REPORT

Groundwater Specialist Investigation for Belfast Expansion Project (BEP)

Exxaro Coal Mpumalanga (Pty) Ltd.

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Executive Summary

The main objective of the groundwater specialist study was to support Exxaro's BEP Integrated Water and Waste Management Plan (IWWMP) and Integrated Water Use Licence Application (IWULA) authorisations process.

This report contains an overview of the groundwater conditions as well as an impact assessment at the proposed BEP investigation area. Based on the existing reports, drilling and aquifer testing results, three aquifer systems can be distinguished at the BEP area namely:

- Top weathered aquifer system; unconfined aquifer system with an average thickness of ~ 10 m.
- Fractured aquifer system; confined to semi confined aquifer system with an average thickness of ~20m below the weathered aquifer system and is characterised by secondary fractures resulting in preferential flow paths for the groundwater flow and possible contaminant migration.
- Deep fractured aquifer system; confined aquifer system with reported water strikes between 118 to 120 mbgl, and is present in the basement rocks below the fractured aquifer system.

The weathered and fractured aquifer systems are present in the Karoo Supergroup, whereas the deep fractured aquifer system is present in the Transvaal Supergroup.

The numerical model was conducted to simulate the inflows into the BEP opencast and underground mining areas. For the opencast mining, the pit recharge was removed to obtain lateral groundwater inflow into the pits. The opencast mining is scheduled from 2031 to 2039 and the highest simulated inflow occurs in 2032 with an expected lateral inflow rate of 4.4 L/s for the west pits and 9.9 L/s for the east pits. This is a total inflow of 14.3 L/s (1234 m^3/d). The underground mining is scheduled from 2037 to 2042 and the highest simulated inflow occurs in 2041 with an expected rate of 11.7 L/s (1014.2 m^3/d).

During the operational period, the contamination plume is contained in the mining areas. Post closure water levels recover until decanting starts. Nevertheless, the water level continues to recover, although in the higher topographical areas the water level does not recover to pre-mining levels after 100 years.

The following decant volumes were simulated after closure:

- No decant from the underground mining areas due to the water level that does not recover to the original levels in 100 years after closure.
- No decant from Pit 10 and Pit 12 areas due to the water level that does not recover to the original levels in 100 years after closure.
- Pit 11 starts to decant 38 years after closure (in 2080). The decant rate gradually increases to 0.83 L/s 100 years after closure.
- Pit 8 starts to decant 17 years after closure (in 2059). The decant rate gradually increases to 6.6 L/s 100 years after closure.
- Pit 9 starts to decant 60 years after closure. The decant rate gradually increases to 1.2 L/s 100 years after closure in 2102.
- There are several decant points in the BIP opencast mining area with total decant rates of 15.8 L/s for the western BIP area and 15.7 L/s for the easter BIP area.

The sulphate and TDS plumes show a similar pattern, moving to the south and south-west of the mining areas. The 100 mg/L concentration reaches the Klein Komati River and the upper reaches of the Leeubank River 20 years after closure.

The impact assessment considered the potential impacts from dewatering and groundwater. Table 34 gives a summary of the impacts and shows that the highest impact is associated baseflow reduction during the operational phase of BEP opencast mining.

Table 1: Summary of Impacts

Impact	Phase	Impact	Significance	Mitigation	Significance after mitigation
Dewatering	Operational	BEP underground mining impact on baseflow	21 (Low)	No mitigation	
		BEP underground mining impact on farmers	16 (Low)	Exxaro is the owner of the adjacent land. Mine to supply alternative source of water to affected users if necessary.	8 (Low)
		BEP opencast mining impact on baseflow	60 (Medium)	Operational rehabilitation of open pits to re-establish run-off and baseflow.	40 (Medium)
		BEP opencast mining impact on farmers	16 (Low)	Exxaro is the owner of the adjacent land. Mine to supply alternative source of water to affected users if necessary.	8 (Low)
	Post Closure	BEP underground mining impact on baseflow	30 (Low)	No mitigation	
		BEP underground mining impact on farmers	16 (Low)	Exxaro is the owner of the adjacent land. Mine to supply alternative source of water to affected users if necessary.	8 (Low)
		BEP opencast mining impact on baseflow	65 (High)	Operational rehabilitation of open pits to re-establish run-off and baseflow.	40 (Medium)
		BEP opencast mining impact on farmers	16 (Low)	Exxaro is the owner of the adjacent land. Mine to supply alternative source of water to affected users if necessary.	8 (Low)
Groundwater contamination	Operational	Stockpiles on BEP opencast mining areas: Decline infrastructure Option 1	0 (Low)	No mitigation	
		Stockpiles on unmined areas: Decline infrastructure Option 2 (preferred)	24 (Low)	Stormwater management, clean and dirty water separation to reduce contaminant migration to groundwater.	6 (Low)
		Conveyor Route - all options on opencast mining areas	0 (Low)	No mitigation	
		Conveyor Route D - where not on mining areas	12 (Low)	Comply to operational procedures.	0 (Low)
	Post Closure	Discard dump extension (MRF)	52 (Medium)	To add a soil cover and vegetate the area. Closure options to be evaluated and licensed at closure. Continue decant water management system in pit.	22 (Low)
		BEP underground mining	40 (Medium)	Opencast decant management and water treatment from mining voids	16 (Low)
		BEP opencast mining	40 (Medium)	Decant management and water treatment from mining voids	16 (Low)

Acronyms and abbreviations

bgl	below ground level
BEP	Belfast Expansion Project
BIP	Belfast Implementation Project
CoC	Contaminant of Concern
CMA	Catchment Management Agency
DWS	Department of Water and Sanitation
EC	Electrical Conductivity
GAA	Golder Associates Africa (Pty) Ltd.
ha	hectares
mamsl	meter above mean sea level
MAP	mean annual precipitation
NWA	National Water Act, 1998 (Act 36 of 1998)
PCD	Pollution Control Dam
SS	Suspended solids
TOC	Total organic carbon
TDS	Total dissolved solids
TSS	Total suspended solids
WMA	Water Management Area
WUL	Water Use License number 05/X11D/ABCFGIJ/2613
WULA	Water Use Licence Application

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DETAILS OF THE SPECIALIST

Specialist Information	
Name:	Talita van Zyl
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Telephone number:	011 254 4800
Email:	tvanzyl@golder.co.za
Qualifications:	■ Masters in Geohydrology – University of Zululand ■ Pr.Sci.Nat. – Hydrological Science (400045/06)

Qualifications of specialist

Education

Masters in Geohydrology – University of Zululand

BSc – University of Pretoria

Professional Affiliations

SACNASP 400045/06 (Hydrological Science)

PLATO G0551 (GISc Technologist)

Summary of past experience

Talita van Zyl is a registered Professional Scientist as well as a registered GISc Technologist with more than 20 years of experience. She is employed as a groundwater modeller and as such develops conceptual models, analyses and interprets data and conducts numerical flow and transport modelling. Other experience includes unsaturated flow modelling and sediment transport modelling. Talita joined Golder Associates Africa in 2009 and has worked on projects for the mining industry, agricultural sector and industrial sites.

Declaration of Independence by Specialist

I, Talita van Zyl, declare that I –

- Act as the independent specialist for the undertaking of a specialist section for the proposed BEP Project
- Do not have and will not have any financial interest in the undertaking of the activity, other than remuneration for work performed;
- Do not have nor will have a vested interest in the proposed activity proceeding;
- Have no, and will not engage in, conflicting interests in the undertaking of the activity;
- Undertake to disclose, to the competent authority, any information that have or may have the potential to influence the decision of the competent authority or the objectivity of any report, plan or document.

APPENDIX 6 OF THE EIA REGULATIONS

Where applicable, this baseline report has been written in compliance with Appendix 6 of the EIA Regulations.

Section	Requirements	Section addressed in report
1.(1)	A specialist report prepared in terms of these Regulations must contain	
(a)	Details of	
(i)	the specialist who prepared the report; and	See preceding page
(ii)	the expertise of that specialist to compile a specialist report including a curriculum vitae	See preceding page
(b)	a declaration that the specialist is independent in a form as may be specified by the competent authority	See preceding page
(c)	an indication of the scope of, and the purpose for which, the report was prepared;	Section 3.0
(cA)	an indication of the quality and age of base data used for the specialist report;	Section 5.0 to 7.0
(cB)	a description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change;	Section 9.0 describes the baseline conditions
(d)	the duration, date and season of the site investigation and the relevance of the season to the outcome of the assessment;	This was a desktop study
(e)	a description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of equipment and modelling used;	Section 8.0
(f)	details of an assessment of the specific identified sensitivity of the site related to the proposed activity or activities and its associated structures and infrastructure, inclusive of a site plan identifying site alternatives;	Section 9.0
(g)	an identification of any areas to be avoided, including buffers;	None identified in terms of groundwater
(h)	a map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	Figure 2 indicates the mining areas – no areas to be avoided in terms of groundwater
(i)	a description of any assumptions made and any uncertainties or gaps in knowledge;	Section 7.0 Section 8.5
(j)	a description of the findings and potential implications of such findings on the impact of the proposed activity	Section 9.0

Section	Requirements	Section addressed in report
	(including identified alternatives on the environment) or activities;	
(k)	any mitigation measures for inclusion in the EMPr;	Section 9.0
(l)	any conditions for inclusion in the environmental authorisation;	None - Section 9.0 mitigations can be used as guidance
(m)	any monitoring requirements for inclusion in the EMPr or environmental authorisation;	Section 7.0
(n)	a reasoned opinion—	
(i)	**(as to)** whether the proposed activity, activities or portions thereof should be authorised;	No avoidances identified in terms of groundwater
(iA)	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, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan;	
(o)	a description of any consultation process that was undertaken during the course of preparing the specialist report;	-
(p)	a summary and copies of any comments received during any consultation process and where applicable all responses thereto; and	
(q)	any other information requested by the competent authority.	-
2.	Where a government notice *gazetted* by the Minister provides for any protocol or minimum information requirement to be applied to a specialist report, the requirements as indicated in such notice will apply.	-

1.0 BACKGROUND

Golder Associates Africa (Pty) Ltd. (herein referenced Golder) has been appointed by Exxaro Coal Mpumalanga (Pty) Ltd (Exxaro) to conduct a groundwater specialist investigation for their Belfast Expansion Project (BEP) and railway loop, which falls inside their Belfast mining right area.

The mining right area is for an area in extent of approximately 5 819.18 ha on various portions of the farms Zoekop 426JS, Leeuwbank 427 JS and Blyvooruitzicht 383 in the Magisterial district of Belfast in Mpumalanga Province.

The Belfast Implementation Project (BIP) has an existing approved Water Use License (WUL) number 05/X11D/ABCFGIJ/2613, and the new Water Use License Application (WULA) will be an expansion of the BEP area.

This groundwater report was completed based on existing hydrogeological information and reports and gives an overview of the groundwater conditions as well as an impact assessment at the proposed BEP investigation area.

2.0 OBJECTIVE

The main objective of the groundwater specialist study was to support Exxaro's BEP Integrated Water and Waste Management Plan (IWWMP) and Integrated Water Use Licence Application (IWULA) authorisations process.

3.0 SCOPE OF WORK

The hydrogeological investigation scope of work followed was:

- Desk study Review of existing Groundwater Information.
- Groundwater Numerical Model and Impact Assessment.
- Review and update Existing Groundwater Monitoring Programme.
- Groundwater Report and Recommendations.

4.0 GEOGRAPHICAL SETTING

4.1 Locality

The BEP area is located under Exxaro Coal Mpumalanga (Pty) Ltd and subsequently forms part of the resource pertaining to Belfast, situated in the province of Mpumalanga, 10 km south east of Emakhazeni (Belfast) on the farms Leeubank, Zoekop and Blyvooruitzicht as shown in Figure 1. The site layout and infrastructure are indicated on Figure 2. The study area falls within quaternary catchment B41A, X11C and X11D (also indicated on Figure 2).

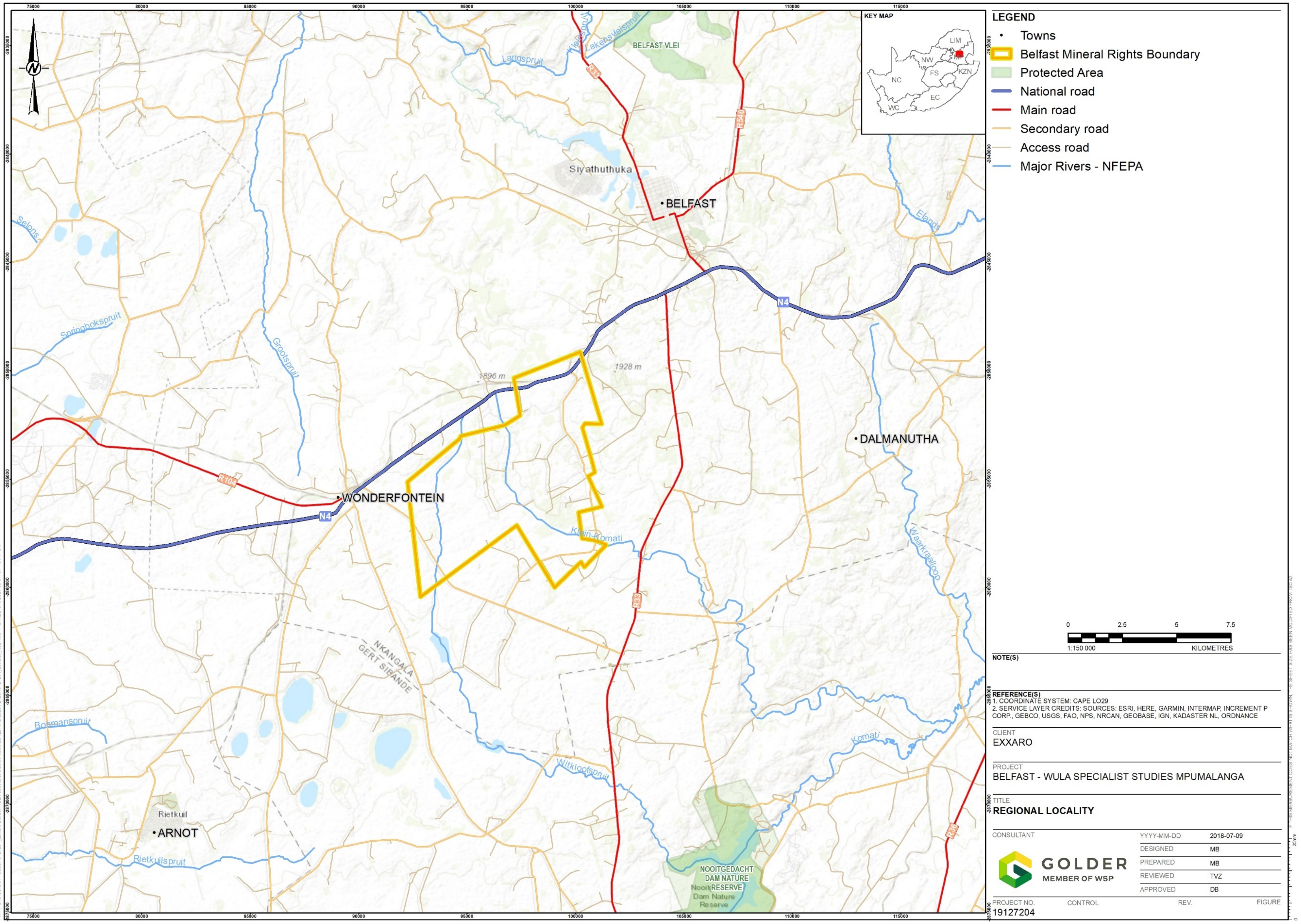


Figure 1: Locality Map

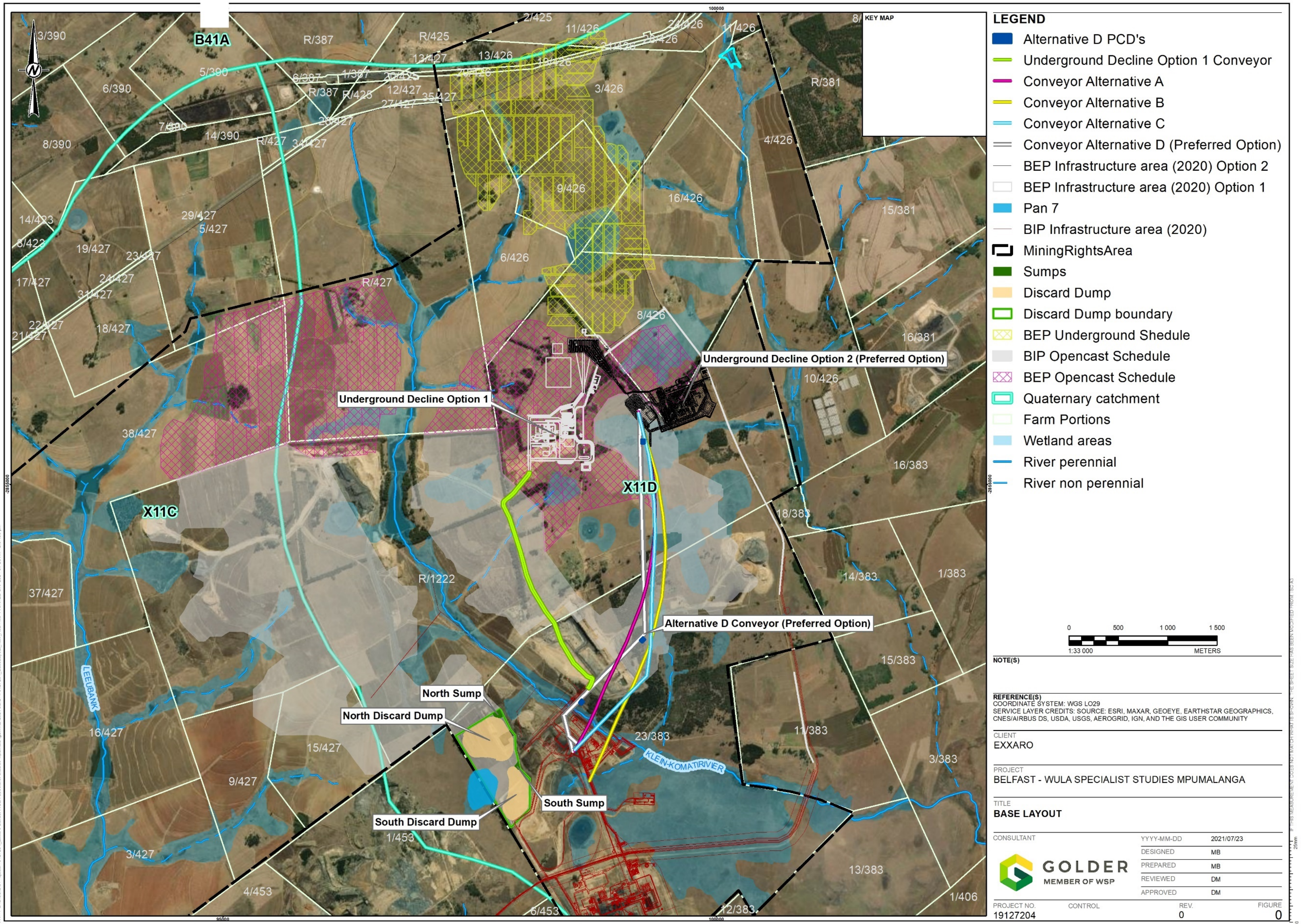


Figure 2: Site Layout and Infrastructure

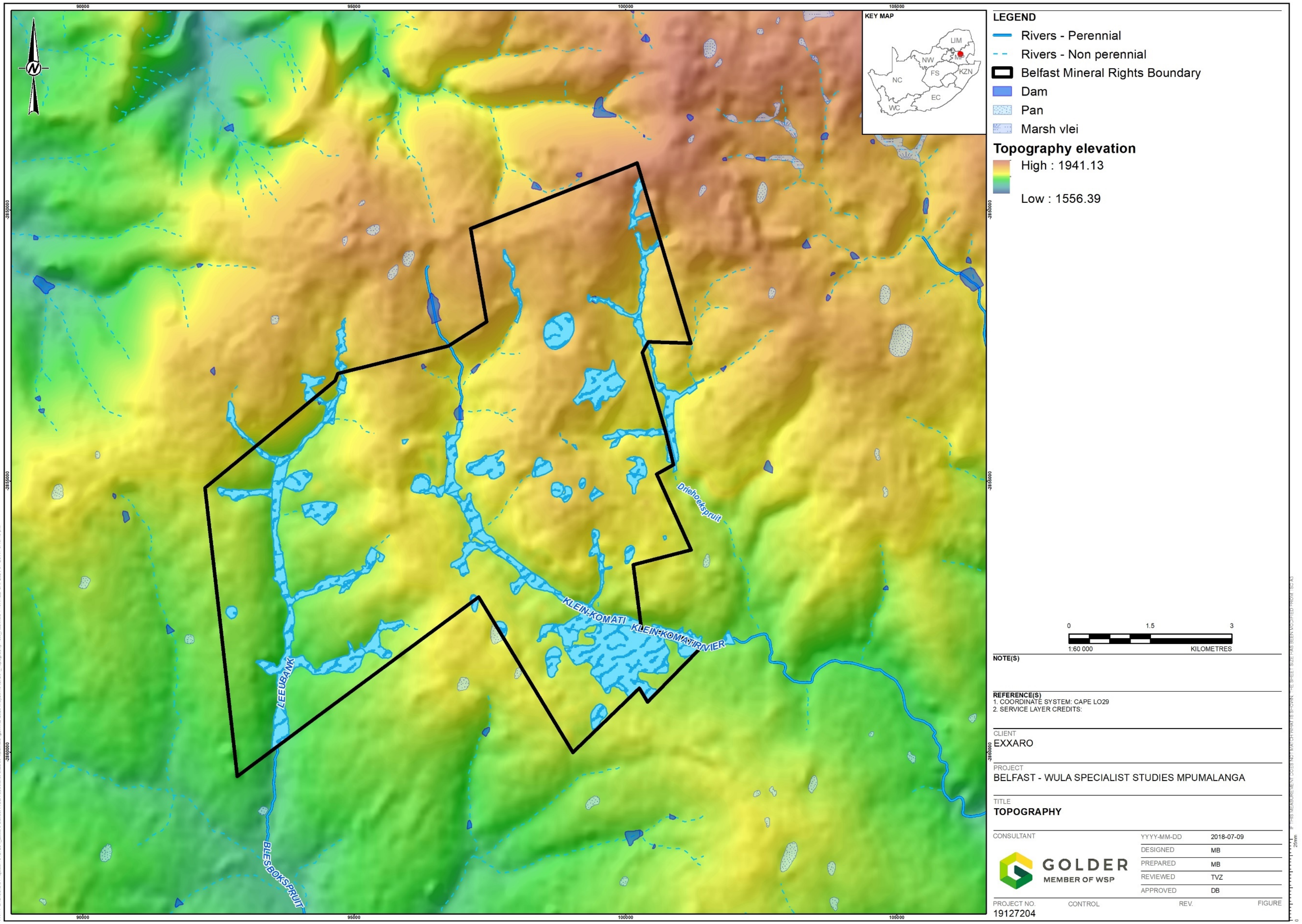


Figure 3: Topography

4.2 Topography and Drainage

The topography of the investigation area consists of slightly undulating topography of open grassland, typically found in the central Highveld (Figure 3). The topography of the area slopes in a general south-easterly direction towards the Perennial Blesbokspruit and Klein-Komati River. The site is located on a topographical high with drainage occurring radially in a south westerly and south easterly direction.

The highest topographical point is situated to the north with an altitude of approximately 1875 meter above main sea level (mamsl). The lowest topography is towards the south of the study area at 1725 mamsl. In the Belfast mining area itself, the highest elevation is at approximately 1850 mamsl, while the lowest elevations are at 1775 mamsl (Groundwater Complete October 2014).

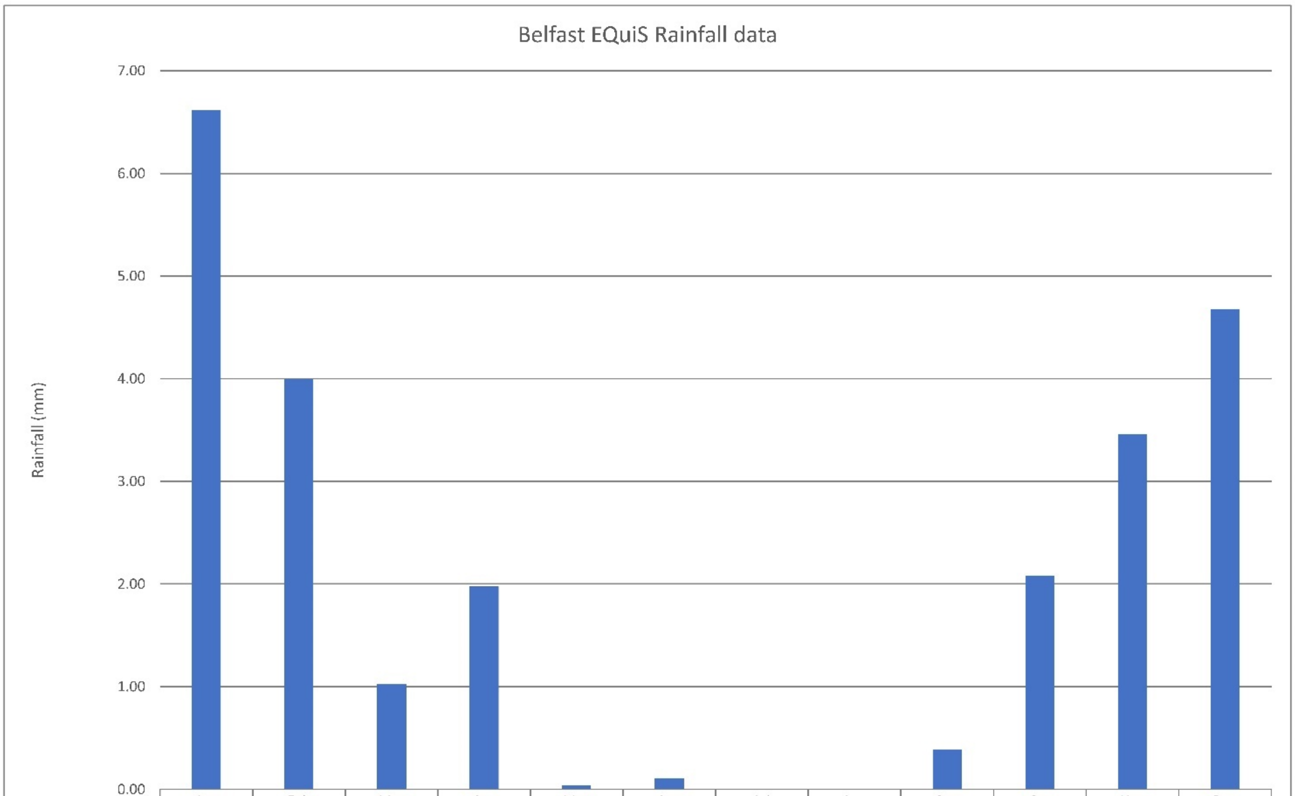
4.3 Climate and Temperature

The regional climate in the area is defined by the South African Weather Bureau as sub-humid and can be locally described as normally hot and drought stricken. Average daily temperatures in July are 14.7° and in January 22.5°. (Groundwater Complete August 2014).

4.4 Rainfall

4.4.1 Equis™ Rainfall Data

Rainfall data from Equis™ database, for Belfast colliery was available for a limited time period, from 10/2018 to 07/2021. The mean monthly rainfall data as recorded for this period is displayed in Figure 4.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Belfaste Rainfall	6.62	4.00	1.02	1.97	0.04	0.11	0.00	0.00	0.39	2.08	3.46	4.68

Figure 4: Mean Monthly Rainfall for Period 10/2018 to 07/2021 (Belfast Colliery - Equis Rainfall data)

4.4.2 Mean Annual Precipitation

The mean annual precipitation (MAP) in the investigation area is approximately 674 mm/a. The investigation is situated in a summer rainfall region with the highest rainfall in January. The lowest rainfall occurs in July. Thunderstorms are common during the summer rainfall period, during which higher rainfall occurs within a short period of time (SRK 2014).

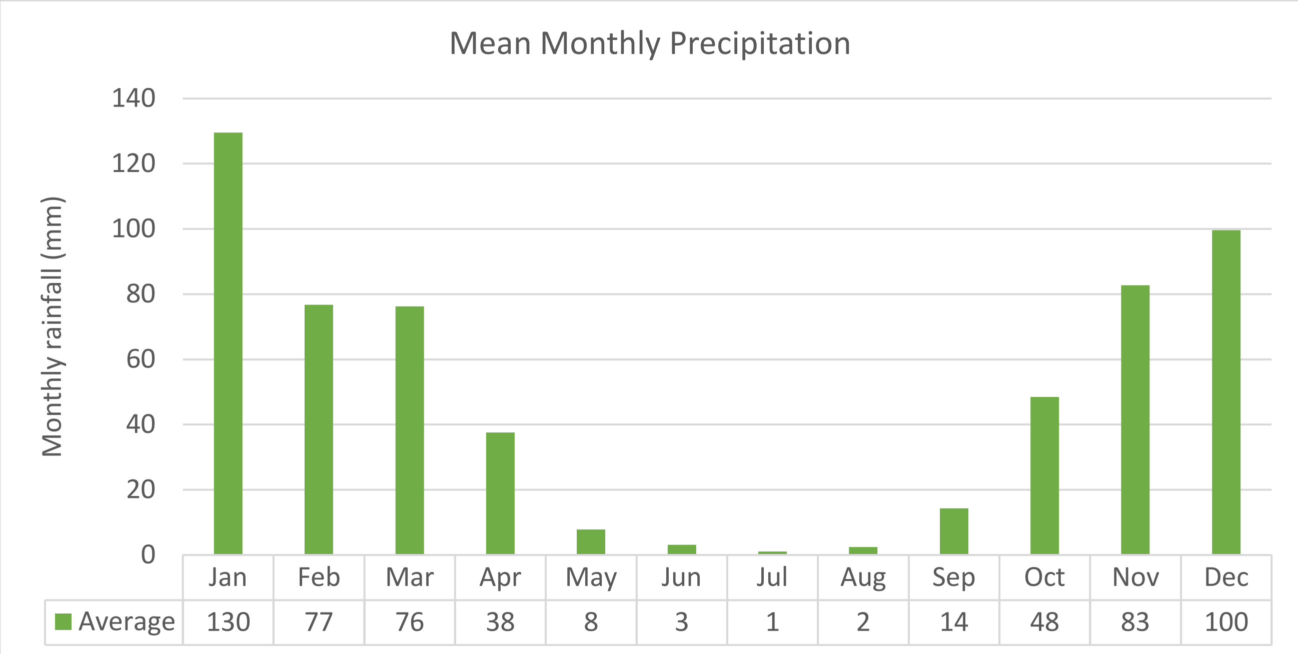


Figure 5: Mean Monthly Precipitation (SRK 2014)

The cumulative rainfall departure (CRD) is an indication of periods of above and below average rainfall. The CRD and monthly rainfall from 1990 to 2019 are shown in Figure 6. When the CRD graph drops below zero, it indicates a dry cycle e.g. 1992 to 2008. The start of a wet rainfall cycle is evident from .2010 to 2016.

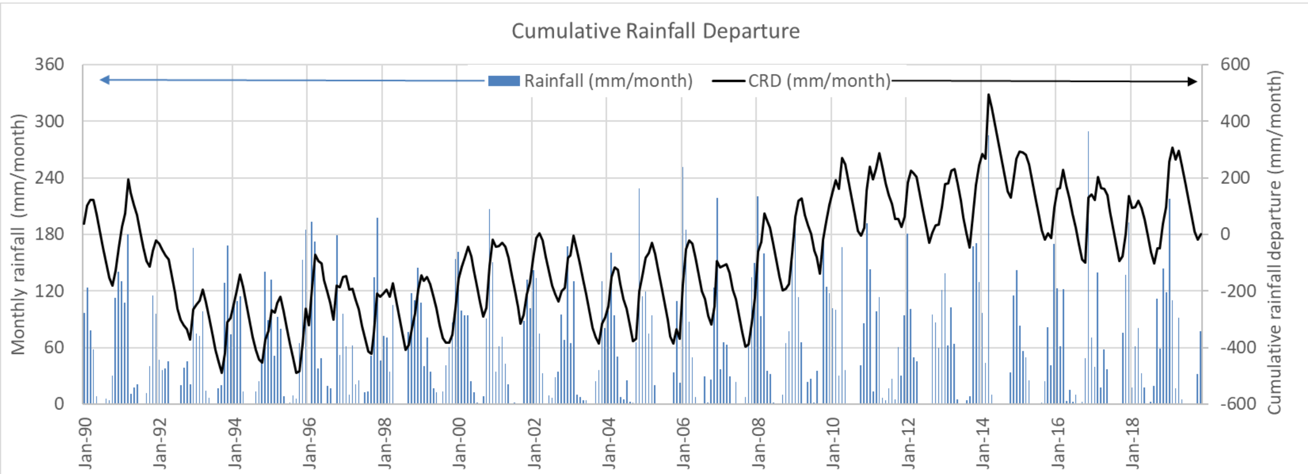


Figure 6: Cumulative Rainfall Departure (CRD) and Monthly Rainfall

5.0 DESK STUDY

The following information and data were utilised during the desk study and information review task:

- 1:250 000 Geological Map series;

- 1:2 500 000 Groundwater Resources map of RSA –Sheet 1 (WRC.DWAF 1995);
- 1:4 000 000 Groundwater Resources map of RSA – Sheet 2 (WRC.DWAF 1995);
- 1: 500 000 Hydrogeological Map Series of RSA (1996);
- Groundwater monitoring data from Equis™ database;
- Review of existing reports as referenced in Section 12.0. All reports and appendices (geophysical, drilling aquifer testing and analytical results) as referenced are available on request from Exxaro; and
- For the ease of understanding layout of the document, some sections with multiple groundwater studies are summarised in Table 2.

Table 2: Multiple Groundwater Studies

Groundwater Reporting Institution/Consultant	Study Date	Groundwater Study/section	Key Findings/Comments	Report Section
Hydrocensus				
Groundwater Complete	2009	Hydrocensus	Fifty-one (51) boreholes and eleven (11) fountains were surveyed. Minor aquifer system low yielding borehole ranging between 0.01 and 2.0 l/s.	5.1.1
Aquatico Scientific Services	2014	Repeat/update of 2009 Hydrocensus	Regional static groundwater levels around the BEP area vary between 0.2 mbgl and approximately 35 mbgl.	5.1.2
Geophysical Survey				
Groundwater Complete	2009	Geophysical Survey	Study to delineate dolerite intrusions or fault zones where boreholes were to be placed for geohydrological characterization and later monitoring purposes.	5.2.1
Groundwater Complete	2014	Geophysical Survey	Conducted by Georay Geophysical Services –Two traverse targeting interpreted geological structures near the plant and southern mining area.	5.2.2
Exxaro		Aeromagnetic Geophysical Survey	Total magnetic field (TMF) coverage of the survey area – Interpretation by Dr. Edgar Stettler.	5.2.3
Drilling				
Groundwater Complete	2009	Drilling of eight (8) new monitoring boreholes	The drilling targeted geological structures such as dykes or faults around the planned opencast mining operation.	5.3.1
Groundwater Complete	2014	Drilling of four (4) additional monitoring boreholes	Additional monitoring boreholes.	5.3.2
Groundwater Complete	2014	Drilling of two (2)) potential water supply boreholes	Both boreholes BBH03 (drilled to 50m and backfilled to 20m) and BBH06 (20m, blow yield of 0.3l/s) was constructed as monitoring boreholes.	5.3.3
Aquifer Testing				
Groundwater Complete	2009	Aquifer testing of seven (7) new monitoring boreholes	The pump tested boreholes harmonic and geometric mean of the late transmissivity values are 0.4 m2/d and 1.2 m2/day respectively.	5.4.2

Groundwater Reporting Institution/Consultant	Study Date	Groundwater Study/section	Key Findings/Comments	Report Section
Groundwater Complete	2014	Aquifer Testing of five (5) boreholes and slug testing of BBH05		5.4.3
GCS	2018	Aquifer Testing of three (3) boreholes drilled as water supply boreholes for BIP by Exxaro, BT35GW, ZP22GW and ZP23GW	The average late time T value of the two pump tested boreholes (BT35GW and ZP22GW) is 0.42 m2/d. Borehole ZP23GW was not subjected to a CDT.	5.4.4
Groundwater Recharge				
Regional Groundwater Recharge	Published hydrogeological maps (DWAF 1996)		The average recharge of the BEP investigation area is shown as between 50 and 75 mm per annum (8 to 11% of the MAP of 674mm/a)	5.5.1
Groundwater Complete	2009		2009 groundwater recharge calculations for the entire Belfast mining project area (BIP and BEP), is estimated at between 1 and 3 % of MAP (6.7 to 20.2 mm/a).	5.5.2
Groundwater Complete	2014		2014 recharge calculation in the BIP opencast project area is estimated to be between 2 and 5% of MAP (13.5 to 34mm/a of a MAP of 674mm/a).	5.5.3
Groundwater Numerical Modelling				
Groundwater Complete	2009	A groundwater numerical model was developed by Groundwater Complete in 2009 to evaluate the potential impact of the proposed Belfast mine on the groundwater environment.	2009 numerical modelling report available on request, not discussed as part of this report – Update 2020/21 Golder numerical model discussed.	5.6.1
Groundwater Complete	2014	Update of the 2009 groundwater numerical model	2014 numerical modelling report available on request, not discussed as part of this report – Update 2020/21 Golder numerical model discussed.	5.6.2
Golder	2020/21	Updated numerical model to include the Belfast		5.6.3

Groundwater Reporting Institution/Consultant	Study Date	Groundwater Study/section	Key Findings/Comments	Report Section
		Expansion Project (BEP) and railway loop		
Groundwater Quality				
Groundwater Complete	2009	Groundwater sampling and analyses	During the 2009 hydrocensus Clean Stream Scientific Services sampled 39 boreholes and springs around the proposed Belfast project area.	5.12.1
Groundwater Complete	2014	Groundwater sampling and analyses	During the 2014 hydrocensus update, groundwater samples were collected from 36 sampling localities to include seven (7) springs.	5.12.2
Golder	2019	Groundwater sampling and analyses	Golder conducted surface and groundwater monitoring and analysis for Exxaro Belfast Implementation Project (BIP). 20 monitoring boreholes are monitored on a quarterly basis as per IWUL regulation.	5.12.4

5.1 Hydrocensus

A comprehensive hydrocensus of the BEP investigation area was conducted by Groundwater Complete during 2009 and repeated/updated during January 2014 by Aquatico Scientific Services.

5.1.1 Hydrocensus – 2009 Groundwater Complete

A comprehensive hydrocensus was conducted during 2009 by Groundwater Complete as indicated on Figure 7. Fifty-one (51) boreholes and eleven (11) fountains were surveyed as listed in Table 3 and indicated on Figure 7.

Groundwater is used mainly for domestic supply, stock watering and small-scale irrigation at farmsteads. The groundwater levels measured during the 2009 hydrocensus range from 0.7 to 34.4 metre below ground level (mbgl) with an average of 8.4 mbgl. Hydrocensus borehole yields reported for the investigation area, correspond with literature and regional yields ranging between 0.01 and 2.0 l/s (minor aquifer system).

Widespread pollution or depletion of the groundwater resource will impact negatively not only on the resource, but also on the existing groundwater users. Apart from the groundwater use, the aquifers in the area provide a widespread base flow component to an abundance of surface water courses that will be affected should adverse impacts occur on the quality or availability of the resource (Groundwater Complete 2009).

