Ballengeich operations are situated in the 1–100-year flood line and a GN704 exception in terms of the National Water Act (NWA) of 1998 (Act No. 36 of 1998).
- ✚ A water and coupled salt balance was developed for the mine (refer to Section 6):
 - The water balance was developed by calculating the volumes of water that flow in and out of each component at the Ballengeich Mine. A simulation of water movement within the mine was carried out. The water balances indicate 333 994 m³/yr of water into/onto the mine.
 - An average of 1 22 859 kg/year 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. It was estimated that the semi-passive treatment system needs to remove about 515 440 kg/year to achieve the WQO <500 mg/l SO₄ for discharge into the Horn River. The reduced impact on the watercourse is estimated to be 41% if the semi-passive treatment system is implemented.

- ✚ EC and pH stream profiles were completed on the Horn and Ingagane Rivers (refer to Section 4.4). 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. Surface water can be classified as water influenced by active ion exchange.
- ✚ A hydrological risk assessment is available in Section 7, where site-specific and regional cumulative impacts have been assessed. The hydrological risks associated with the construction phase of the proposed Project range from moderate to high and reduced to low after mitigation is considered. The operational phase risks are marginal, and the proposed semi-passive treatment system aims to improve the environmental status of the Horn and Ingagane Rivers.

9.1 Mitigation measures for inclusion in the EMPr

The following mitigation measures can be implemented as part of the EMPr to further reduce the risk of flooding on site and contribute to stormwater generation potential (mainly **construction phase** focused):

Assess the site constraints and any site-specific concerns, including:

- ✚ Specific vegetation that may need to be identified and/or isolated from the site disturbance.
- ✚ The type of construction should consider landform. Avoid slab-on-ground construction on steep sites.
- ✚ Up-slope drainage catchments that may need to be diverted around the work site.
- ✚ Workspace limitations may require site-specific sediment control measures and/or the extensive use of skips or bins for material storage and waste management.
- ✚ Expected rainfall intensity during the period of disturbance (wet season vs dry season).
- ✚ Stabilise the site entry/exiting points:
 - ✚ A stabilised site access must be established and, if possible, limited to one point only. The access allows for construction vehicles to enter the work area while preventing the unnecessary tracking of sediment onto the nearby environment from multiple locations. A stabilised entry/exit point normally consists of a stabilised rock pad.

Prevent erosion & manage stockpiles:

- ✚ Suitable material storage areas must be located up-slope of the main sediment barrier (e.g., sediment fence).

- ✚ On steep sites and sites with limited available space, erodible materials may need to be stored in commercial-sized bins or mini-skips before use.

Manage site waste:

- ✚ Adequate waste containers must be provided on-site and maintained in a way that potential and actual environmental harm resulting from such material waste is minimised.
- ✚ Building activities must be carried out on a pervious surface, such as grass or open soil, or in such a manner that all sediment-laden run-off is prevented from discharging into a water body.

The following mitigation measures can be considered during the lifecycle of the Project:

- ✚ Use sediment barriers to control sediment run-off as required (e.g., sediment fences).
- ✚ Re-vegetate pastures and disturbed land areas as required to buffer against sedimentation and erosion.
- ✚ Install flood barriers and flood diversion berms to prevent flooding of the artificial wetland areas as well as the remainder of the Ballengeich operations.
- ✚ Have fuel/oil spill cleanup kits on site.

9.2 Identification of any areas that should be avoided

A moderate to low probability of erosion of the banks of the rivers/streams associated with the project area is anticipated. The 1:100-year flood line should be considered an avoidance area (buffer area). Proper flooding protocols and erosion prevention measures should be implemented.

9.3 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.

10 BIBLIOGRAPHY

- Adamson, P., 1981. *Southern African Storm Rainfall: Technical Report TR102*, Pretoria: Department of Environmental Affairs.
- Alexander, J., 2002. The Standard Design Flood. *South African Institution of Engineers*, pp. 26-30.
- 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.
- 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: s.n.
- 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.
- Campbell, .. W. A. M. B., 1986. *Evaluation of flood estimation methods- Phase II: An evaluation of hydrological techniques for making flood estimations on small unguaged catchments*, Pretoria: Water Research Commission.
- 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, 2006b. *Best Practice Guideline G2: Water and Salt Balances*, Pretoria: Department of Water Affairs and Forestry.
- DWAF, 2006. *Best Practice Guideline G2: Water and Salt Balances*, South Africa: Department of Water Affairs and Forestry.
- 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.
- ESRI, 2024. *ArcView 10.8.2*, s.l.: Environmental Systems Research Institute, California.
- European Commission, 2015. *Guidance document on the application of water balances for supporting the implementation of the WFD. Technical Report - 2015 - 090. Final – Version 6.1 – 18/05/2015*, 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/>.
- 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.
- Hodgson, F. & Krantz, R., 1998. *Groundwater Quality Deterioration in the Olifants River Catchment Above the Loskop Dam with Specialised Investigation in the Witbank Dam Sub-Catchment*. WRC Report No 291-1-98 , s.l.: s.n.
- Hughes, D. A. & Hannart, P., 2003. A desktop model used to provide an initial estimate of the ecological instream flow requirements of rivers in South Africa.. *J. Hydrol* 270 (3-4), pp. 167-181.
- JAXA, 2025. *Advanced Land Observation Satellite (ALOS) Global Digital Surface Model (DSM)*, Tokyo: Earth Observation Research Center (EORC), Japan Aerospace Exploration Agency (JAXA).

- King, G., Maritz, E. & 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.
- SANRAL, 2013. *South African Drainage Manual*. Pretoria: South African National Road Agency.
- 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>.
- US Army Corps of Engineers, 2016. *HEC RAS Hydraulic Modelling Software. Version 5.0*. California: s.n.
- 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: PEAK FLOW CALCULATIONS