Table 3: Hydrocensus Boreholes and Fountains (Groundwater Complete 2009)

Site Name	Latitude	Longitude	Altitude (mamsl)	Site Type Description	Water level (m)	Water Use	Owner
Bly01	-25.81791	30.02980	1771	Fountain	-	Livestock	Petri Badenhorst
Bly03	-25.81816	30.03195	1784	Borehole	-	Domestic, Livestock	
Bly05	-25.82852	30.01940	1740	Fountain	-	Livestock	
Blyvoor01	-25.83483	29.98314	1784	Fountain	-	Livestock	W.P. Pretorius
Blyvoor02	-25.84396	29.99989	1790	Borehole	-	Livestock	A Mahlango
Blyvoor05	-25.82410	30.00826	1772	Borehole	-	Domestic	Mr Msibi
Blyvoor06	-25.82473	30.00940	1770	Borehole	-	Domestic	
Bv01	-25.80399	30.03095	1797	Fountain	-	Livestock	Mr de Villiers
Coet01	-25.80243	30.00287	1801	Borehole	2.71	Domestic, Livestock	W Coetzer
Ef01	-25.86420	30.00070	1759	Borehole	-	Not in use	P. J. Doyer
Ef02	-25.86604	30.01105	1782	Fountain	-	Livestock	
Ef03	-25.85852	30.00566	1767	Dam	-	Livestock	
Ef04	-25.85808	30.01066	1774	Fountain	-	Livestock	
Ef05	-25.85015	30.00221	1777	Fountain	-	Livestock	
Ef07	-25.84401	30.00131	1788	Borehole	-	Domestic	
Eg01	-25.71260	30.04312	1916	Borehole	1.98	Domestic	Mr. Erasmus
Eg02	-25.71705	30.03743	1912	Borehole	3.65	Not in use	
Eg03	-25.71705	30.03741	1914	Borehole	3.40	Not in use	
JouG01	-25.82348	30.00378	1778	Borehole	15.99	Domestic, Livestock	Mr R. Joubert

Site Name	Latitude	Longitude	Altitude (mamsl)	Site Type Description	Water level (m)	Water Use	Owner
Kotze01	-25.79028	30.03842	1842	Borehole	8.25	Domestic, Livestock	Mr Kotze
Kotze02	-25.78876	30.03961	1849	Borehole	4.06	Not in use	
Kotze04	-25.78303	30.03855	1864	Borehole	6.44	Not in use	
Kotze05	-25.78580	30.03396	1839	Borehole	14.90	Domestic	
Kuiper02	-25.87140	29.91760	1705	Borehole	-	Domestic	Mr Gerhard Kuiper
Kuiper03	-25.87610	29.92145	1712	Borehole	-	Domestic	
Lb01	-25.81169	29.97737	1795	Borehole	34.35	Domestic	Mr Jan Burger
Lb02	-25.81592	29.98302	1801	Borehole	23.85	Domestic	
Lb03	-25.81775	29.97033	1798	Borehole	20.17	Domestic	
Lb04	-25.82115	29.97685	1785	Borehole	-	Not in use	
Lb05	-25.82073	29.97654	1780	Fountain	-	Livestock	
Lb07	-25.81311	29.96045	1801	Borehole	6.99	Not in use	
Lb08	-25.80416	29.95466	1809	Borehole	27.32	Livestock	
Paarde03	-25.74315	30.00325	1911	Borehole	-	Domestic	Mr Welroven
Paarde04	-25.74276	30.00354	1912	Borehole	-	Domestic	
Pp01	-25.72860	30.03370	1920	Borehole	-	Not in use	Mr Pieter Roets
Pp02	-25.72836	30.03468	1920	Borehole	2.90	Domestic, Livestock	
Vaal01	-25.86434	30.00084	1801	Borehole	-	Domestic, Livestock	Mr Johan Burger
Vaal02	-25.77976	29.91956	1840	Borehole	3.70	Livestock	
Vaal03	-25.78752	29.91999	1834	Borehole	3.70	Livestock	
Vil03	-25.76543	29.99928	1836	Borehole	-	Livestock	Mr A. Viljoen
VwG01	-25.79223	29.92558	1823	Borehole	6.37	Domestic	Mr PC v Wyk
Wt01	-25.73706	30.04186	1893	Fountain	-	Livestock	Mr Wannenburg
Wt02	-25.73549	30.03513	1913	Borehole	6.25	Domestic, Livestock	Mr L van Rooyen
Wt05	-25.73709	30.03597	1906	Fountain	-	Livestock	
Z01	-25.77999	29.99238	1836	Fountain	-	Domestic, Livestock	Mr Kowie Gerrits
Z04	-25.78298	29.99199	1844	Borehole	9.50	Domestic	
Z05	-25.78311	29.99111	1849	Borehole	1.40	Domestic	
Z06	-25.78567	29.98871	1854	Borehole	3.95	Livestock	
Z07	-25.78510	29.99202	1843	Borehole	9.75	Not in use	
Z08	-25.78809	29.99288	1834	Borehole	0.70	Not in use	
Z11	-25.80863	30.00937	1784	Borehole	9.90	Domestic, Livestock	
Z12	-25.80726	30.00965	1782	Borehole	-	Not in use	

Site Name	Latitude	Longitude	Altitude (mamsl)	Site Type Description	Water level (m)	Water Use	Owner
Zk01	-25.80857	30.00937	1807	Borehole	-	Livestock	Ester Botha
Zk02	-25.78732	29.97854	1839	Borehole	0.81	Domestic	
Zk03	-25.78800	29.97922	1846	Borehole	2.04	Not in use	
Zk07	-25.79946	29.95647	1814	Borehole	4.65	Not in use	
Zk08	-25.79882	29.96362	1791	Borehole	-	Monitoring Borehole	
Zk09	-25.79513	29.97345	1829	Borehole	-	Monitoring Borehole	
Zk10	-25.79393	29.97660	1840	Borehole	-	Not in use	
Zoekop01	-25.80796	29.98259	1830	Borehole	-	Domestic	W.P. Pretorius
Zoekop04	-25.83668	29.99958	1735	Borehole	3.43	Not in use	
Zoekop05	-25.80927	29.99250	1817	Borehole	-	Domestic	
Zoekop06	-25.78257	29.95203	1838	Borehole	-	Livestock	

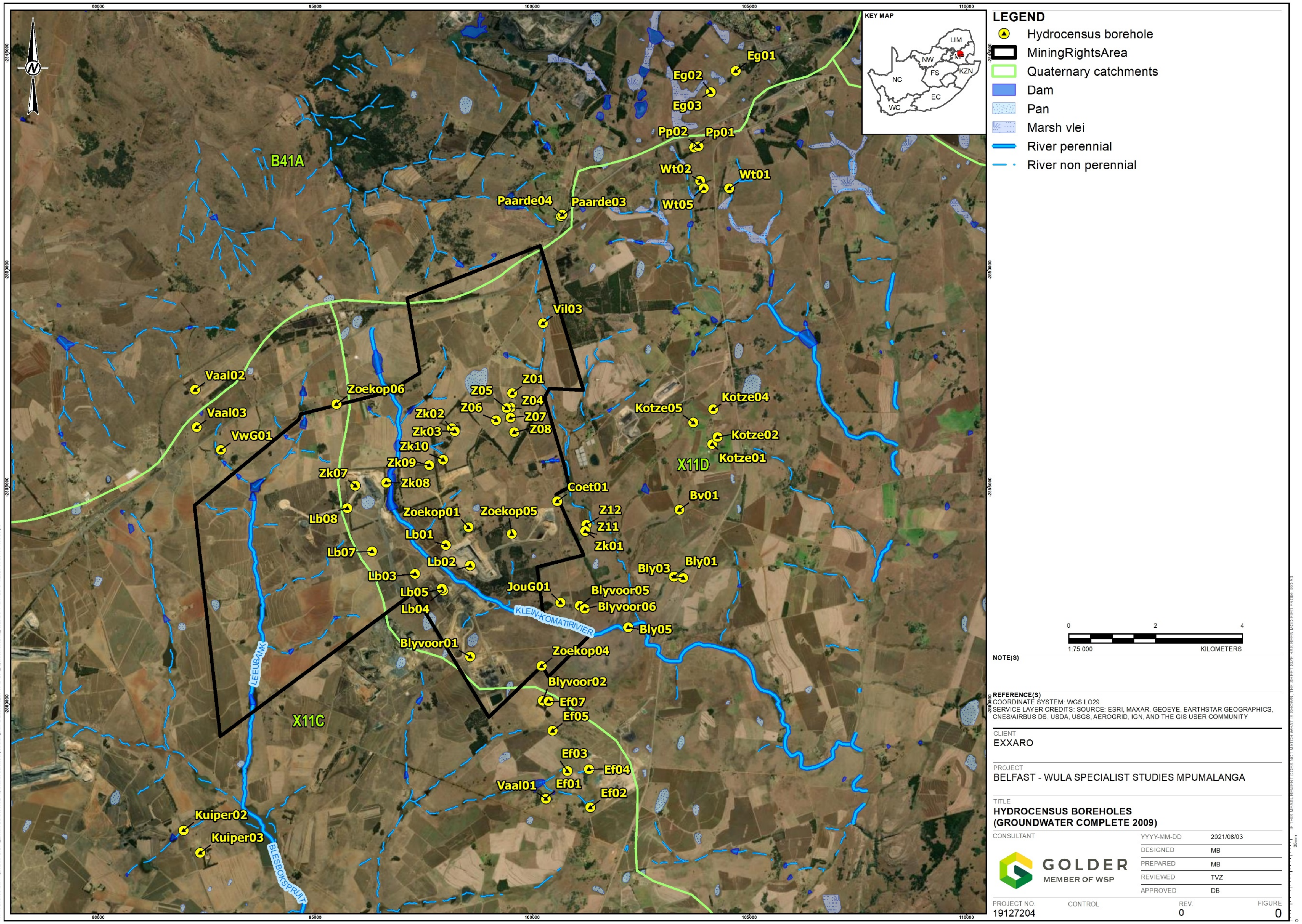


Figure 7: Hydrocensus Boreholes (Groundwater Complete 2009)

5.1.2 Hydrocensus - 2014 Groundwater Complete

The 2009 hydrocensus was repeated/updated in January 2014 by Aquatico Scientific Services for the 2014 Belfast update. The 2014 survey confirm groundwater use to be similar as in 2009, as mainly being used for domestic and stock watering purposes.

Eleven fountains were recorded during the survey (Bly01, Blyvoor01, Bv01, Ef02, EF04, Ef05, Lb05, Vaal01, Wt01, Wt5 and Z01). These are mostly used for livestock water. One of the springs is used for domestic purposes. Also recorded during the 2014 hydrocensus survey are 10 mine monitoring boreholes drilled in 2009 and 2 wells (Z05, Z08).

Regional static groundwater levels around the BEP area vary between 0.2 mbgl and approximately 35 mbgl. (Groundwater Complete - August 2014).

5.2 Geophysical Survey and Results

5.2.1 Geophysical Survey (Groundwater Complete 2009)

Geophysical investigations were conducted at the proposed Belfast project area during the exploration phase in the form of an aeromagnetic survey and during the groundwater study to delineate dolerite intrusions or fault zones where boreholes were to be placed for geohydrological characterization and later monitoring purposes (Groundwater Complete 2009).

5.2.2 Geophysical Survey (Groundwater Complete 2014)

Groundwater Complete contracted Georay Geophysical Services during 2014 to conduct two resistivity traverse lines (Figure 8) with a combined length of approximately 1 km. The traverse lines were set out over inferred geological structures near the plant and southern mining area.

Two drill sites were selected on Line 1 at station positions 170 m and 410 m respectively on Lund 2D resistivity profile (Figure 9).

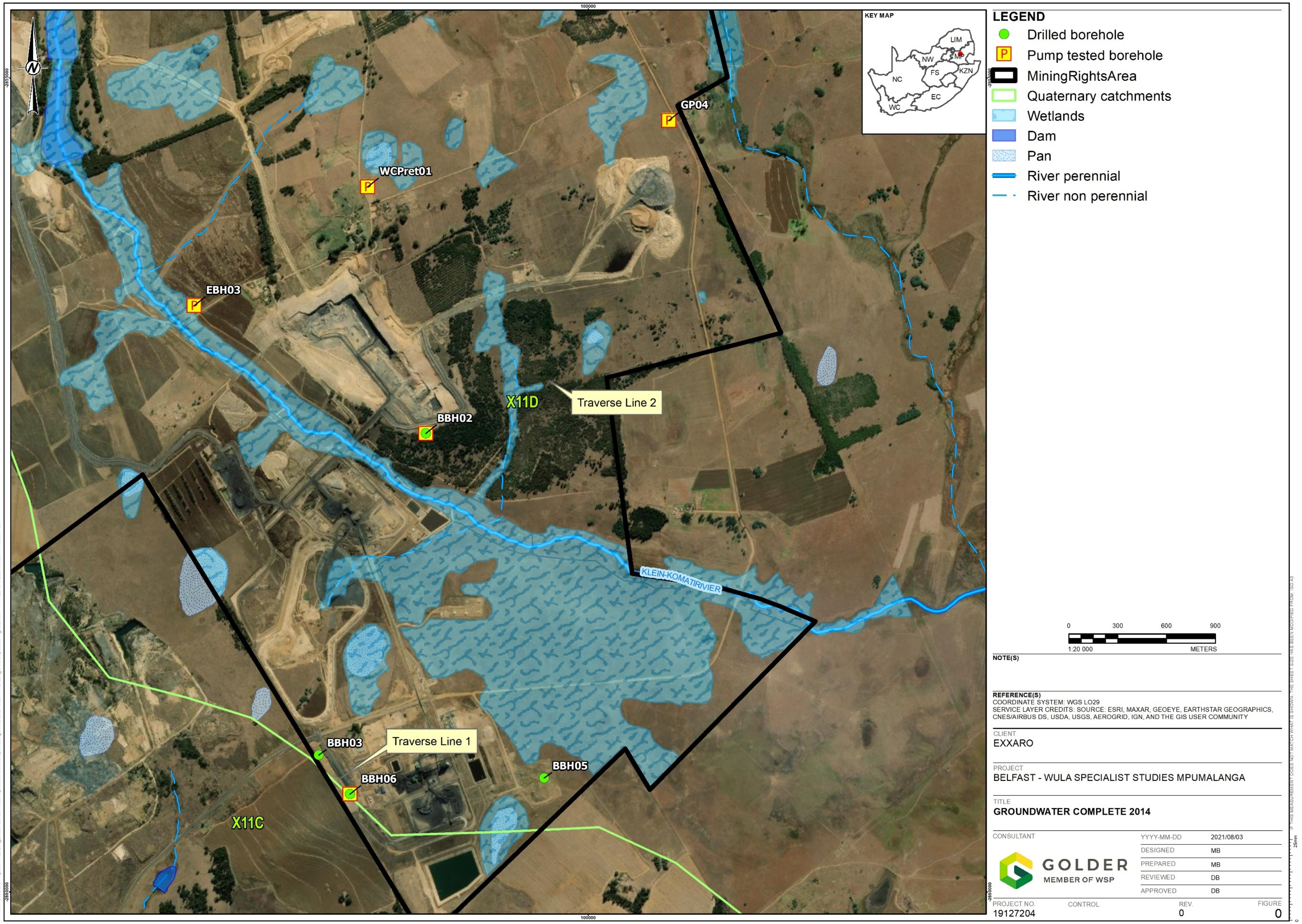


Figure 8: Geophysical Traverse Positions, Drilled and Pump Tested Boreholes (Groundwater Complete 2014)

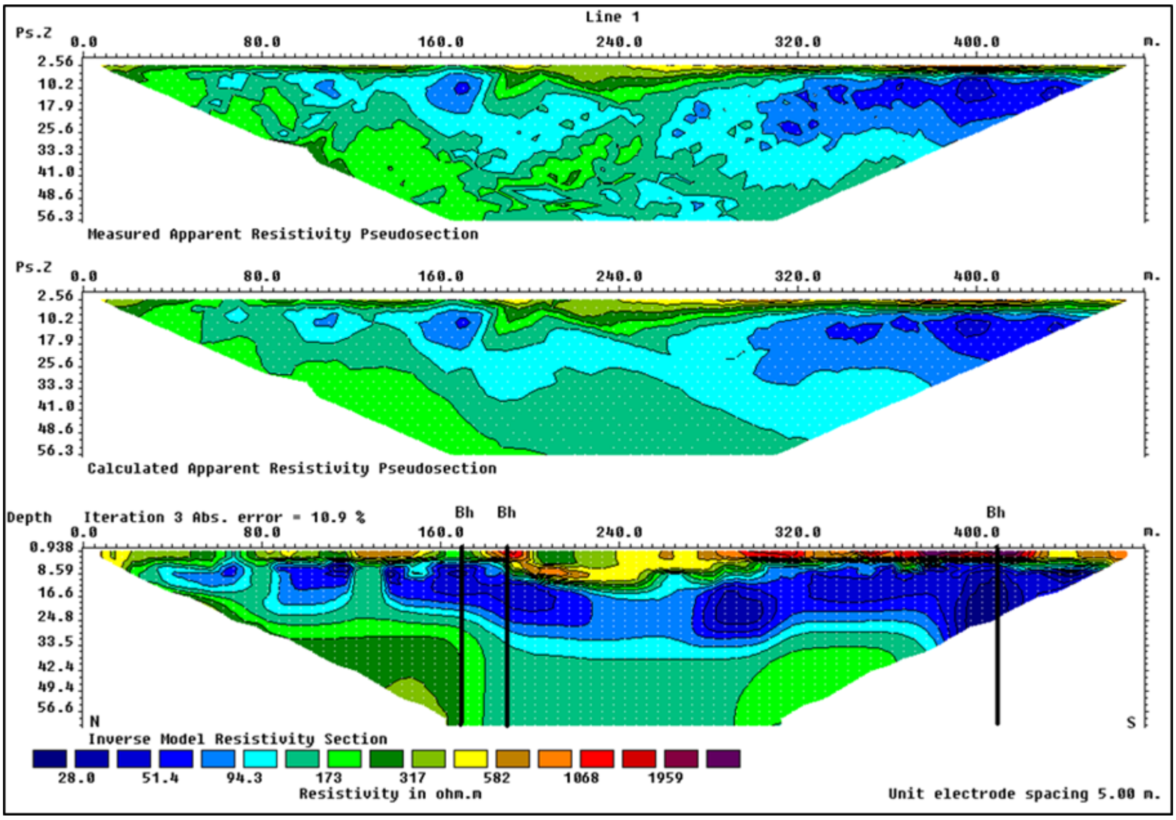


Figure 9: Resistivity profiles of Line 1 (Groundwater Complete 2014)

5.2.3 Aeromagnetic Geophysical Survey

Exxaro required a 3-4 l/s borehole for the development of infra-structure for their coal mine. The water level in the vicinity range between 5 and 10mbgl but on farmer Willie Pretorius's homestead the level is at 30m and the yield is at 6l/s.

An aeromagnetic geophysical survey was flown by Exxaro as part of their Belfast Coal Mine investigation. The Total Magnetic Field (TMF) image of the investigation area, marked with a red outline is displayed in Figure 10. Increases in the magnetic field strength or 'magnetic highs' are portrayed as ridges or hills coloured in a (warm), reddish hue and decreases in the field strength appear as valleys or troughs and are coloured in a (cold) bluish hue.

Post Karoo age dykes with a normal and remanent magnetic field direction and mostly NE-SW strike direction are visible, while possible faults have an approximate E-W strike. The investigation area is underlain by magnetic sills that can overlay one another as is evident from the slightly elevated magnetic amplitudes that form the background to the dykes (Figure 10).

Four traverses, positions indicated on Figure 10, were interpreted by Dr. E H Stettler and is displayed as Figure 11 to Figure 14 . The top image of each respective traverse represents a possible scenario of possible magnetic bodies displaced by faulting or joints, whereas the middle image indicates the AMT derived resistivity depth image and the lower image the DC resistivity depth image.

Five (5) provisional drill sites were identified from the four traverses as summarised in Table 4. Drill sites selected are indicated on Figure 11, Figure 12 and Figure 14.

The complete report is available on request.

Table 4: Summarised TMF Drill Sites.

ID	X_utm35S_wg84	Y_utm35S_wg84	Distance on AMT	Dip	Depth	Comment
1	800910	7140716	135m on Line AB	90	>20	Priority 3 - targets a conductive zone below the sill
2	801065	7141085	535m on Line AB	90	>20	Priority 2 - is a lack luster target barely showing up on the AMT and no response on the DC resistivity
3A	800457	7143027	390m on Line CD	90	>20	Priority 1 - 3 A and B attempts to target the inferred fault shown up in the magnetic data of Traverse CD
3B	800452	7143016	365m on Line CD	90	>20	
4	798931	7142258	725m on Line GH	90	>20	Priority 4 - between 2 sills where the AMT and DC resistivity indicate a deepening of less resistive material from surface

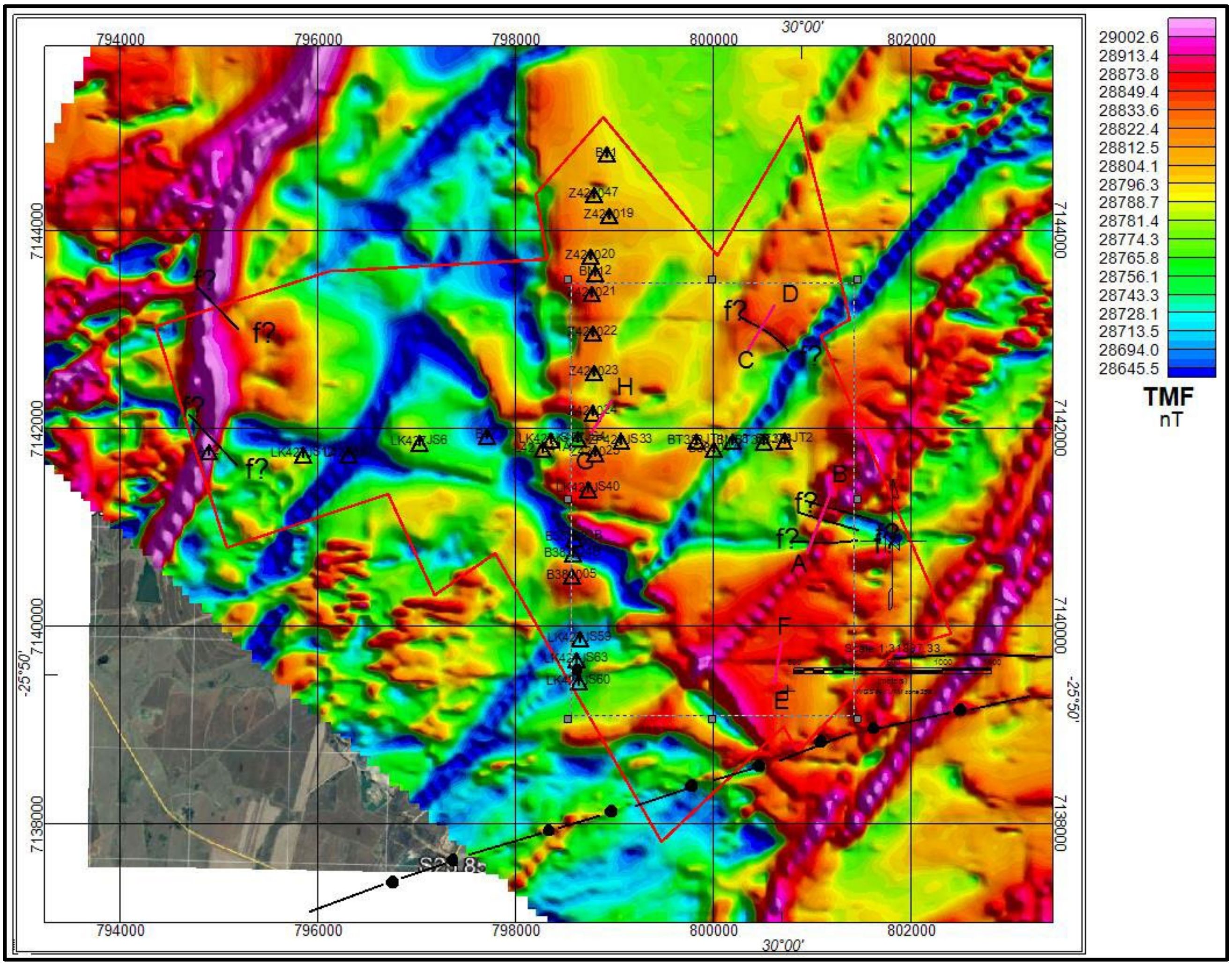


Figure 10: Total Magnetic Field (TMF) Image (Exxaro)

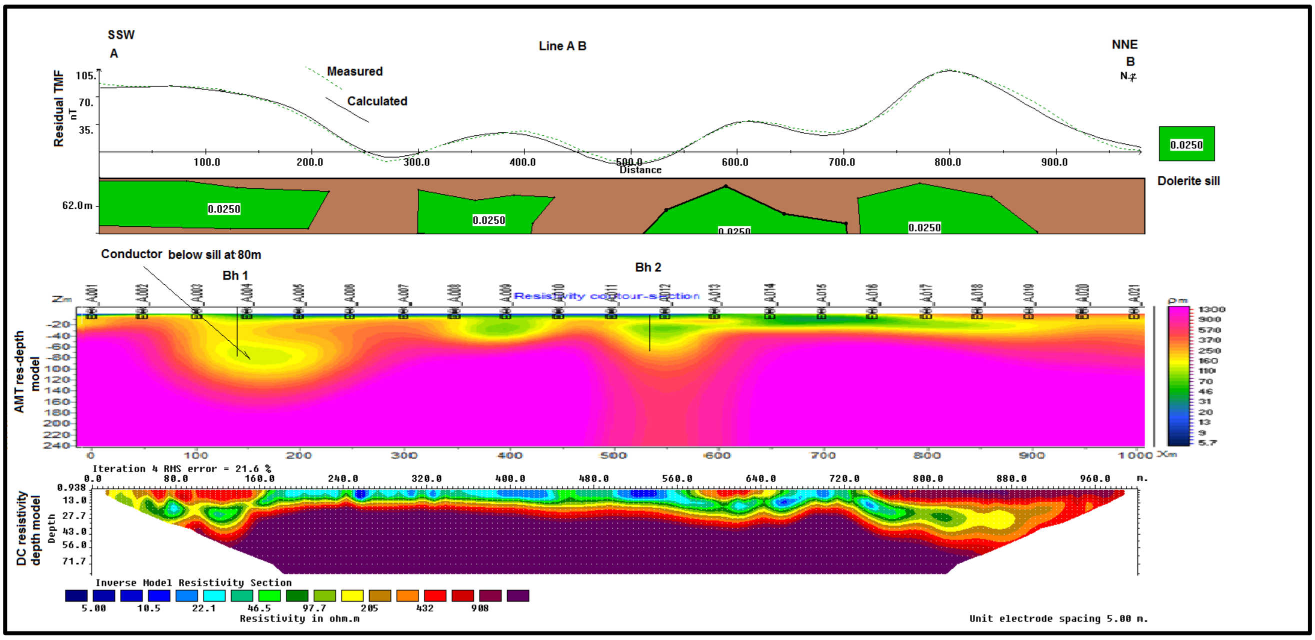


Figure 11: Traverse A-B Montage

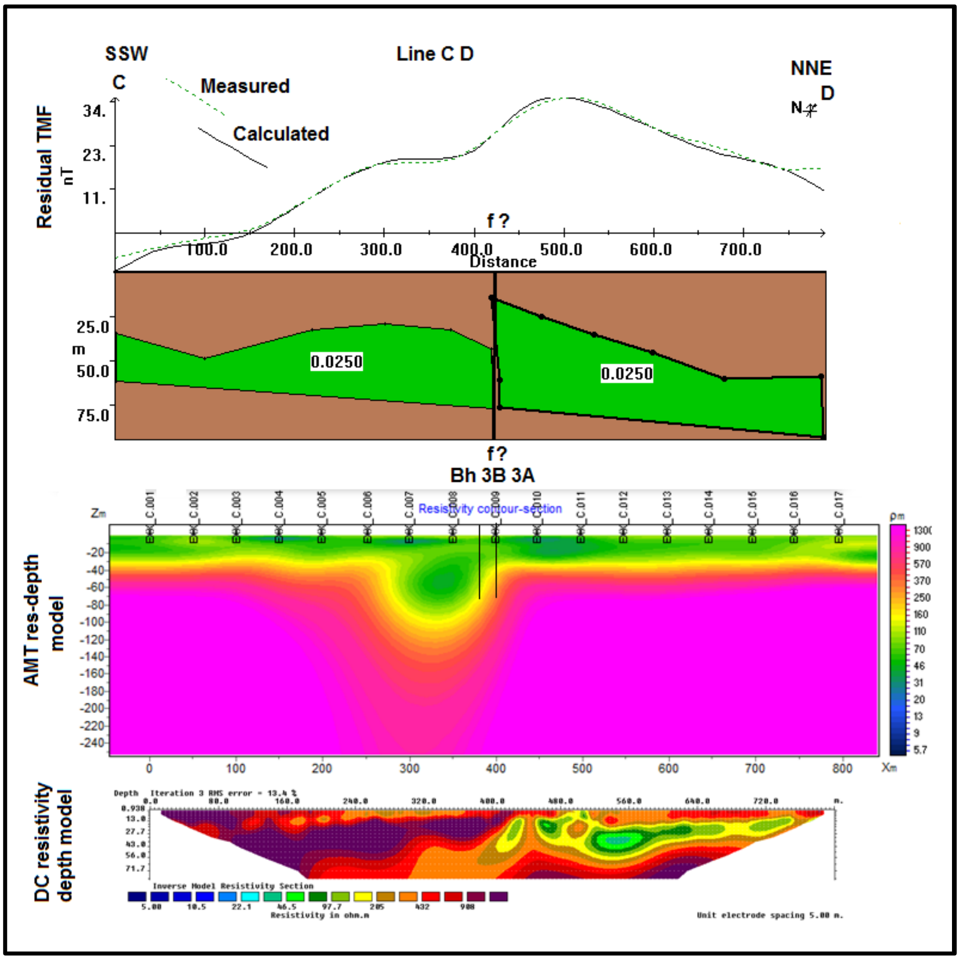


Figure 12: Traverse C-D Montage

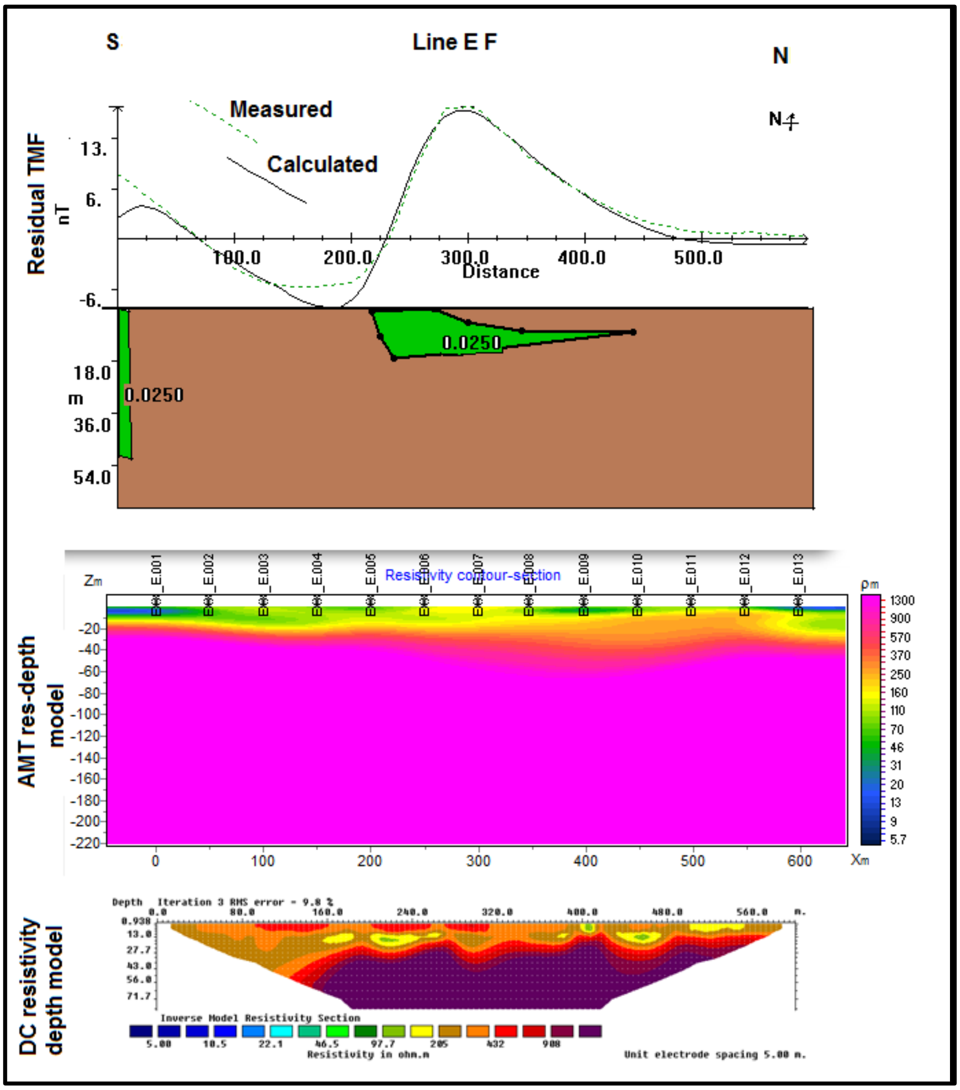


Figure 13: Traverse E-F Montage

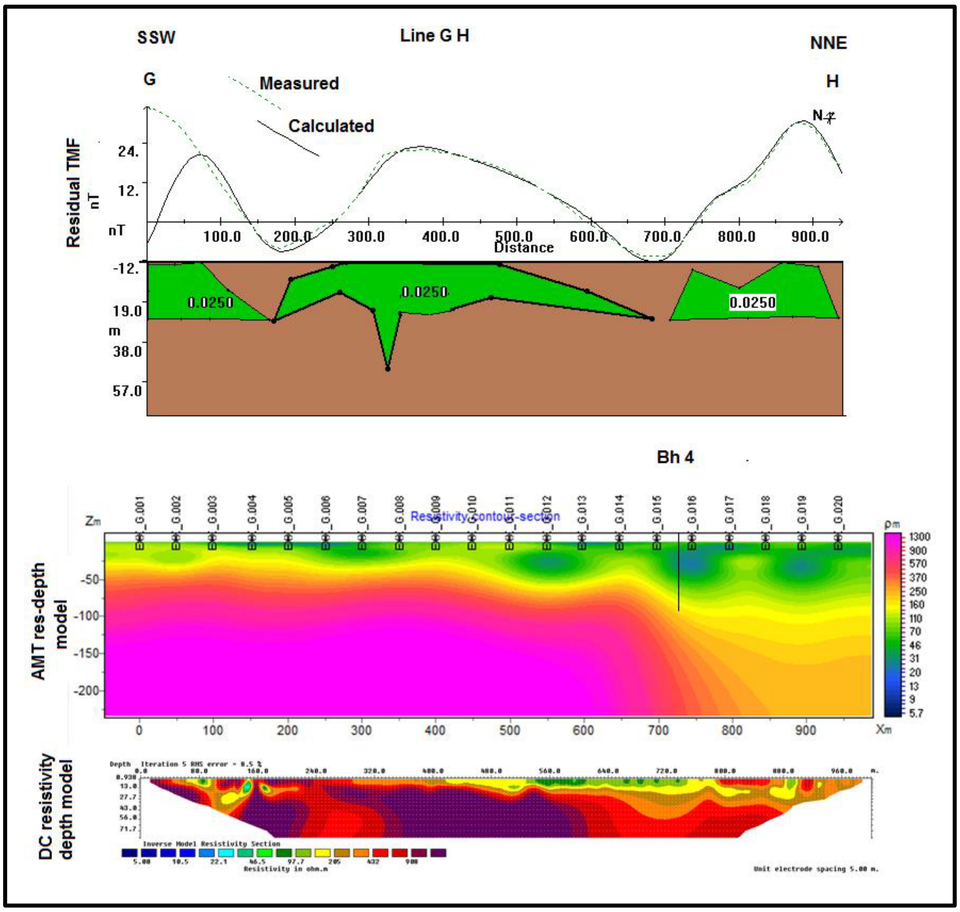


Figure 14: Traverse G-H Montage

5.3 Drilling and Siting of Boreholes

5.3.1 Drilling of Monitoring Boreholes (Groundwater Complete 2009)

Eight (8) monitoring boreholes drilled during 2009, were sited by means of ground geophysical surveys by means of a combination of magnetic and electro-magnetic methods by Groundwater Complete.

The groundwater monitoring boreholes in the proposed Belfast project area have been sited mainly on geological structures such as dykes or faults around the planned opencast mining operation (Groundwater Complete 2009). The drilling results are summarised in Table 5, positions are indicated on Figure 16, with an example of the borehole logs (GP02) in Figure 15.

Table 5: Summarised Drilling Results of Monitoring Boreholes (Groundwater Complete 2009)

Borehole	Depth	Lithology*	X-Coord (LO29 WGS)	Y-Coord	WL mbgl	Casing depth
GP01	31	Samples lost before logging	99802	-2850160	7.6	11
GP02	31	SOIL, SNDS	100452	-2853109	6.7	5
GP04	31	SOIL, SNDS	100494	-2855021	6.9	11
GP05	31	SOIL, SNDS, SHLE, COAL, SDSL	98656	-2854725	3.1	13
GP06	31	SOIL, SNDS	98721	-2856886	7.4	11
GP08	31	SOIL, SHLE	96591	-2857316	8.2	7
GP09	31	SOIL, SNDS, SHLE, COAL, SDSL	95380	-2855815	1.2	12

Borehole	Depth	Lithology*	X-Coord (LO29 WGS)	Y-Coord	WL mbgl	Casing depth
GP11	31	SOIL, SHLE, SNDS	94338	-2854716	4.6	11

Note: SHLE - Shale, SNDS- Sandstone, SDSL - Sandstone and Shale – interlaminated, WL – Water Level (meters below surface), Casing – casing, depth (m), Co-ordinate system – Cape LO29

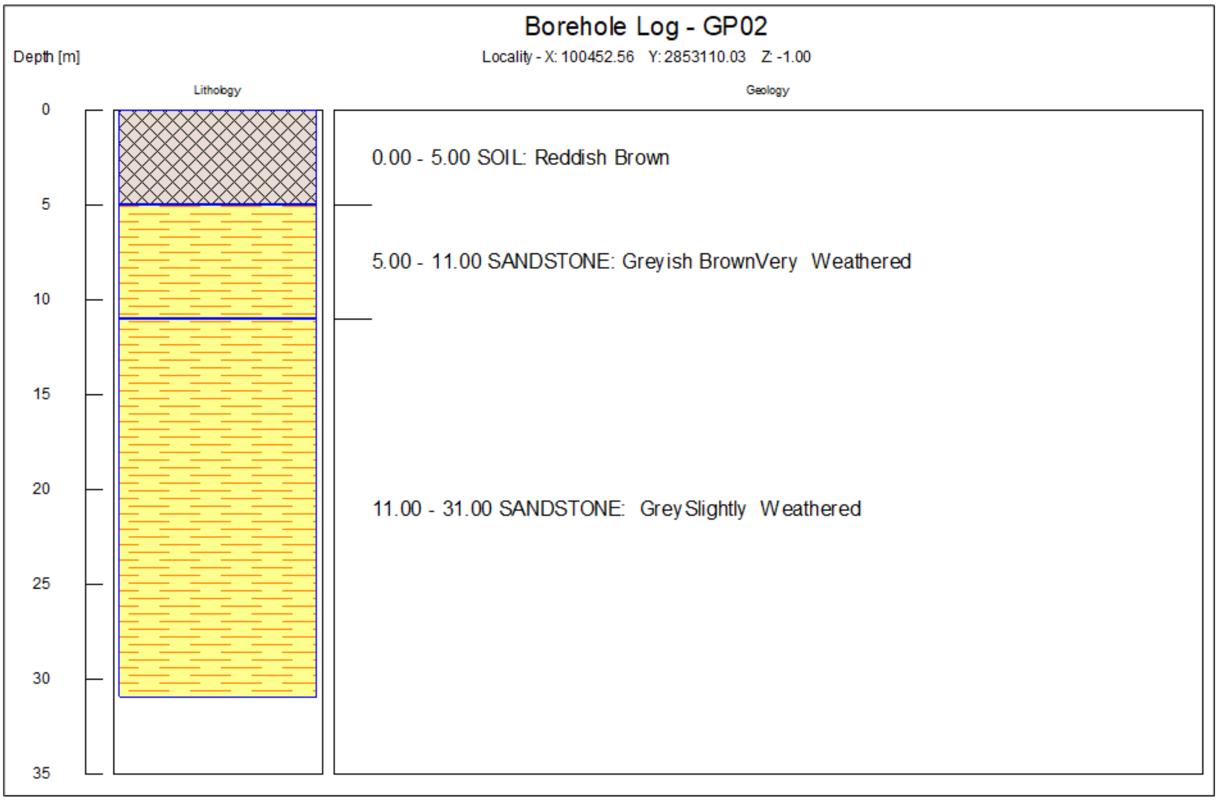


Figure 15: Borehole Log - GP02 (Groundwater Complete 2009)

5.3.2 Drilling of Monitoring Boreholes (Groundwater Complete 2014)

In 2009, eight (8) monitoring boreholes (Table 5) were drilled for the proposed Belfast mining project (Figure 17). In 2014 a total of four (4) additional boreholes (BBH01-BBH05) were drilled for monitoring and potable water supply (Figure 17). The positions of both the 2009 and 2014 boreholes are indicated in Figure 16 and the drilling results are summarised in Table 6.

Table 6: Summarised Drilling Information of 2009 and 2014 Monitoring Boreholes (Groundwater Complete 2014)

Borehole ID	Borehole Depth (m)	Steel Casing Depth (m)	Date Drilled	PVC Casing Depth (m)	Lithology
GP01	30	3	2009	27	Soil, Sandstone, Mudstone, Carbonaceous shale.
GP02	35	3	2009	32	Soil, Sandstone, Mudstone, Carbonaceous shale, Siltstone.
GP04	35	3	2009	32	Soil, Siltstone, Mudstone, Carbonaceous shale, Dolerite.
GP05	40	3	2009	37	Soil, Coaly Sandstone, Dolerite, Siltstone
GP06	70	3	2009	67	Soil, Sandstone, Siltstone, Coaly Sandstone, Coal.
GP08	33	3	2009	30	Soil, Sandstone, Mudstone, Coal.
GP09	20	3	2009	17	Soil, Siltstone, Mudstone.
GP11	20	3	2009	27	Soil, Sandstone, Mudstone, Dolerite.
BBH01	50	na	2014	0 - 15 PVC Solid 15 - 18 PVC Perforated 18 - 47 PVC Solid 47 - 50 PVC Perforated	Soil, Clay, Sandstone
BBH02	50	na	2014	0 - 28 PVC Solid 28 - 31 PVC Perforated 31 - 47 PVC Solid 47 - 50 PVC Perforated	Soil, Sandstone, Shale, Carbonaceous shale, Dolerite
BBH04	30	na	2014	0 - 14 PVC Solid 14 - 17 PVC Perforated 17 - 23 PVC Solid 23 - 30 PVC Perforated	Soil, Clay, Shale, Sandstone
BBH05	30	na	2014	0 - 3 PVC Solid 3 - 6 PVC Perforated 6 - 27 PVC Solid 27 - 30 PVC Perforated	Soil, clay, Sandstone, Shale

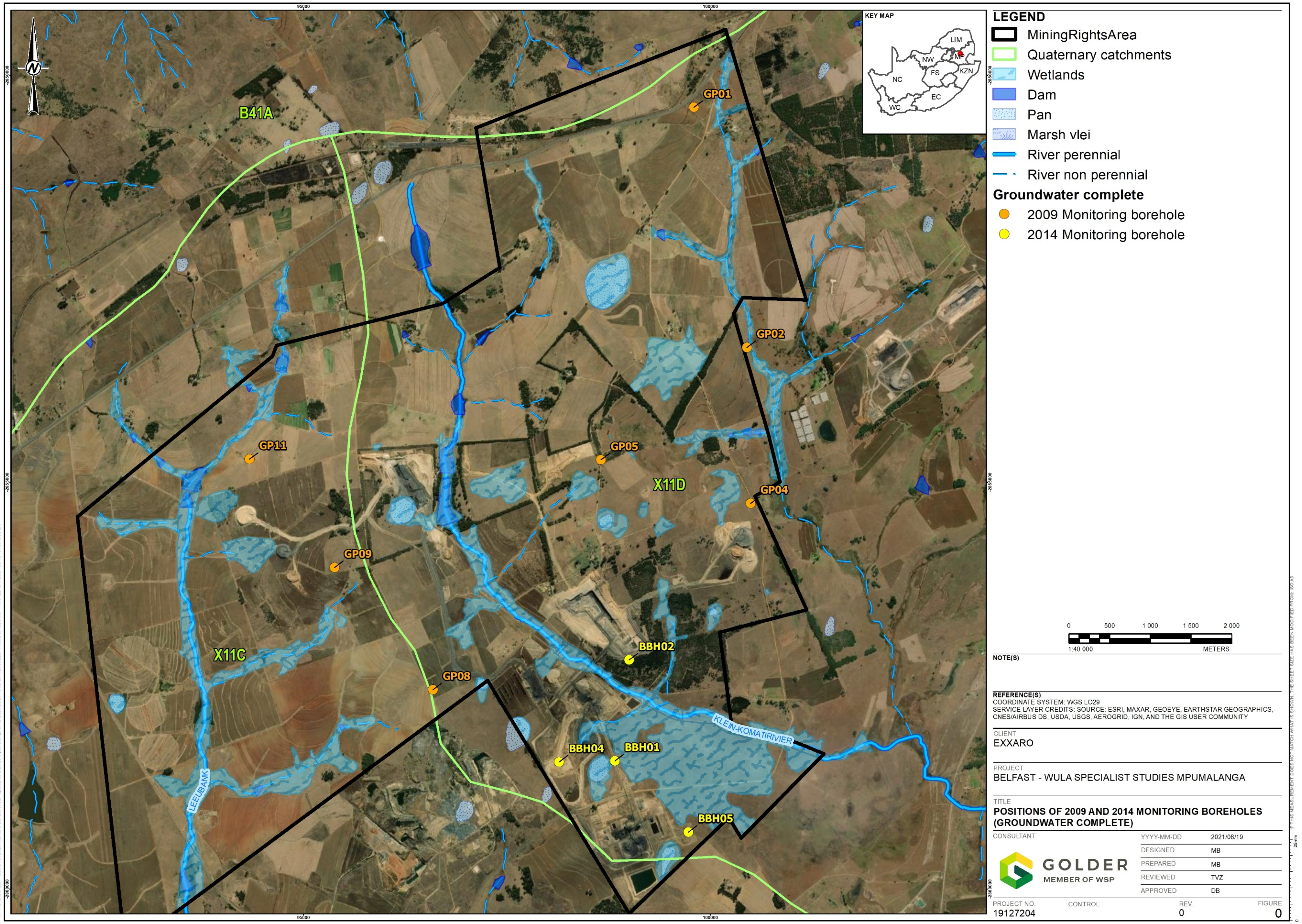


Figure 16: Positions of 2009 and 2014 Drilled Monitoring Boreholes (Groundwater Complete)

5.3.3 Drilling of Potential Water Supply Boreholes (Groundwater Complete 2014)

Two (2) additional boreholes were drilled in 2014 for water supply. Borehole BBH03 was drilled at position 170m on Line 1 (Figure 8). The borehole was drilled to a depth of 50m into the older basement rhyolite below the Karoo sediments without any significant water strikes (Figure 17). The borehole was backfilled to a depth of 20 meters below ground level (mbgl) and constructed as a monitoring borehole (Groundwater Complete 2014).

Borehole BBH06 was drilled at position 410m on Line 1(Figure 8). The borehole intersected the basement rhyolite at 15 mbgl and was drilled to a final depth of 20 mbgl. A blow yield of approximately 0.3 l/s was measured at around 15 mbgl. The borehole was also constructed as a monitoring borehole (Groundwater Complete 2014).

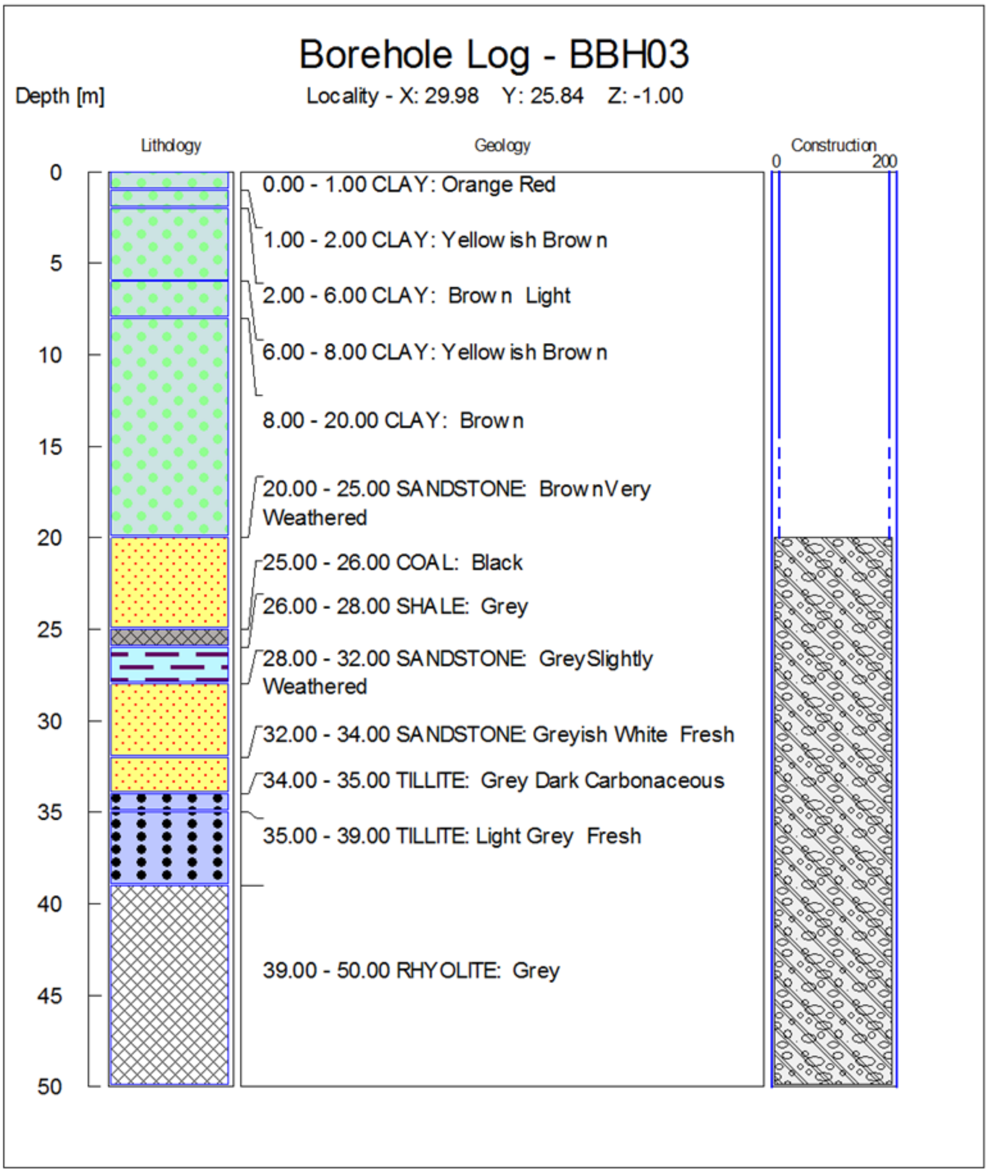


Figure 17: Example of Borehole log BBH03 (Groundwater Complete 2014)

5.4 Aquifer Testing

Aquifer testing was conducted at five boreholes during 2009 by Groundwater Complete (5.4.2) and during 2014 (5.4.3).

5.4.1 Aquifer Testing Procedures

The aquifer testing procedures consists out of a step drawdown/discharge test (SDT) followed by a constant discharge test (CDT), and a water level recovery test. The SDT test comprised three 60-minute steps at increasing pumping rates. The aim of the SDT is to assess the performance of the borehole under different pumping yields and determine the pumping rate for the CDT.

The CDT is conducted to determine the hydraulic parameters of the aquifer and identify possible aquifer boundaries. The CDT's was conducted mostly for periods of 24 hours after which the water level recovery was measured. The CDT pumping rates were set at yields determined from the SDT to be sustainable for the planned duration of the test.

5.4.1.1 Slug Testing

Slug tests provide a rapid means of assessing the in-situ hydraulic conductivity in boreholes with insufficient yields (low yields) to undertake pumping tests. The test involves measuring the water-level response in a borehole to a rapid displacement of water. The displacement was induced through the introduction of a slug below the rest water level. The rate of recession of the water level displacement provides an indication of the hydraulic conductivity of the borehole. The water level responses were measured using an electronic water level data logger.

5.4.2 Aquifer Testing (Groundwater Complete 2009)

Aquifer testing was conducted at seven (7) of the new 2009 monitoring boreholes. These pump tests were performed using a low yield pump with the main aim of determining the transmissivity and storage characteristics of the solid geological formation (viz. aquifer matrix). These low-rate pump tests are performed instead of the more commonly used slug tests because of the much-improved accuracy obtained with the pump tests, resulting in much more reliable aquifer parameters calculated from the tests (Groundwater Complete 2009).

The transmissivity values for boreholes in the proposed open pit mining areas were calculated and averaged (Table 7) to use as model input and calibration parameters.

The pump tested boreholes harmonic and geometric mean of the late transmissivity values are 0.4 m^2/d and 1.2 m^2/day respectively.

Table 7: Aquifer Parameters of Monitoring Boreholes (Groundwater Complete 2009)

Borehole Unit	Tf m^2/d	Tm m^2/d	Sf	Sm
EBH01	1.7	0.2	0.005	NA
EBH02	1.9	0.2	0.004	NA
EBH03	59	14	0.005	0.1
EBH08	1.7	0.5	0.004	0.007
GP01	1.1	0.2	0.002	NA
GP02	29	7.7	NA	0.005
GP04	29	8.8	NA	0.007
GP05	13.6	5.5	0.006	0.04

Borehole Unit	Tf m^2/d	Tm m^2/d	Sf	Sm
GP08	1.6	0.2	0.004	0.005
GP09	1.5	0.4	0.003	0.01
GP11	10.3	4.8	0.001	0.007
Harmonic Mean	**2.6**	**0.4**	**0.003**	**0.01**
Geometric Mean	**5.3**	**1.2**	**0.004**	**0.015**

***Note**:*

Tf – Transmissivity at the start of the test, usually fracture dominated flow.

Tm – Transmissivity at the end of the test, usually matrix dominated flow.

Sf – Storativity at the start of the test, usually fracture dominated flow.

Sm – Storativity at the end of the test, usually matrix dominated flow.

NA – not accurately determinable by the specific method or test or unrealistic result.

5.4.3 Aquifer Testing (Groundwater Complete 2014)

Five (5) boreholes were subjected to aquifer testing during 2014 and are summarised in Table 8 and displayed on Figure 8. The intention was also to test BBH05 but the water level in the borehole has dropped to below the water strike (3 meters below surface). Borehole BBH05 was tested with a slug test, which confirmed that little or no yield capacity remained in the borehole (Groundwater Complete 2014).

Table 8: Summarised Aquifer Tested Borehole Information (Groundwater Complete 2014)

Borehole	Latitude (WGS84)	Longitude (WGS84)	BH depth (m)	SWL (mbgl)	Water strike depth (mbgl)	Pump Test Rate (l/s)
EBH03	-25.81286	29.97285	29.5	2.40	N/A	1.0
GP04	-25.80237	30.00185	30.5	7.32	23	0.7
WCPret01	-25.80776	29.98273	120	29.10	118	>1.5
BBH02	-25.81969	29.98707	50	18.91	28	0.72
BBH06	-25.83929	29.98284	21	10.30	17-18	0.25

5.4.4 Aquifer Testing (GCS 2018)

Three (3) boreholes drilled as water supply boreholes for BIP by Exxaro, BT35GW, ZP22GW and ZP23GW was pump tested during April 2018 by GCS Water and Environment Consultants (GCS) (Table 9). The positions of the pump tested boreholes are indicated on Figure 18.

The CDT's were conducted for a period of 24 hours at two boreholes (BT35GW and ZP22GW), after which the water level recovery was measured (Figure 19).

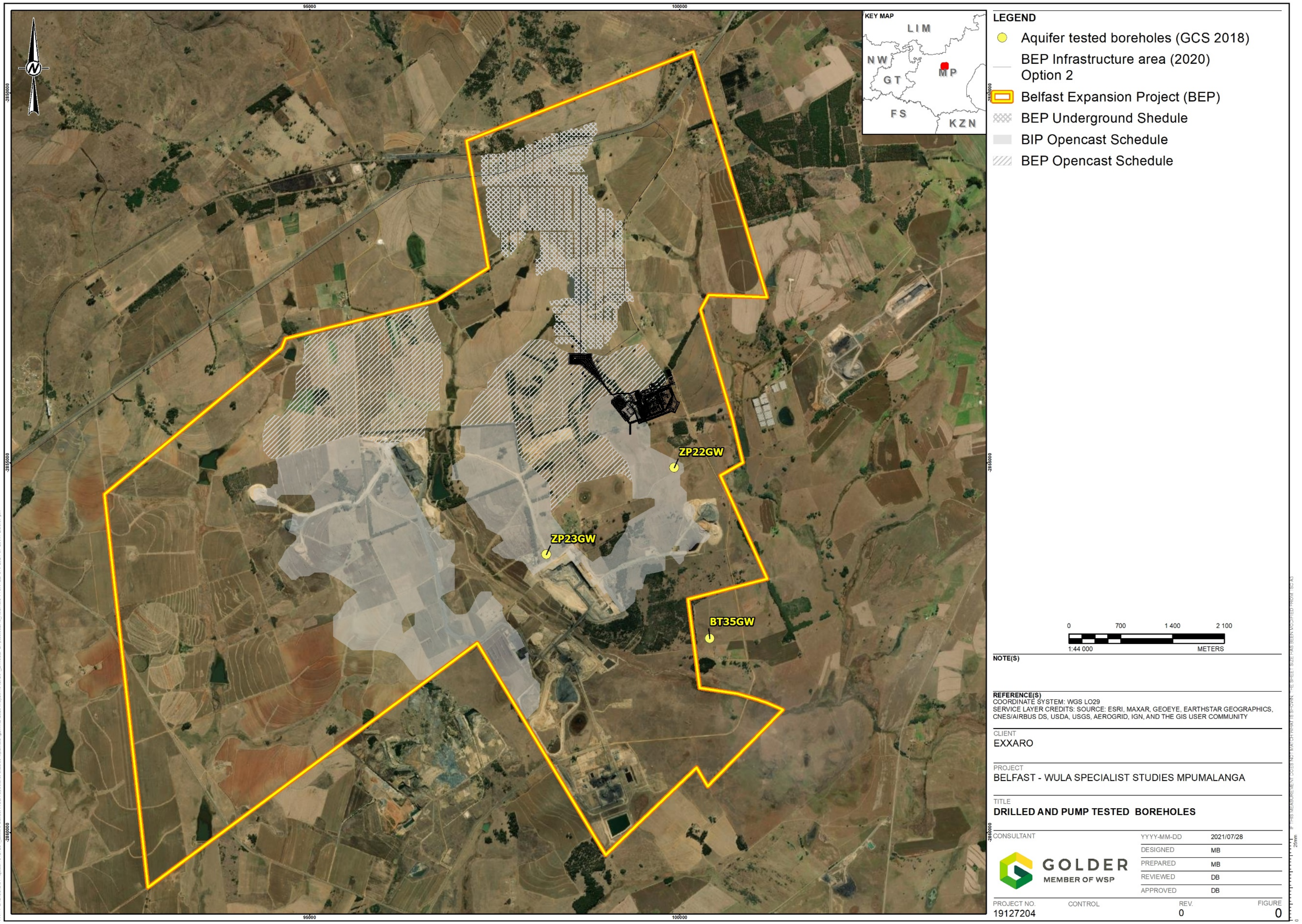


Figure 18: Pump Tested Boreholes (GCS 2018)

Two of these boreholes (BT35GW and ZP22GW) have been tested to determine their abstraction volumes. A total drawdown of 77.18m was achieved in ZP23GW after 1 hour and 15 minutes whereby pump suction was reached and was not subjected to a CDT.

Table 9: Aquifer Tested Boreholes (GCS 2018)

Borehole ID	Latitude	Longitude	Depth (m)	Collar Height (m)	Water Level (mbgl)	SWL (mbgl)
BT35GW	-25.8209	30.00137	130.7	0.6	3.12	2.52
ZP22GW	-25.8001	29.99638	131.47	0.55	12	11.45
ZP23GW	-25.8108	29.97924	198.8	0.38	40.8	40.42

The water strike depths recorded during drilling programme (Exxaro 2015) is summarised in Table 10.

Table 10: Reported Water Strikes (GCS 2018)

BH ID	Water strikes minor (mbgl)	Water strike Major (mbgl)	BH depth (m)	SWL (mbgl)
ZP22GW	20 and 80	119	130	12
BT35GW	20 and 52	120	130	2.8
ZP23GW	N/A	N/A	200	42

The aquifer testing programme is summarised in in Table 11 and the aquifer testing parameter are summarised in Table 12 .

Table 11: Summarised Aquifer Testing Programme

Borehole Number	Borehole Depth (m)	Static Water level (mbgl)	No of SDT's	Final Yield of SDT (l/s)	DD (m)	Duration of CDT (Min)	Yield of CDT (l/s)	DD of CDT (m)	% Recovery
BT35GW	130.7	2.52	4	2.7	24.26	1440	1.9	54.24	63
ZP22GW	131.47	11.45	4	3.3	15.47	1440	3.0	97.9	91

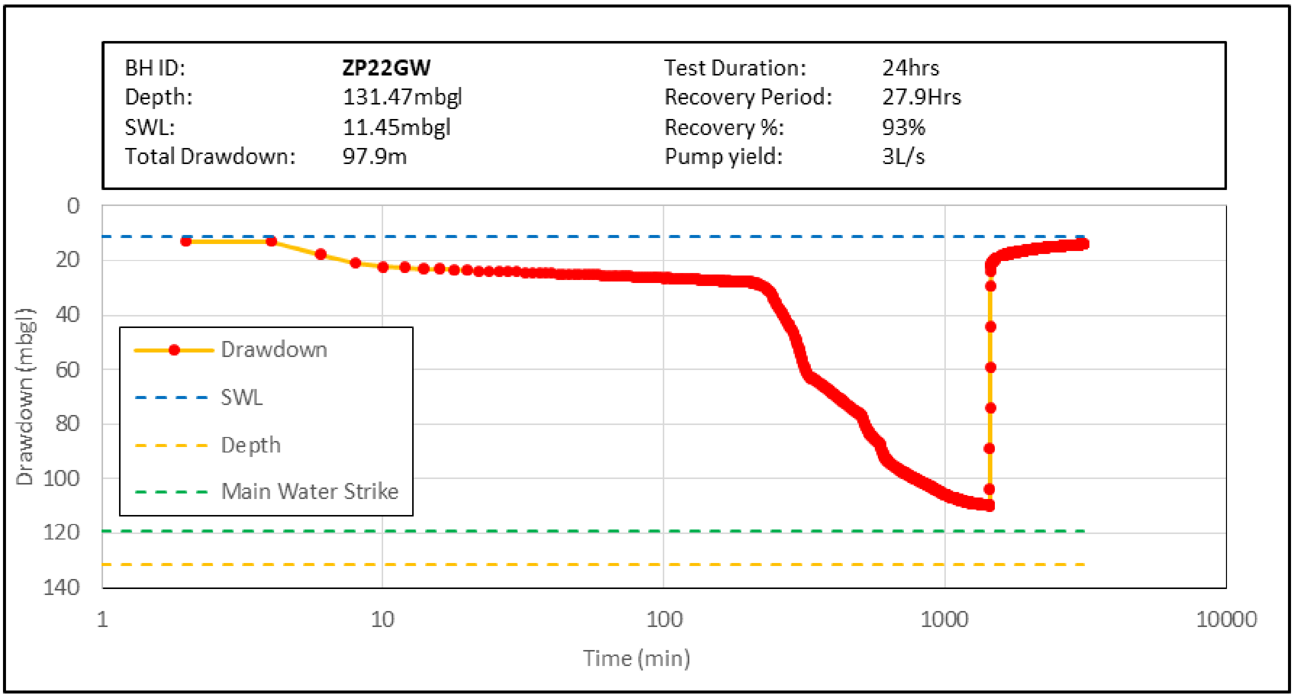


Figure 19: Example of CDT Graph at ZP22GP (GCS 2018).

The pump tested boreholes can be pumped at a sustainable yield of 1 l/s (BT35GW) and 2 l/s (ZP22GW), respectively. Total volume of 259 200 l/d can be abstracted from BT35GW and ZP22GW. The average late time T value of the two pump tested boreholes is 0.42 m^2/d.

Table 12: Aquifer Testing Results (GCS 2018)

Borehole ID	Total Drawdown (m)	Recovery Period (hrs)	Recovery %	Transmissivity (m^2/day)	
				Early	Late
BT35GW	54.24	2.7	100	5.66	0.125
ZP22GW	97.9	27.9	93	12.96	0.715
Average				**9.31**	**0.42**

5.5 Groundwater Recharge

5.5.1 Regional Aquifer Recharge

From the published hydrogeological maps (DWAF 1996) the average recharge of the BEP investigation area is shown as between 50 and 75 mm per annum (8 to 11% of the MAP of 674mm/a) (Figure 20).

5.5.2 Groundwater Recharge Calculations – Groundwater Complete 2009

2009 groundwater recharge calculations for the entire Belfast mining project area (BIP and BEP), is estimated at between 1 and 3 % of MAP (6.7 to 20.2 mm/a). Where sandstone outcrop occurs, the effective recharge percentage can be slightly higher while in low-lying topographies where discharge generally occurs and thicker sediment deposition, the effective recharge will be lower. Based on this estimate, the average recharge to the pre-mined East mine block area is approximately 920 m^3/d (337 000 m^3/y) and to the West block approximately 510 m^3/d (188 000 m^3/y) (Groundwater Complete 2009).

Despite the significant annual rainfall, the effective recharge to the aquifer(s) is estimated to be around 5% (or less) of MAP. This low figure is a direct result of several factors including most notably:

- Surface geology consisting of relatively low permeability Karoo type sediments.
- High rate of evapo-transpiration that exceeds the precipitation and causes a net environmental water deficit for most of the year.

Qualified assumptions from general equations and expert opinions have been made by scientists for recharge in this Karoo Supergroup geology (v. Tonder & Xu, 2001). Depending on the soil cover thickness the estimated recharge to the typical Karoo aquifers (sandstone, mudstone and siltstone) varies between 2 and 5% of the MAP (Table 13). A 5% recharge for Karoo sediments of the MAP of 674mm/a is 34mm/a, which is lower than the regional recharge of 50 to 75 mm/a as per regional recharge map (Figure 20).

Table 13: Typical Recharge Values for Different Geology (v. Tonder & Xu, 2001)

Geology	% Recharge (soil cover <5m)	%Recharge (soil cover >5 m)
Sandstone, mudstone, siltstone	5	2
Hard Rock (granite, gneiss etc.)	7	4
Dolomite	12	8
Calcrete	9	5
Alluvial sand	20	15
Coastal sand	30	20
Alluvium	12	8

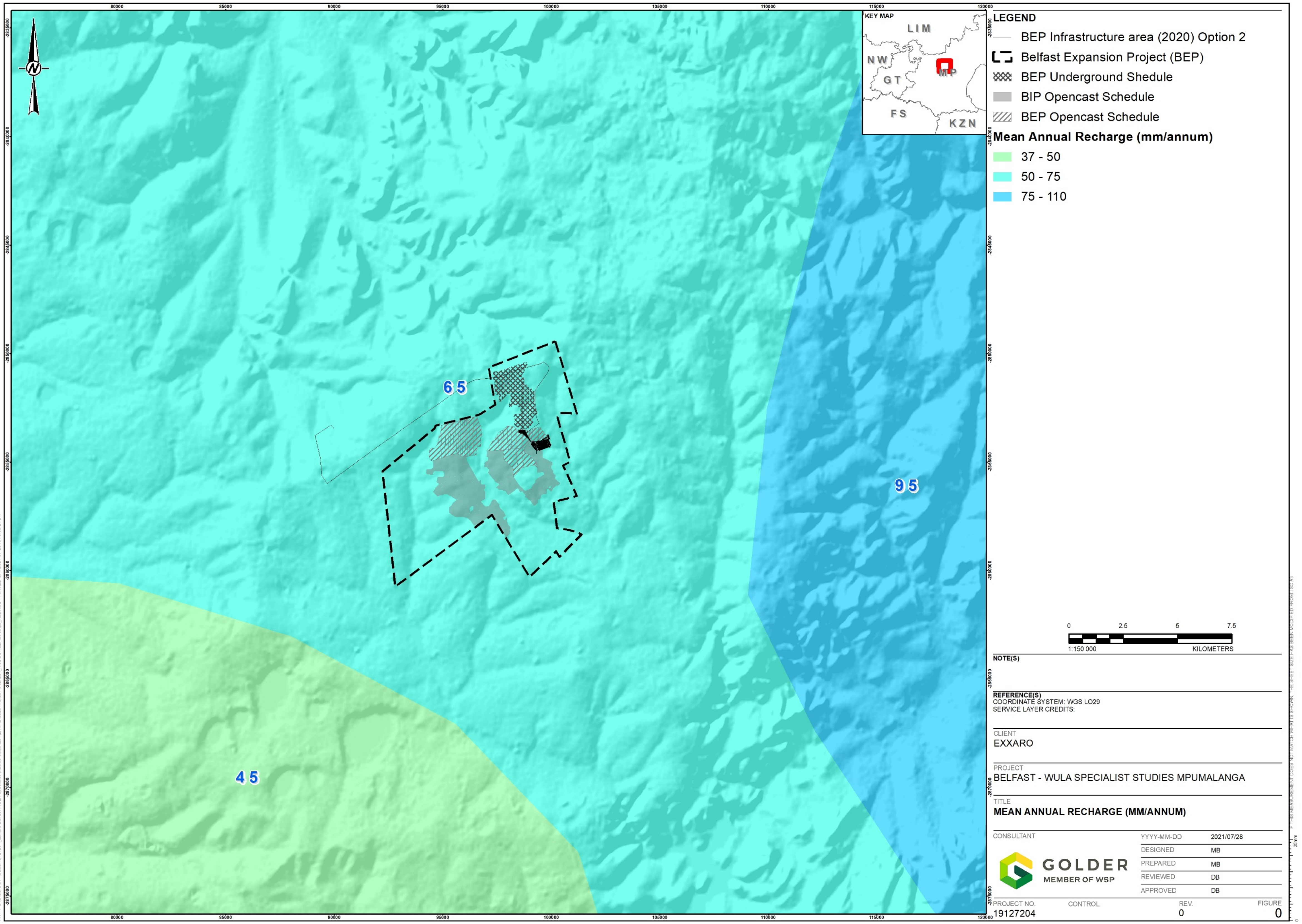


Figure 20: Regional Groundwater Recharge

5.5.3 Groundwater Recharge Calculations – Groundwater Complete 2014

2014 recharge calculation in the BIP opencast project area is estimated to be between 2 and 5% of MAP (13.5 to 34mm/a of a MAP of 674mm/a). Where sandstone outcrop occurs, the effective recharge percentage can be slightly higher while in low-lying topographies where discharge generally occurs and thicker sediment deposition, the effective recharge will be lower. Based on this estimate, the average recharge to the pre-mined East mine block area is approximately 300 m^3/d (110 000 m^3/y) and to the West block approximately 370 m^3/d (135 000 m^3/y). The 2014 recharge values vary significantly from the 2009 calculations due to the much smaller mining areas of the BIP.

After mine closure, however, recharge is usually significantly higher to the backfilled mine void compared to the pre-mining aquifer and after filling up, the discharge is usually higher than before the disruption by mining. The effective recharge is especially higher for opencast mining and can be as much as <u>5 to 15 times</u> the natural recharge without the effect of mining. With all proposed mining in the BIP project area being opencast operations, the recharge pattern will thus be changed dramatically.

Surface water features like dams (tailings, slurry, process water, storm water, return water etc.) will also usually increase the recharge to the aquifer but compacted or concrete surfaces and roads will decrease the recharge (Groundwater Complete August 2014).

5.6 Groundwater Modelling

Groundwater numerical was conducted by Groundwater Complete in 2009 (Section 5.6.1) and updated in 2014 (Section 5.6.2). For purposes of this report an updated numerical model by Golder in 2020/21 to include the Belfast Expansion Project (BEP) and railway loop will be discussed (Section 5.6.3).

5.6.1 Groundwater Modelling – Groundwater Complete 2009

A groundwater numerical model was developed by Groundwater Complete in 2009 to evaluate the potential impact of the proposed mine on the groundwater environment.

The modelling package PMWIN Pro (Processing Modflow Professional for Windows) was used for the simulation. The regional Belfast project model (BIP) that includes both the West and East proposed new mining blocks covers an area of ± 98 km^2 (8.5 by 11.5 km). The model was run in steady state conditions until representative transmissivity and recharge distributions were obtained with a simulated hydraulic head distribution closely mimicking the average measured conditions. Two model layers were constructed in the model. Layer 1 simulates the upper weathered zone aquifer conditions, which has both the characteristics of a primary and secondary aquifer. Layer 2 represents the fractured rock, or secondary aquifer (Groundwater Complete 2009).

5.6.2 Groundwater Modelling – Groundwater Complete 2014

Numerical flow and mass transport groundwater models were constructed to simulate current aquifer conditions and to provide a tool for evaluation of different management options for the future. A risk analysis could also be performed where effects of different flow and concentration parameters as well as the impacts of nearby existing operations and management options could be evaluated.

The modelling package PMWIN Pro (Processing Modflow Professional for Windows) was used for the simulation. The regional Belfast model (BIP) that includes the proposed new mining areas covers an area of ± 93 km^2 (8.8 by 10.6 km). Two model layers were constructed in the model. Layer 1 simulates the upper weathered zone aquifer conditions, which has both the characteristics of a primary and secondary aquifer. Layer 2 represents the fractured rock, or secondary aquifer (Groundwater Complete – August 2014).

5.6.3 Groundwater Modelling – Golder 2020/21

The available data was interpreted and used to update the existing groundwater conceptual model. The conceptual model was used to provide the basic input to the groundwater model.

Golder uses FEFLOW for groundwater modelling as the preferred modelling package. FEFLOW is a highly sophisticated and powerful 3D finite element modelling package and is designed to cope with complex hydrogeological and mining situations.

5.6.4 Integrated Impact Assessment

The modelling was used to assess (predictive simulations) the likely impacts of the BEP on the existing groundwater regime:

- Possible impacts on the groundwater quality and quantity of existing groundwater users.
- Possible development of pollution plumes emanating from the site activities.
- Impacts on the existing groundwater level.
- Transport model for pollution impact assessment and control.

5.7 Groundwater Availability Assessment

Based on the published hydrogeological maps (DWAF 1996) the BEP investigation area is classified as a minor intergranular and fractured aquifer with yield ranging between 0.1 to 0.5 l/s (Figure 21).

The aquifer system comprises of weathered and fractured aquifer systems are present in the Karoo Supergroup (6.2):

- Top weathered aquifer system (6.2.1), with yields <0.3l/s is an unconfined aquifer system with an average thickness of ~ 10 m; and
- Fractured aquifer system (6.2.2), with yields ranging between 0.15 to >1.5.0l/s is a confined to semi confined aquifer system with an average thickness of ~20m below the weathered aquifer system. This aquifer system is characterised by secondary fractures resulting in preferential flow paths for the groundwater flow and possible contaminant migration.

Whereases the deep fractured aquifer system, with yields ranging between 0.1 to 2.0l/s is a confined aquifer system present in the Transvaal Supergroup (6.2.3) with deep water strikes between 118 to 120 mbgl.

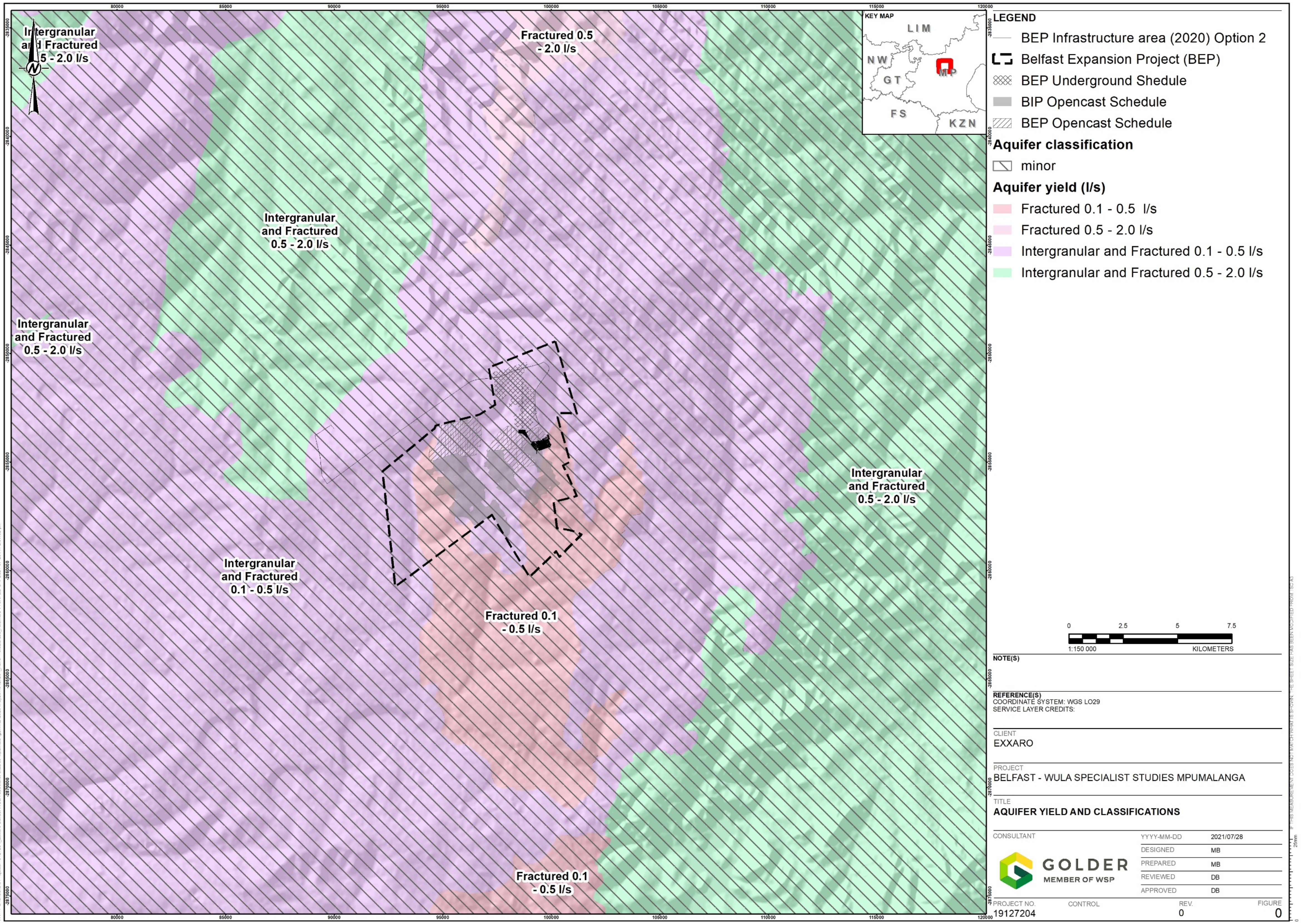


Figure 21: Aquifer Yield and Classification

5.7.1 Groundwater Complete 2009

The first aquifer system is a shallow weathered aquifer that occurs in the transitional soil and weathered bedrock zone or sub-outcrop horizon. This aquifer generally has a low yield with phreatic water levels sometimes occurring on un-weathered bedrock or clayey layers. Yields in this aquifer are low (generally less than 0.3 l/s) and the aquifer is not usable as a groundwater supply source on a continuous basis (Groundwater Complete 2009).

The second aquifer system is the fractured Karoo rock-type aquifer where groundwater yields, although more heterogeneous, can be higher than the weathered zone aquifer. This aquifer system usually displays semi-confined or confined characteristics with piezometric heads often significantly higher than the water-bearing fracture position. Yields from this aquifer could be sufficient to supply drinking and sanitation water to mining operations but are too low to use as a source of process water supply. In the boreholes tested as well as surveyed during the hydrocensus, sustainable yields of between 0.1 and 2 l/s were determined.

According to the Parsons Classification system, the aquifer could be regarded as a minor, but often a sole aquifer system (Groundwater Complete 2009).

5.7.2 Groundwater Complete 2014

Pump tests analyses and estimating sustainable yields, confirm that there are sufficient groundwater resources in the investigated properties to supply the project with potable water and make-up water for season start-up, i.e. a demand of 1.5 litres per second (l/s). The recommended sustainable yields, representative of the deep fractured aquifer system of the five (5) boreholes subjected to aquifer testing during 2014 by Groundwater Complete are summarised in Table 14.

Table 14: Recommended Sustainable Yield (Groundwater Complete 2014)

Borehole	Q (l/s)	Q (m^3/d)
EBH03	1.0	85
GP04	0.7	60
WCPret01	>1.5	>130
BBH02	0.3 for 12 h/d	13
BBH06	0.15 for 12 h/d	6
Total:	**>3.2**	**>275**

5.8 Geology

5.8.1 Regional Geology

Based on the 1:250 000 geological map series (2528 Pretoria), the BEP area is underlain by sedimentary rocks of the Karoo Supergroup as indicated on Figure 22. The basement is made up of pre-Karoo rocks of the Pretoria Group of the Transvaal Supergroup comprising of quartzite, shale, subgraywacke and minor hornfels. Pre-Karoo diabase is present to the east of the site.

The Karoo Supergroup comprises mainly a sedimentary succession of sandstones, siltstone, shale and coal seams. The coal seams are contained within the Vryheid Formation that forms part of the Middle Ecca Group. The sedimentary succession overlies the Dwyka formation, comprising of diamictite and tillite at the base of the Karoo Supergroup. Igneous intrusive rocks (dolerite dykes/sills) of late Karoo age invariably characterize the Mpumalanga coal fields, however no dolerite intrusions were indicted at the proposed BEP area.

The number 2, 3 and 4 seams will be mined. The number 3 coal seam, however, is described in the area and used mainly as a marker layer since it is not an economically mineable seam. Portions of the number 4 seam have been eroded away and vary significantly in thickness and quality (due to weathering).

A generalized vertical section of the sub-surface geology in the BEP area is presented in Figure 23 (Groundwater Complete August 2014).

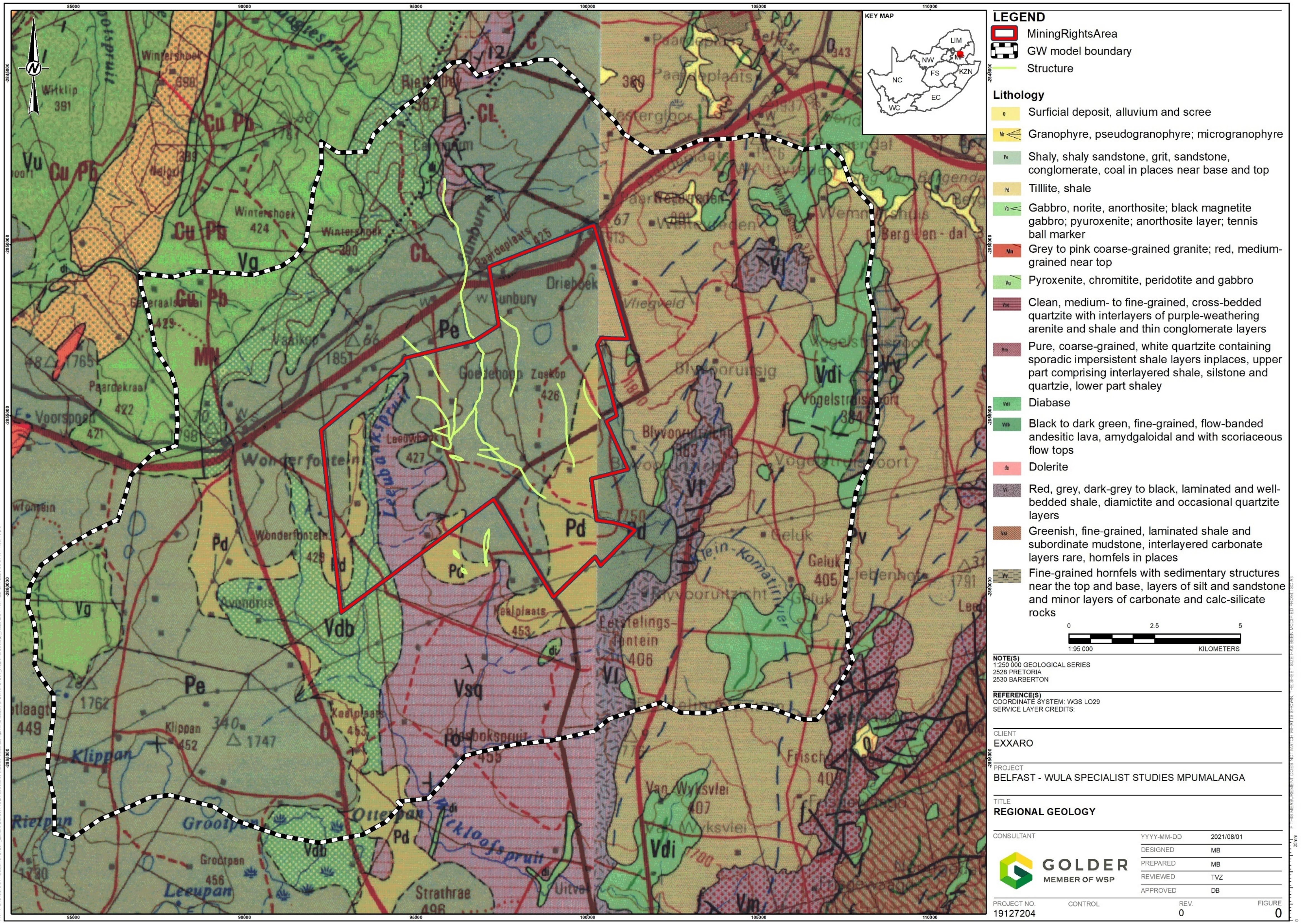


Figure 22: Regional Geology

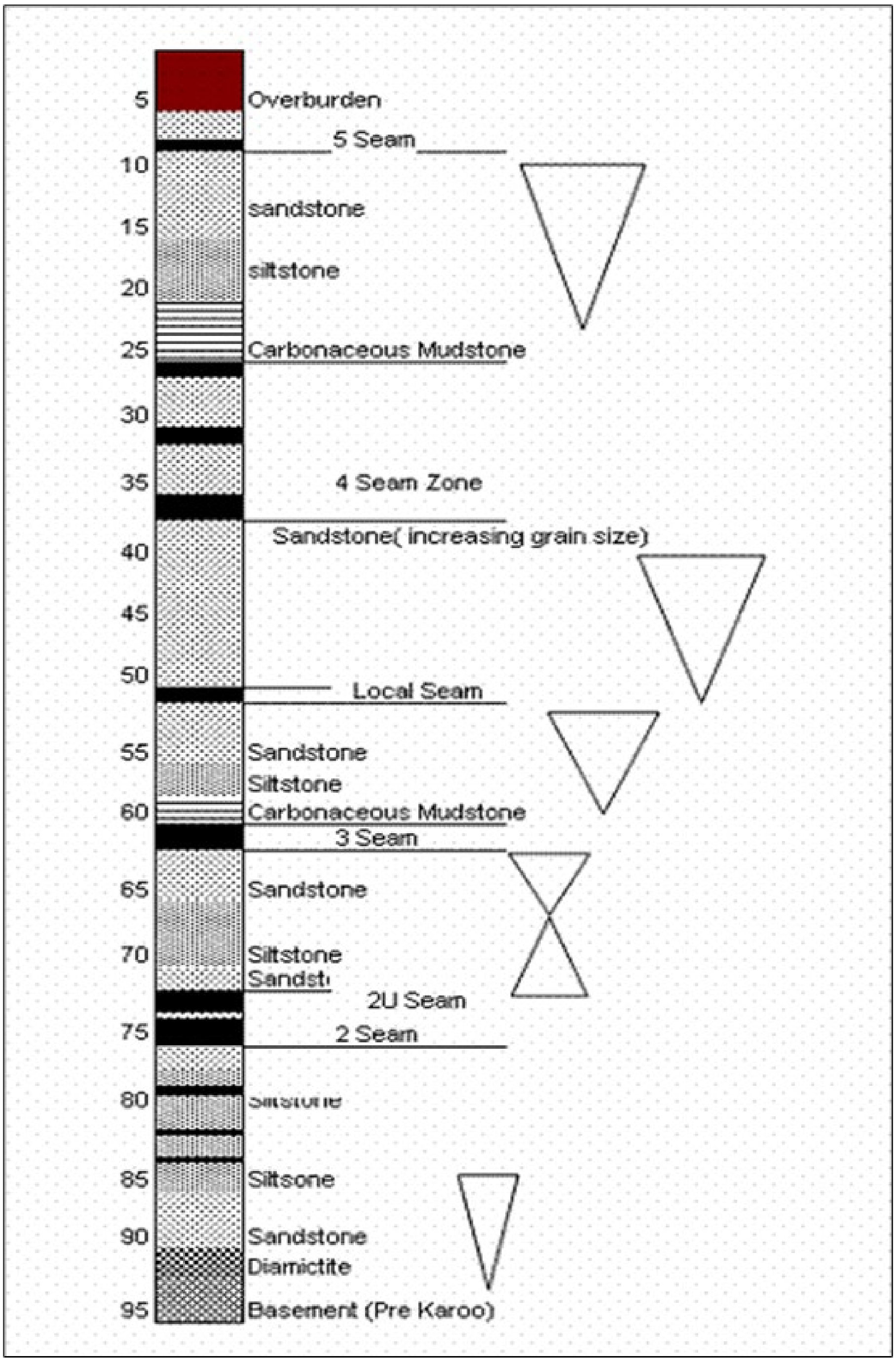


Figure 23: Simplified Stratigraphic Column of Belfast Project (July 2009)

5.8.2 Local Geology

The local geology is simplified in Figure 25 by Dr. Edgar Stettler (2016), representing the surface geology as reproduced from the 1:250 000 scale geological maps of the investigation area.