HRU01

RATIONAL METHOD 3							
Description of catchment		HRU01					
River detail		Refer to Report					
Calculated by		Hendrik Botha			Date	Tuesday, 22 April 2025	
Physical characteristics							
Size of catchment (A)	880.21	km ²		Rainfall region		V3B	
Longest watercourse (L)	47.9	km		Area distribution factors			
Average slope (S _{av})	0.0020	m/m		Rural (α)	Urban (β)	Lakes (γ)	
Dolomite area (D%)	0	%		1	0	0	
Mean annual rainfall(MAR)	739.19	mm					
Rural				URBAN			
Surface slope	%	Factor	C _s	Description	%	Factor	C2
Vleis and pans (<3%)	22.57	0.03	0.68	Lawns			
Flat areas (3 - 10%)	46.77	0.08	3.74	Sandy,flat<2%	0	0.08	0
Hilly (10 - 30%)	20.70	0.16	3.31	Sandy,steep>7%	0	0.16	0
Steep Areas (>30%)	10.58	0.26	2.75	Heavy s,flat<2%	0	0.15	0
Total	100.62	0.53	10.48	Heavy s,steep>7%	0	0.3	0
Permeability	%	Factor	C _p	Residential Areas			
Very permeable	80	0.04	3.20	Houses	0	0.5	0
Permeable	20	0.08	1.60	Flats	0	0.6	0
Semi-permeable	0	0.16	0.00	Industry			
Impermeable	0	0.26	0.00	Light industry	0	0.6	0
Total	100	0.54	4.80	Heavy industry	0	0.7	0
Vegetation	%	Factor	C _v	Business			
Thick bush & plantation	11.38	0.04	0.46	City centre	0	0.8	0
Light bush & farm-lands	24.6	0.11	2.71	Suburban	0	0.65	0
Grasslands	59.55	0.21	12.51	Streets	0	0.75	0
No vegetation	4.46	0.25	1.12	Max flood	0	1	0
Total	99.99	0.61	16.78	Total (C2)	0		0
Time of concentration (TC)							
Overland flow		Defined watercourse			Use Defined watercourse		
$T_C = 0.604 \left(\frac{rL}{\sqrt{S_{av}}} \right)^{0.467}$		$T_c = \left[\frac{0.87 L^2}{1000 S_{AV}} \right]^{0.385}$					
10.236	hours	14.278	hours				
Run-off coefficient							
Return Period (years)	2	5	10	20	50	100	PMF
Run-off coefficient, C ₁	0.321	0.321	0.321	0.321	0.321	0.321	0.900
Adjusted for dolomitic areas, C _{1D}	0.321	0.321	0.321	0.321	0.321	0.321	0.900
Adj factor for initial saturation, F _t	0.5	0.55	0.6	0.67	0.83	1	1.00
Adjusted run - off coefficient, C _{1T}	0.160316	0.1763476	0.1923792	0.215	0.266	0.321	0.900
Combined run - off coefficient, C _T	0.160316	0.1763476	0.1923792	0.215	0.266	0.321	0.900
Rainfall							
Return Period (years)	2	5	10	20	50	100	PMF
Point rainfall (mm), P _T	76.19	101.82	119.51	137.01	161.23	179.72	199.33
Point Intensity (mm/h), P _{it}	5.34	7.13	8.37	9.60	11.29	12.59	13.96
Area reduction factor (%),ARF _T	0.865	0.865	0.865	0.865	0.865	0.865	0.865
Average intensity (mm/hour),I _T	4.616	6.169	7.241	8.300	9.768	10.888	12.076
Return Period (years)	2	5	10	20	50	100	PMF
Peak flow (m3/s)	180.931	265.975	340.578	435.983	635.567	853.58	2657.35

STANDARD DESIGN FLOOD (SDF) METHOD								
Description of catchment		HRU01						
River detail		Refer to Report						
Calculated by		Hendrik Botha			Date	2025/04/22		
Physical characteristics								
Size of catchment (A)	880.21	km ²		Days of thunder per year (R)		17	days	
Longest watercourse (L)	47.9	km		Time of concentration, t		856.698	minutes	
Average slope (S _{av})	0.002	m/m		Time of concentration, T _c	$T_c = \left[\frac{0.87 L^2}{1000 S_{AV}} \right]^{0.385}$	14.2783		
SDF Basin	26							
2-year return period rainfall (M)	61	mm						
TR102 n-day rainfall data								
Weather Service Station		BALLENLEICH			MAP		739.1927333	mm
Weather Service Station no.		0370834_W			Coordinates			
Duration		Return Period (years)						
		2	5	10	20	50	100	200
Rainfall								
Return Period (years), T		2	5	10	20	50	100	200
Point precipitation depth (mm) P _{L,T}		39.2	66.2	86.6	107.0	134.0	154.3	174.7
Area reduction factor (%),ARF _T		0.865	0.865	0.865	0.865	0.865	0.865	0.865
Average intensity (mm/hour),I _T		2.4	4.0	5.2	6.5	8.1	9.4	10.6
Run-off coefficient								
Calibration factors	C ₂ (%)	15		C ₁₀₀ (%)		50		
Return Period (years), T		2	5	10	20	50	100	200
Return period factors (Y _T)		0	0.84	1.28	1.64	2.05	2.33	2.58
Run-off coefficient, C _T		0.150	0.276	0.342	0.396	0.458	0.500	0.538
Peak flow (m3/s)		87.20	270.85	439.07	628.18	908.68	1143.19	1391.45

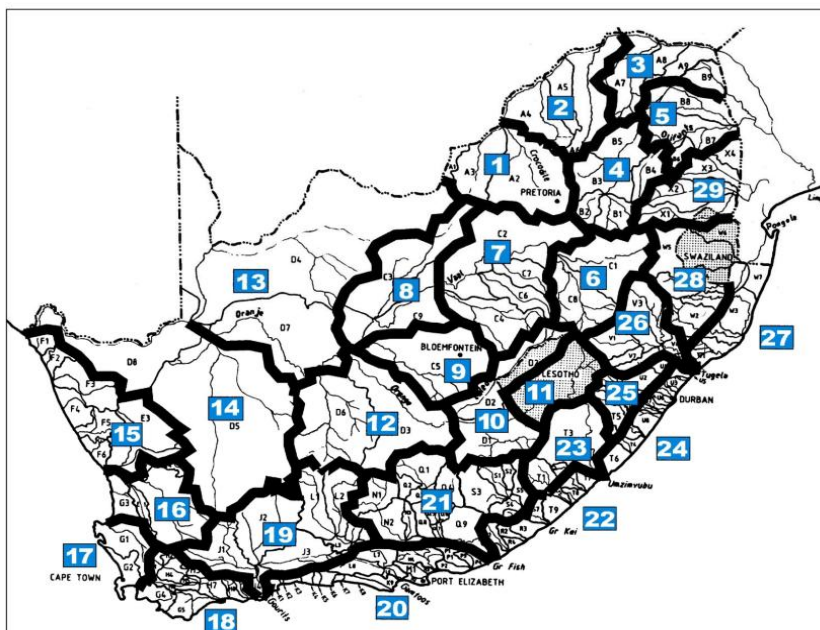
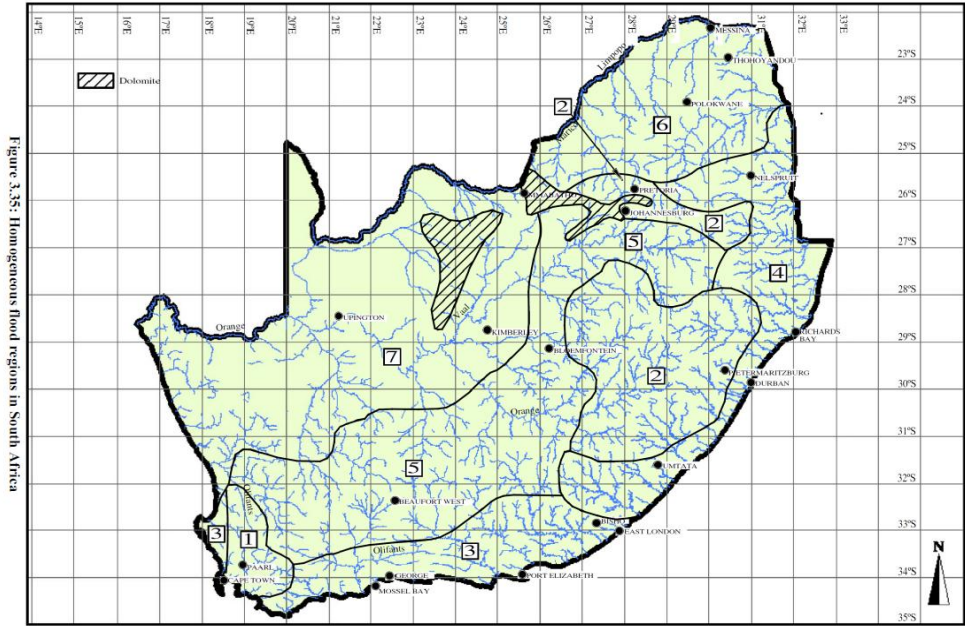


Figure 3.30: Standard Design Flood drainage basins

MIDGLEY & PITMAN (MIPI) METHOD														
River Detail	Catchment Area	MAP	S	L	Lc	Constant K_T				Catchment Paramete	Peak Flows			
	(km ²)	(mm)	m/m	km	km	1:10 year	1:20 Year	1: 50 year	1: 100 year	(Dimensionless)	1:10 year	1:20 Year	1: 50 year	1: 100 year
HRU01	880.21	739	0.0020	47.9	21.7	0.83	1.04	1.36	1.6	0.0379	702.41	880.13	1150.94	1354.04



HRU02

RATIONAL METHOD 3							
Description of catchment		HRU02					
River detail		Refer to Report					
Calculated by		Hendrik Botha			Date	Tuesday, 22 April 2025	
Physical characteristics							
Size of catchment (A)	198.59	km ²	Rainfall region			V3B	
Longest watercourse (L)	6.41	km	Area distribution factors				
Average slope (S _{av})	0.0018	m/m	Rural (α)	Urban (β)	Lakes (γ)		
Dolomite area (D%)	0	%	1	0	0		
Mean annual rainfall(MAR)	739.19	mm					
Rural			URBAN				
Surface slope	%	Factor	C _s	Description	%	Factor	C ₂
Vleis and pans (<3%)	21.23	0.03	0.64	Lawns			
Flat areas (3 - 10%)	65.62	0.08	5.25	Sandy,flat<2%	0	0.08	0
Hilly (10 - 30%)	12.61	0.16	2.02	Sandy,steep>7%	0	0.16	0
Steep Areas (>30%)	0.53	0.26	0.14	Heavy s,flat<2%	0	0.15	0
Total	99.99	0.53	8.04	Heavy s,steep>7%	0	0.3	0
Permeability	%	Factor	C _p	Residential Areas			
Very permeable	80	0.04	3.20	Houses	0	0.5	0
Permeable	20	0.08	1.60	Flats	0	0.6	0
Semi-permeable	0	0.16	0.00	Industry			
Impermeable	0	0.26	0.00	Light industry	0	0.6	0
Total	100	0.54	4.80	Heavy industry	0	0.7	0
Vegetation	%	Factor	C _v	Business			
Thick bush & plantation	1.24	0.04	0.05	City centre	0	0.8	0
Light bush & farm-lands	21.46	0.11	2.36	Suburban	0	0.65	0
Grasslands	70.56	0.21	14.82	Streets	0	0.75	0
No vegetation	6.73	0.25	1.68	Max flood	0	1	0
Total	99.99	0.61	18.91	Total (C ₂)	0		0
Time of concentration (TC)							
Overland flow		Defined watercourse			Use Defined watercourse		
$T_c = 0.604 \left(\frac{rL}{\sqrt{S_{av}}} \right)^{0.467}$		$T_c = \left[\frac{0.87 L^2}{1000 S_{AV}} \right]^{0.385}$					
4.101	hours	3.160	hours				
Run-off coefficient							
Return Period (years)	2	5	10	20	50	100	PMF
Run-off coefficient, C ₁	0.318	0.318	0.318	0.318	0.318	0.318	0.900
Adjusted for dolomitic areas, C _{1D}	0.318	0.318	0.318	0.318	0.318	0.318	0.900
Adj factor for initial saturation, F _i	0.5	0.55	0.6	0.67	0.83	1	1.00
Adjusted run - off coefficient, C _{1T}	0.158761	0.1746371	0.1905132	0.213	0.264	0.318	0.900
Combined run - off coefficient, C _T	0.158761	0.1746371	0.1905132	0.213	0.264	0.318	0.900
Rainfall							
Return Period (years)	2	5	10	20	50	100	PMF
Point rainfall (mm), P _T	61.41	82.01	96.29	110.46	129.86	144.83	160.61
Point Intensity (mm/h), P _{it}	19.43	25.95	30.47	34.95	41.09	45.83	50.82
Area reduction factor (%),ARF _T	0.886	0.886	0.886	0.886	0.886	0.886	0.886
Average intensity (mm/hour),I _T	17.211	22.986	26.986	30.958	36.395	40.591	45.014
Return Period (years)	2	5	10	20	50	100	PMF
Peak flow (m3/s)	150.731	221.442	283.607	363.304	529.115	710.98	2234.83

STANDARD DESIGN FLOOD (SDF) METHOD								
Description of catchment		HRU02						
River detail		Refer to Report						
Calculated by		Hendrik Botha			Date	2025/04/22		
Physical characteristics								
Size of catchment (A)	198.59	km ²		Days of thunder per year (R)		17	days	
Longest watercourse (L)	6.41	km		Time of concentration, t		189.612	minutes	
Average slope (S _{av})	0.002	m/m		Time of concentration, T _c	$T_c = \left[\frac{0.87 L^2}{1000 S_{AV}} \right]^{0.385}$		3.1602	
SDF Basin	26							
2-year return period rainfall (M)	61	mm						
TR102 n-day rainfall data								
Weather Service Station		BALLENLEICH			MAP		739.1927333	mm
Weather Service Station no.		0370834_W			Coordinates			
Duration		Return Period (years)						
		2	5	10	20	50	100	200
Rainfall								
Return Period (years), T	2	5	10	20	50	100	200	
Point precipitation depth (mm) P _{L,T}	29.9	50.5	66.0	81.6	102.1	117.7	133.2	
Area reduction factor (%),ARF _T	0.886	0.886	0.886	0.886	0.886	0.886	0.886	
Average intensity (mm/hour),I _T	8.4	14.1	18.5	22.9	28.6	33.0	37.3	
Run-off coefficient								
Calibration factors	C ₂ (%)	15		C ₁₀₀ (%)		50		
Return Period (years), T	2	5	10	20	50	100	200	
Return period factors (Y _T)	0	0.84	1.28	1.64	2.05	2.33	2.58	
Run-off coefficient, C _T	0.150	0.276	0.342	0.396	0.458	0.500	0.538	
Peak flow (m3/s)	69.38	215.51	349.36	499.83	723.02	909.62	1107.15	