Faults, dolerite dykes and sills indicated in Figure 24 were mostly delineated during interpretation of the aeromagnetic survey conducted during the exploration phase (Figure 10). The intrusive dykes mostly trend NE-SW while the faults strike in random directions (Groundwater Complete August 2014).

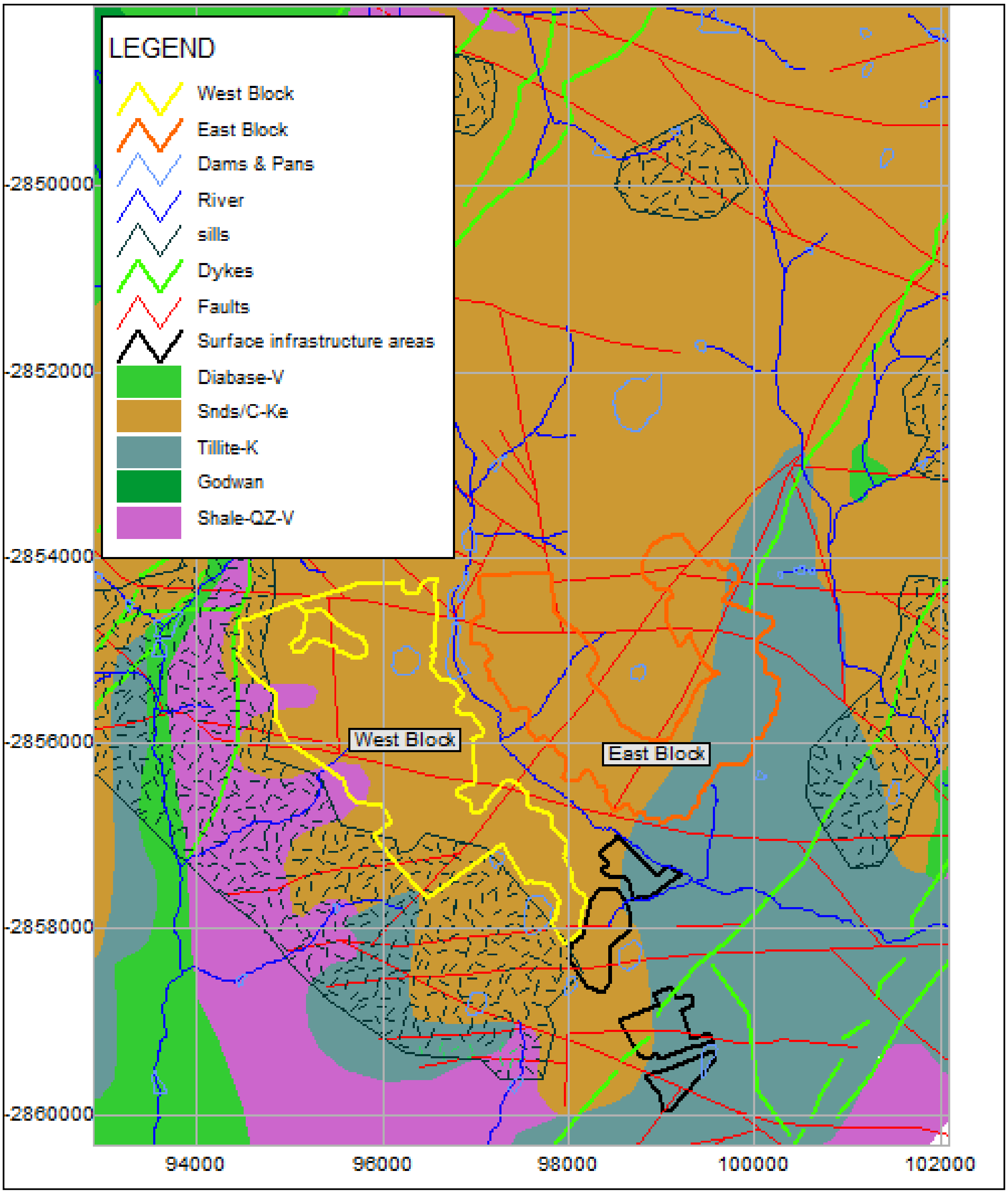


Figure 24: Simplified Site Geological 1:250 000 scale – (Adapted Groundwater Complete 2014)

In a hard rock aquifer environment such as the Belfast project, a good understanding of the structural geology is of utmost importance since geological structures largely govern the flow and mass transport in the area. Fault zones may contain highly transmissive fracture zones that will act as preferred pathways for groundwater flow and mass transport. Intrusive dykes can play different roles, namely:

- As barriers for horizontal groundwater flow and pollution movement so that the aquifer is compartmentalized;

- The outer contact zones between the dyke and the sedimentary rocks are usually fractured and acts the same as a fault zone, namely as a preferred pathway for flow and mass transport along the sub-vertical fracture zone; and
- The dolerite sill can act in the same manner as a dyke, but the orientation is generally horizontal, resulting in a barrier for vertical groundwater movement and horizontal seepage planes along the top and bottom contacts of the sill (Groundwater Complete August 2014).

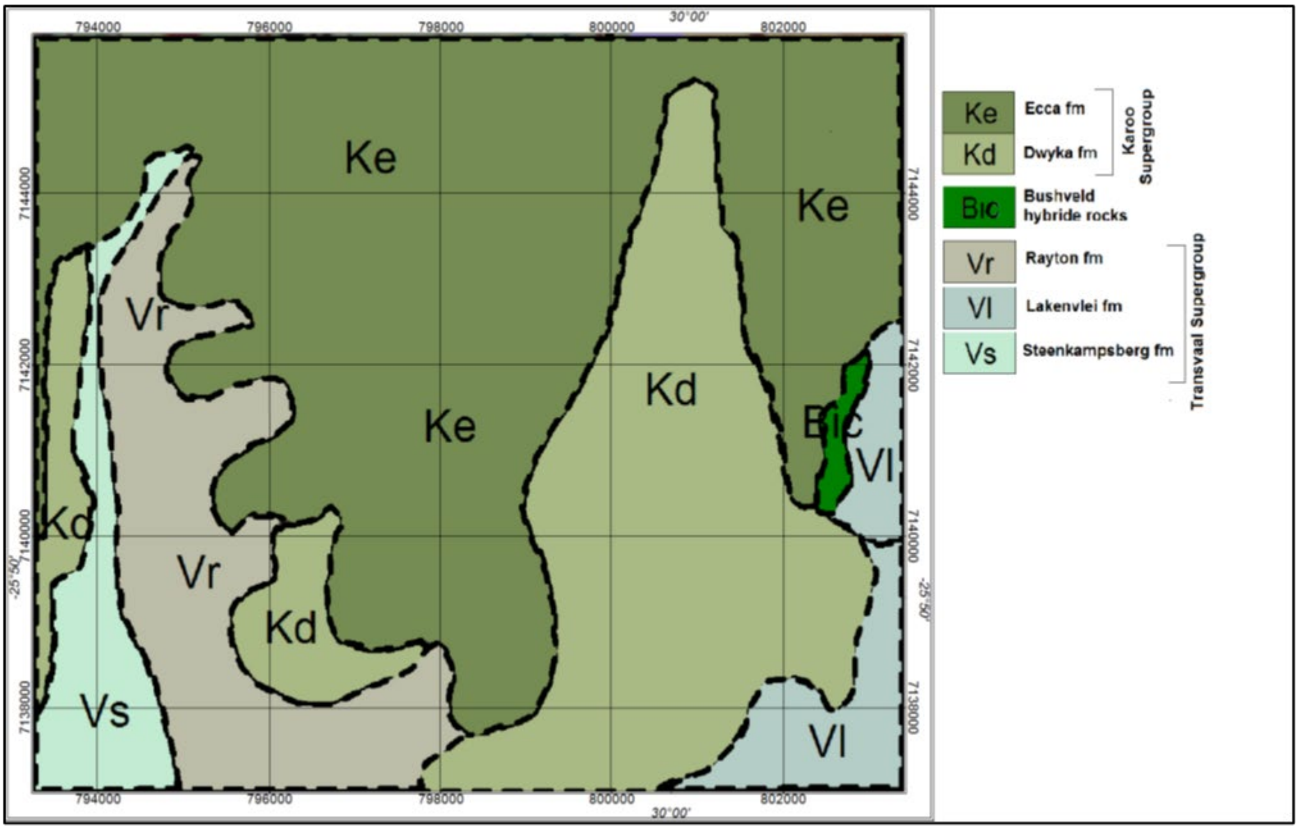


Figure 25: Simplified Geological Map – Dr. Edgar Stettler (2016)

5.9 Hydrogeology

5.9.1 Aquifer Transmissivity and Storativity

Aquifer transmissivity is defined as a measure of the amount of water that could be transmitted horizontally through a unit width of aquifer by the full-saturated thickness of the aquifer under a hydraulic gradient of 1. Transmissivity is the product of the aquifer thickness and the hydraulic conductivity of the aquifer, usually expressed as m^2/day (Length^2/Time).

Storativity (or the storage coefficient) is the volume of water that a permeable unit will absorb or expel from storage per unit surface area per unit change in piezometric head.

Hydraulic parameters derived from previous groundwater investigations are summarised in Table 24 and discussed in sections 8.1.2 and 8.8.

5.10 Groundwater Levels and Flow Direction

5.10.1 Groundwater Levels and Flow Direction – 2009 Groundwater Complete

Regional static groundwater levels around the proposed Belfast project areas vary between 1 mbgl and approximately 16 mbgl.

With all the available groundwater level data, the water level distribution was used to construct a groundwater level iso-surface (contour) map (Figure 26) with the use of steady state flow model calibration. Groundwater flow is from the higher hydraulic head areas towards the lower hydraulic head areas perpendicular to the groundwater contours (Figure 26). Flow is therefore from north to south, south-west and south-east (Groundwater Complete 2009).

5.10.2 Groundwater Levels and Flow Direction – 2014 Groundwater Complete

Groundwater levels in the Belfast project area are available from both the new and existing monitoring and hydrocensus boreholes.

The groundwater levels available from the hydrocensus and monitoring boreholes in and around the proposed opencast mining areas are presented in Figure 27. With all the available groundwater level data, the water level distribution was used to construct a groundwater level contour map with the use of Bayesian interpolation (Figure 28).

Regional static groundwater levels around the proposed Belfast project areas vary between 0.2 mbgl and approximately 35 mbgl (Figure 27).

Due to impacts from groundwater abstraction areas as well as other potential impacts, the groundwater level does not always follow the trend of the surface topography. For the BIP the highest static water level elevations are approximately 1 875 mamsl and occur in the topographically higher region north-east of the East mining block (Figure 28). The lowest static water level elevations where no impact from abstraction occurs are at approximately 1 700 mamsl south-west of the West block.

Groundwater flow will therefore be from the higher hydraulic head areas (1875 mamsl) towards the lower hydraulic head areas (1700 mamsl), perpendicular to the groundwater contours. Flow will therefore be from north to south, south-west and south-east.

Average groundwater gradients were calculated from the water level elevation data. Groundwater generally flows from north to south at the East block and north-east to south-west at the West block. The average groundwater gradient at both blocks is relatively low and is estimated at between 1 and 1.2% (Groundwater Complete August 2014).

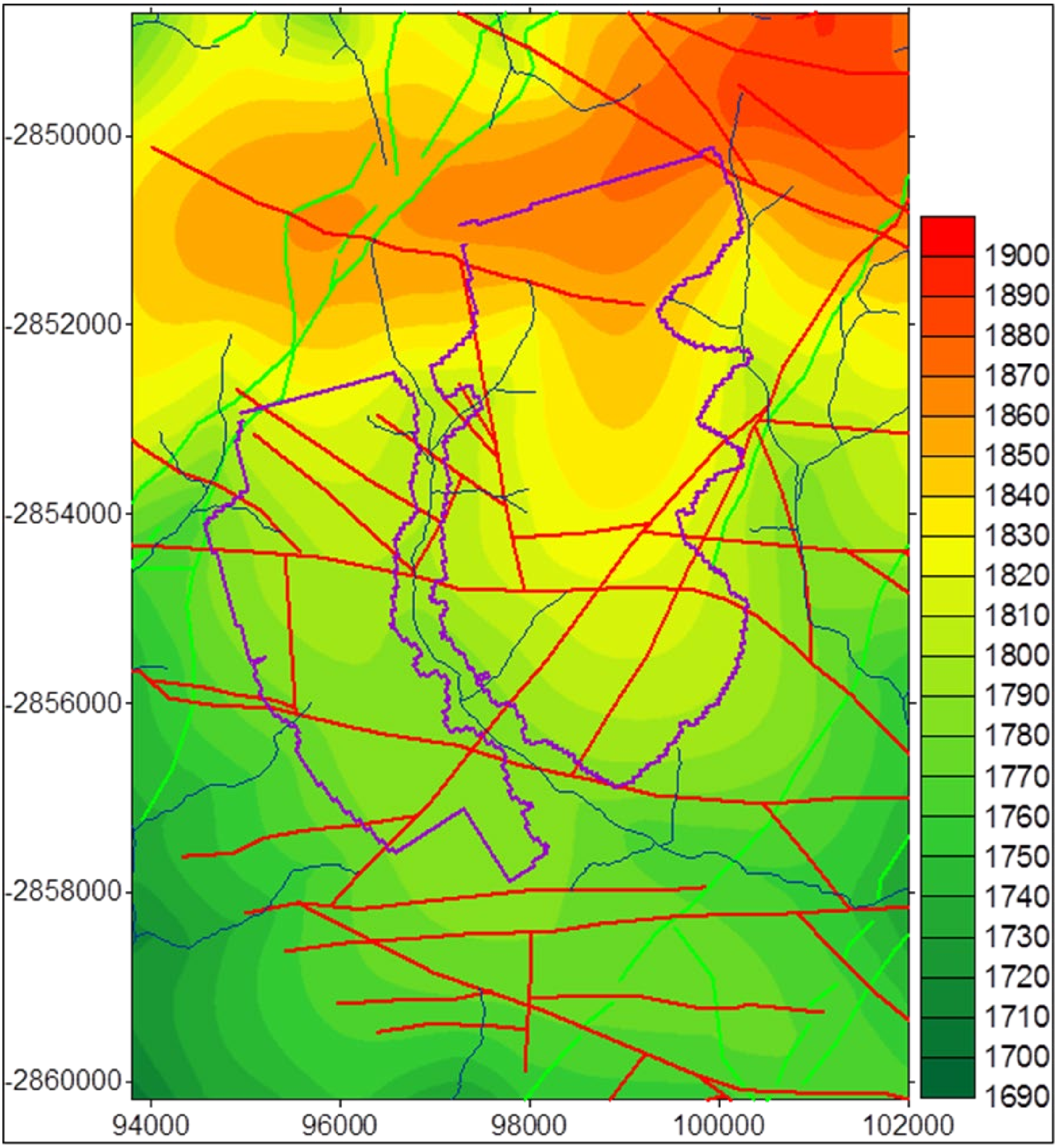


Figure 26: Steady State Calibrated Groundwater Level Contour Map of the BIP (Adapted from Groundwater Complete 2009).

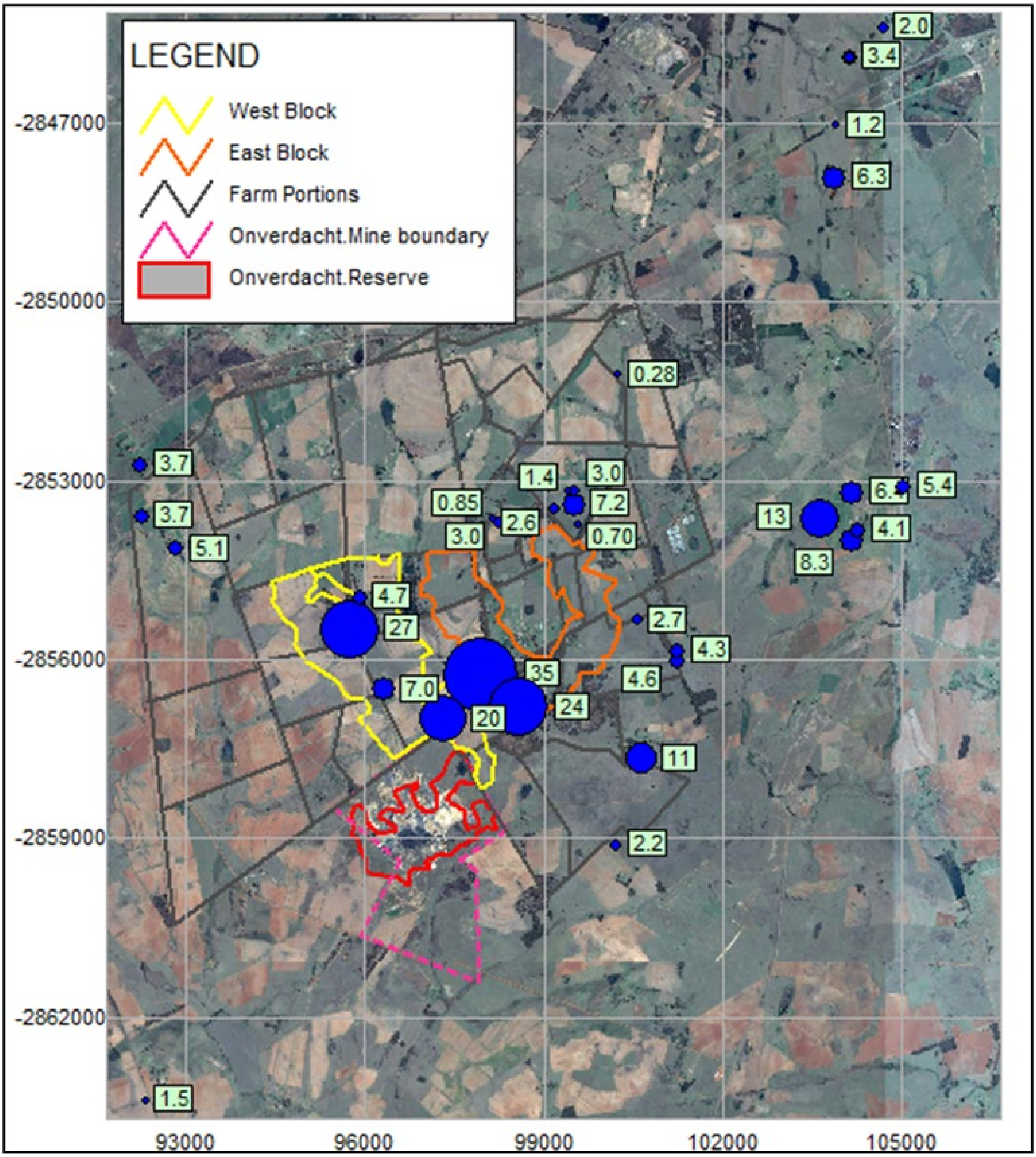


Figure 27: Thematic Water Levels of both Hydrocensus and Monitoring Boreholes. Water level depths are indicated on map as mbgl (Adpted from Groundwater Complete 2014).

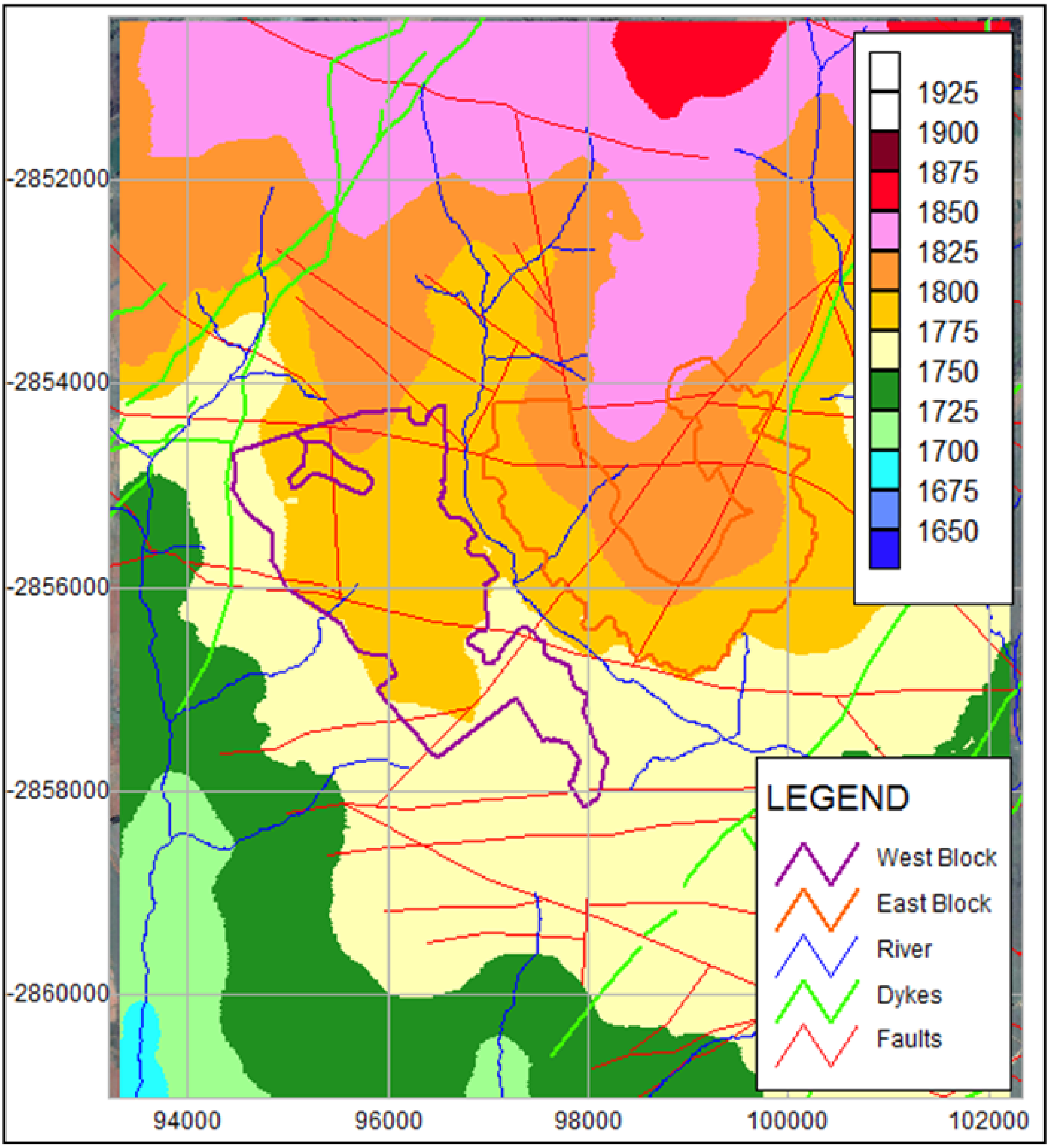


Figure 28: Bayesian Interpolated Groundwater Level Contour Map of the BIP (Adapted from Groundwater Complete 2014).

5.11 Groundwater Levels and Flow Direction- 2021

To compare groundwater levels with topography a large number of water level measurements is required. The hydrocensus groundwater levels from Groundwater complete (2009) were plotted and correlated against the surface elevation (Figure 29). The graph shows that there is a very good correlation between groundwater level and topography indicating that the groundwater contours mimic the topography.

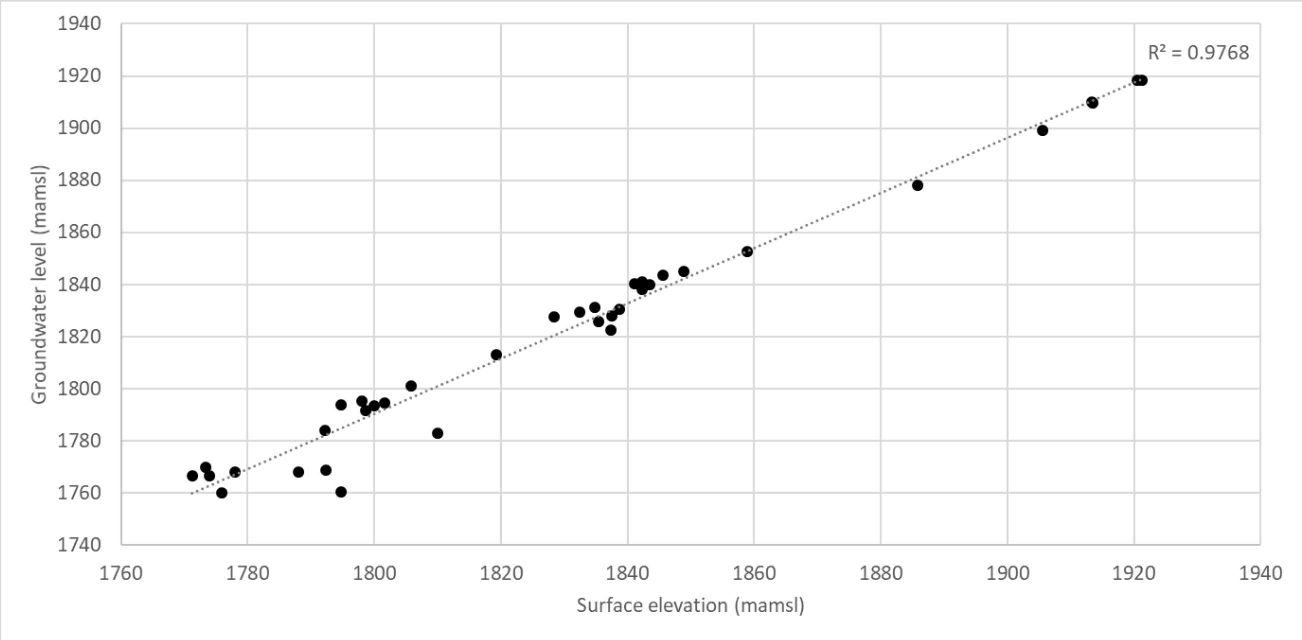


Figure 29: Correlation between Groundwater Level against Surface Elevation

Water levels measured at all the sites recorded were corrected for elevation and the Bayesian interpolation was then undertaken to generate a piezometric contour map for the general project area (Figure 30). The Bayes interpolation technique assumes a relationship between the topography metre above main sea level (mamsl) and the water level height (mamsl). It is realistic to assume that the water table depth will decrease with proximity to the rivers. This interpolation method is justified because a linear relationship and a very good correlation between groundwater level and topography was observed.

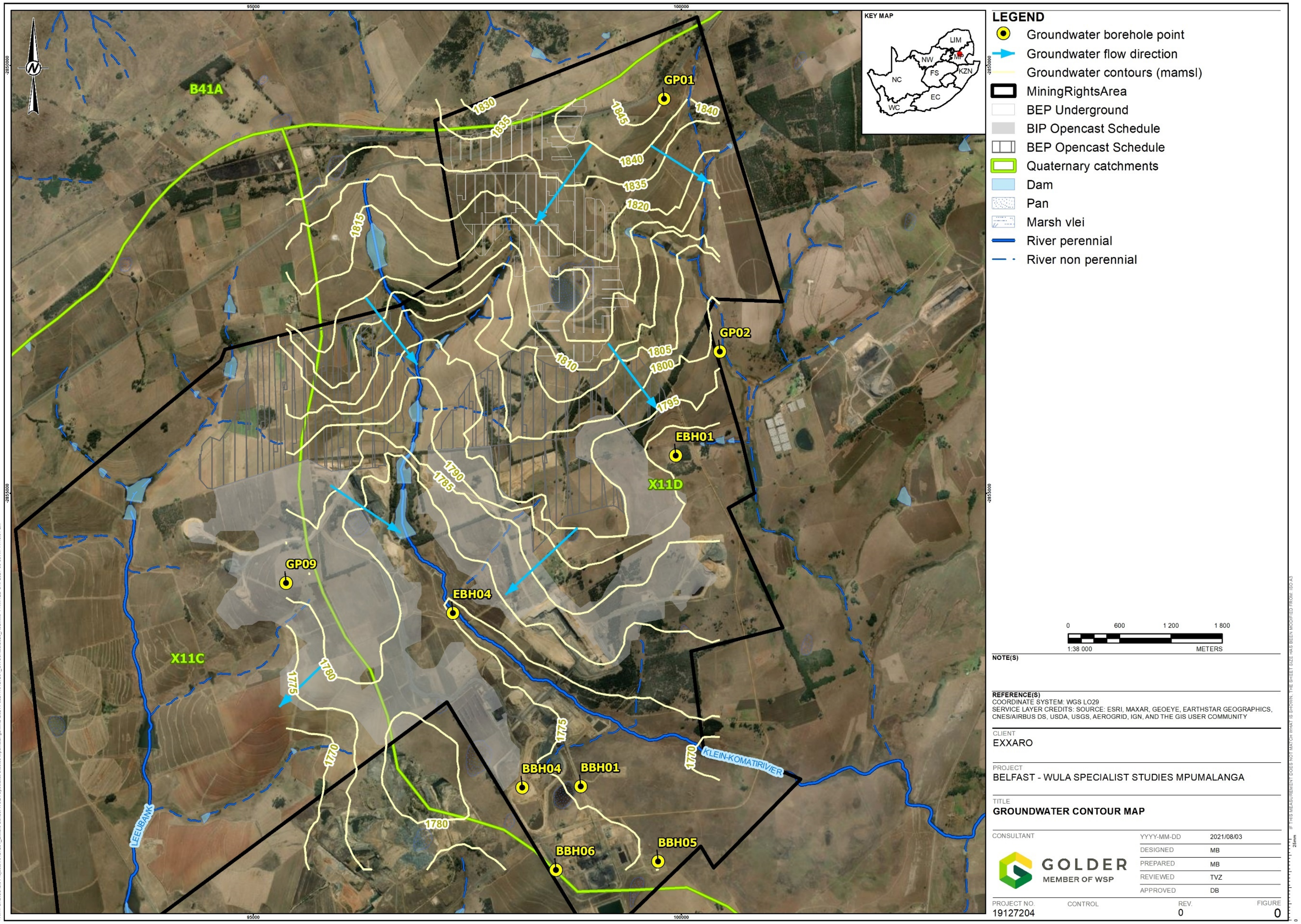


Figure 30: Groundwater Contours and Flow Direction

5.12 Groundwater Quality

The latest's groundwater quality results (2019 -2020) are used to discuss the current groundwater conditions of the BEP investigation area 5.12.4, 5.12.5 and 5.12.6. Other documented groundwater sampling events are listed as referenced below (5.12.1 to 5.12.3).

5.12.1 Groundwater Quality – Groundwater Complete 2009

During the site investigation and hydrocensus conducted by Clean Stream Scientific Services, groundwater qualities around the proposed Belfast project areas were measured at 39 boreholes and springs.

In the wider Belfast project area, most of the boreholes of surrounding users display very good groundwater quality. The reason for the good ambient quality is the fact that no groundwater quality impacts from mining or similar operations occur in the area and the aquifer host rocks are mostly inert.

The highest measured electrical conductivity is 210 mS/m at Ef5, which exceeds the ideal limits for domestic use. Electrical conductivity exceeds the ideal limits only in Ef5. Ef5 is impacted on by some source, with sulphate concentrations in Ef5 exceeding the maximum permissible limits for drinking water. Elevated fluoride concentrations are visible in Zk1 (1.3 mg/l) and Lb3 (1.9 mg/l). The fluoride concentrations in Lb3 exceed the maximum permissible limits for drinking water.

If the spatial distribution of qualities over the area is considered, no definite trend of better or poorer quality is discernible. The ambient groundwater levels are usually relatively shallow with rest water levels generally less than 16 m below surface. The average rainfall is in the order of 700 mm per year and even with a low effective recharge percentage, a good natural groundwater quality is to be expected since active recharge occurs and stagnation of groundwater in aquifers is very uncommon.

Seven of the new monitoring boreholes and four already existing monitoring boreholes were sampled for site specific quality characteristics:

- The site-specific groundwater is of excellent quality and is suitable for human consumption.
- Elevated iron and aluminium concentrations are observed in some of the monitoring boreholes. The reason for the high concentrations is unclear since the pH of the groundwater varies between 6.5 and 8.6, which represent close to neutral groundwater (Groundwater Complete 2009).

5.12.2 Groundwater Quality – Groundwater Complete 2014

The groundwater quality data of the 2014 hydrocensus and monitoring points compared to the South African National Standard for drinking water (SANS241:2011) standards for drinking water (Table 15).

Table 15: South African National Standard for drinking water (SANS241:2011)

SANS 241:2011			
Chemical Parameter	Class 0	Class 1	Class 2
	Ideal	Recommended	Maximum
mg/l			
Aluminium	0 - 0.3	0.3 - 0.5	> 0.5
Calcium	No Guide	No Guide	No Guide
Chloride	0 - 300	300 - 600	> 600
Fluoride	0 – 1.5	0 – 1.5	>1.5

Iron	2	2	> 2
Magnesium	No Guide	No Guide	No Guide
Manganese	0 - 0.5	0.5 – 1	> 1
Nitrate	0 - 11	11 - 20	> 20
pH	5 - 9.7	9.7 - 10	< 5, > 10
Potassium	No Guide	No Guide	No Guide
Sodium	0 - 200	200 - 400	> 400
Sulphate	0 - 500	500 - 600	> 600
TDS	0 - 1200	1200 - 2400	> 2400

The 2014 hydrocensus groundwater analytical results are summarised in Table 16 and borehole positions are displayed in Figure 31 . These localities were selected to give a good distribution of points over the proposed mining area. Borehole's parameters exceeding the maximum allowable limits for drinking water are highlighted Table 16 (Groundwater Complete 2014).

5.12.2.1 Groundwater Quality Summary

- Groundwater quality in the hydrocensus boreholes is mostly good water quality;
- The chemical parameters exceeding the ideal and maximum permissible limits for drinking water are; F, SO_4, Fe, and Mn;
- Acidic conditions are observed in Kotze01 and Kotze02, while basic conditions are observed in Vaal01-pH in these boreholes are outside the maximum permissible limits for drinking water;
- Groundwater make-up differs significantly over the area with several types of groundwater; and
- The groundwater qualities measured in 2014 were however very similar to 2009 qualities. Exceptions are decreases in qualities in several boreholes (EBH02, Vaal01, Wt5, Zoekop04, Jou01 and Bly03) and increase in qualities in especially EBH03 and EBH08 (Groundwater Complete 2014).

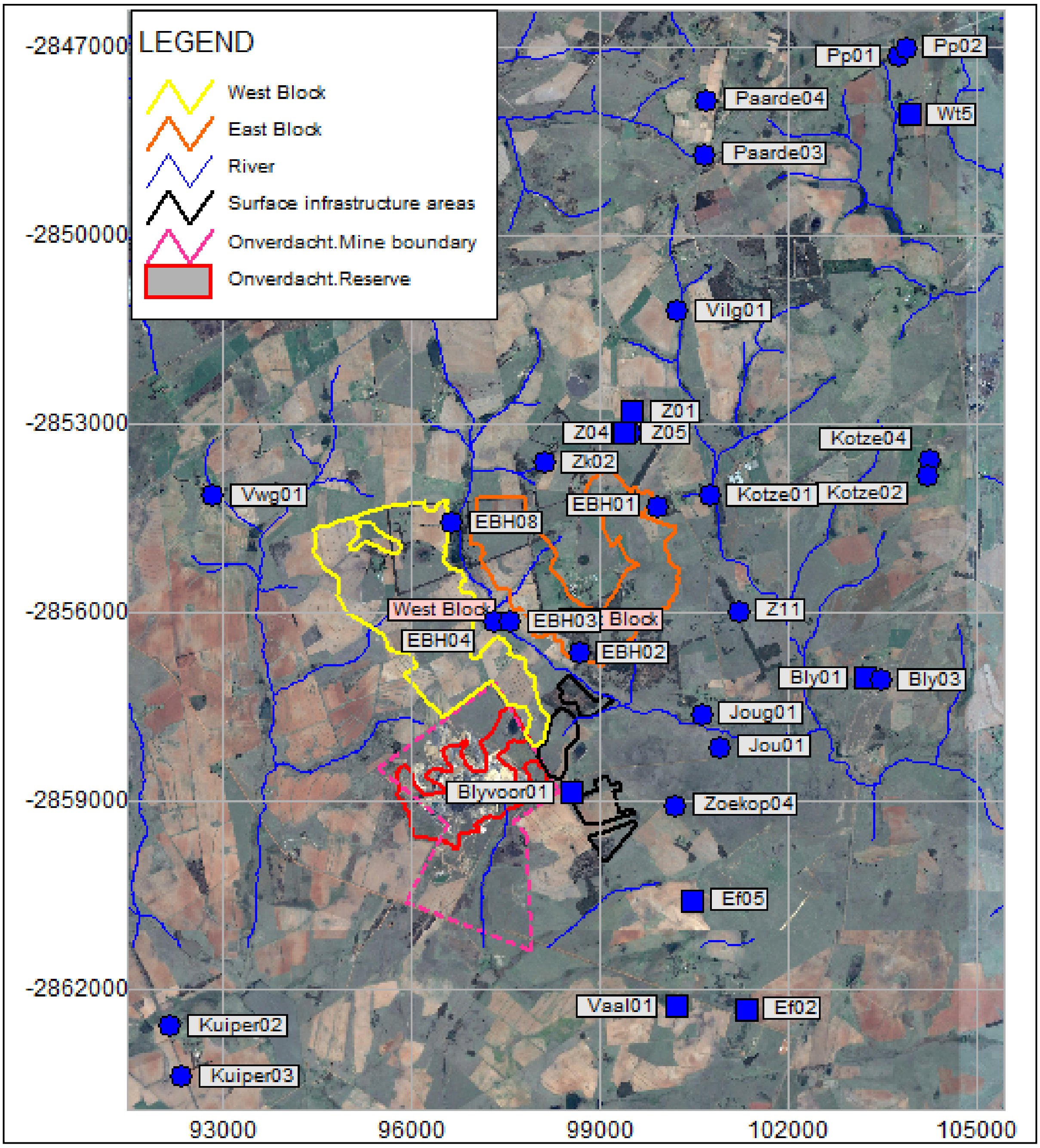


Figure 31: Sampled Hydrocensus Boreholes (Adapted from Groundwater Complete 2014).