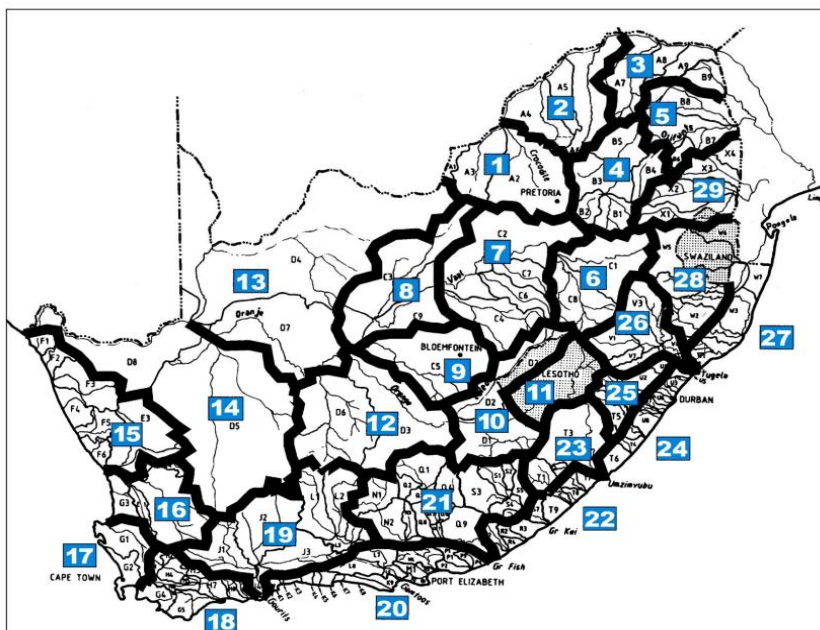
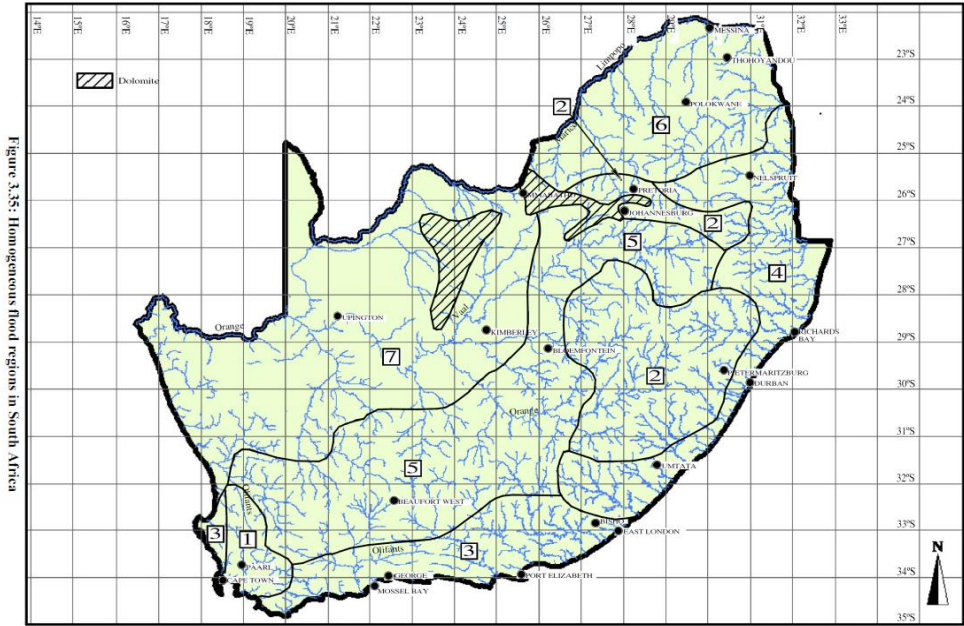


Figure 3.30: Standard Design Flood drainage basins

MIDGLEY & PITMAN (MIPI) METHOD														
River Detail	Catchment Area	MAP	S	L	Lc	Constant K_T				Catchment Paramete	Peak Flows			
	(km ²)	(mm)	m/m	km	km	1:10 year	1:20 Year	1: 50 year	1: 100 year	(Dimensionless)	1:10 year	1:20 Year	1: 50 year	1: 100 year
HRU02	198.59	739	0.0018	6.41	9.15	0.83	1.04	1.36	1.6	0.1437	375.33	470.29	615.00	723.53



HRU03

RATIONAL METHOD 3							
Description of catchment		HRU03					
River detail		Refer to Report					
Calculated by		Hendrik Botha			Date	Tuesday, 22 April 2025	
Physical characteristics							
Size of catchment (A)	155.61	km ²		Rainfall region		V3B	
Longest watercourse (L)	17.48	km		Area distribution factors			
Average slope (S _{av})	0.0060	m/m		Rural (α)	Urban (β)	Lakes (γ)	
Dolomite area (D%)	0	%		1	0	0	
Mean annual rainfall(MAR)	739.19	mm					
Rural				URBAN			
Surface slope	%	Factor	C _s	Description	%	Factor	C2
Vleis and pans (<3%)	21.33	0.03	0.64	Lawns			
Flat areas (3 - 10%)	48.00	0.08	3.84	Sandy,flat<2%	0	0.08	0
Hilly (10 - 30%)	22.12	0.16	3.54	Sandy,steep>7%	0	0.16	0
Steep Areas (>30%)	8.55	0.26	2.22	Heavy s,flat<2%	0	0.15	0
Total	100.00	0.53	10.24	Heavy s,steep>7%	0	0.3	0
Permeability	%	Factor	C _p	Residential Areas			
Very permeable	80	0.04	3.20	Houses	0	0.5	0
Permeable	20	0.08	1.60	Flats	0	0.6	0
Semi-permeable	0	0.16	0.00	Industry			
Impermeable	0	0.26	0.00	Light industry	0	0.6	0
Total	100	0.54	4.80	Heavy industry	0	0.7	0
Vegetation	%	Factor	C _v	Business			
Thick bush & plantation	22.88	0.04	0.92	City centre	0	0.8	0
Light bush & farm-lands	24.98	0.11	2.75	Suburban	0	0.65	0
Grasslands	49.24	0.21	10.34	Streets	0	0.75	0
No vegetation	2.9	0.25	0.73	Max flood	0	1	0
Total	100	0.61	14.73	Total (C2)	0		0
Time of concentration (TC)							
Overland flow		Defined watercourse			Use Defined watercourse		
$T_C = 0.604 \left(\frac{rL}{\sqrt{S_{av}}} \right)^{0.467}$		$T_c = \left[\frac{0.87 L^2}{1000 S_{AV}} \right]^{0.385}$					
4.946	hours	4.304	hours				
Run-off coefficient							
Return Period (years)	2	5	10	20	50	100	PMF
Run-off coefficient, C ₁	0.298	0.298	0.298	0.298	0.298	0.298	0.900
Adjusted for dolomitic areas, C _{1D}	0.298	0.298	0.298	0.298	0.298	0.298	0.900
Adj factor for initial saturation, F _t	0.5	0.55	0.6	0.67	0.83	1	1.00
Adjusted run - off coefficient, C _{1T}	0.1488525	0.16373775	0.178623	0.199	0.247	0.298	0.900
Combined run - off coefficient, C _T	0.1488525	0.16373775	0.178623	0.199	0.247	0.298	0.900
Rainfall							
Return Period (years)	2	5	10	20	50	100	PMF
Point rainfall (mm), P _T	63.99	85.48	100.34	115.10	135.35	150.91	167.37
Point Intensity (mm/h), P _{it}	14.87	19.86	23.31	26.74	31.45	35.06	38.89
Area reduction factor (%),ARF _T	0.915	0.915	0.915	0.915	0.915	0.915	0.915
Average intensity (mm/hour),I _T	13.596	18.163	21.321	24.458	28.760	32.067	35.563
Return Period (years)	2	5	10	20	50	100	PMF
Peak flow (m3/s)	87.479	128.550	164.620	210.870	307.175	412.64	1383.51

STANDARD DESIGN FLOOD (SDF) METHOD								
Description of catchment		HRU03						
River detail		Refer to Report						
Calculated by		Hendrik Botha			Date	2025/04/22		
Physical characteristics								
Size of catchment (A)	155.61	km ²		Days of thunder per year (R)		17	days	
Longest watercourse (L)	17.48	km		Time of concentration, t		258.247	minutes	
Average slope (S _{av})	0.006	m/m		Time of concentration, T _c	$T_c = \left[\frac{0.87 L^2}{1000 S_{AV}} \right]^{0.385}$		4.3041	
SDF Basin	26							
2-year return period rainfall (M)	61	mm						
TR102 n-day rainfall data								
Weather Service Station		BALLENLEICH			MAP		739.1927333	mm
Weather Service Station no.		0370834_W			Coordinates			
Duration		Return Period (years)						
		2	5	10	20	50	100	200
Rainfall								
Return Period (years), T	2	5	10	20	50	100	200	
Point precipitation depth (mm) P _{L,T}	31.8	53.7	70.2	86.8	108.6	125.2	141.7	
Area reduction factor (%),ARF _T	0.915	0.915	0.915	0.915	0.915	0.915	0.915	
Average intensity (mm/hour),I _T	6.8	11.4	14.9	18.4	23.1	26.6	30.1	
Run-off coefficient								
Calibration factors	C ₂ (%)	15		C ₁₀₀ (%)		50		
Return Period (years), T	2	5	10	20	50	100	200	
Return period factors (Y _T)	0	0.84	1.28	1.64	2.05	2.33	2.58	
Run-off coefficient, C _T	0.150	0.276	0.342	0.396	0.458	0.500	0.538	
Peak flow (m3/s)	43.85	136.20	220.79	315.89	456.95	574.88	699.72	

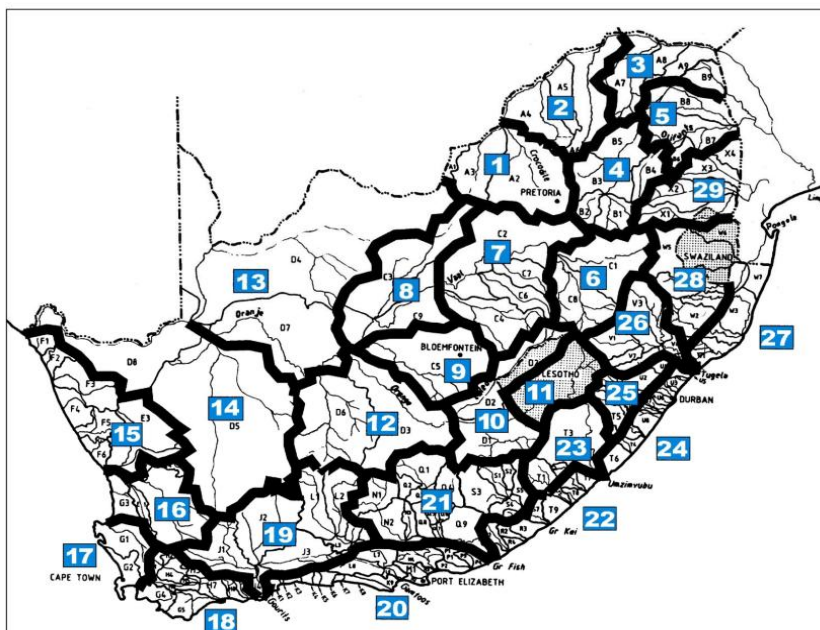
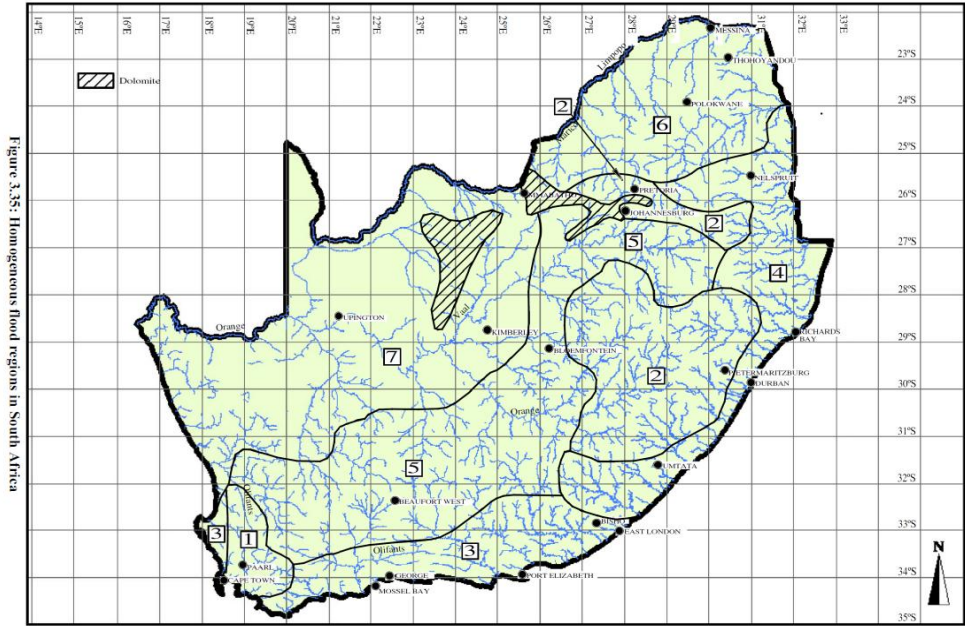


Figure 3.30: Standard Design Flood drainage basins

MIDGLEY & PITMAN (MIPI) METHOD														
River Detail	Catchment Area	MAP	S	L	Lc	Constant K _T				Catchment Paramete	Peak Flows			
	(km ²)	(mm)	m/m	km	km	1:10 year	1:20 Year	1: 50 year	1: 100 year	(Dimensionless)	1:10 year	1:20 Year	1: 50 year	1: 100 year
HRU03	155.61	739	0.0060	17.5	15.21	0.83	1.04	1.36	1.6	0.0453	257.45	322.58	421.84	496.28