Table 16: Summarised Groundwater Quality (Groundwater Complete 2014)

SiteName	pH	TDS mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Cl mg/l	SO_4 mg/l	N mg/l	F mg/l	Al mg/l	Fe mg/l	Mn mg/l
Bly01	7.4	41	3.8	3.4	4.0	1.3	13	3	1.4	<0.18	<0.006	<0.006	<0.001
Bly03	7.4	17	1.6	1.2	2.3	0.9	<1.4	3	0.3	1.7	<0.006	<0.006	<0.001
Blyvoor01	6.6	53	3.8	3.0	7.8	0.5	14.1	4	3.4	<0.18	<0.006	0.178	<0.001
EBH01	7.2	122	20.2	11.9	5.9	3.5	9.05	2	0.4	0.2	<0.006	0.135	0.38
EBH02	6.5	425	44.4	34.7	13.2	13.1	12.4	276	0.4	1.9	<0.006	12	1.9
EBH03	8.9	185	3.9	1.6	67.7	1.4	12.1	4	0.6	1.1	<0.006	<0.006	<0.001
EBH04	7.1	53	1.5	1.0	10.7	6.1	13.8	3	0.4	0.3	<0.006	0.259	<0.001
EBH08	6.8	99	8.9	5.3	19.6	1.9	8.7	2	0.4	0.4	<0.006	<0.006	0.20
Ef02	7.2	45	3.9	2.9	3.1	2.7	6.0	3	4.4	<0.183	<0.006	<0.006	<0.001
Ef05	6.9	1188	215	126	14.3	17.3	7.5	535	0.4	<0.183	<0.006	<0.006	<0.001
Jou01	6.9	86	7.8	7.0	12.1	1.9	24.0	3	0.3	0.2	<0.006	2.7	<0.001
Joug01	7.2	26	2.9	2.4	2.3	1.8	6.5	3	0.3	<0.183	<0.006	<0.006	<0.001
Kotze01	3.6	189	24.7	17.9	6.7	4.4	8.3	126	0.2	<0.183	<0.006	<0.006	0.57
Kotze02	3.7	189	24.6	17.8	6.7	4.4	7.5	127	0.2	<0.183	<0.006	<0.006	0.56
Kotze04	7.3	88	17.1	4.5	4.4	3.6	6.0	31	1.8	<0.183	<0.006	<0.006	0.123

SiteName	pH	TDS mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Cl mg/l	SO_4 mg/l	N mg/l	F mg/l	Al mg/l	Fe mg/l	Mn mg/l
Kuiper02	6.9	163	12.6	7.9	34.8	4.1	40.4	21	3.0	<0.183	<0.006	<0.006	<0.001
Kuiper03	7.4	67	10.6	4.4	5.6	4.4	7.1	3	0.6	<0.183	<0.006	<0.006	<0.001
Paarde03	7.4	126	20.8	8.1	7.5	6.7	14.6	38	1.3	<0.183	<0.006	<0.006	<0.001
Paarde04	7.7	125	21.0	8.2	7.4	6.6	14.7	37	1.0	<0.183	<0.006	<0.006	<0.001
Pp01	7.2	179	26.1	21.5	11.2	1.8	49.4	4	0.6	0.2	<0.006	<0.006	<0.001
Pp02	8.0	52	6.1	6.2	3.6	0.3	6.2	2	0.5	<0.183	<0.006	<0.006	<0.001
Vaal01	10.5	41	4.9	3.4	3.0	3.5	7.3	2	0.2	<0.183	<0.006	0.31	<0.001
Vilg01	5.8	24	1.0	1.3	3.6	1.5	3.9	2	1.7	<0.183	<0.006	<0.006	<0.001
Vwg01	7.1	81	9.9	4.3	7.1	2.2	11.9	3	6.4	<0.183	<0.006	<0.006	<0.001
Wt5	6.6	29	1.3	1.3	4.2	<0.04	10.2	2	0.4	1.5	<0.006	5.4	<0.001
Z01	5.9	45	1.6	2.2	7.4	3.5	9.5	5	2.0	<0.183	<0.006	<0.006	<0.001
Z04	5.9	92	3.6	4.1	12.0	7.5	18.5	3	8.9	<0.183	<0.006	<0.006	<0.001
Z05	5.8	43	1.2	2.7	3.9	4.1	2.9	1	5.5	<0.183	<0.006	<0.006	<0.001
Z11	7.6	96	16.5	5.4	8.1	4.0	9.8	8	0.6	<0.183	<0.006	<0.006	<0.001
Zk02	7.6	31	2.4	2.4	3.3	3.1	9.0	4	0.4	<0.183	<0.006	<0.006	0.26
Zoekop04	6.7	38	2.9	0.4	6.3	1.5	10.3	2	0.3	1.6	<0.006	4.7	0.09

SiteName	pH	TDS mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Cl mg/l	SO_4 mg/l	N mg/l	F mg/l	Al mg/l	Fe mg/l	Mn mg/l
Class 1 Max. Allowable Limit	9.5	<450	<80	<70	<100	<25	<100	<200		<0.7		<0.01	<0.1
Class 2 Max. Allowable Limit	10	1000	150	100	200	50	200	400		0.7-1.0		0.01-0.2	0.1-0.4
Class 3 Max. Allowable Limit	10.5	2400	300	200	400	100	600	600		1.0-1.5		0.2-2.0	0.4-4.0
Class 4 Max. Allowable Limit	11	3400	>300	400	1000	500	1200	1000		1.5-3.5		2.0-10.0	4.0-10.0

5.12.3 Groundwater Quality – GCS 2018

During the 2018 GCS BIP aquifer testing programme, groundwater samples were collected by Exxaro from boreholes, ZP22GW and BT35GW2. The laboratory results indicated good water quality with all parameters within the SANS standards for drinking water, except for total coliform and total viable count detected in ZP22GW and BT35GW, respectively (GCS 2018).

5.12.4 Groundwater Quality (Golder 2019)

Golder was appointed by Exxaro to conduct surface and groundwater monitoring and analysis for their Belfast Implementation Project (BIP) to ensure compliance to their approved Integrated Water Use License (IWUL) No.: 05/X11D/ABCFGIJ/2613.

Twenty monitoring boreholes listed in Table 17 and indicated in Figure 32 are monitored on a quarterly basis as per IWUL regulation. The latest's groundwater quality results (2019 -2020) are discussed below. Monitoring data are submitted to Exxaro monthly in Equis™ database.

Table 17: Groundwater Monitoring Boreholes (Equis™)

Site Name Borehole No.	Latitude	Longitude	Latest Sampled Date	Status	Comment
WP (Willie Pretorius)	-25.80562	29.98364	19/06/2019	Maintained	In use – monitored quarterly
EBH03	-25.81228	29.97308	19/04/2019	Maintained	In use – monitored quarterly
EBH02	-25.81682	29.98418	-	Maintained	Borehole to be relocated (LOM)
BBH02	-25.81926	29.98732	-	Discontinued	Not in use
FB (Farmer Borehole)	-25.80181	30.00354	-	Discontinued	Not in use
GP04	-25.80182	30.00207	19/05/2019	Maintained	In use – monitored quarterly
BBH05	-25.83831	29.99473	18/02/2020	Maintained	In use – monitored quarterly
BBH04	-25.83064	29.97883	20/02/2020	Maintained	Borehole to be relocated
BBH01	-25.83047	29.98567	20/02/2020	Maintained	In use – monitored quarterly
EBH01	-25.79552	29.99643	18/02/2020	Maintained	In use – monitored quarterly
EBH04	-25.81230	29.97062	19/02/2020	Maintained	In use – monitored quarterly
EBH08	-25.79821	29.96383	15/03/2019	Maintained	In use – monitored quarterly
GP01	-25.75793	29.99475	20/02/2020	Maintained	In use – monitored quarterly
GP02	-25.78451	30.00146	21/01/2020	Maintained	In use – monitored quarterly
GP08	-25.82273	29.96331	-	Maintained	Borehole need to be relocated (LOM))
GP09	-25.80926	29.95115	19/02/2020	Maintained	Borehole need to be relocated (LOM)
BBH06	-25.83929	29.98284	20/02/2020	Maintained	In use – monitored quarterly
KP (Swarts ZZK Farm)	-25.7873	30.01083	18/02/2020	Maintained	In use – monitored quarterly
BRBH05	-25.7588	29.96888	19/05/2019	Maintained	In use – monitored quarterly
BRBH06	-25.7583	29.96506	19/05/2019	Maintained	In use – monitored quarterly

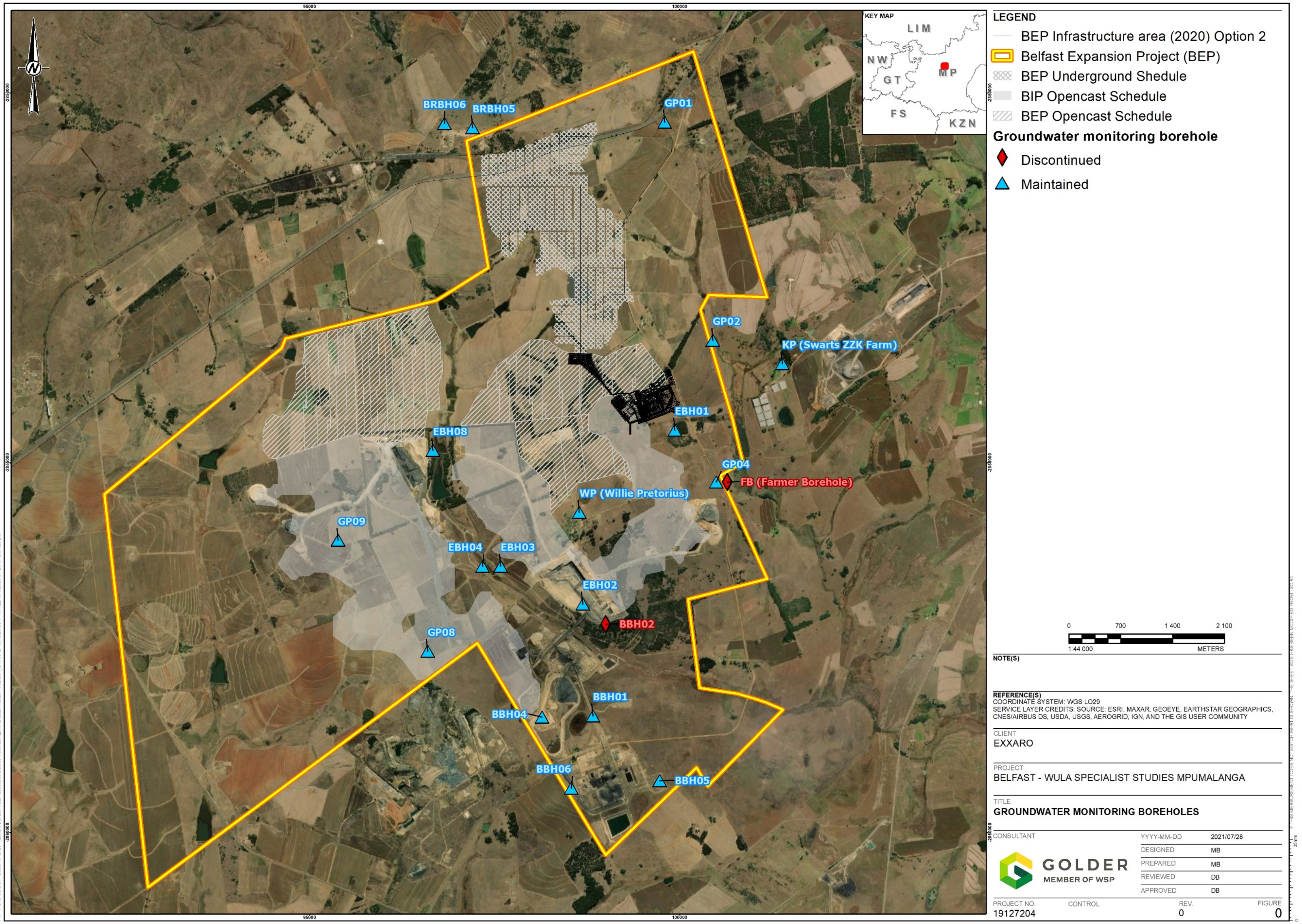


Figure 32: Groundwater Monitoring Boreholes

5.12.4.1 Water Quality Standards

The analytical results of the latest groundwater results (Table 20) were compared to the following standards:

- South African National Standards, drinking water standards, 2011 (SANS 241:2011).
- WUL 05/X11D/ABCFGIJ/2613, Groundwater parameters maximum allowable limits (Table 18).
- Department of Water Affairs and Forestry (DWAF), domestic water quality guidelines, volume 1,1996 and Water Research Commission, water quality guidelines, 1998 (Table 19).

The SANS 241:2011 and IWUL standards were used as reference guideline, whereas the DWAF 1998 guidelines were used to classify and discuss the water quality classes (Table 19). The analytical results are summarised in Table 20.

A highlighted value in red exceeds the SANS 2011 maximum allowable limits and cells highlighted in yellow exceeds the IWUL maximum allowable limits. The water quality classes listed are classified using the DWAF (1998) drinking water standards.

The groundwater quality of the investigation area is mainly represented by Ideal water quality (Class 0 – 50%) to marginal water quality (Class 2 – 31 %). Monitoring boreholes BBH01 and WP is of poor water quality (Class 3). Borehole WP a farm borehole owned by Willie Pretorius is Class 3 due to elevated Fluoride concentration(1.6mg/l) and poses a risk of chronic health effects, especially in babies, children and the elderly. May be used for short-term emergency supply with no alternative supplies available. This deep borehole (WP) is probably getting water from pre-Karoo formations of the Transvaal supergroup.

Monitoring borehole KP (Swarts ZZK Farm) however is Ideal water quality (Class 0) with no health effects, suitable for many generations. Both the farm boreholes are reported to be used for stock watering, irrigation and for domestic use but not for human consumption.

Table 18: General Groundwater (Target Water Quality Ranges) stipulated in the WUL 05/X11D/ABCFGIJ/2613

Parameter	Limit
pH	6.5 – 8.5
Electrical Conductivity (EC) mS/m	40
Total Dissolved Solids (TDS) mg/l	450
Calcium (Ca) mg/l	32
Potassium (K) mg/l	***
Chloride (Cl) mg/l	100
Sulphate (SO_4^{2-}) mg/l	200
Sodium (Na) mg/l	70
Magnesium (Mg) mg/l	30
Nitrate (NO_{3-} as N) mg/l	6
Fluoride (F-) mg/l	1
Aluminium (Al) mg/l	***
Manganese (Mn) mg/l	***
Iron (Fe) mg/l	***
Dissolved Oxygen	***

Parameter	Limit
BTEX & TPH (mg/l)	***
Faecal Coliforms (counts/100ml)	0

**** No limits specified*

Table 19: DWAF Water Quality Classes (1998)

Water quality class	Description	Drinking health effects
Class 0	Ideal water quality	No effects, suitable for many generations.
Class 1	Good water quality	Suitable for lifetime use. Rare instances of sub-clinical effects
Class 2	Marginal water quality, water suitable for short-term use only	May be used without health effects by majority of users but may cause effects in some sensitive groups. Some effects possible after lifetime use.
Class 3	Poor water quality	Poses a risk of chronic health effects, especially in babies, children and the elderly. May be used for short-term emergency supply with no alternative supplies available.
Class 4	Unacceptable water quality	Severe acute health effects, even with short-term use.

Table 20: Summarised Analytical Results - Monitoring Boreholes

Borehole Number	Sampled Date	pH	TDS	EC	Sulphate	Chloride	NO_3 as N	Total Alkalinity as $CaCO^3$	Aluminium	Calcium	Iron	Magnesium	Manganese	Potassium	Sodium	Fluoride	Water Quality
		pH units	mg/l	mS/m	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	Class
GP02	21/01/2020	6.81	100	16	0.25	5.2	**7.48**	31	0.01	7.2	0.01	5	0.028	2.4	7.6	0.15	1
BBH01	20/02/2020	7.73	163	28.3	1.1	3.8	0.025	132	0.01	6.6	**3.148**	1.9	**0.541**	2.1	53.9	0.15	3
BBH04	20/02/2020	7.45	44	4.5	0.25	0.7	0.025	21	0.01	5.4	0.03	1.6	0.11	2.3	3.1	0.15	0
BBH05	18/02/2020	7.17	35	6	0.25	9.7	0.93	6	0.01	4.9	**1.31**	1.6	0.024	1.9	5.3	0.15	2
BBH06	20/02/2020	7.26	17.5	3.1	0.25	1.3	0.025	13	0.01	4.1	**0.474**	1.2	0.087	2	2.1	0.15	2
EBH01	18/02/2020	6.9	17.5	7.8	0.25	5.6	0.23	25	0.01	5.8	0.025	2.3	0.106	2.8	4.9	0.15	0
EBH04	19/02/2020	6.76	63	10.8	4.6	10.2	0.025	26	0.025	5.5	**26.42**	2.4	**0.133**	4.4	9.5	0.15	4
KP	18/02/2020	7.25	84	11.7	0.25	7.9	4.13	240	0.01	7.1	0.01	3.4	0.003	2.2	7	0.15	0
GP09	19/02/2020	7.76	71	16.4	1.4	2.1	0.18	72	0.01	11.2	0.01	5.5	0.035	5.6	3.6	0.15	0
GP01	20/02/2020	7.67	89	18.4	0.6	1	0.025	10	0.01	12.1	**0.596**	5.4	0.048	4.1	6.4	0.15	2
WP	19/06/2019	8.11	254	46.3	4.7	6.4	0.52	222	0.059	2.1	0.09	0.7	0.004	1	**116.9**	**1.6**	3
EBH03	19/04/2019	7.68	64	17.9	0.25	22.3	0.025	56	0.01	10.5	0.273	5.3	0.056	2.7	16.2	0.15	0
GP04	19/05/2019	6.4	17.5	4	1.8	4.8	1.08	9	0.026	1.5	0.051	0.9	0.033	3.7	3.8	0.15	0
BRBH05	19/05/2019	7.72	101	19.1	11	2.8	0.025	81	0.01	19.8	0.01	7.1	0.049	3.8	9.7	0.15	0
BRBH06	19/05/2019	7.8	110	18.9	10.7	2.5	0.025	82	0.01	19.6	0.198	7.7	0.03	4.1	8.8	0.15	0
EBH08	15/03/2019	7.98	158	30.9	0.25	3.8	<0.05	151	0.01	11.5	0.101	6.7	0.022	1.5	47.3	**1.5**	2
SANS241: 2011		9.7	1200	<170	500	300	11	-	<0.3	-	0.3	-	0.5	-	200	1.5	
IWUL: 05/X11D/ABCFGIJ/2613 Limit: Max. Limit		6.5-8.5	450	40	200	100	6					30			70	1	
Class 0 Max. Allowable Limit		9.5	<450	<70	<200	<100	<6	-	-	<80	<0.01	<70	<0.1	<25	<100	<0.7	
Class 1 Max. Allowable Limit		10	1000	150	400	200	10	-	-	150	0.01-0.2	100	0.1-0.4	50	200	0.7-1.0	
Class 2 Max. Allowable Limit		10.5	2400	370	600	600	20	-	-	300	0.2-2.0	200	0.4-4.0	100	400	1.0-1.5	
Class 3 Max. Allowable Limit		11	3400	520	1000	1200	40	-	-	>300	2.0-10.0	400	4.0-10.0	500	1000	1.5-3.5	
Class 4 Max. Allowable Limit		>11	>3400	>520	>1000	>1200	>40	-	-	>300	>10.0	>400	>10.0	>500	>1000	>3.5	

NOTE: Red values exceed the SANS 2011 maximum allowable limits

5.12.5 Groundwater Classification

The latest groundwater quality results of the BIP monitoring boreholes are visually represented on an expanded Durov (Figure 33) and Piper diagrams (Figure 34) to distinguish between the different water quality classes/types.

5.12.5.1 Expanded Durov

Expanded Durov diagrams graphically represent the relative percentages of anions and cations in water samples. The cation percentages are plotted in the top part of the diagram and the anion percentages in the left part. A projection of these cation and anion percentages onto the central area presents the chemical signature of the major ion composition of the water. The chemical signature can be related to various hydrochemical environments and conditions.

On the Expanded Durov Diagram (Figure 33) the majority of the plot on blue sector of the diagram and represent background groundwater (calcium magnesium bicarbonate type of water ((Ca, Mg)(HCO_3)$_2$).

The monitoring boreholes (WP, BBH01, EBH08, EBH04 and GP04) that plot on the green sector of the diagram is representative of sodium potassium bicarbonate type of water Na/K–(HCO_3)$_2$. The plot position on the diagram indicates minor sodium enrichment diluted by precipitation.

Monitoring borehole BBH05 plot on the red sector (type of water is seldom found), and is representative of magnesium chloride type of water (Mg)Cl. The plot position on the diagram indicates water with minor magnesium and chloride enrichment.

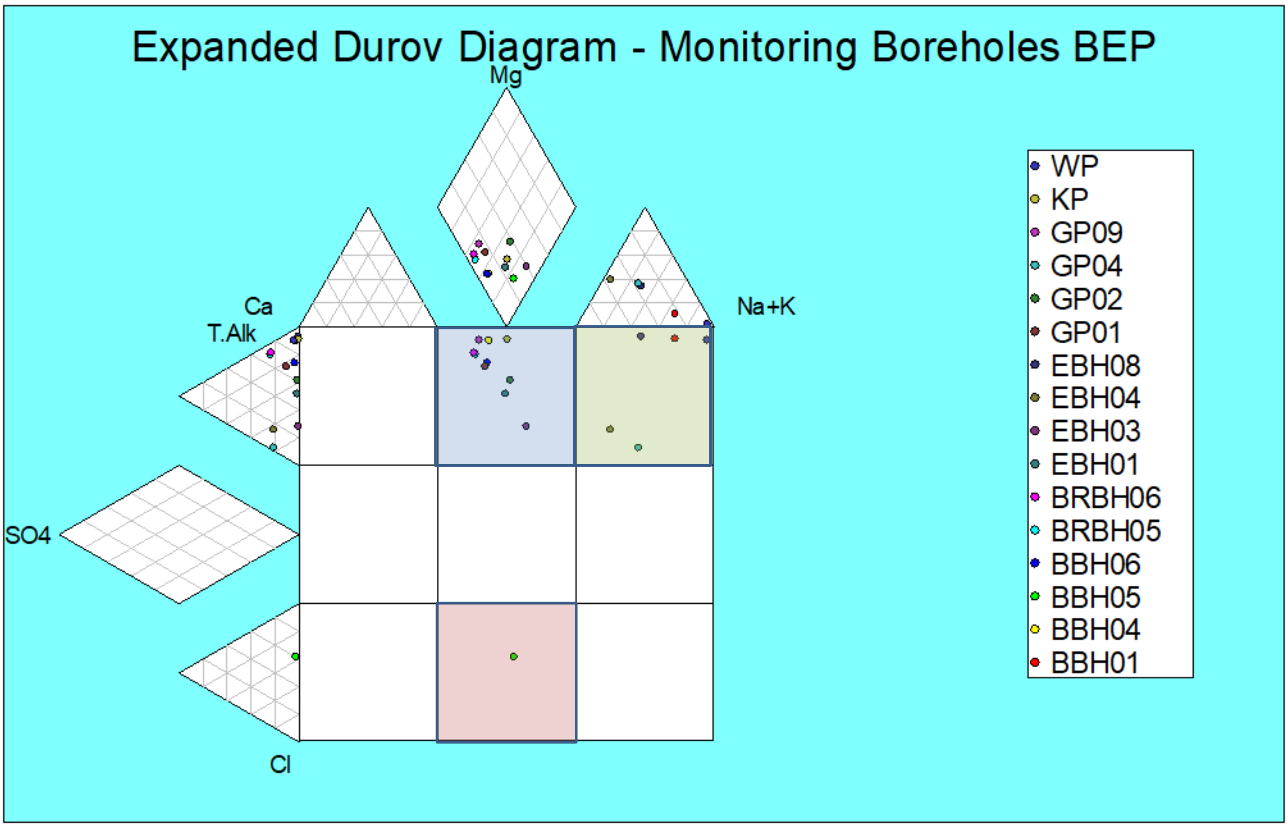


Figure 33: Expanded Durov Diagram

5.12.5.2 Piper Diagram

Piper diagrams graphically represent the relative percentages of anions and cations in water samples. The cation percentages are plotted in the left triangle and the anion percentages in the right triangle. A projection of these cation and anion presentations onto the central diamond presents the chemical signature of the major ion composition of the water.

The majority of the sampled boreholes plot on blue sector of the Piper diagram and show a signature of calcium magnesium bicarbonate type of water (Ca, Mg)$(HCO_3)_2$.This type of water is associated with recent rainfall recharge and not impacted groundwater.

The green sector represents a sodium bicarbonate (i.e. Na–$(HCO_3)_2$) water type signature and follows the typical dynamic groundwater flow evolution (monitoring boreholes WP, BBH01, EBH08, EBH04 and GP04).

The red sector of the Piper Diagram shows a signature of magnesium chloride type of water (Mg)Cl type of water (monitoring borehole BBH05).

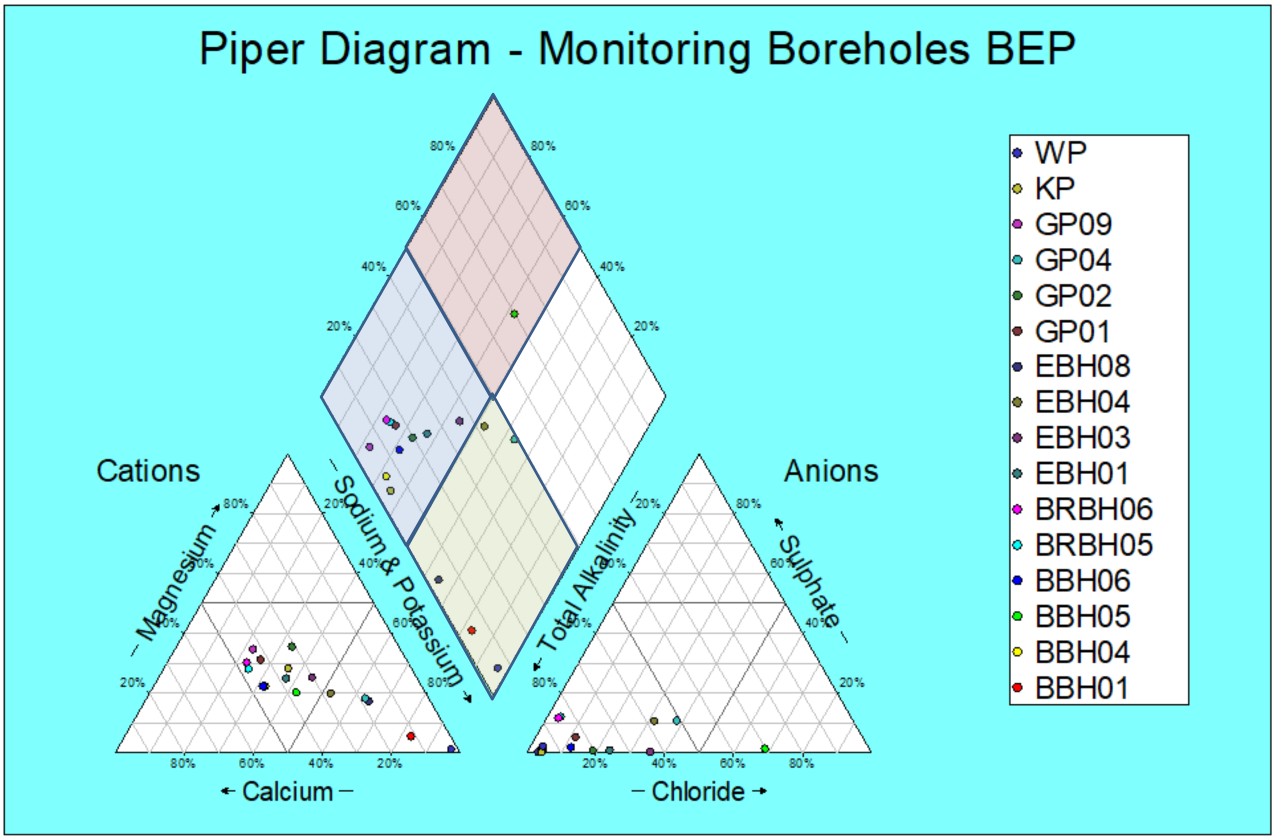


Figure 34: Piper Diagram

5.12.6 Baseline/Background Groundwater Quality (Golder 2021a)

Golder (2021a) describes the water qualities for each of the measured boreholes in detail (not described here).

The baseline ranges and 90th percentiles for the groundwater overall are presented and screened against IWUL limits in Table 21. The baseline ranges for fluoride, nitrate and pH are not compliant with the current IWUL limits.

Table 21: Overall Groundwater Quality Baseline

Constituent of concern	Units	IWUL Limits	Valid Entries	Mean – Standard Deviation	*Mean Value*	Mean + Standard Deviation	90th Percentile
Calcium	mg/l	32	231	<0.2	5.941	20.181	9.700
Magnesium	mg/l	<30	231	<0.1	3.828	14.695	5.700
Sodium	mg/l	<70	231	<0.1	26.824	58.359	60.600
Fluoride	mg/l	<1	231	<0.3	0.324	0.848	1.300
Sulphate	mg/l	<200	231	<0.5	2.566	5.420	8.100
Chloride	mg/l	<100	231	0.751	4.748	8.746	9.800
Nitrate as NO_3^-	mg/l	<6	222	<0.2	5.408	18.134	10.530
Total Alkalinity as $CaCO_3$	mg/l	nl	191	<4	86.415	190.623	184.000
Electrical Conductivity	mS/m	<40	231	<2	18.136	37.593	34.500
pH	mg/l	6.5-8.5	231	6.177	7.029	7.880	8.290
Total Dissolved Solids	mg/l	<450	231	<10	120.439	241.369	229.000

Highlighted values exceed the IWUL limits

6.0 AQUIFER CHARACTERISATION

6.1 Groundwater Vulnerability

Groundwater vulnerability gives an indication of how susceptible an aquifer is to contamination. Aquifer vulnerability is used to represent the intrinsic characteristics that determine the sensitivity of various parts of an aquifer to being adversely affected by an imposed contaminant load.

A national scale groundwater vulnerability map of South Africa was prepared by the WRC (Water Research Commission), using the DRASTIC methodology that includes the following components:

- Depth to groundwater.
- Recharge due to rainfall.
- Aquifer media.
- Soil media.
- Topography.
- Impact of the vadose zone.
- Hydraulic conductivity.

Groundwater vulnerability was classified into six classes ranging from very low to very high. Groundwater vulnerability at BEP site is shown on the national groundwater vulnerability map mainly as medium, with some areas indicated as low and medium-high to the south and west respectively (Figure 35).

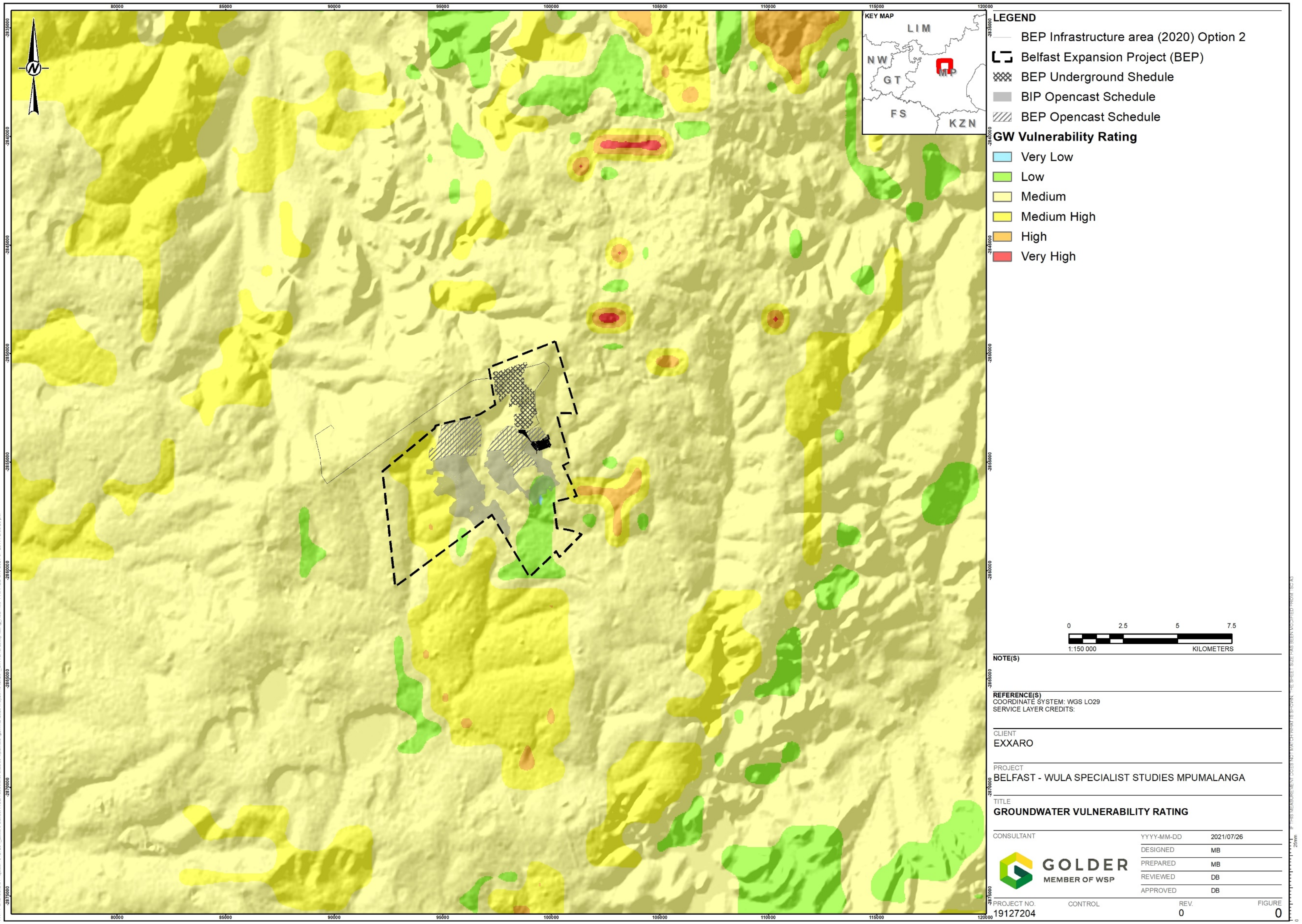


Figure 35: Groundwater Vulnerability

6.2 Aquifer Classification

Based on the existing reports, drilling, and aquifer testing results, three aquifer systems (Section 6.2) can be distinguished at the BEP area namely:

- Top weathered aquifer system; an unconfined aquifer system with an average thickness of ~ 10 m.
- Fractured aquifer system; a confined to semi confined aquifer system with an average thickness of ~20m below the weathered aquifer system. This aquifer system is characterised by secondary fractures resulting in preferential flow paths for the groundwater flow and possible contaminant migration.
- Deep fractured aquifer system; confined aquifer system with reported water strikes between 118 to 120 mbgl (Table 23) and is present in the basement rocks (Transvaal Supergroup) below the fractured aquifer system.

Although previous reports may only have identified two aquifers the numerical model presented in this report represent the weathered and fractured Karoo Supergroup aquifer systems and the Transvaal Supergroup's deep fractured aquifer.

6.2.1 Top Weathered Aquifer System

The shallow weathered aquifer system occurs in the transitional soil and weathered bedrock zone or sub-outcrop horizon. This aquifer generally has a low yield with phreatic water levels sometimes occurring on un-weathered bedrock or clayey layers. Yields in this aquifer are low (generally less than 0.3 l/s) and the aquifer is not usable as a groundwater supply source on a continuous basis. Where consideration of the shallow aquifer system becomes important is during seepage estimations into open pit voids and mass transport simulations from mine-induced contamination sources because a lateral seepage component in the shallow water table zone in the weathered zone often occurs.

According to the Parsons Classification system, the aquifer is usually regarded as a minor or even a non-aquifer system. By definition, an aquifer is a geological formation or group of formations that can yield groundwater in economical exploitable quantities.

Although groundwater seepage does occur in the weathered zone, the yields are very low, and this zone cannot really be defined as an 'aquifer' according to the true meaning of the term. The main value and function of the shallow weathered zone 'aquifer' lies in the storage and transfer of moisture from rainfall to soil (laterally), vegetation (upwards) and the deeper aquifer (downwards) (Groundwater Complete 2014).

6.2.2 Fractured Aquifer system

The Fractured aquifer system where groundwater yields, although more heterogeneous, can be higher than the weathered zone aquifer. This aquifer system usually displays semi-confined or confined characteristics with piezometric heads often significantly higher than the water-bearing fracture position. The aquifer forms in transmissive fractures in the consolidated and mostly impervious bedrock. The fractures may occur in any of the co-existing host rocks due to different tectonic, structural and depositional processes. Aquifer yields in this system vary from zero to approximately 2 l/s in the Karoo rock types that occur in the Belfast project area.

Yields from this aquifer could be sufficient to supply drinking and sanitation water to mining operations but are too low to use as a source of process water supply. In the boreholes tested as well as surveyed during the hydrocensus, sustainable yields of between 0.1 and 2 l/s were determined. According to the Parsons Classification system (Table 22), the aquifer could be regarded as a minor, but often a sole aquifer system (Groundwater Complete 2014).

Table 22: Parsons Aquifer Classification (Parsons 1995)

Type of Aquifer	Description
Sole Aquifer System	An aquifer that is used to supply 50% or more of domestic water for a given area, and for which there is no reasonably available alternative sources should the aquifer be impacted upon or depleted. Aquifer yields and natural water quality are immaterial.
Major Aquifer System	Highly permeable formation, usually with a known or probable presence of significant fracturing. They may be highly productive and able to support large abstractions for public supply and other purposes. Water quality is generally very good (Less than 150 mS/m).
Minor Aquifer System	These can be fractured or potentially fractured rocks that do not have a primary permeability, or other formations of variable permeability. Aquifer extent may be limited and water quality variable. Although these aquifers seldom produce large volumes of water, they are important both for local suppliers and in supplying base flow for rivers.
Non-Aquifer System	These are formations with negligible permeability that are generally regarded as not containing groundwater in exploitable quantities. Water quality may also be such that it renders the aquifer unusable. However, groundwater flow through such rocks, although impermeable, does take place, and needs to be considered when assessing the risk associated with persistent pollutants.
Special Aquifer System	An aquifer designated as such by the Minister of Water Affairs, after due process.

6.2.3 Deep Fractured Aquifer System

Based on the existing reports a third aquifer system – Deep fractured aquifer system (Table 23), fresh to fractured (confined) can also been identified (Section 5.4.3 and 5.4.4).This aquifer system is present within the Transvaal Supergroup with reported water strikes intersected between 118 to 120 mbgl.

Borehole WCPret01 on the farm Zoekop of Mr. WP Pretorius was reported to have a yield of 5.6 l/s, was tested by Groundwater Complete during 2014 with a test yield >1.5l/s (Table 8).

Table 23: Deep Boreholes

BH ID	Water Strikes Minor (mbgl)	Water Strike Major (mbgl)	BH Depth (m)	SWL (mbgl)
ZP22GW	20 and 80	119	130	12
BT35GW	20 and 52	120	130	2.8
ZP23GW	N/A	N/A	200	42
WCPret01	N/A	118	120	29.10

6.3 Aquifer Protection Classification

The BEP aquifer system is classified as a minor aquifer system (Table 22 and Table 23). These aquifers can be fractured or potentially fractured rocks that do not have a primary permeability, or other formations of variable permeability.

Minor aquifers systems are vulnerable to:

- Direct pollution due to the presence of preferential flow paths associated with fractured and weathering of rock formations and geological structures (dykes and fault zones) to the deeper parts of the aquifer system.

- The impact of possible contamination from infrastructure on the aquifer zone and preferential flow paths should be limited. Groundwater monitoring must adhere to the IWUL conditions and water quality must not exceed the water resource protection limits (Table 18).

7.0 GROUNDWATER MONITORING SYSTEM

7.1 Monitoring Objective

Any groundwater monitoring network design should be guided by a risk-based source-pathway-receptor principle. A groundwater monitoring network should contain monitoring positions which can assess the groundwater status at certain areas. Both the impact on water quality and water quantity should be catered for in the monitoring system. The boreholes in the network should cover the following:

- Source monitoring – monitoring close to possible contaminant sources.
- Plume (pathway) monitoring – monitoring along identified contamination plumes (if any).
- Impact (receptor) monitoring – monitoring at expected sensitive receptors.
- Monitoring of the background water quality and levels.

It is required for future rehabilitation purposes to determine the occurrence, source and extent of contamination to verify predictions from groundwater modelling and to determine whether water treatment needs to be done as a part of rehabilitation.

7.2 Monitoring Network

The existing monitoring network as indicated in Figure 32 should be maintained and monitored as per WUL No.: 05/X11D/ABCFGIJ/2613.

Several monitoring boreholes which fall within the LOM will need to be re-drilled at positions indicated in Figure 36 and as per Golder Optimization GW map (Golder - December 2018 – awaiting approval from DWS) that was done for Exxaro for the proposed removal of sites or relocation of sites owing to the mining operation and LOM.

Additional monitoring boreholes may need to be installed and identified as BEP mining activities progress and monitoring requirements change.

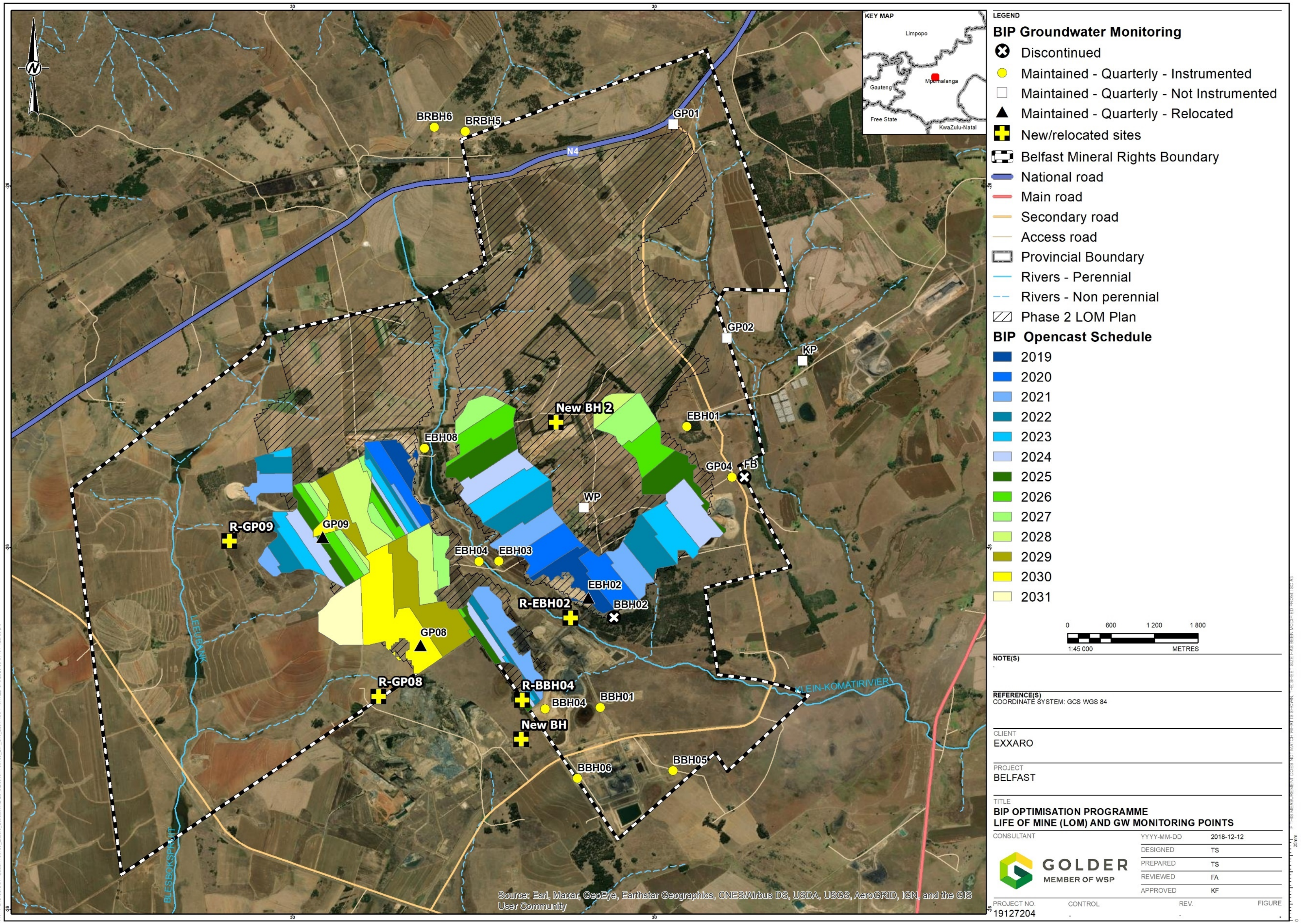


Figure 36: Replacement Monitoring Boreholes

7.2.1 Monitoring Frequency

It is recommended that the groundwater monitoring frequency for both groundwater levels and quality are conducted quarterly.