HRU04

RATIONAL METHOD 3							
Description of catchment		HRU04					
River detail	Refer to Report						
Calculated by	Hendrik Botha				Date	Tuesday, 22 April 2025	
Physical characteristics							
Size of catchment (A)	1.97	km ²		Rainfall region		V3B	
Longest watercourse (L)	2.32	km		Area distribution factors			
Average slope (S _{av})	0.0004	m/m		Rural (α)	Urban (β)	Lakes (γ)	
Dolomite area (D%)	0	%		1	0	0	
Mean annual rainfall(MAR)	739.19	mm					
Rural				URBAN			
Surface slope	%	Factor	C _s	Description	%	Factor	C2
Vleis and pans (<3%)	29.66	0.03	0.89	Lawns			
Flat areas (3 - 10%)	62.38	0.08	4.99	Sandy,flat<2%	0	0.08	0
Hilly (10 - 30%)	7.65	0.16	1.22	Sandy,steep>7%	0	0.16	0
Steep Areas (>30%)	0.30	0.26	0.08	Heavy s,flat<2%	0	0.15	0
Total	99.99	0.53	7.18	Heavy s,steep>7%	0	0.3	0
Permeability	%	Factor	C _p	Residential Areas			
Very permeable	80	0.04	3.20	Houses	0	0.5	0
Permeable	20	0.08	1.60	Flats	0	0.6	0
Semi-permeable	0	0.16	0.00	Industry			
Impermeable	0	0.26	0.00	Light industry	0	0.6	0
Total	100	0.54	4.80	Heavy industry	0	0.7	0
Vegetation	%	Factor	C _v	Business			
Thick bush & plantation	0.16	0.04	0.01	City centre	0	0.8	0
Light bush & farm-lands	26.5	0.11	2.92	Suburban	0	0.65	0
Grasslands	23.67	0.21	4.97	Streets	0	0.75	0
No vegetation	49.67	0.25	12.42	Max flood	0	1	0
Total	100	0.61	20.31	Total (C2)	0		0
Time of concentration (TC)							
Overland flow		Defined watercourse		Use Defined watercourse			
$T_c = 0.604 \left(\frac{rL}{\sqrt{S_{av}}} \right)^{0.467}$		$T_c = \left[\frac{0.87 L^2}{1000 S_{AV}} \right]^{0.385}$					
3.625	hours	2.578	hours				
Run-off coefficient							
Return Period (years)	2	5	10	20	50	100	PMF
Run-off coefficient, C ₁	0.323	0.323	0.323	0.323	0.323	0.323	0.900
Adjusted for dolomitic areas, C _{1D}	0.323	0.323	0.323	0.323	0.323	0.323	0.900
Adj factor for initial saturation, F _i	0.5	0.55	0.6	0.67	0.83	1	1.00
Adjusted run - off coefficient, C _{1T}	0.161459	0.1776049	0.1937508	0.216	0.268	0.323	0.900
Combined run - off coefficient, C _T	0.161459	0.1776049	0.1937508	0.216	0.268	0.323	0.900
Rainfall							
Return Period (years)	2	5	10	20	50	100	PMF
Point rainfall (mm), P _T	59.37	79.29	93.10	106.79	125.56	140.03	155.28
Point Intensity (mm/h), P _{It}	23.03	30.75	36.11	41.42	48.70	54.31	60.22
Area reduction factor (%),ARF _T	1.114	1.114	1.114	1.114	1.114	1.114	1.114
Average intensity (mm/hour),I _T	25.645	34.248	40.211	46.123	54.232	60.482	67.068
Return Period (years)	2	5	10	20	50	100	PMF
Peak flow (m3/s)	2.266	3.329	4.263	5.461	7.954	10.69	33.03

STANDARD DESIGN FLOOD (SDF) METHOD								
Description of catchment		HRU04						
River detail		Refer to Report						
Calculated by		Hendrik Botha			Date	2025/04/22		
Physical characteristics								
Size of catchment (A)	1.97	km ²		Days of thunder per year (R)		17	days	
Longest watercourse (L)	2.32	km		Time of concentration, t		154.703	minutes	
Average slope (S _{av})	0.000	m/m		Time of concentration, T _c	$T_c = \left[\frac{0.87 L^2}{1000 S_{AV}} \right]^{0.385}$		2.5784	
SDF Basin	26							
2-year return period rainfall (M)	61	mm						
TR102 n-day rainfall data								
Weather Service Station		BALLENGLEICH			MAP		739.1927333	mm
Weather Service Station no.		0370834_W			Coordinates			
Duration	Return Period (years)							
	2	5	10	20	50	100	200	
Rainfall								
Return Period (years), T	2	5	10	20	50	100	200	
Point precipitation depth (mm) P _{t,T}	28.7	48.3	63.2	78.1	97.8	112.7	127.6	
Area reduction factor (%),ARF _T	1.114	1.114	1.114	1.114	1.114	1.114	1.114	
Average intensity (mm/hour),I _T	12.4	20.9	27.3	33.7	42.3	48.7	55.1	
Run-off coefficient								
Calibration factors	C ₂ (%)	15		C ₁₀₀ (%)		50		
Return Period (years), T	2	5	10	20	50	100	200	
Return period factors (Y _T)	0	0.84	1.28	1.64	2.05	2.33	2.58	
Run-off coefficient, C _T	0.150	0.276	0.342	0.396	0.458	0.500	0.538	
Peak flow (m3/s)	1.02	3.16	5.12	7.32	10.59	13.32	16.21	

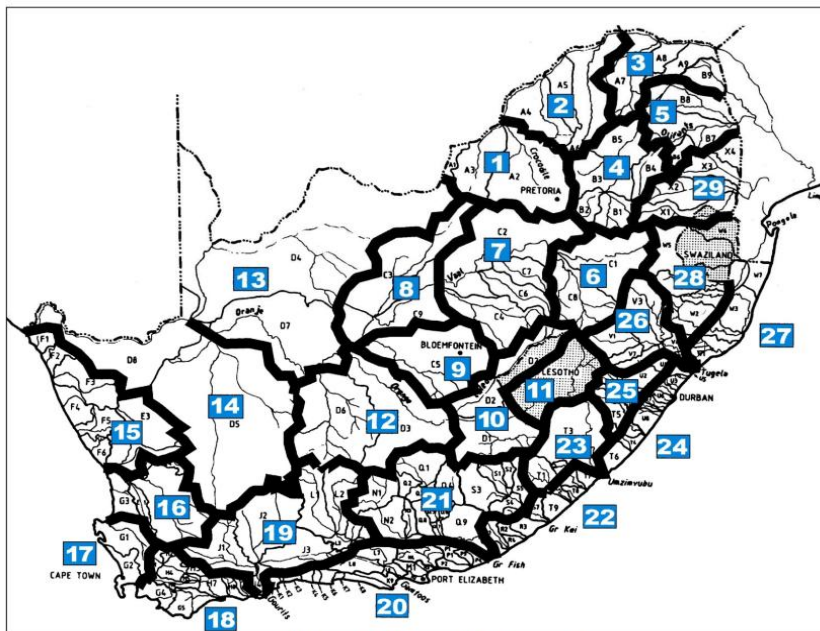
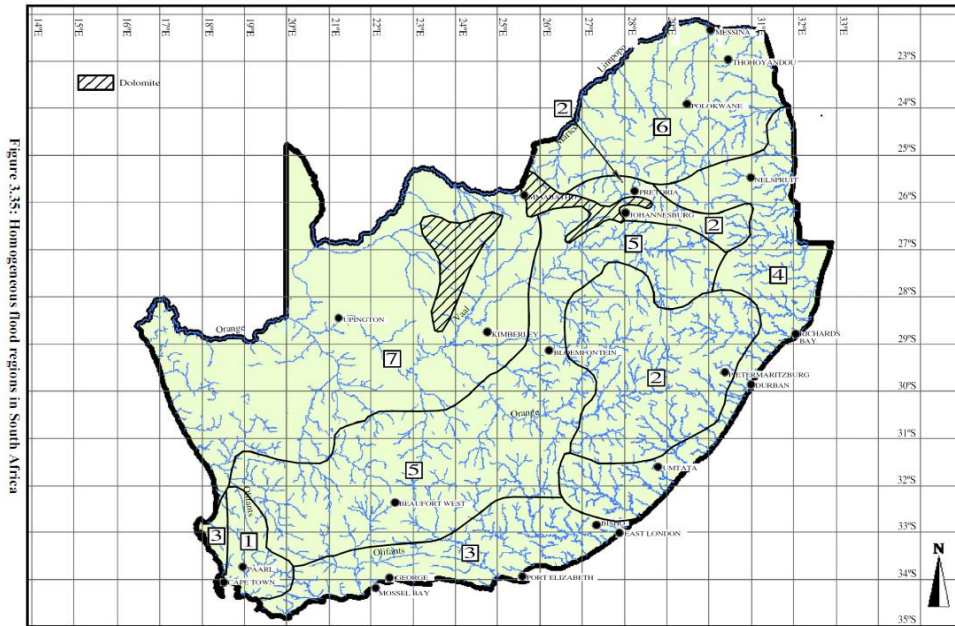


Figure 3.30: Standard Design Flood drainage basins

MIDGLEY & PITMAN (MIPI) METHOD														
River Detail	Catchment Area	MAP	S	L	Lc	Constant K_T				Catchment Paramete	Peak Flows			
	(km ²)	(mm)	m/m	km	km	1:10 year	1:20 Year	1: 50 year	1: 100 year	(Dimensionless)	1:10 year	1:20 Year	1: 50 year	1: 100 year
HRU04	1.97	739	0.0004	2.32	1	0.83	1.04	1.36	1.6	0.0170	15.38	19.27	25.20	29.64



HRU05

RATIONAL METHOD 3							
Description of catchment		HRU05					
River detail	Refer to Report						
Calculated by	Hendrik Botha				Date	Tuesday, 22 April 2025	
Physical characteristics							
Size of catchment (A)	173.08	km ²		Rainfall region		V3B	
Longest watercourse (L)	23.54	km		Area distribution factors			
Average slope (S _{av})	0.0003	m/m		Rural (α)	Urban (β)	Lakes (γ)	
Dolomite area (D%)	0	%		1	0	0	
Mean annual rainfall(MAR)	739.19	mm					
Rural				URBAN			
Surface slope	%	Factor	C _s	Description	%	Factor	C2
Vleis and pans (<3%)	29.01	0.03	0.87	Lawns			
Flat areas (3 - 10%)	56.91	0.08	4.55	Sandy,flat<2%	0	0.08	0
Hilly (10 - 30%)	13.09	0.16	2.09	Sandy,steep>7%	0	0.16	0
Steep Areas (>30%)	1.00	0.26	0.26	Heavy s,flat<2%	0	0.15	0
Total	100.01	0.53	7.78	Heavy s,steep>7%	0	0.3	0
Permeability	%	Factor	C _p	Residential Areas			
Very permeable	80	0.04	3.20	Houses	0	0.5	0
Permeable	20	0.08	1.60	Flats	0	0.6	0
Semi-permeable	0	0.16	0.00	Industry			
Impermeable	0	0.26	0.00	Light industry	0	0.6	0
Total	100	0.54	4.80	Heavy industry	0	0.7	0
Vegetation	%	Factor	C _v	Business			
Thick bush & plantation	1.58	0.04	0.06	City centre	0	0.8	0
Light bush & farm-lands	16.76	0.11	1.84	Suburban	0	0.65	0
Grasslands	74.69	0.21	15.68	Streets	0	0.75	0
No vegetation	6.97	0.25	1.74	Max flood	0	1	0
Total	100	0.61	19.33	Total (C2)	0		0
Time of concentration (TC)							
Overland flow		Defined watercourse		Use Defined watercourse			
$T_c = 0.604 \left(\frac{rL}{\sqrt{S_{av}}} \right)^{0.467}$		$T_c = \left[\frac{0.87 L^2}{1000 S_{AV}} \right]^{0.385}$					
11.440	hours	17.152	hours				
Run-off coefficient							
Return Period (years)	2	5	10	20	50	100	PMF
Run-off coefficient, C ₁	0.319	0.319	0.319	0.319	0.319	0.319	0.900
Adjusted for dolomitic areas, C _{1D}	0.319	0.319	0.319	0.319	0.319	0.319	0.900
Adj factor for initial saturation, F _i	0.5	0.55	0.6	0.67	0.83	1	1.00
Adjusted run - off coefficient, C _{1T}	0.1595585	0.17551435	0.1914702	0.214	0.265	0.319	0.900
Combined run - off coefficient, C _T	0.1595585	0.17551435	0.1914702	0.214	0.265	0.319	0.900
Rainfall							
Return Period (years)	2	5	10	20	50	100	PMF
Point rainfall (mm), P _T	78.18	104.47	122.64	140.62	165.44	184.42	204.56
Point Intensity (mm/h), P _{It}	4.56	6.09	7.15	8.20	9.65	10.75	11.93
Area reduction factor (%),ARF _T	0.968	0.968	0.968	0.968	0.968	0.968	0.968
Average intensity (mm/hour),I _T	4.412	5.896	6.922	7.937	9.338	10.409	11.546
Return Period (years)	2	5	10	20	50	100	PMF
Peak flow (m3/s)	33.849	49.757	63.724	81.588	118.911	159.70	499.60