7.2.2 Monitoring Parameters

Groundwater quality parameters and limits are listed in Table 18.

8.0 GROUNDWATER MODELLING

The Golder 2020/21 numerical model is discussed in Section 8 below.

8.1 Conceptual Model

8.1.1 Initial Groundwater Conceptual Model (Golder 2020)

An initial groundwater conceptual model was constructed based on existing hydrogeological reports and data. The initial conceptual model/understanding of BEP is indicated as a cross sections in Figure 37. The coal seam floor elevations in relation to topography as used in the numerical model are displayed in Figure 38 to Figure 40.

Based on the existing reports, drilling, and aquifer testing results, three aquifer systems (6.2) can be distinguished at the BEP area namely:

- Top weathered aquifer system; unconfined aquifer system with an average thickness of ~ 10 m.
- Fractured aquifer system; confined to semi confined aquifer system with an average thickness of ~20m below the weathered aquifer system and is characterised by secondary fractures resulting in preferential flow paths for the groundwater flow and possible contaminant migration.
- Deep fractured aquifer system; confined aquifer system with reported water strikes between 118 to 120 mbgl (Table 23) and is present in the basement rocks below the fractured aquifer system.

The weathered and fractured aquifer systems are present in the Karoo Supergroup, whereas the deep fractured aquifer system is present in the Transvaal Supergroup.

The three aquifer systems as identified (6.2), hydraulic parameters are summarised in Table 24. The storativity values has been calculated by numerous different methods with the results published widely and a value of 0.002 to 0.01 is taken as representative for the Karoo Supergroup sediments (Groundwater Complete August 2014).

8.1.2 Conceptual Model Applied to the Numerical Model

The coal seam floor elevations in relation to topography, were extrapolated to the non-mining areas to generate the model layers. The received floor elevations were plotted as follow:

- North to south cross section in Figure 38.
- West to east cross section in Figure 39.
- North-west to south-east cross section in Figure 40.

Based on the averages between the coal seams, a typical geological layering was developed and is presented in Figure 41.

Table 24: Summarised Aquifer System Hydraulic Parameters

Aquifer System	Aquifer Thickness (m)	Water Strikes (m)	Yields (l/s)	Late Time Transmissivity (m^2/day)					Storativity
				Minimum	Maximum	Average	Geomean	Harmonic mean	
Weathered aquifer system	10	Below Water Level (<10m)	<0.3	-	-	3.0	-	-	0.002-0.01
Fractured aquifer system	20	13-28	0.1 – 2.0	0.1	14	3.6	0.9	0.3	0.017
Deep fractured aquifer system	>100	118 -120	1.0 – 2.0	0.1	0.7	0.4	0.3	0.2	0.002-0.01

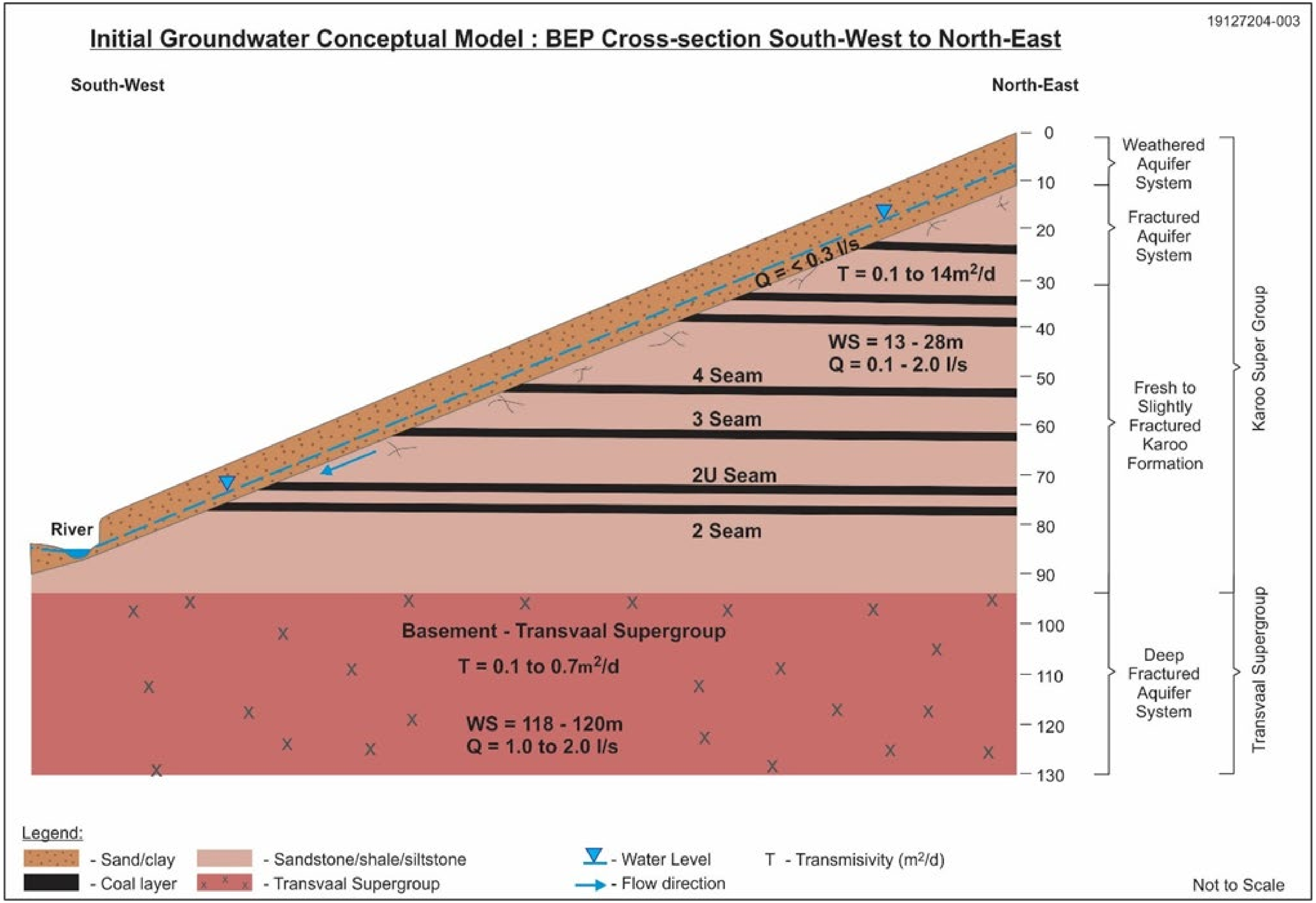
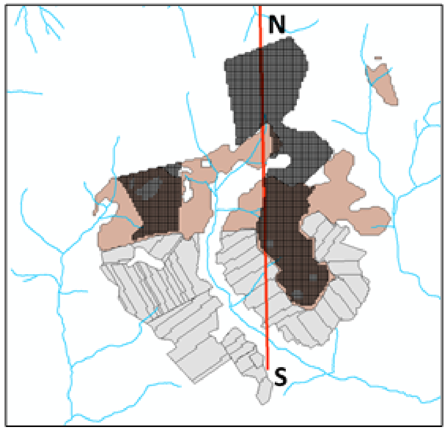
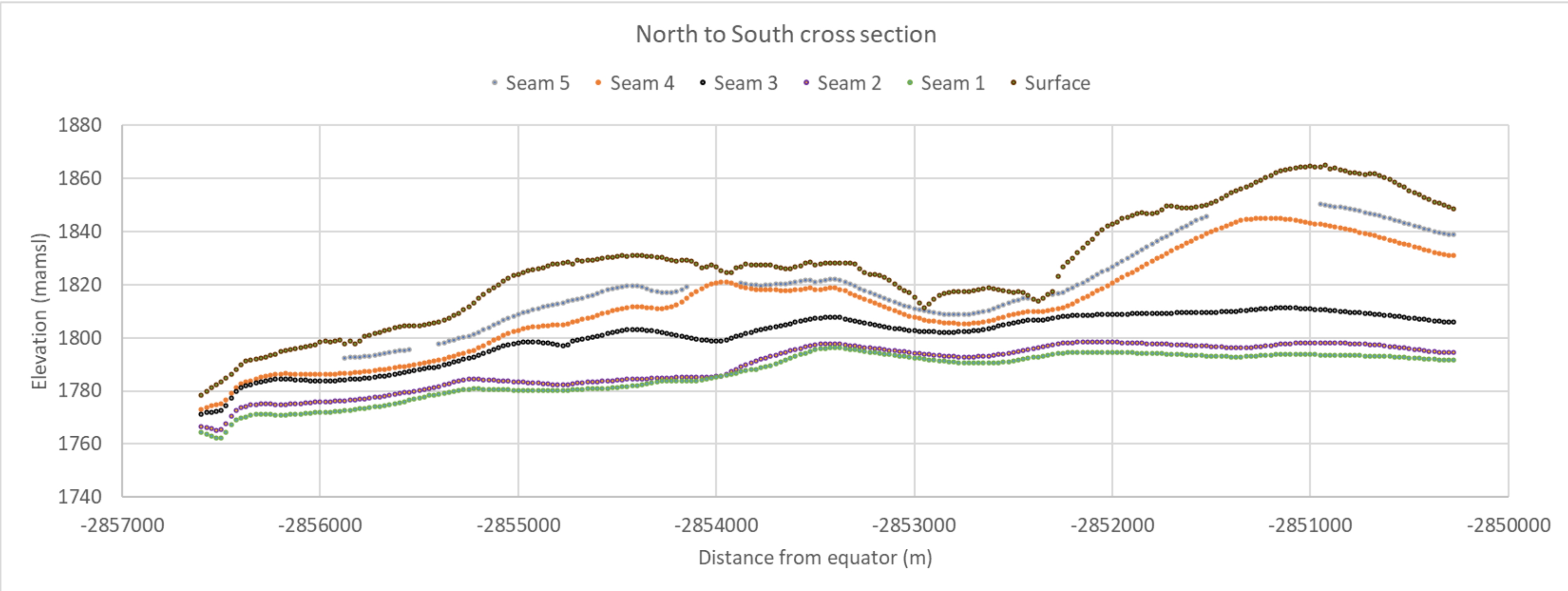


Figure 37: Conceptual South-West to North-East Cross Section



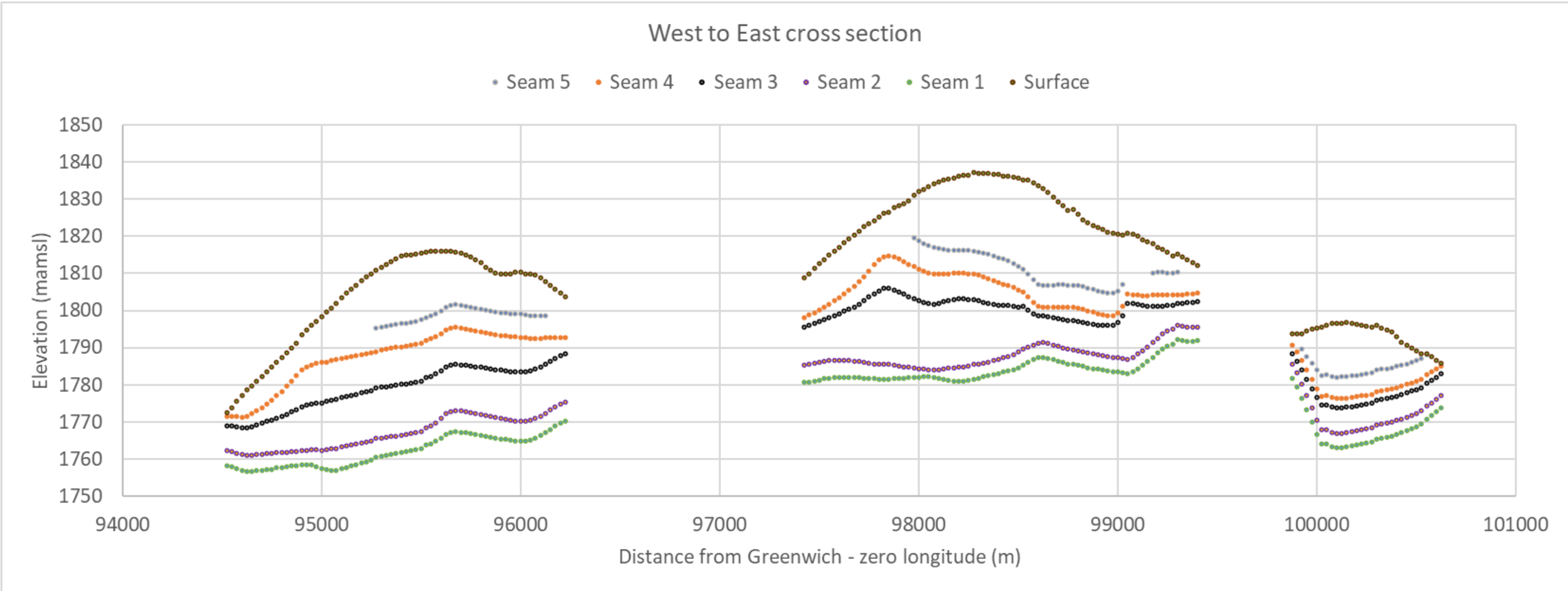
(a)



(b)

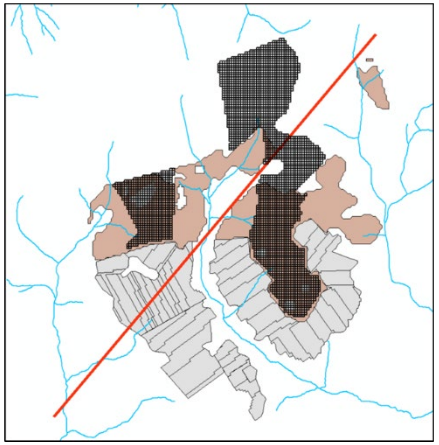
Figure 38: North to South Section (a) position and (b) cross section

(a)

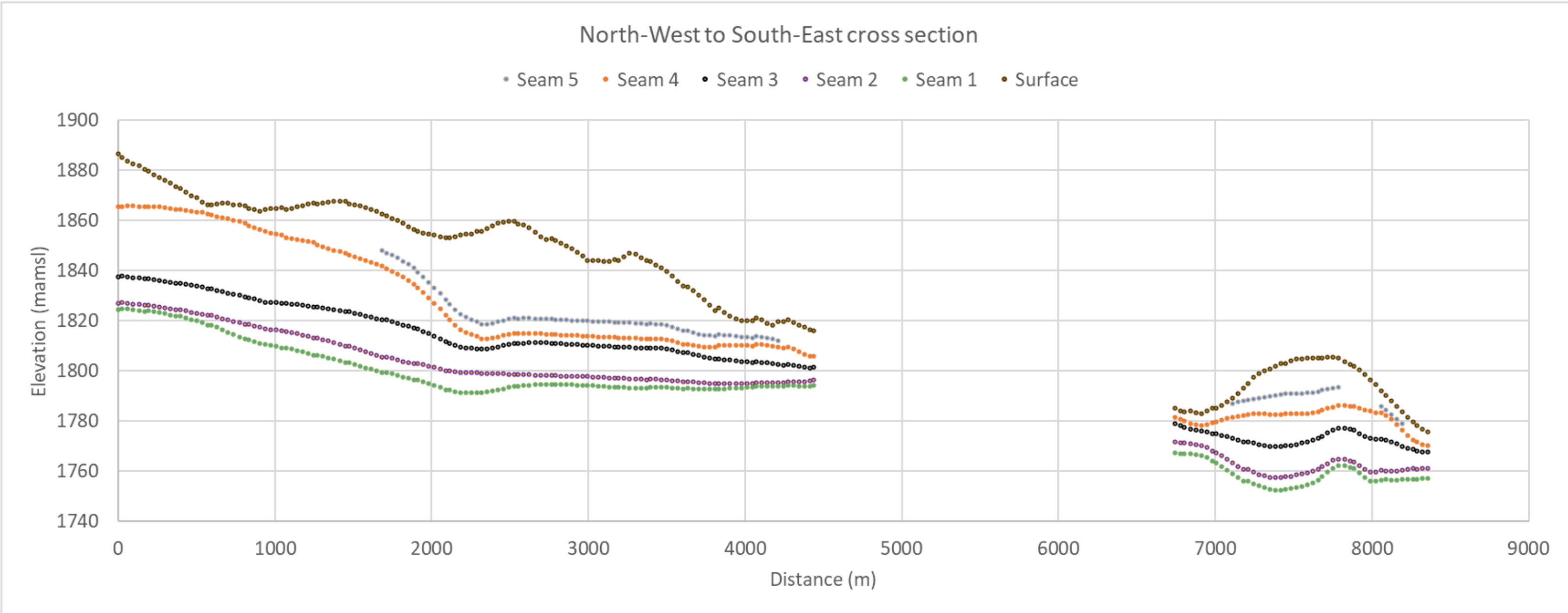


(b)

Figure 39: West to East Section (a) position and (b) cross section



(a)



(b)

Figure 40: North-west to south-east Section (a) position and (b) cross section

Lithology	Thickness (m)
Soils	1.2
Weathered zone	8.8
Sandstone	6
Coal seam 4	5
Sandstone	12
Coal seam 3	2
Sandstone	8
Coal seam 2	4
Sandstone	25
Pre-Karoo Basement	35

Figure 41: Average Thickness of Geological Layers

8.2 Software Selection

The code selected for conducting the modelling of the study area is Feflow developed by the WASY Institute for Water Resources Planning and Systems Research, Ltd. Berlin, Germany. Feflow is an interactive groundwater modelling system for three and two-dimensional, aerial and cross-sectional, fluid density-coupled, thermohaline or uncoupled, variably saturated, transient or steady state flow, mass and heat transport in subsurface water resources with or without one or multiple free surfaces.

Feflow can be efficiently used to describe the spatial and temporal distribution of groundwater contaminants, to model geothermal processes, to estimate the duration and travel times of pollutants in aquifers, to plan and design remediation strategies and interception techniques, and to assist in designing alternatives and effective monitoring schemes.

8.3 Groundwater Flow Equation

A steady state groundwater flow model for the study area was constructed to simulate groundwater flow conditions in September 2019. These conditions serve as starting heads for the transient simulations of groundwater flow and mass transport. A dynamic flow model using the modelling package FEFLOW (Diersch, 2014) was constructed for the study area. The simulation model (FEFLOW) used in this modelling study is based on three-dimensional groundwater flow and may be described by the following equation:

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

Where,

h = hydraulic head [L]

K_x,K_y,K_z = Hydraulic Conductivity [L/T]

S = storage coefficient

t = time [T]

W = source (recharge) or sink (pumping) per unit area [L/T]

x,y,z = spatial co-ordinates [L]

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

$$\frac{\partial}{\partial x}\left(Kx \frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(Ky \frac{\partial h}{\partial y}\right)+\frac{\partial}{\partial z}\left(kz \frac{\partial h}{\partial z}\right)\pm W = 0 \qquad (2)$$

According to the conceptual model for the system the calculated hydraulic head distribution (hx,hy,hz) is dependent upon the recharge from rainfall, hydraulic conductivity and boundary conditions. For a given hydraulic conductivity value (transmissivity value) and a set of boundary conditions, the head distribution across the aquifer can be obtained for a specific recharge value.

8.4 Model Domain

The model domain covers a surface area of about 395 km^2. The modelling area was selected based on a combination of both topographical (surface catchment boundaries) and hydrogeological controls (rivers). The model was delineated to coincide with rivers and assumed groundwater divides. This is a reasonable approach since a correlation exists between groundwater level elevation and surface topography. The model domain was chosen large enough to ensure that the solute transport simulation is unaffected by assigned boundary conditions.

The model was set up as a three-dimensional groundwater flow model. The model was constructed with nine layers (10 slices) corresponding with the conceptual model. The mesh was designed to incorporate the BIP and BEP operations as well as relevant infrastructure with a refined mesh in these areas of interest. The finite element mesh generated by FEFLOW used the triangular prism mesh made up of 996 870 elements and 549 879 nodes. Figure 42 illustrates the model domain for the study area.

The mesh quality is regarded suitable based on the following criterion:

- Interior holes: 0
- Obtuse angled triangles: 1.2% > 120°, 11.1% > 90º
- Delaunay-violating triangles: 4.8%

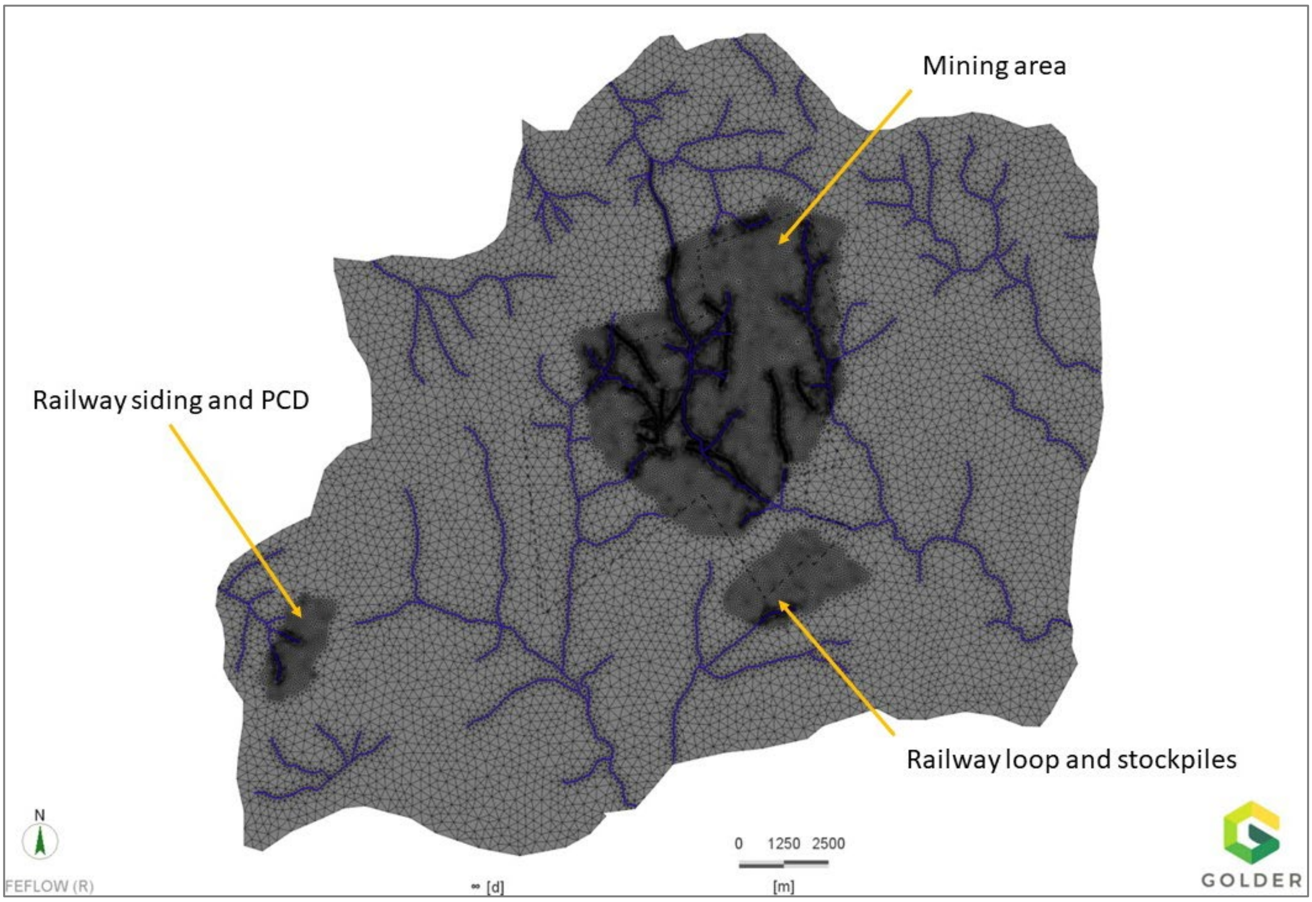


Figure 42: Model mesh with refinement in areas of interest

8.5 Limitations and assumptions

Groundwater models are simplified mathematical representations of complex natural systems. Because of this, there are limits to the accuracy with which groundwater systems can be simulated. Generally model uncertainty is based on assumptions of homogeneity and temporal averaging.

Calibration depends on the interaction between water levels, abstraction, hydraulic conductivity and recharge. There is a level of uncertainty in each of these. The uncertainties are described below:

- Uncertainty will always be present due to aquifer heterogeneity.
- Some uncertainty arises from measurement errors.
- The model is a simplification / approximation of reality.
- The zonation of recharge areas is uncertain at best.

The following assumptions were made in the model:

- The mining is assumed to follow the mine plan provided early 2020 when modelling commenced.
- The mine plan was assigned within the model on an annual schedule. Consequently, it is appropriate to view the outputs from the model as an average rate per year.
- Geological structures were included as per the structures that were provided and it was assumed that:
  - The structures are associated with high hydraulic conductivity.

- The structures go down vertically from the top to the base of the model.

8.6 Model Boundary Conditions

The groundwater model boundary was selected for an area of at least 5 km around the mining area and is shown in Figure 42. The boundary follows rivers or catchment boundaries as follow:

- The northern model boundary follows non-perennial rivers;
- The north-east and west model boundaries follow catchment boundaries;
- The eastern and southern model boundaries are formed by tributaries of the Klein-Komati River.

8.6.1 Internal Boundary Conditions

Locally groundwater in both the shallow and deep aquifers flows from the high to low elevations, towards the rivers or drainages and follow topography. Dirichlet (seepage face) boundary conditions were specified along the river drainages and wetland areas which are known to receive base flow from groundwater. The seepage face boundaries on slice 1 of the numerical model are shown in Figure 43.

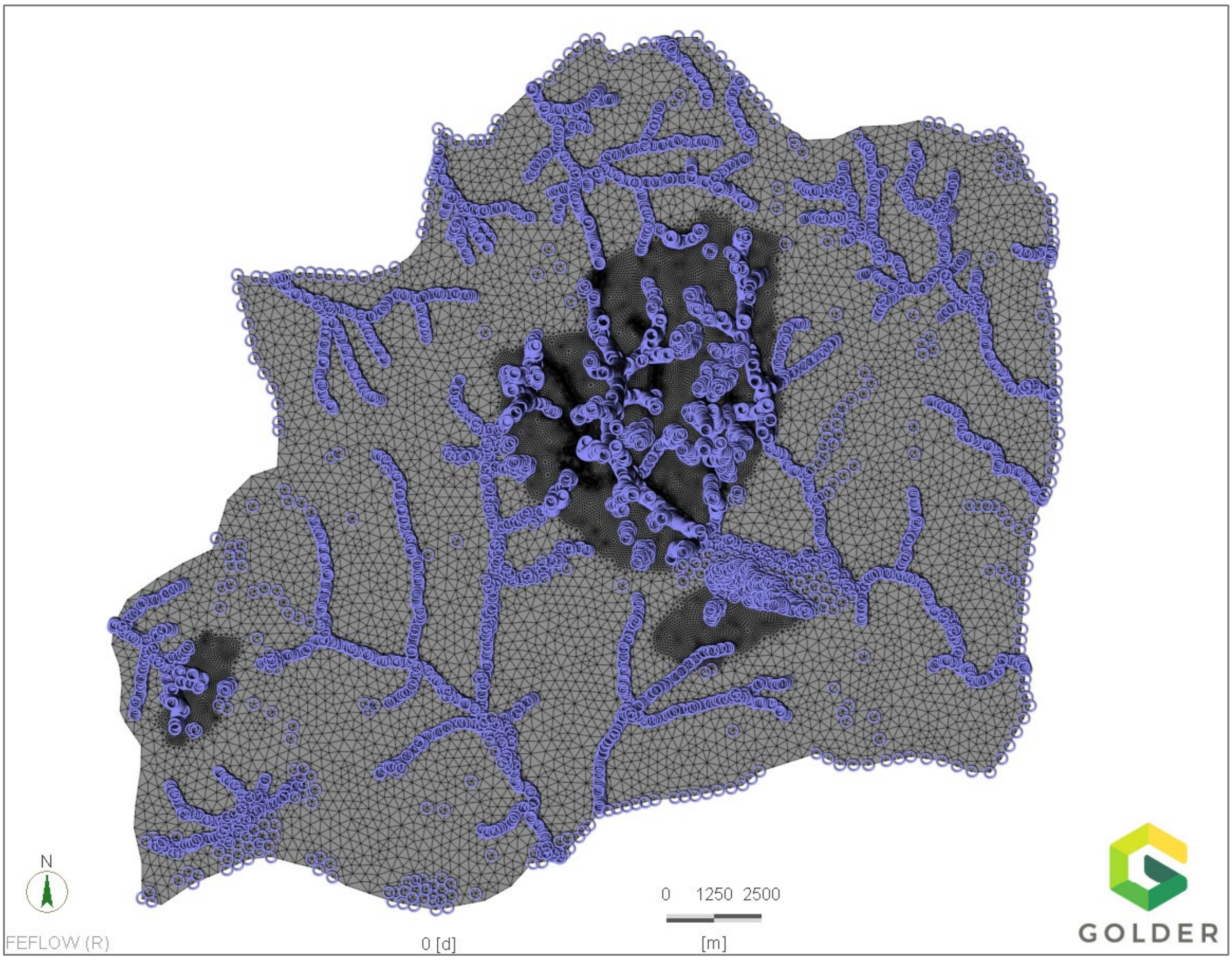


Figure 43: Boundary conditions on slice 1 (rivers and wetlands)

8.7 Model Layers

The study area is represented by a 10-layered model based on existing data and a simplified geological section. The model domain was assumed to extend vertically to encompass the following coal seams: Seam 4, Seam 3 and Seam 2. It is assumed that the base of the model is impermeable. Table 25 presents the model layers and average thickness. Layer 4, 6 and 8 represents the coal seams.

Table 25: Model Layers

Model Layer	Layer No.	Average Thickness (m)
Soils	1	0.8
Weathered zone	2	1.2
Sandstone	3	6
Coal Seam 4	4	5
Sandstone	5	12
Coal Seam 3	6	2
Sandstone	7	6
Coal Seam 2	8	4
Sandstone	9	25
Pre-Karoo	10	35

8.8 Model Hydraulic Properties

The major hydrogeological units built into the model consist of the major aquifer zones and lithologies. Initial estimates of the hydraulic conductivity (K) values are from representative Karoo aquifers and values recognised to be representative for sandstones/shale/siltstone sedimentary sequences of the Vryheid Formation. The aquifer K value is based on the conceptual understanding of the study area and Golder's experience with the Witbank coal fields. Generally accepted and recognised K values for sandstones/shale/ siltstone and sedimentary sequences of the Vryheid Formation vary between 0.001 m/day and 0.1 m/day**.** These numbers were used as the starting aquifer parameter values prior to model calibration.

8.9 Model Calibration

8.9.1 Steady State Calibration

The steady state flow model is calibrated on the known geological, hydrogeological and piezometric head distribution data. Calibration was done by changing recharge and hydraulic conductivity values until an acceptable fit between the measured and simulated heads was obtained.

The groundwater level (GWL) data from nine (9) observation boreholes were available for the calibration of the flow model. The following errors were calculated:

- Mean Error (ME): Mean difference between the measured and simulated water levels.
- Mean Absolute Error (MAE): Mean of the absolute value of the differences between the measured and simulated heads.
- Root Mean Square Error (RMSE): Average of the squared differences between the measured and simulated heads.

- Normalised Root Mean Square Error (NRMSE): The RMSE is divided by the difference between the shallowest and deepest GWL. Normalising is required when comparing datasets with different scales.

Negative and positive values and differences can cancel each other out, thus the ME is not necessarily a good indication for assessment of calibration. The MAE addresses this as the absolute values. The RMSE is evaluated as a ratio of the total water level change across the model domain. When the ratio is small, the errors are small relative to the overall water level and model response.

The RMSE was evaluated as a ratio to the total water level change across the model domain. If the ratio is small, the errors are only a small part of the overall model response (Anderson and Woessner, 1992). Table 26 provides a summary of the calibration results with a NRMSE of 5.99%, which is considered reasonable for the study area.

Table 26: Calibration error calculation

Name	Measured GWL (mamsl)	Simulated GWL (mamsl)	ME	MAE	RMSE
BBH01	1769	1773	-4.2	4.2	17.9
BBH04	1781	1780	0.8	0.8	0.7
BBH05	1771	1774	-3.3	3.3	10.7
BBH06	1781	1776	5.4	5.4	29.6
EBH01	1785	1795	-9.5	9.5	89.3
EBH04	1767	1770	-3.2	3.2	10.5
GP01	1868	1864	3.7	3.7	13.8
GP02	1788	1796	-7.1	7.1	50.5
GP09	1785	1777	7.6	7.6	57.4
RMSE					**5.58 m**
Water Level Difference from lowest to highest measured GWL					100.6 m
NRMSE%					**5.5%**

A scatterplot and a bar chart of the simulated vs measured groundwater level are presented in in Figure 44 and Figure 45. The simulated steady state groundwater level is presented in Figure 46.

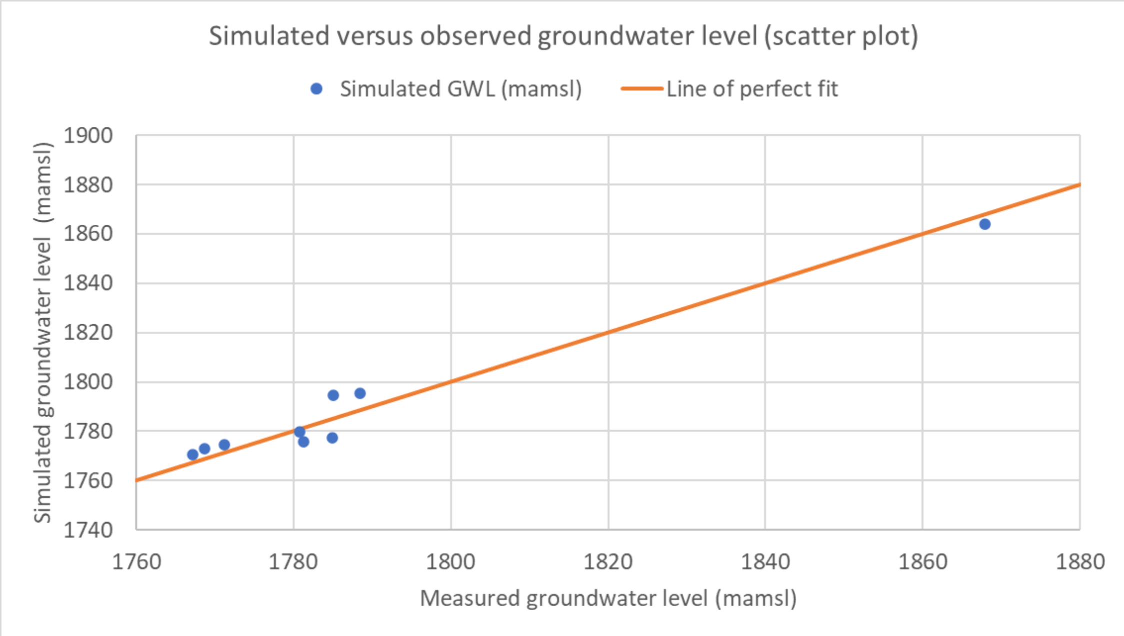


Figure 44: Scatterplot of measured versus simulated groundwater levels

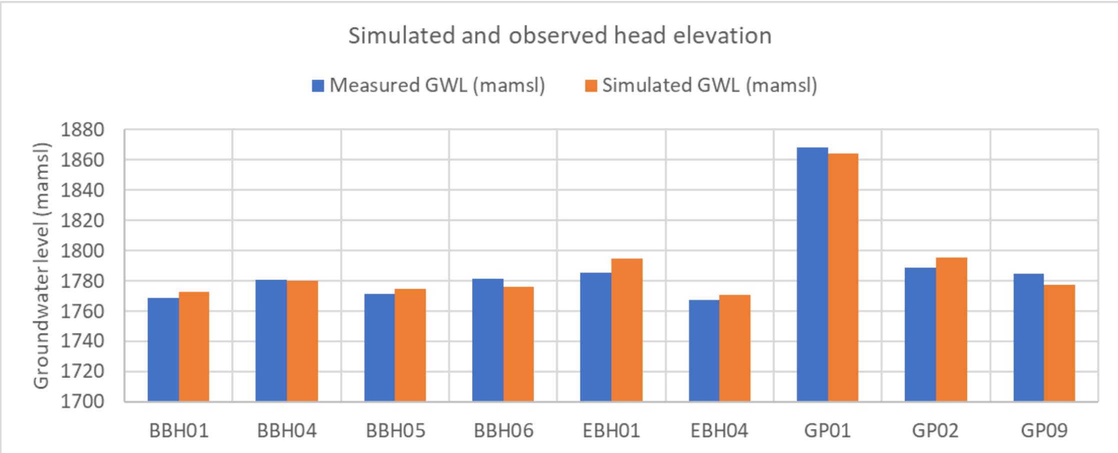


Figure 45: Bar chart of measured vs simulated hydraulic head elevations

The three boreholes where the simulated water level is higher than the measured (GP01, GP09 and BBH06), are all in cultivated lands. A possible explanation could be that the tilling of soil and building of contours to prevent erosion cause higher recharge in these areas and the water level is below extinction depth and not available for plant use.

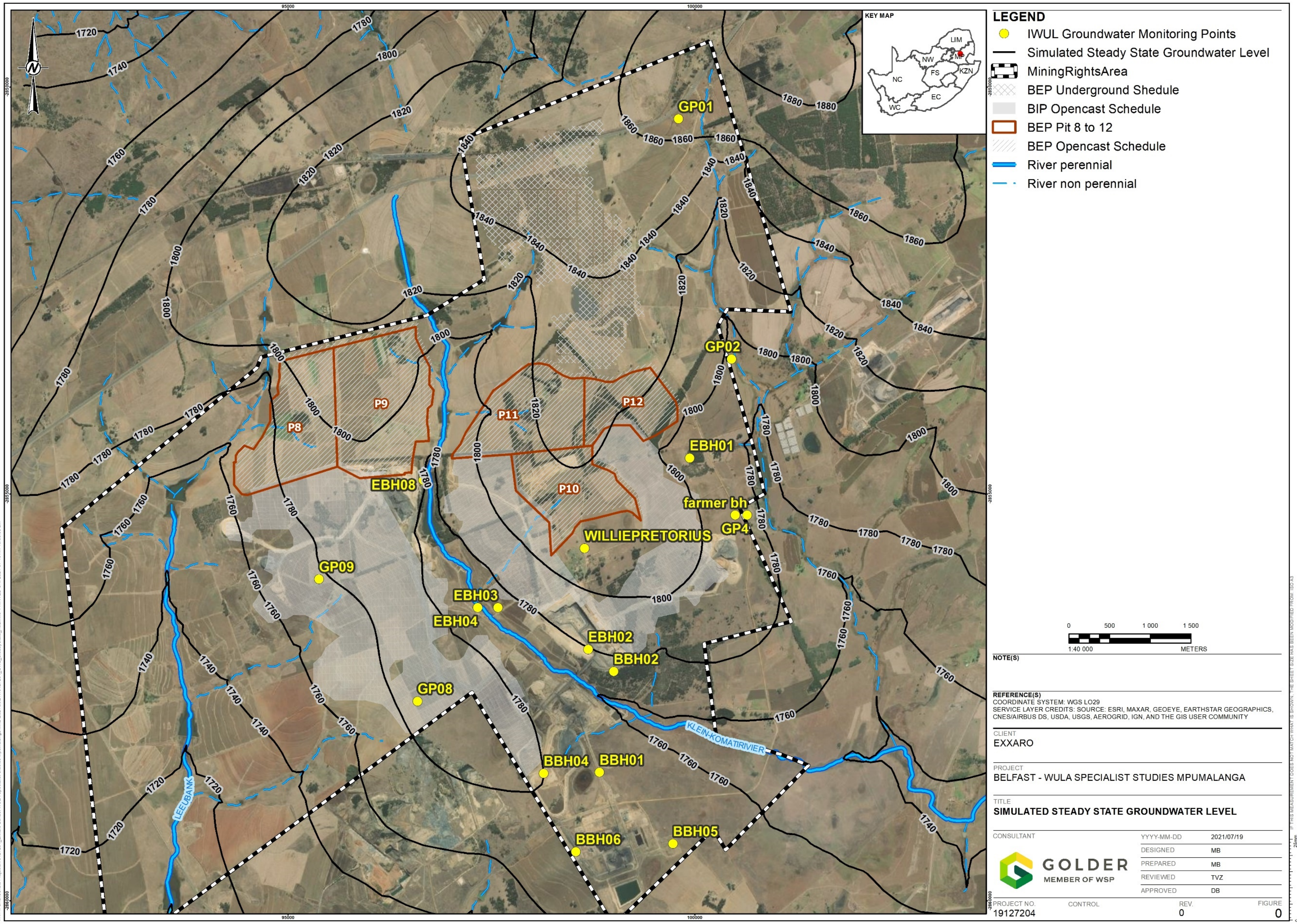


Figure 46: Simulated steady state groundwater level

The calibrated model parameters are shown in Table 27.

Table 27: Calibrated model parameters

Geology	Layer	K_x (m/d)	K_y (m/d)	K_z (m/d)	Recharge (mm/a)
Recharge Soils	1	0.043	0.043	0.0043	6
Interflow and Responsive Soils	1	0.014	0.014	0.0014	6
Weathered zone	2	0.014	0.014	0.0014	-
Sandstone	3, 5, 7	0.007	0.007	0.0007	-
Sandstone	9	0.0007	0.0007	0.00007	-
Coal Seams	4, 6, 8	0.014	0.014	0.0014	-
Pre-Karoo areas	3 to 9	0.043	0.043	0.0043	-
Pre-Karoo	10	0.00043	0.00043	0.000043	-
Faults	1 to 10	0.143	0.143	0.0143	-

The calibrated recharge is 1% of MAP and within the range of 1 – 3% of MAP suggested by Groundwater Complete (2009). It is however lower than most of the other estimates.

Steady state (pre-mining) water budget is presented below in Table 28.

Table 28: Steady state (pre-mining) water budget

	IN (Recharge)	OUT (Dirichlet boundary conditions)	
Units	m^3/d	m^3/d	%
Domain	42 543	42 543	
Rivers		30 934	72.7%
Wetlands		11 609	27.3%

Table 28 shows that of all the recharge coming into the model area, 73% ends up in rivers and the other 27% ends up in wetlands.