STANDARD DESIGN FLOOD (SDF) METHOD								
Description of catchment		HRU05						
River detail		Refer to Report						
Calculated by		Hendrik Botha			Date	2025/04/22		
Physical characteristics								
Size of catchment (A)	173.08	km ²		Days of thunder per year (R)		17	days	
Longest watercourse (L)	23.54	km		Time of concentration, t		1029.119	minutes	
Average slope (S _{av})	0.000	m/m		Time of concentration, T _c	$T_c = \left[\frac{0.87 L^2}{1000 S_{AV}} \right]^{0.385}$		17.1520	
SDF Basin	26							
2-year return period rainfall (M)	61	mm						
TR102 n-day rainfall data								
Weather Service Station		BALLENLEICH			MAP		739.1927333	mm
Weather Service Station no.		0370834_W			Coordinates			
Duration		Return Period (years)						
		2	5	10	20	50	100	200
Rainfall								
Return Period (years), T		2	5	10	20	50	100	200
Point precipitation depth (mm) P _{L,T}		40.4	68.1	89.1	110.1	137.8	158.8	179.8
Area reduction factor (%),ARF _T		0.968	0.968	0.968	0.968	0.968	0.968	0.968
Average intensity (mm/hour),I _T		2.3	3.8	5.0	6.2	7.8	9.0	10.1
Run-off coefficient								
Calibration factors	C ₂ (%)	15		C ₁₀₀ (%)		50		
Return Period (years), T		2	5	10	20	50	100	200
Return period factors (Y _T)		0	0.84	1.28	1.64	2.05	2.33	2.58
Run-off coefficient, C _T		0.150	0.276	0.342	0.396	0.458	0.500	0.538
Peak flow (m3/s)		16.44	51.05	82.76	118.40	171.28	215.48	262.27

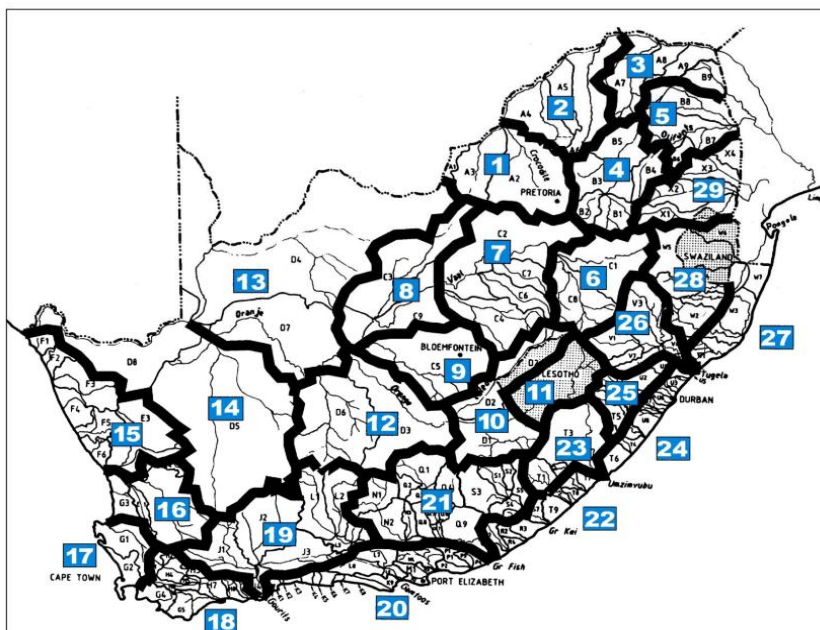
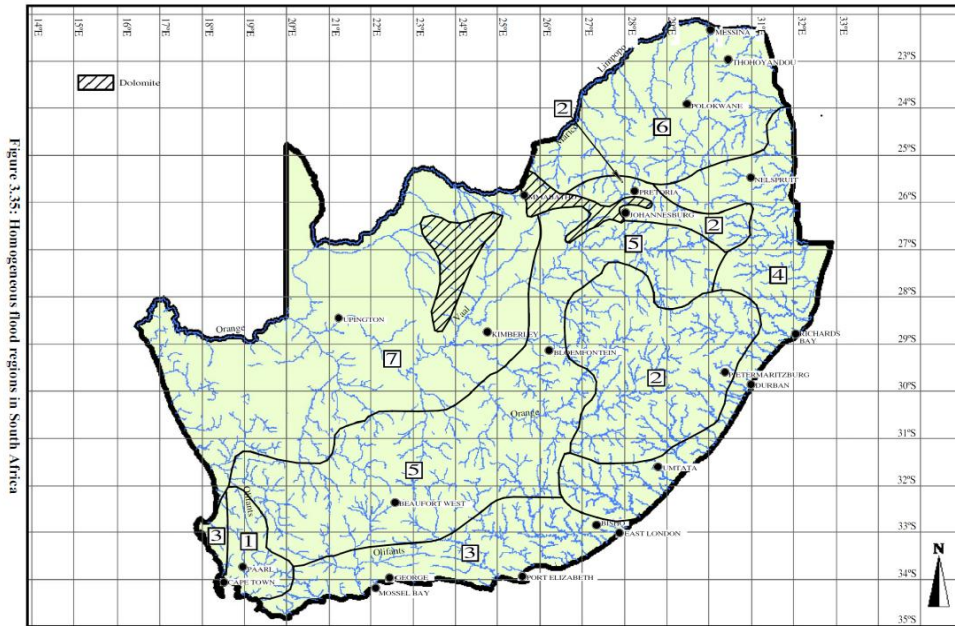


Figure 3.30: Standard Design Flood drainage basins

MIDGLEY & PITMAN (MIPI) METHOD														
River Detail	Catchment Area	MAP	S	L	Lc	Constant K_T				Catchment Paramete	Peak Flows			
	(km ²)	(mm)	m/m	km	km	1:10 year	1:20 Year	1: 50 year	1: 100 year	(Dimensionless)	1:10 year	1:20 Year	1: 50 year	1: 100 year
HRU05	173.08	739	0.0003	23.5	6.5	0.83	1.04	1.36	1.6	0.0196	232.03	290.74	380.19	447.29



APPENDIX B: 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/l	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/l	22	10.0
233	Dissolved Potassium	mg K/l	2.66	2.73
233	Dissolved Magnesium	mg Mg/l	16.1	5.55
233	Sodium	mg Na/l	8.73	7.57
94	Dissolved Aluminium	µg Al/l	10.8	127
94	Dissolved Iron	µg Fe/l	13.0	313
94	Dissolved Manganese	µg Mn/l	13.6	<10
10G	Total Alkalinity	mg CaCO ₃ /l	104	38
Calc.	Bicarbonate Alkalinity	mg CaCO ₃ /l	104	NR
16G	Chloride	mg Cl/l	<2.5	3.33
2B	Electrical Conductivity at 25°C	mS/m	30	14
18G	Fluoride	mg F/l	0.10	0.06
65Gc	Nitrate	mg N/l	<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 /l	25.6	22.7
5	Suspended Solids at 105°C	mg/l	NR	18
41	Total Dissolved Solids at 180°C	mg/l	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/l	12.6	11.3
233	Dissolved Potassium	mg K/l	2.81	2.37
233	Dissolved Magnesium	mg Mg/l	8.42	6.89
233	Sodium	mg Na/l	9.96	9.26
94	Dissolved Aluminium	µg Al/l	112	50
94	Dissolved Iron	µg Fe/l	466	133
94	Dissolved Manganese	µg Mn/l	<10	<10
10G	Total Alkalinity	mg CaCO ₃ /l	34	36
16G	Chloride	mg Cl/l	4.09	4.12
2B	Electrical Conductivity at 25°C	mS/m	19	16
18G	Fluoride	mg F/l	0.09	0.08
65Gc	Nitrate	mg N/l	<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.
a	Testing has deviated from Method.

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

APPENDIX C: 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 D: 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