8.9.2 Transient Calibration

For transient state simulations the specific storage (SS) is required. SS can be calculated from measured storativity values using the following equation:

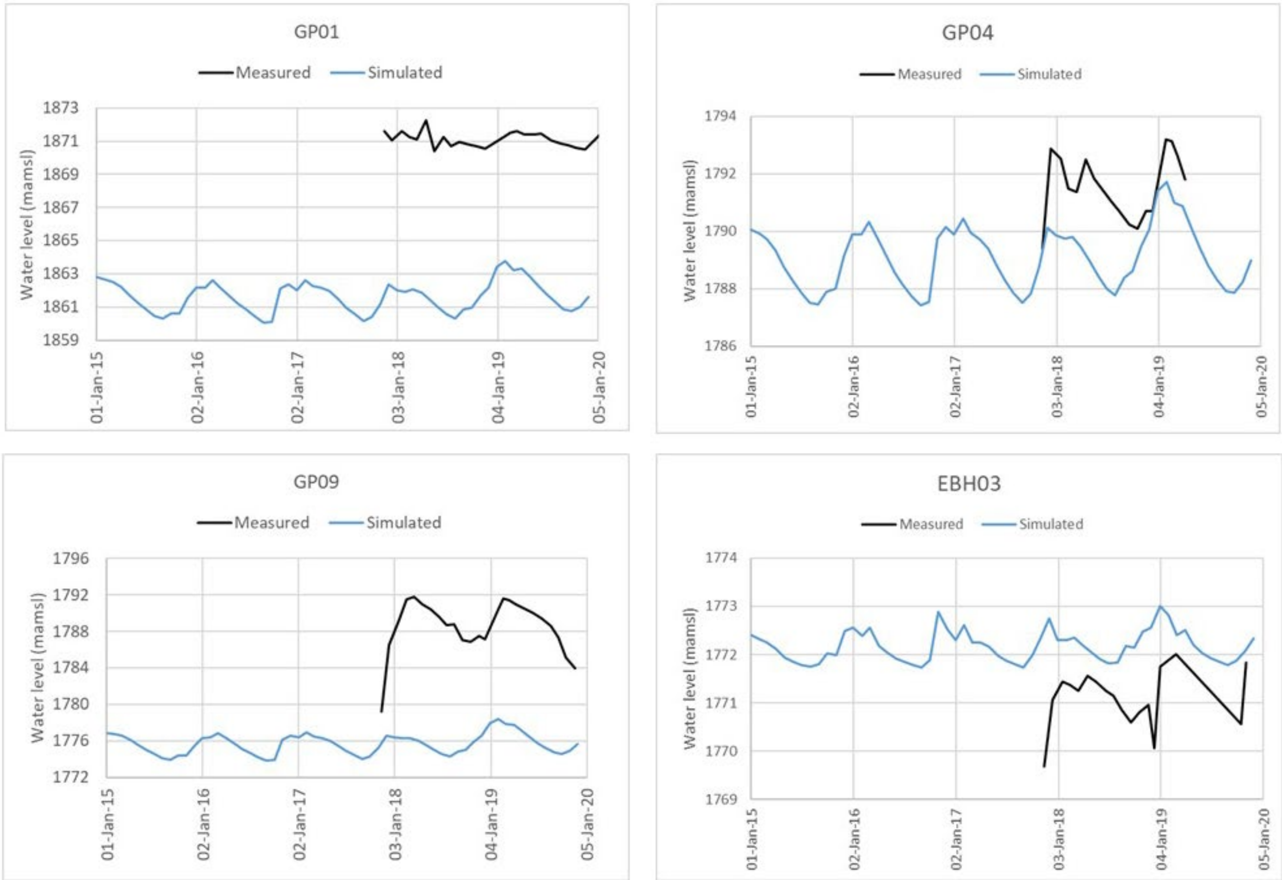
$$\text{Storativity} = \text{Specific storage (SS)} \times \text{aquifer thickness (B)}$$

Groundwater Complete (2009) measured storativity and supplied Sf and Sm values, with:

- Sf – Storativity at the start of the test, usually fracture dominated flow.
- Sm – Storativity at the end of the test, usually matrix dominated flow.

The specific storage (SS) used in the model was 6.00E-05 m^{-1}. The calibration period was selected from 2015 to 2019 when water level data was available, and the simulated vs measured time series is presented in Figure 47 for selected boreholes. The difference between the simulated and measured water levels originating from the steady state calibration.

For the transient calibration the aim was to get the change in water level between the wet and dry seasons (seasonality) well represented. The seasonal trends were achieved for most of the boreholes, except for boreholes GP01 and BBH01. For both these boreholes the model simulates more variation between wet and dry seasons than measured.



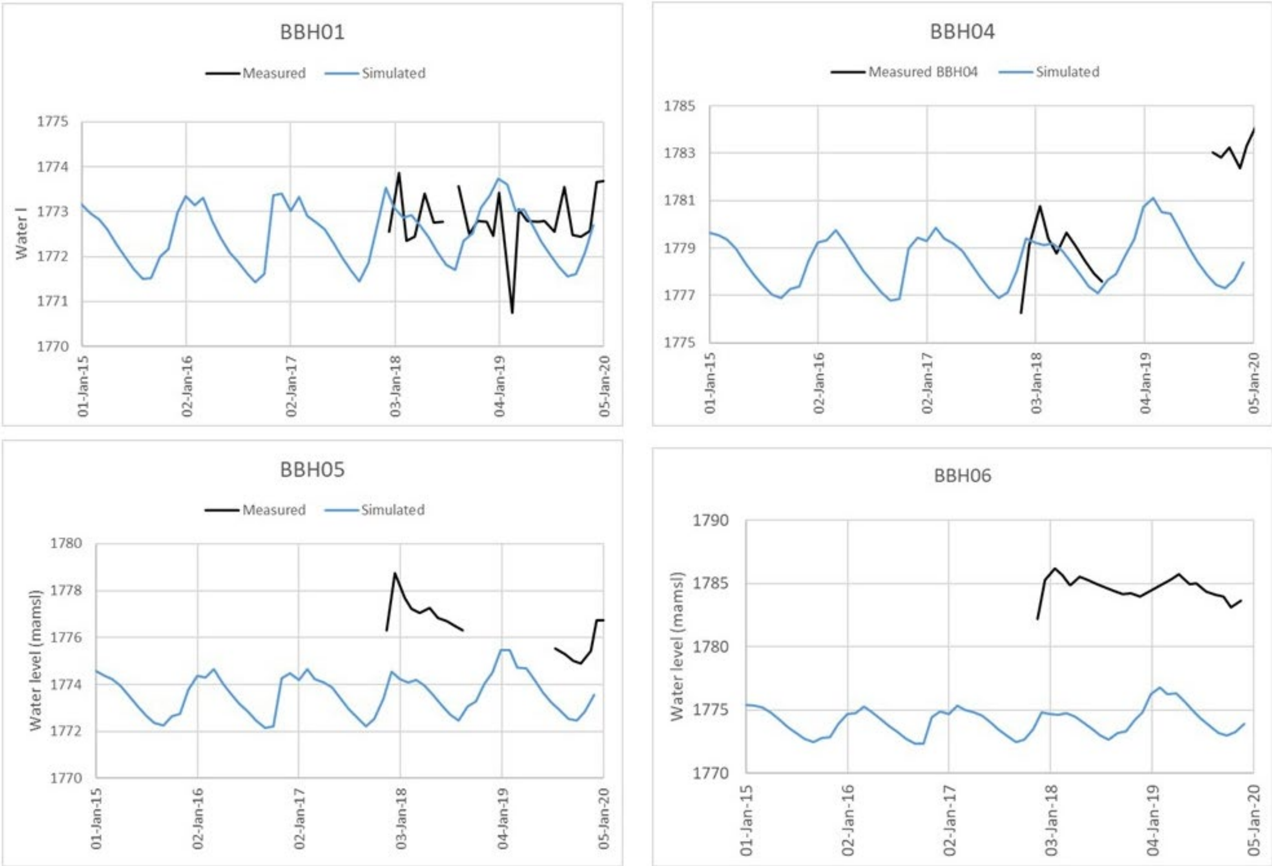


Figure 47: Simulated vs measured time series

8.10 Setup for Operational and Post-Closure Flow Models

The transient model was setup to run from the start of 2019, when the mining started, to the end of 2042, when mining will end according to the mine plans received on 7 July 2020. The mining schedule from these plans are presented in Figure 48 and they show that:

- The BIP opencast mining started in 2019 and will end in 2031 (according to the Wings scenario 4, November 2019).
- The BEP opencast mining will be active from 2031 to 2039.
- The BEP underground mining will be active from 2037 to 2042.

Mining was simulated by applying Dirichlet boundary conditions from the start of mining till the end of the modelling period which is 2042 for the operational model. Backfilling was modelled by changing the following parameters, one year after mining finished:

- Recharge was increased from 1% to 15% of MAP (101 mm/a)
- Hydraulic conductivity was increased to 1 m/d.
- Storativity was increased to 25% (Specific storage = 0.25/thickness).

For the underground mining, only hydraulic conductivity was increased to 1 m/d and storativity was increased to 66% (Specific storage = 0.66/thickness).

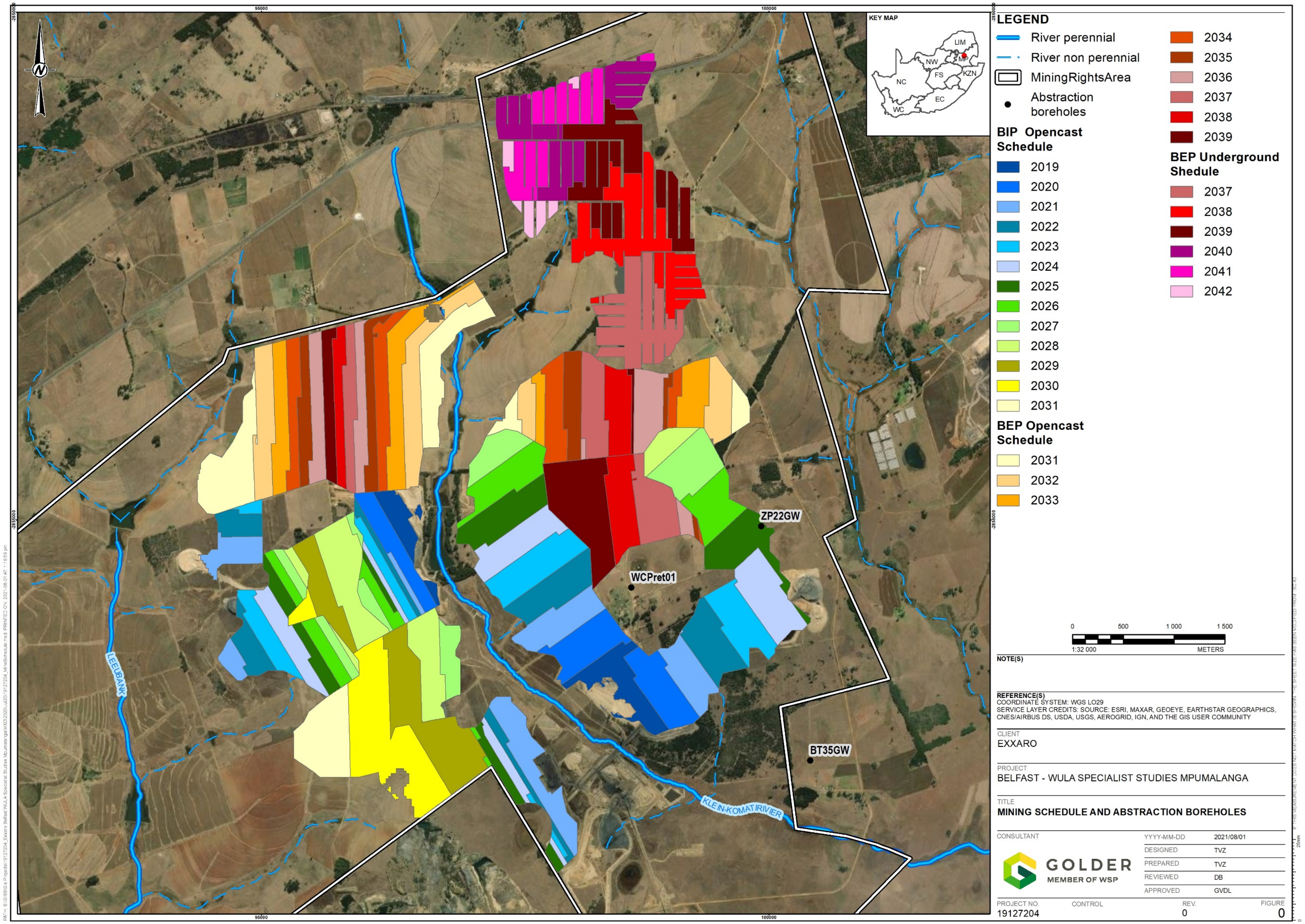


Figure 48: Mining schedule

8.11 Setup for Contaminant Transport Model

During operations there is a cone of depression associated with mining and all contaminants associated with mining, will only migrate to the lowest point in the cone of depression. As the cone of depression will contain all mining related contamination it was not considered as a source during the operational period.

However, the Old Discard Dump and the proposed MRF was added as sources of contamination during the operational period. It was assumed that the MRF will be active from 2026.

After closure, the opencast pits and the underground workings were added as sources of contamination.

The source terms were determined by the Golder geochemistry team (Golder, 2021b) and is summarised in Table 29.

Table 29: Source terms

Area	TDS (mg/L)	SO_4 (mg/L)
BEP Pit 12	322.8	138.3
BEP Pit 11	276.2	118.8
BEP Pit 7,8,9 & BIP west pit	344.4	150.6
BEP Pit 10 & BIP east pit	361.6	158.1
BEP underground workings	624.0	381.8
Discard	2565	1610

The source terms were applied using Neumann type boundary conditions.

8.12 Model Results: Operational

8.12.1 Sensitivity analysis

A sensitivity analysis was conducted in steady state. The transmissivity (T) in the original calibrated model was 0.44 m^2/d which is in line with the harmonic mean of the measured values for matrix dominated flow (Table 7). The sensitivity models considered hydraulic conductivity values of 2 and 5 times higher than for the original calibrated model. These two scenarios relate to transmissivities of 0.88 m^2/d and 2.22 m^2/d, the latter being in line with the harmonic mean of the measured values for fracture dominated flow. Both models were re-calibrated and the following steady state inflows were observed:

- T of 0.44 m^2/d had underground inflow of 2.7 L/s.
- T of 0.88 m^2/d had underground inflow of 4.3 L/s. This is approximately 1.6 times the original predicted inflows.
- T of 2.22 m^2/d had underground inflow of 11.4 L/s which is approximately 4 times more than the original inflow.

. Please note that steady state inflows are not accurate as it does not consider the opening of different sections of the mine at different times. The steady state sensitivity illustrates the relative changes in inflow with increasing hydraulic conductivity with maximum inflows of around 11.2 l/s. It is noted that the transient inflow model in the next section should be used for groundwater inflows.

8.12.2 Simulated Lateral Inflow

To obtain lateral groundwater inflow into the pits, all recharge directly on the pits and backfilled areas (spoils) were removed. Therefore, the simulated inflows presented in Table 30 does not account for the direct recharge on the pits. These groundwater lateral inflows were used by the water balance study (Golder, 2021d) to calculate total inflows over time for the various pits and to account for the changing recharge at the various stages of rehabilitation.

The BEP opencast is scheduled from 2031 to 2039 and the underground is scheduled from 2037 to 2042 as indicated in Figure 48. The cumulative lateral inflows are shown in Table 30, the annual inflows are plotted in Figure 49 and a graph of cumulative inflow are shown in Figure 50.

Table 30: Cumulative lateral inflow into the BEP opencast and underground mines

Year	BEP opencast (EAST)		BEP opencast (WEST)		BEP underground	
	Inflow (m^3/d)	Inflow (L/s)	Inflow (m^3/d)	Inflow (L/s)	Inflow (m^3/d)	Inflow (L/s)
2031	139.6	1.6	182.3	2.1	0.0	0.0
2032	515.6	6.0	1040.3	12.0	0.0	0.0
2033	631.3	7.3	1190.0	13.8	0.0	0.0
2034	704.2	8.2	1234.0	14.3	0.0	0.0
2035	735.8	8.5	1245.3	14.4	0.0	0.0
2036	749.9	8.7	1246.3	14.4	2.1	0.02
2037	752.2	8.7	1246.3	14.4	206.6	2.4
2038	752.2	8.7	1246.3	14.4	727.6	8.4
2039	752.2	8.7	1246.3	14.4	1262.2	14.6
2040	752.2	8.7	1246.3	14.4	1827.1	21.1
2041	752.2	8.7	1246.3	14.4	2841.3	32.9
2042	752.2	8.7	1246.3	14.4	3333.9	38.6

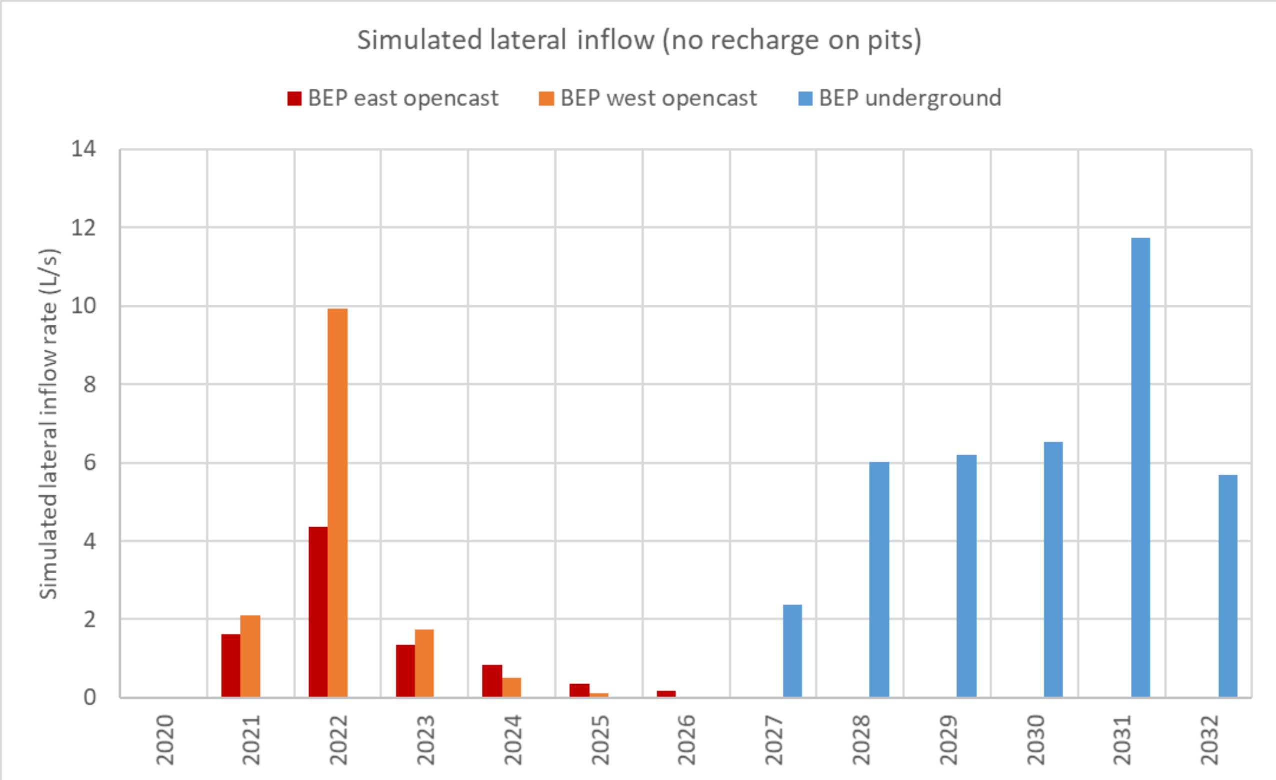


Figure 49: Simulated annual inflow into the BEP opencast and underground mines

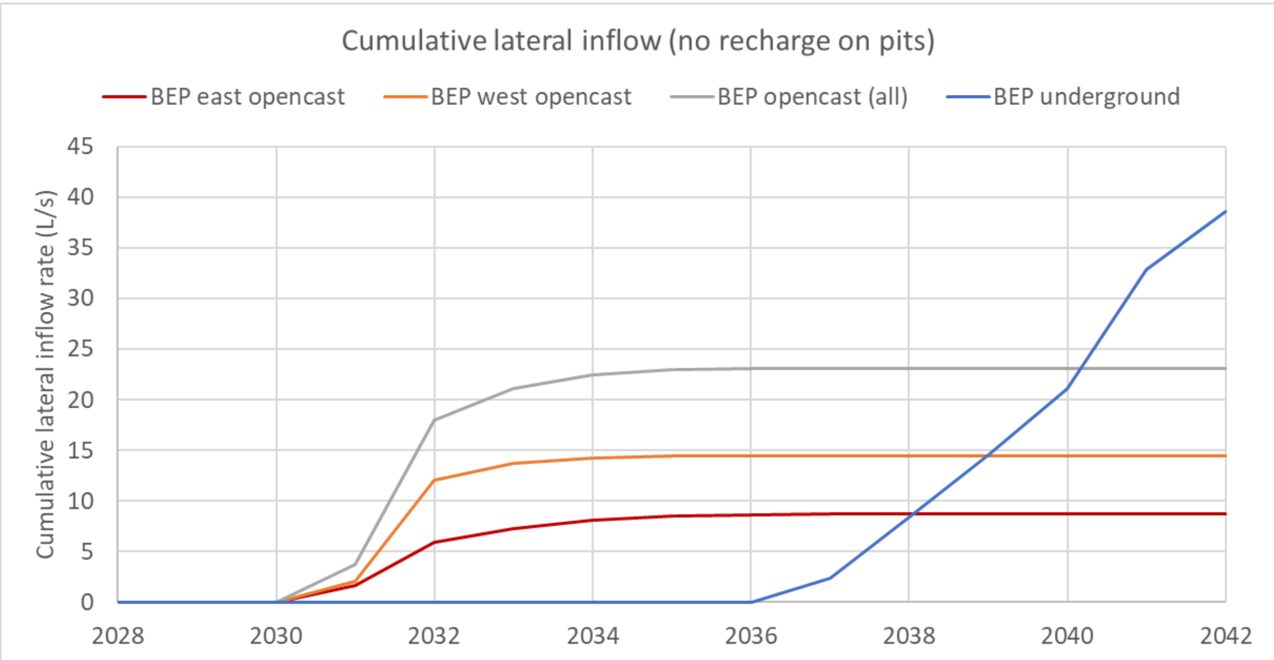


Figure 50: Cumulative lateral inflow into the BEP opencast and underground mines

Based on the steady state sensitivity analyses, the inflows can be expected to increase by 1.6 to 4 times if the hydraulic conductivities increase by 2 to 5 times.

8.12.3 Drawdown from Mining

The cone of depression due to mining changes over time based on the mining schedule. At the end of mining (2042) the cone of depression is at its largest and include the underground mining area. The drawdown extends to the shallow aquifer, which is expected for the opencast mining areas, but limited information is available on the impact from underground mining. The numerical model assumes direct linkages between the two aquifers and therefore the drawdown in the underground mining area should be viewed as a worst-case scenario.

Figure 51 shows the drawdown from mining only. The extent of the drawdown was measured from the mining area up to the point where the water level is 1 m below (-1 on map) the pre-mining water level:

- In the underground mining area, the cone of depression extends 1.4 km beyond the mining area at the most.
- Around the BEP opencast pits, the cone of depression at surface can extend up to 2 km from the active pit areas. This maximum is seen to the north of Pits 8 and 9.
- From Pit 12, the cone of depression extends 900 m north-east and from Pit 11 the cone of depression combines with the cone of depression from Pit 9.

The change in drawdown over time is shown in Figure 52 shows the cone of depression at the end of mining (2042). The effect of the drawdown on wetlands and rivers changes over time. To illustrate this effect, two cross sections were drawn (Figure 53) and the water level over time for these cross sections are shown in Figure 54 for the section through the underground mining area and in Figure 55 for the section through the opencast mining area.

Figure 54 shows how the water level drops down wetland KS05and wetlands DS7 &DS8 after 2035 when mining starts in the area. Figure 55 shows how the water level below wetland KS11 is lowered in 2030 and further lowered in 2035. By 2042 the water level is recovering below wetland KS11. In the area of wetland DS10 and DS11, the water level is slightly deeper from 2035 onward. Refer to the wetland impact assessment report (Golder, 2021c) for more detail on the impact of mining on the wetlands. Pan 11 is not impacted as it is not groundwater fed. KS03 is groundwater fed, but not impacted by mining. Table 31 summarises the impact of drawdown on wetlands.

Table 31: Impact of drawdown on wetlands

Wetland	Impact from drawdown
LS03	Impacted by BIP opencast mining
LS04	Impacted by BIP opencast mining
KS07	Impacted by BIP opencast mining
KS09	Impacted by BIP opencast mining
KS08	Impacted by BIP opencast mining
DS10 & DS11	Impacted by BIP opencast mining
DS12	Impacted by BIP opencast mining
KS11	Impacted by BIP opencast mining
KS10	Impacted by BIP opencast mining
KS04	Impacted by BIP opencast mining
KS02	Impacted by BEP opencast mining

Wetland	Impact from drawdown
KS05	Impacted by BEP underground mining
DS7&8	Impacted by BEP underground mining
KS03	Not impacted
Pan 11	Not impacted

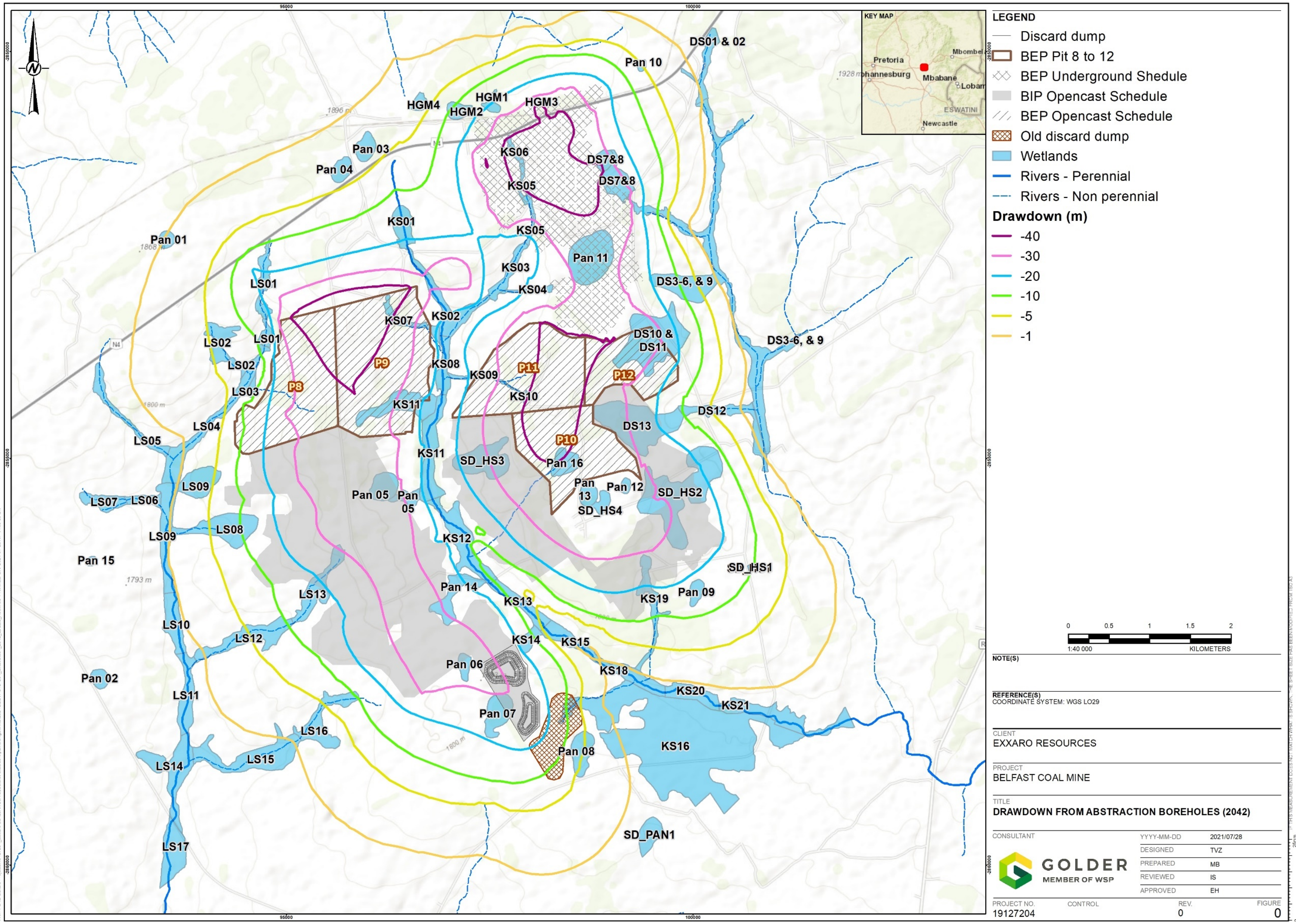


Figure 51: Extent of drawdown at the end of mining (2042)

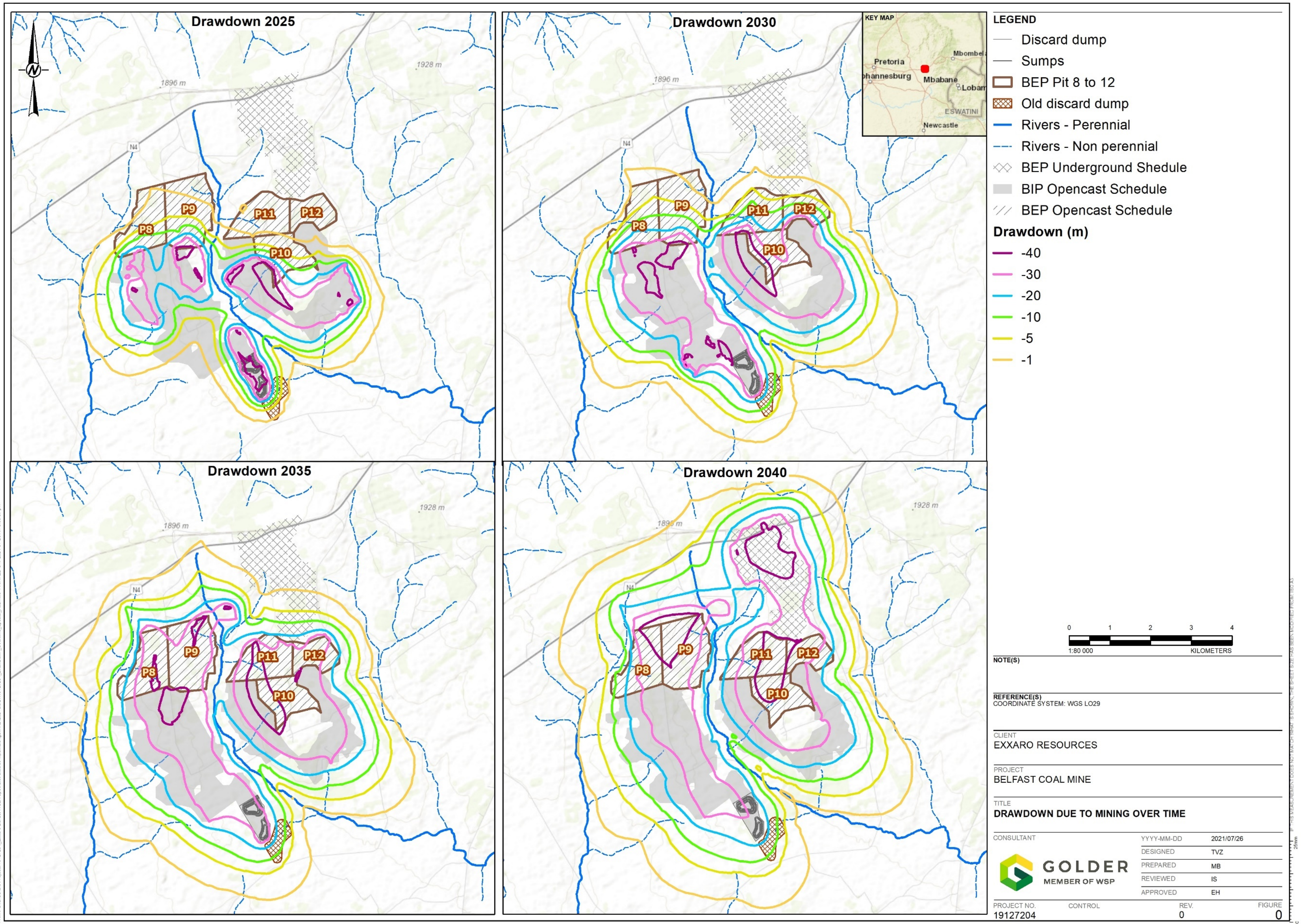


Figure 52: Extent of drawdown over time

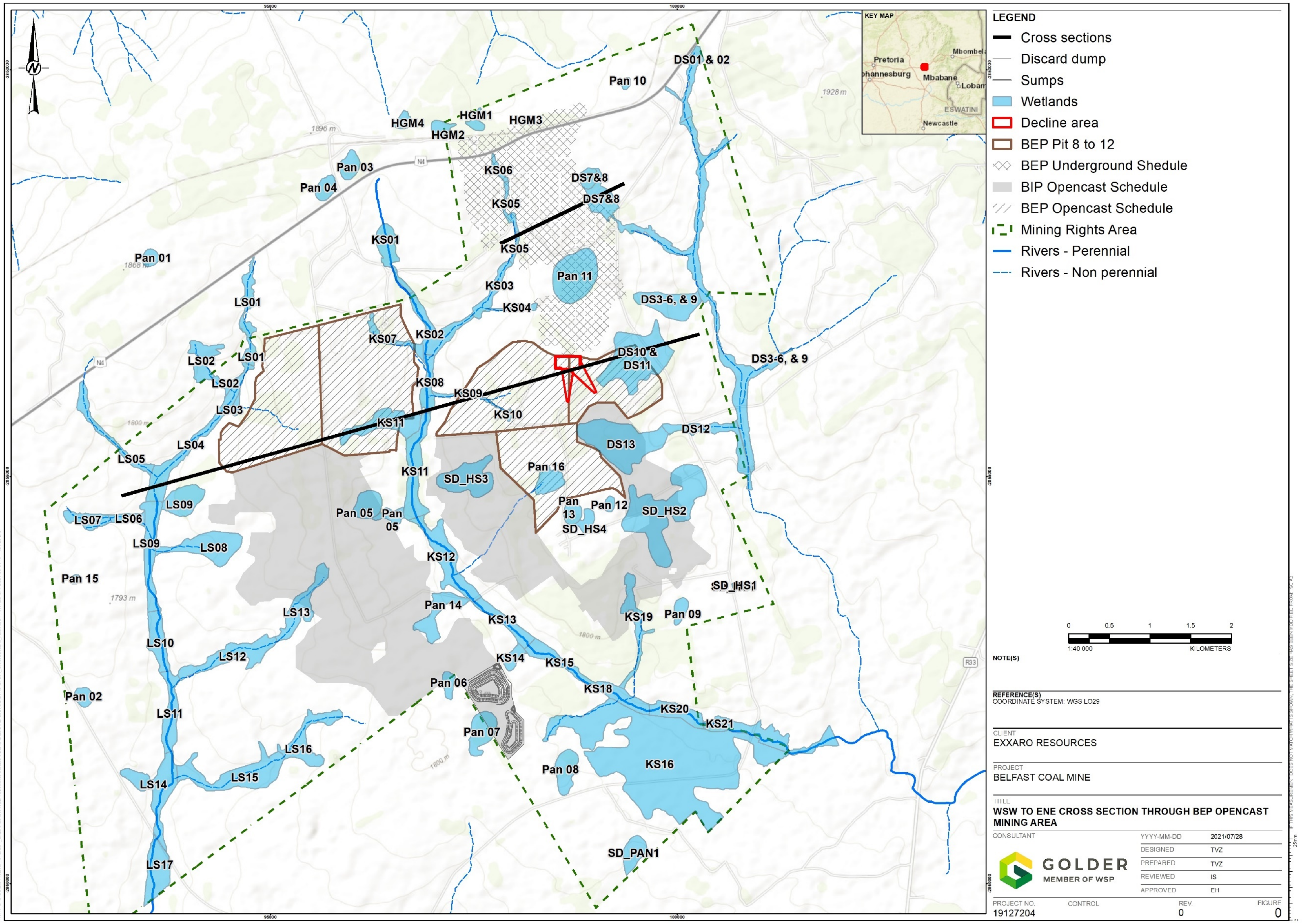


Figure 53: Position of cross section

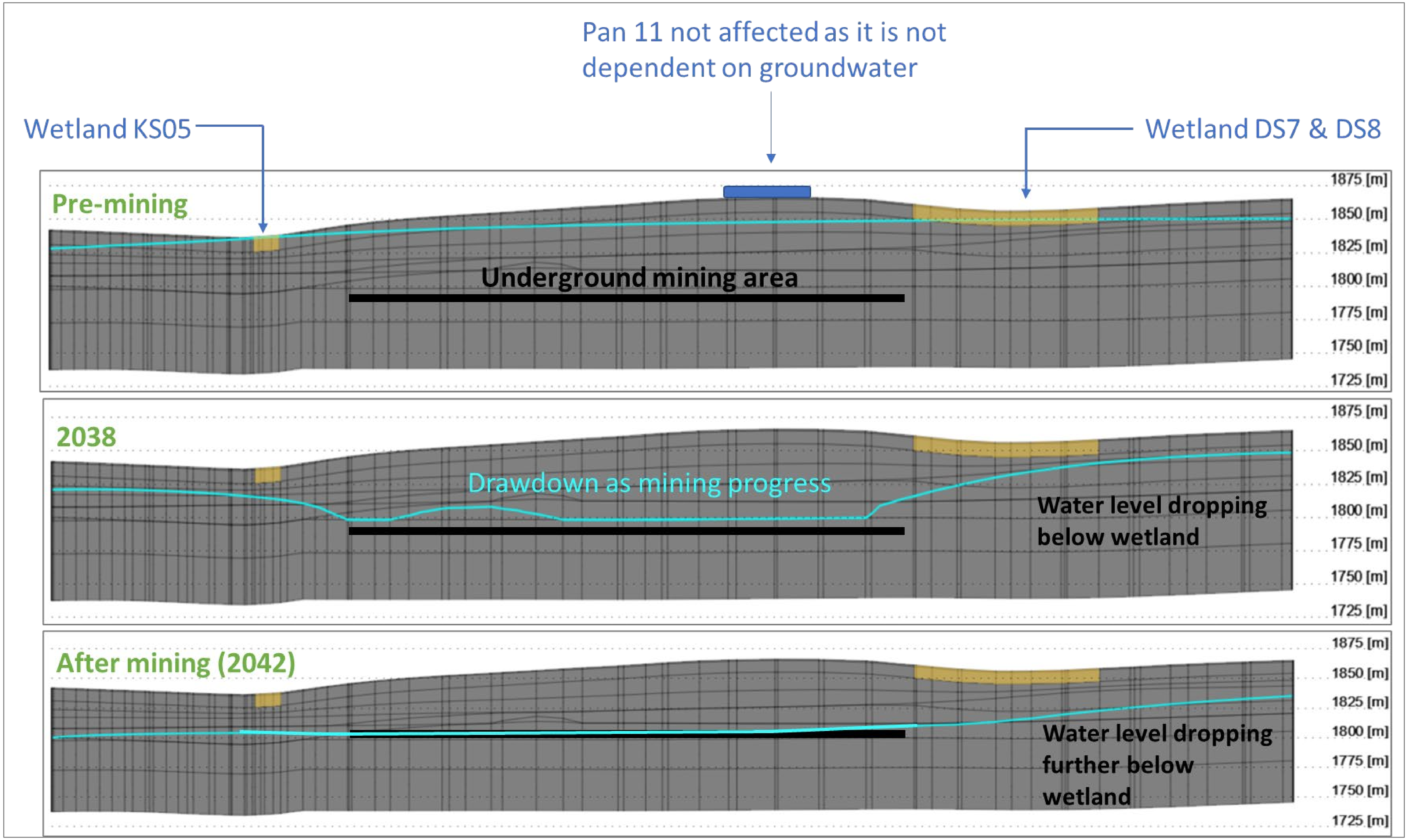


Figure 54: Section through underground mining area

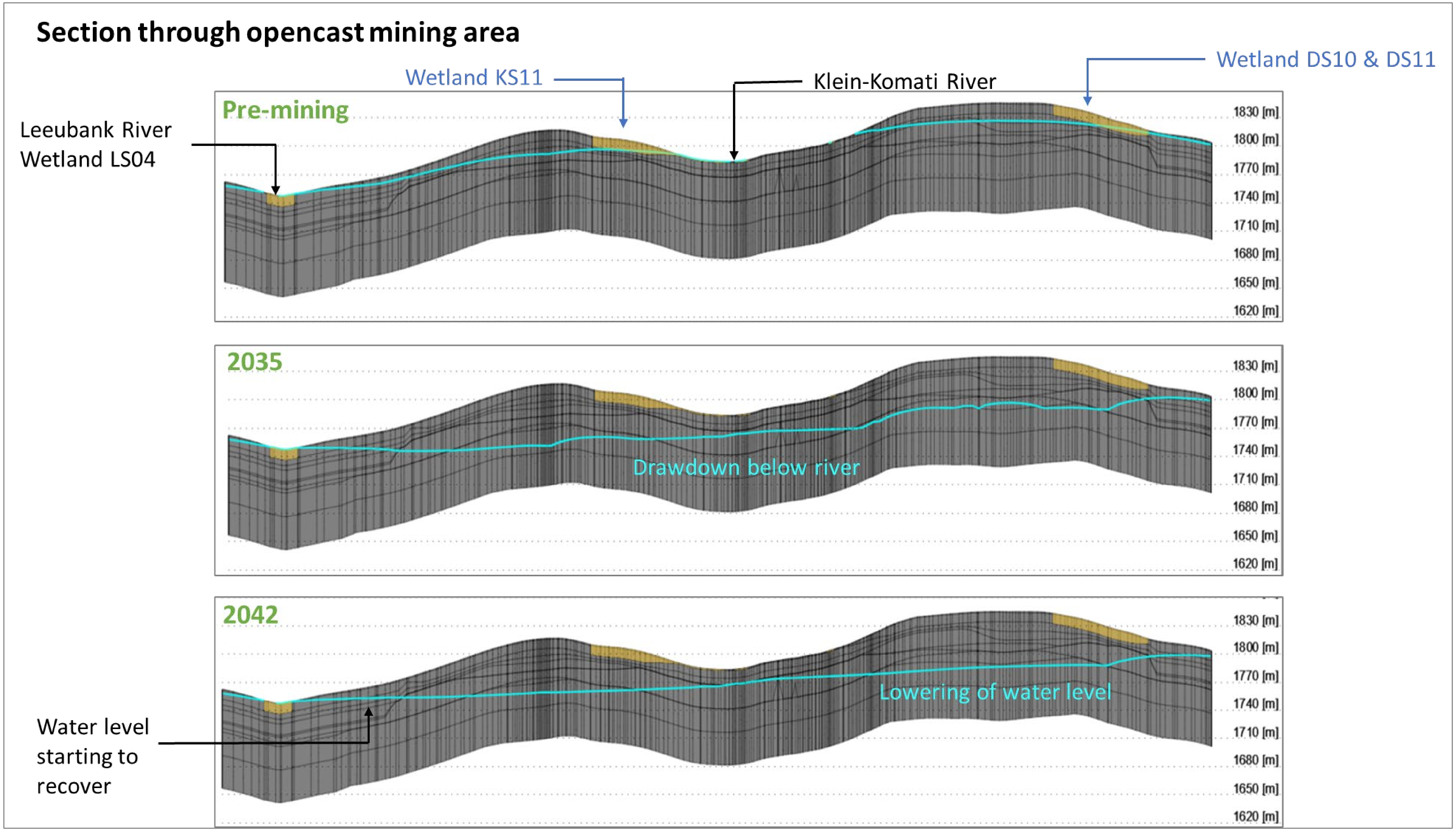


Figure 55: Section through opencast mining area

8.13 Model Results: Post Closure

8.13.1 Water Level Recovery

As expected, the recovery of the water level after mining starts from the low-lying areas. Due to decanting and other properties assigned to the mined-out pits, the water level flattens out and in the higher elevation areas the water level does not recover to pre-mining levels. The simulated water level drawdown and recovery were plotted over time of the centre of the BEP east pits (Pit 10, Pit 11 and Pit 12) and the centre of the of the BEP west pits (Pit 7 and Pit 8) and is shown in Figure 56.

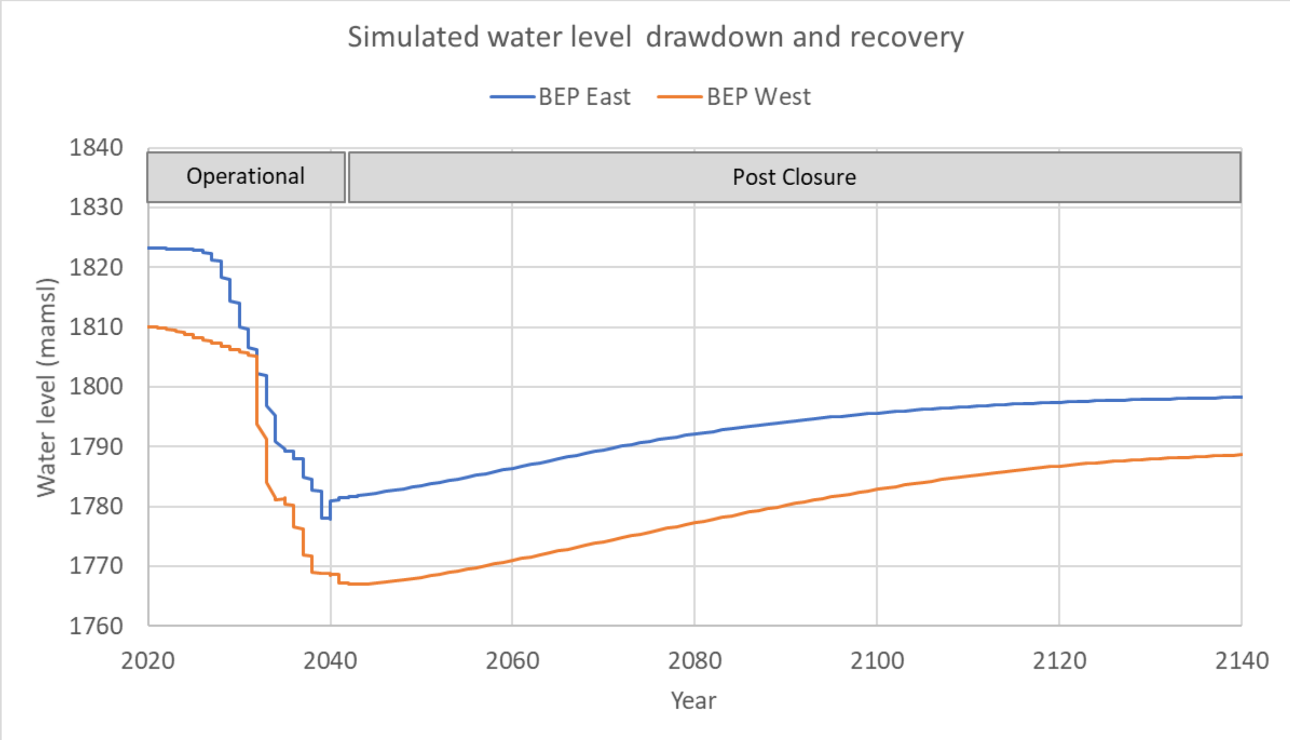


Figure 56: Simulated water level drawdown and recovery for open cast mining

The water level recovery 100 years after closure is shown in Figure 57 and in Figure 58 and the hydraulic head over time is shown in Figure 59.

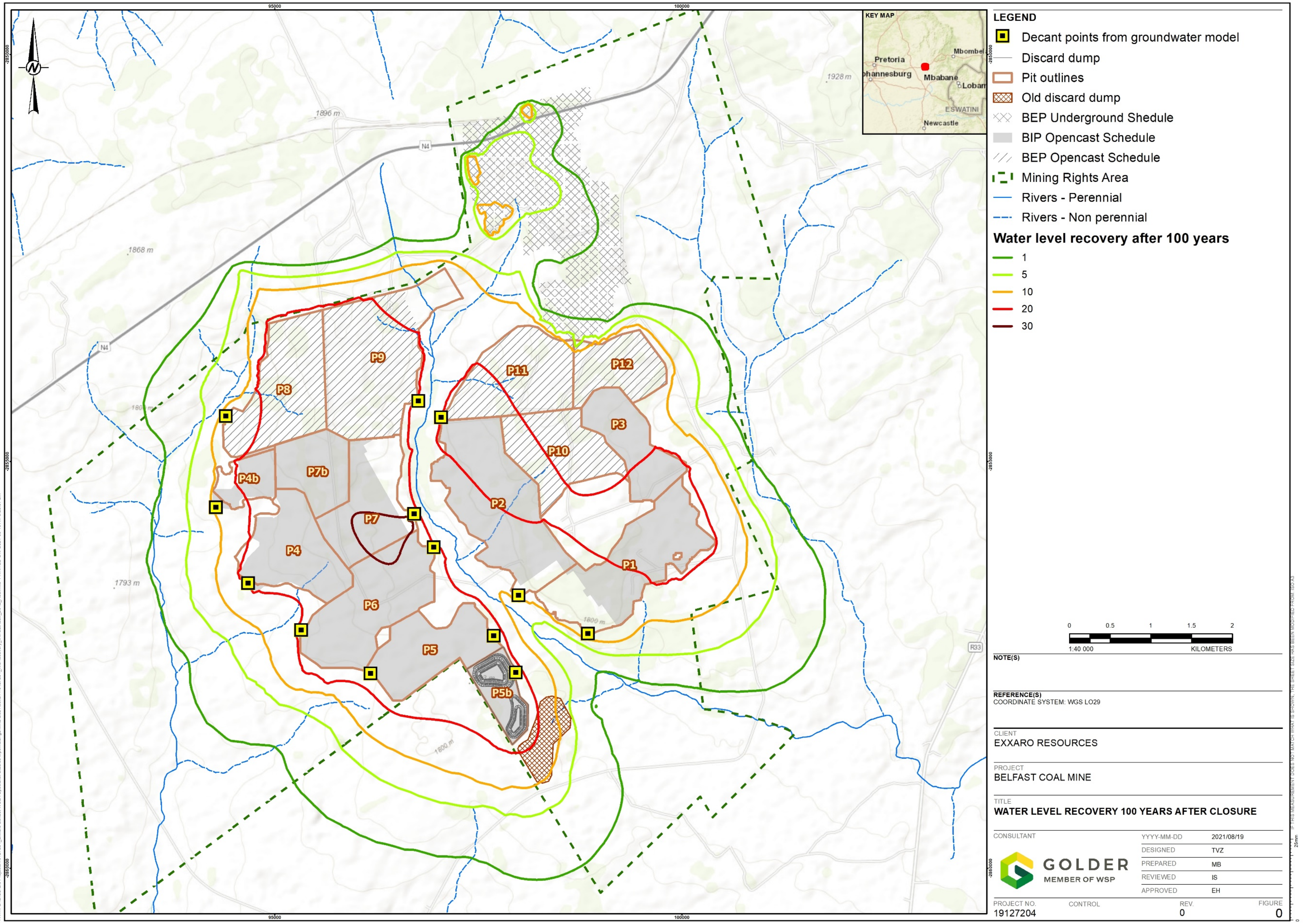


Figure 57: Water level recovery 100 years after closure (include BIP open cast mining areas)

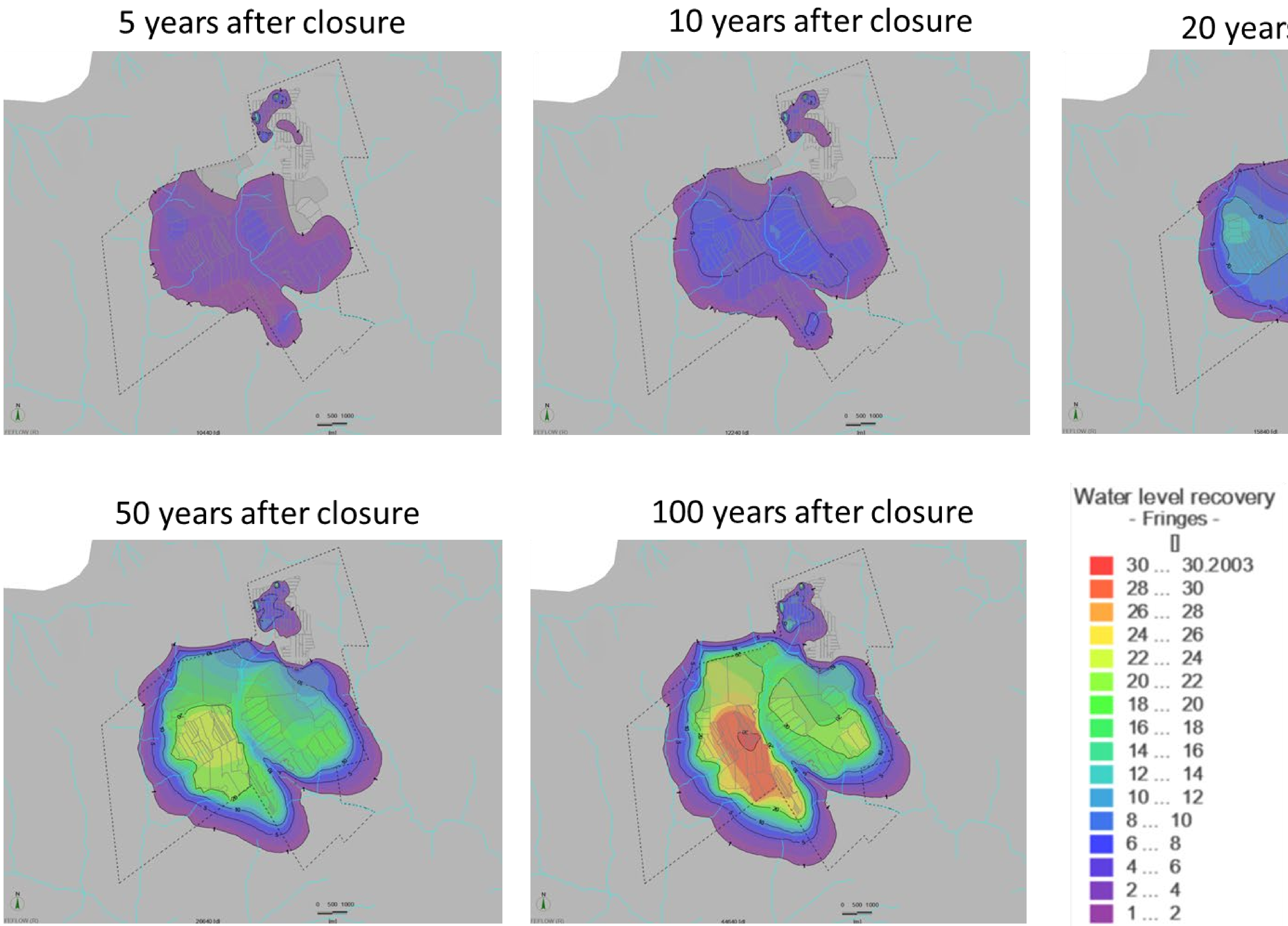


Figure 58: Water level recovery after closure

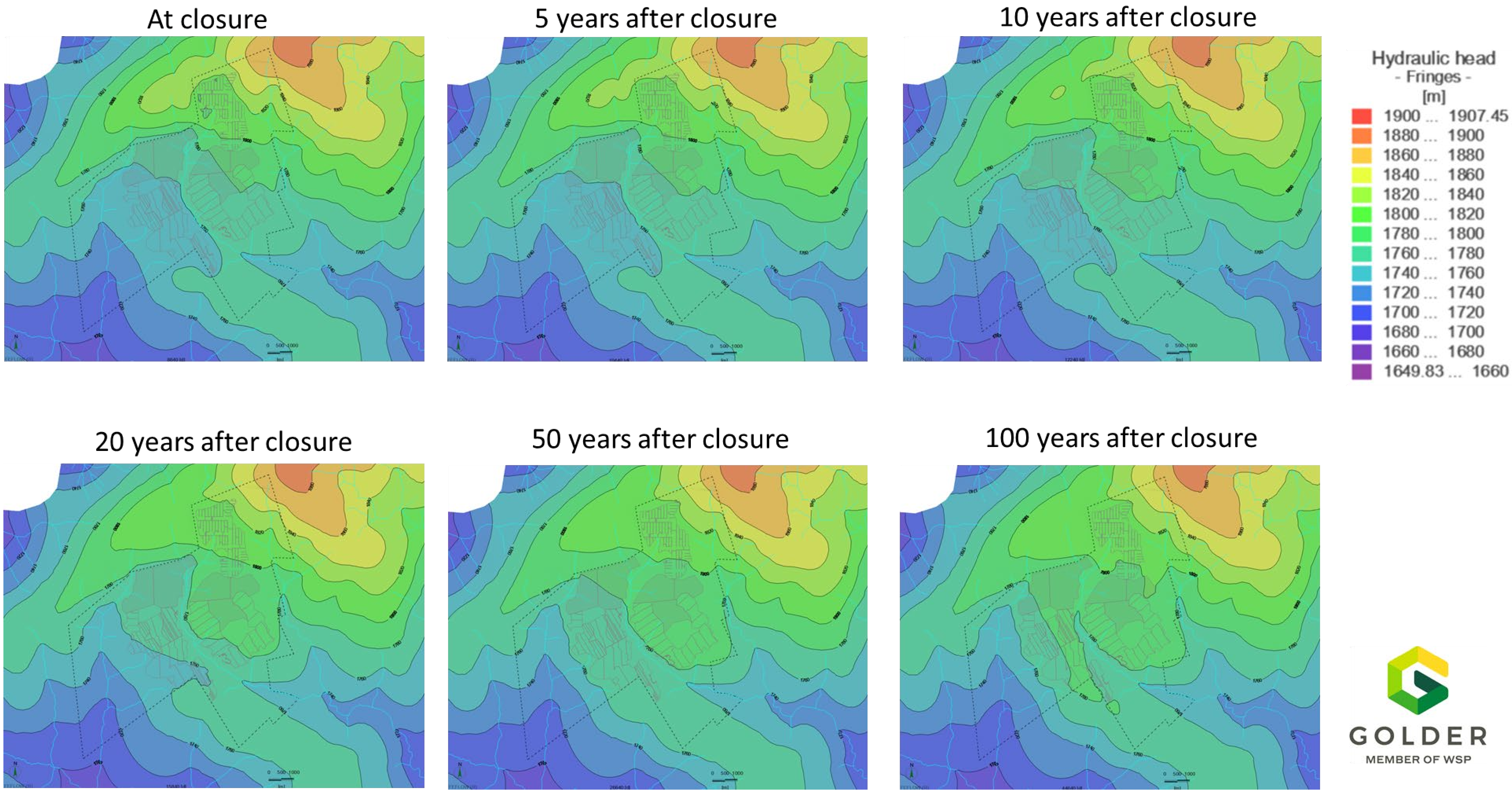


Figure 59: Hydraulic head over time after closure

8.13.2 Decant Rates

The decant points from the groundwater model assumes groundwater intersecting topography elevation. The Water balance manages decant by keeping the water level approximately 1 m below surface. The positions of decant will thus not be the same as the water balance decant management points. (Golder, 2021d).

The groundwater decant points are indicated on Figure 57. The following decant rates were simulated after closure:

- No decant from the underground mining areas due to the water level that does not recover to the original levels in 100 years after closure as shown in Figure 56.
- No decant from Pit 10 and 12 areas due to the water level that does not recover to the original levels in 100 years after closure.
- Pit 11 starts to decant 38 years after closure (in 2080). The decant rate gradually increases to 0.83 L/s 100 years after closure as shown in Figure 60.
- Pit 8 starts to decant 17 years after closure (in 2059). The decant rate gradually increases to 6.6 L/s 100 years after closure (Figure 60).
- Pit 9 starts to decant 60 years after closure. The decant rate gradually increases to 1.2 L/s 100 years after closure in 2102 (Figure 60).
- There are several decant points in the BIP opencast mining area with total decant rates of 15.8 L/s for the western BIP area and 15.7 L/s for the easter BIP area.

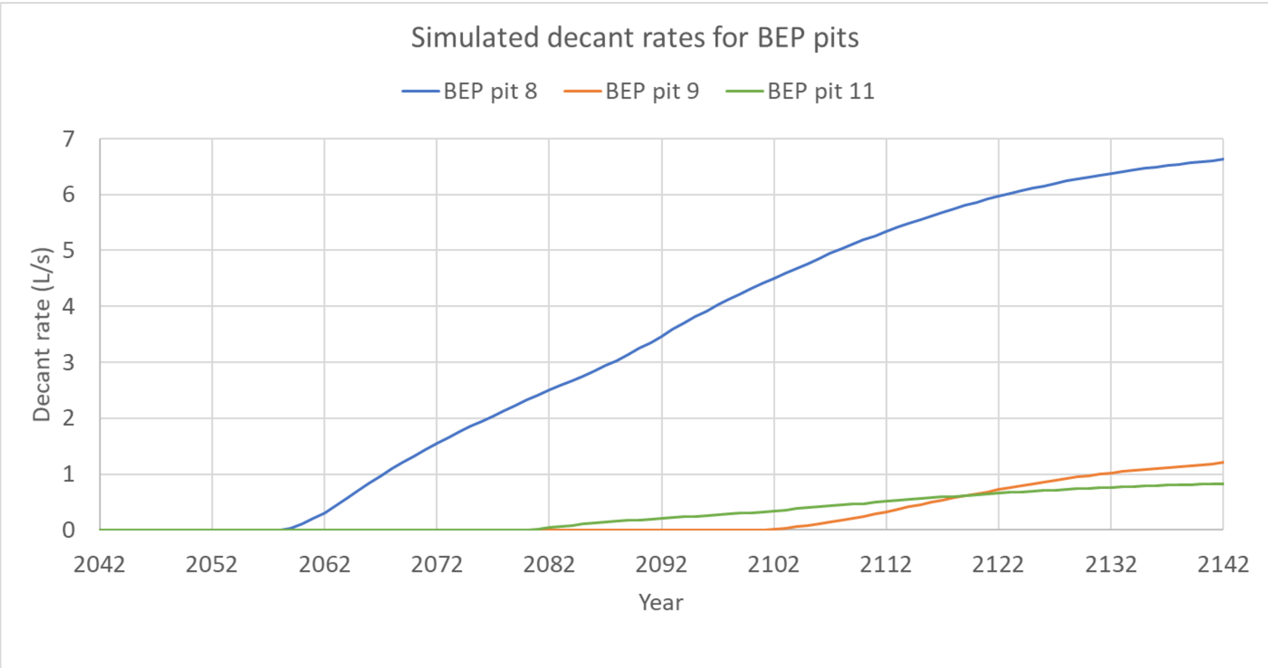


Figure 60: Simulated decant rates for BEP pits

Figure 61 shows where the water level is 100 years after closure. The water level in the Pit 12 area is too low for decant, Due to the decant at Pit 8, the water level is kept low at Pit 9 until 60 years after closure (in the year 2102).

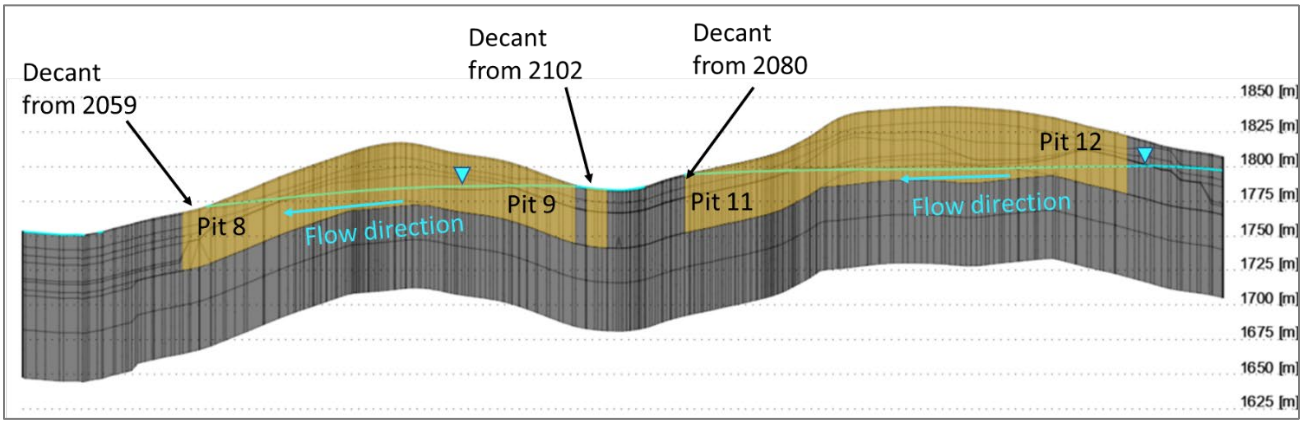


Figure 61: Cross section to indicate water level and decant points

8.13.3 Contaminant Plumes

The contaminant plumes move south-west in the direction of groundwater flow.

Contamination from the underground workings stays mainly within the footprint area of the mine workings and there is only a little movement towards the south-west of the workings.

The contaminant plumes for sulphate and TDS were plotted as the 100 mg/L line for different times after closure. The sulphate (Figure 62) and TDS (Figure 63) plumes show the same pattern, moving to the south and south-west of the mining areas. The 100 mg/L concentration reaches the Klein Komati River and the upper reaches of the Leeubank River 20 years after closure.

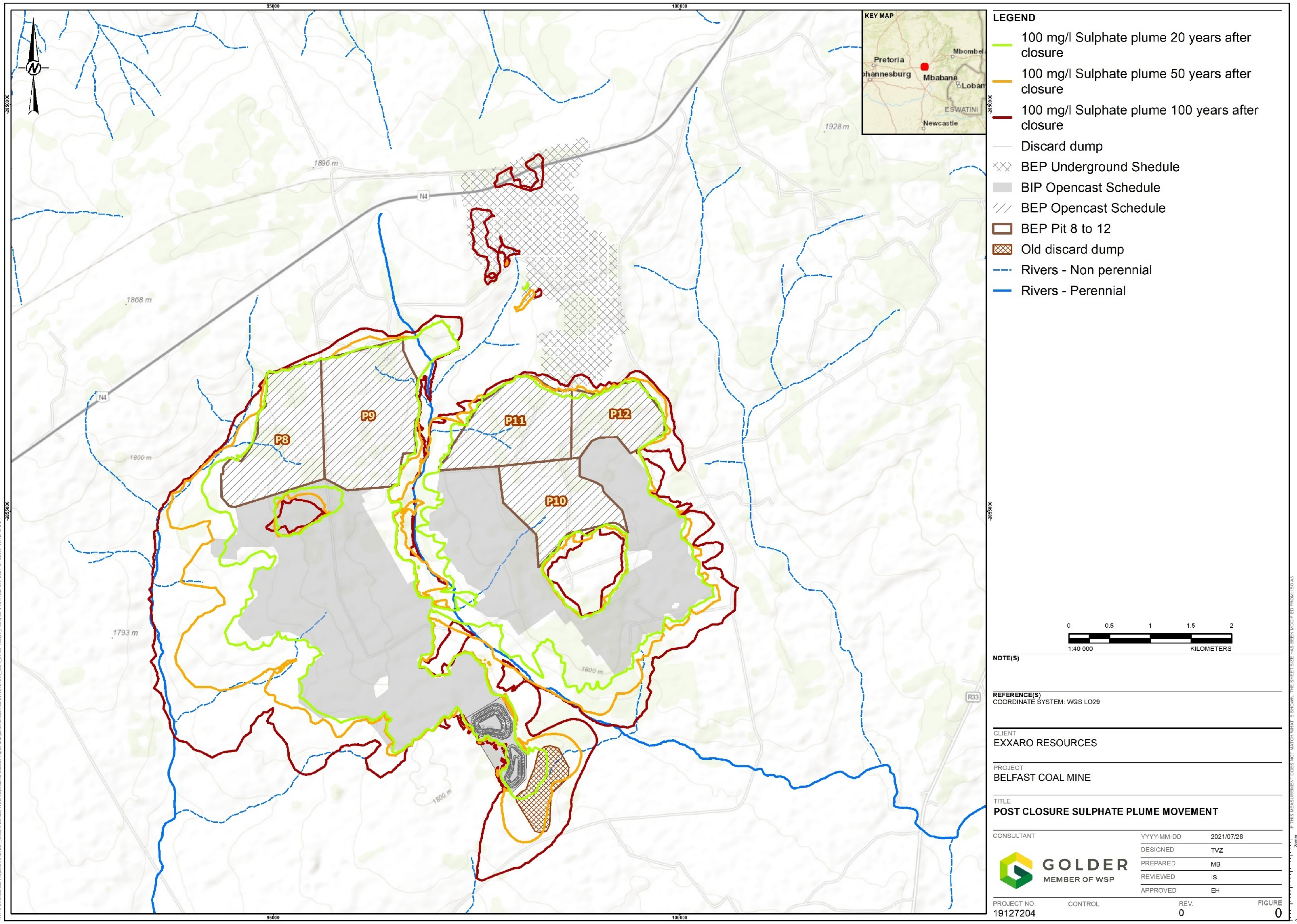


Figure 62: Movement of sulphate plume after closure

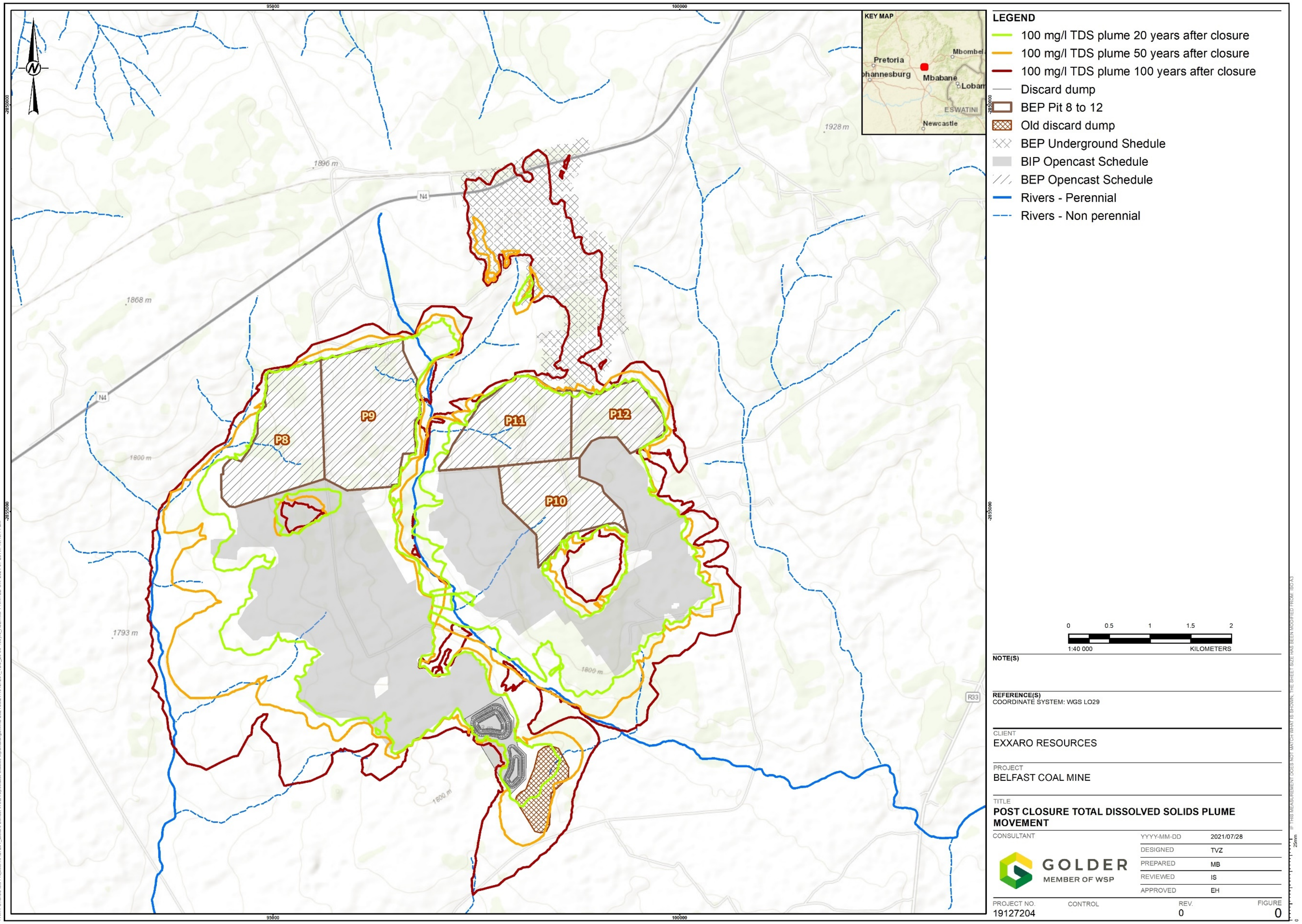


Figure 63: Movement of TDS plume after closure

9.0 IMPACT ASSESSMENT

9.1 Impact Assessment Methodology

This hydrogeological impact assessment was based on the numerical groundwater flow and mass transport model developed for the Belfast mine. For the purposes of this impact assessment, the project timeframe has been subdivided into the following phases:

- Construction Phase – impact assessment was excluded as the construction will be executed as part of the current BIP operational mining.
- Operational Phase.
- Closure Phase.

The methodology supplied is described below.

9.1.1 Nature of the Impact

The impacts are assessed as either having a:

negative effect (i.e. at a cost to the environment),

positive effect (i.e. a benefit to the environment), or

Neutral effect on the environment.

9.1.2 Extent of the Impact

(**1**) Site (site only),

(**2**) Local (site boundary and immediate surrounds),

(**3**) Regional (within the District),

(**4**) National, or

(**5**) International.

9.1.3 Duration of the Impact

The length that the impact will last for is described as either:

(**1**) immediate (<1 year)

(**2**) short term (1-5 years),

(**3**) medium term (5-15 years),

(**4**) long term (ceases after the operational life span of the project),

(**5**) Permanent.

9.1.4 Magnitude of the Impact

The intensity or severity of the impacts is indicated as either:

(**0**) none,

(**2**) Minor,

(**4**) Low,

(**6**) Moderate (environmental functions altered but continue), (**8**) High (environmental functions temporarily cease), or

(**10**) Very high / Unsure (environmental functions permanently cease).

9.1.5 Probability of Occurrence

The likelihood of the impact actually occurring is indicated as either:

(**0**) None (the impact will not occur),

(**1**) improbable (probability very low due to design or experience)

(**2**) low probability (unlikely to occur),

(**3**) medium probability (distinct probability that the impact will occur),

(**4**) high probability (most likely to occur), or

(5) Definite.

9.1.6 Significance of the Impact

Based on the information contained in the sections above, the potential impacts are assigned a significance rating (**S**). This rating is formulated by adding the sum of the numbers assigned to extent (**E**), duration (**D**) and magnitude (**M**) and multiplying this sum by the probability (**P**) of the impact.

$$S=(E+D+M)*P$$

The significance ratings are:

- Low (**S<30**) *i.e.,* where this impact would not have a direct influence on the decision to develop in the area.
- Medium (**30<S<60**) *i.e.,* where the impact could influence the decision to develop in the area unless it is effectively mitigated.
- High (**S>60**) *i.e.,* where the impact must have an influence on the decision process to develop in the area.

9.2 Impact Assessment Results

Three groundwater impacts were identified, namely dewatering, contamination and recharge. Each of the impacts were assessed for the three phases and for the following areas / facilities:

- Discard dump extension (situated on existing opencast pit).
- BEP underground mining.
- BEP opencast mining.
- Water supply boreholes.
- BEP overburden stockpiles (temporary).
- Decline infrastructure Option 1 (situated on existing opencast pit).
- Decline infrastructure Option 2 (preferred option - situated partially on existing opencast pit).
- Conveyor routes A – C (situated on existing opencast pit).
- Conveyor route D (preferred option - situated partially on existing opencast pit).

The assessment tables are presented in Table 32 for the impacts due to dewatering and in Table 33 for impacts due to the contamination of groundwater.

Table 32: Impact Assessment for Dewatering

Issue	Mitigation measures applied	Impact rating criteria					Significance
		Nature	Extent	Duration	Magnitude	Probability	
OPERATIONAL PHASE							
IMPACT: ▪ Dewatering from underground mining resulting in reduction of baseflow to wetlands and streams - Mine designed to prevent subsidence ▪ Dewatering from underground mining related to impact on farmers boreholes. ▪ Dewatering from opencast mining related to subsidence, reduction in baseflow to wetlands and streams ▪ Dewatering from opencast mining related to impact on farmers boreholes.							
BEP underground mining impact on baseflow	No	Negative	1 (Site)	2 (short term)	4 (low)	3 (medium)	21 (LOW)
	No mitigation						
BEP underground mining impact on farmers	No	Negative	1 (Site)	3 (medium term)	4 (low)	2 (low)	16 (LOW)
	Yes	Negative	1 (Site)	3 (medium term)	4 (low)	1 (improbable)	8 (LOW)
BEP opencast mining impact on baseflow	No	Negative	2 (Local)	4 (long term)	6 (moderate)	5 (definite)	60 (MEDIUM)
	Yes, rehabilitation	Negative	2 (Local)	4 (long term)	4 (low)	4 (high)	40 (MEDIUM)
BEP opencast mining impact on farmers	No	Negative	1 (Site)	3 (medium term)	4 (low)	2 (low)	16 (LOW)
	Yes	Negative	1 (Site)	3 (medium term)	4 (low)	1 (improbable)	8 (LOW)
Mitigation Measures							
▪ Underground mining - farmers: Exxaro is the owner of the adjacent land. Mine to supply alternative source of water to affected users if necessary. ▪ Opencast mining - baseflow: Operational rehabilitation of open pits to re-establish run-off and baseflow. ▪ Opencast mining - farmers: Exxaro is the owner of the adjacent land. Mine to supply alternative source of water to affected users if necessary.							

Issue	Mitigation measures applied	Impact rating criteria					Significance
		Nature	Extent	Duration	Magnitude	Probability	
POST CLOSURE PHASE							
■ Dewatering impact from underground mining will remain after closure as a result of limited storage capacity in underground workings ■ Dewatering associated with opencast mining will remain after closure as a result of limited storage capacity in open pit.							
BEP underground mining impact on baseflow	No	Negative	1 (Site)	5 (Permanent)	4 (low)	3 (medium)	30 (LOW)
	No mitigation						
BEP underground mining impact on farmers	No	Negative	1 (Site)	3 (medium term)	4 (low)	2 (low)	16 (LOW)
	Yes	Neutral	1 (Site)	3 (medium term)	4 (low)	1 (improbable)	8 (LOW)
BEP opencast mining impact on baseflow	No	Negative	2 (Local)	5 (Permanent)	6 (moderate)	5 (definite)	65 (HIGH)
	Yes, Rehabilitation	Negative	2 (Local)	4 (long term)	4 (low)	4 (high)	40 (MEDIUM)
BEP opencast mining impact on farmers	No	Negative	1 (Site)	3 (medium term)	4 (low)	2 (low)	16 (LOW)
	Yes	Neutral	1 (Site)	3 (medium term)	4 (low)	1 (improbable)	8 (LOW)
Mitigation Measures							
■ Underground mining - farmers: Exxaro is the owner of the adjacent land. Mine to supply alternative source of water to affected users if necessary. ■ Opencast mining - baseflow: Post closure rehabilitation of open pits to re-establish run-off and baseflow. ■ Opencast mining - farmers: Exxaro is the owner of the adjacent land. Mine to supply alternative source of water to affected users if necessary.							

Table 33: Impact Assessment for Groundwater Contamination

Issue	Mitigation measures applied	Impact rating criteria					Significance
		Nature	Extent	Duration	Magnitude	Probability	
OPERATIONAL PHASE							
During operations, contamination is contained in the underground workings and opencast pits due to dewatering. Contamination is mainly associated with the post closure phase and has not been evaluated for the operational phase, except for: ■ Discard Dump extension: Proposed discard dump is on-pit facility, with the entire discard dump to be located on top of the backfilled pit 5b. Proposed discard dump is within existing dirty water area. Seepage from discard dump goes into spoils, intercepted in pit, pumped out through decant management system. The pumped-out mine-affected water goes to treatment plant (already authorised). ■ Stockpiles for Decline infrastructure option 1: All situated on opencast mining areas ■ Stockpiles for Decline infrastructure option 2: The positions of the overburden stockpiles are unknown. For the assessment it was assumed that they will be on the unmined area. The decline infrastructure Option 2 (preferred) where a part of the infrastructure will be situated on an unmined area. ■ Dust blowing from the transported material: All on opencast mining areas, except for Conveyor route D where a portion is situated on an unmined area.							
Stockpiles on BEP opencast mining areas: Decline infrastructure Option 1	No	Neutral	2 (Local)	3 (medium term)	0	0	0 (LOW)
	No mitigation						
Stockpiles on unmined areas: Decline infrastructure Option 2 (preferred)	No	Negative	1 (Site)	3 (medium term)	2 (minor)	4 (high)	24 (LOW)
	Yes	Negative	1 (Site)	3 (medium term)	2 (minor)	1 (improbable)	6 (LOW)
Conveyor Route - all options on opencast mining areas	No	Neutral	2 (Local)	3 (medium term)	0	0	0 (LOW)
	No mitigation						
Conveyor Route D - where not on mining areas	No	Negative	2 (Local)	3 (medium term)	1 (minor)	2 (low)	12 (LOW)
	Yes	Neutral	2 (Local)	3 (medium term)	0	0	0 (LOW)
Mitigation Measures							

<table>
<tr><th rowspan="2">Issue</th><th rowspan="2">Mitigation measures applied</th><th colspan="5">Impact rating criteria</th><th rowspan="2">Significance</th></tr>
<tr><th>Nature</th><th>Extent</th><th>Duration</th><th>Magnitude</th><th>Probability</th></tr>
<tr><td colspan="8">■ Decline infrastructure Option1: No mitigation
■ Decline infrastructure Option 2: Stormwater management, clean and dirty water separation to reduce contaminant migration to groundwater.
■ Conveyor route D: Comply to operational procedures.
■ Conveyor - all other routes: no mitigation.</td></tr>
<tr><td colspan="8">POST CLOSURE PHASE</td></tr>
<tr><td colspan="8">■ Movement of contamination plume from Discard Dump extension
■ Movement of contamination plume from underground mining
■ Movement of contamination plume from opencast mining areas
■ Decline infrastructure Option 2: Potential contamination from the stockpiles area that will not be on the existing open pit area
■ Assumed that conveyor routes will be removed.</td></tr>
<tr><td rowspan="2">Discard dump extension (MRF)</td><td>No</td><td>Negative</td><td>2 (Local)</td><td>5 (Permanent)</td><td>6 (moderate)</td><td>4 (high)</td><td>52 (MEDIUM)</td></tr>
<tr><td>Yes</td><td>Negative</td><td>2 (Local)</td><td>5 (Permanent)</td><td>4 (low)</td><td>2 (low)</td><td>22 (LOW)</td></tr>
<tr><td rowspan="2">BEP underground mining</td><td>No</td><td>Negative</td><td>1 (Site)</td><td>5 (Permanent)</td><td>4 (low)</td><td>4 (high)</td><td>40 (MEDIUM)</td></tr>
<tr><td>Yes</td><td>Negative</td><td>1 (Site)</td><td>5 (Permanent)</td><td>2 (minor)</td><td>2 (low)</td><td>16 (LOW)</td></tr>
<tr><td rowspan="2">BEP opencast mining</td><td>No</td><td>Negative</td><td>1 (Site)</td><td>5 (Permanent)</td><td>4 (low)</td><td>4 (high)</td><td>40 (MEDIUM)</td></tr>
<tr><td>Yes</td><td>Negative</td><td>1 (Site)</td><td>5 (Permanent)</td><td>2 (minor)</td><td>2 (low)</td><td>16 (LOW)</td></tr>
<tr><td colspan="8">Mitigation Measures</td></tr>
<tr><td colspan="8">■ Discard Dump extension: To add a soil cover and vegetate the area. Closure options to be evaluated and licensed at closure. Continue decant water management system in pit 5b.
■ Underground mining: Opencast decant management and water treatment from mining voids.
■ Opencast mining: Decant management and water treatment from mining voids.</td></tr>
</table>

Any groundwater monitoring network design should be guided by a risk-based source-pathway-receptor principle. A groundwater monitoring network should contain monitoring positions which can assess the groundwater status at certain areas. Both the impact on water quality and water quantity should be catered for in the monitoring system. The boreholes in the network should cover the following:

- Source monitoring – monitoring close to possible contaminant sources.
- Plume (pathway) monitoring – monitoring along identified contamination plumes (if any).
- Impact (receptor) monitoring – monitoring at expected sensitive receptors.
- Monitoring of the background water quality and levels.

The existing groundwater monitoring network at Belfast is effective to monitor the current impacts from the mining activities on the groundwater regime. However, to monitor future impacts and to monitor and contain the pollution plume to site, the monitoring network might need to be updated with additional monitoring boreholes. The proposed additional monitoring borehole positions are indicated in Figure 64. These monitoring borehole positions based on the outcome of the numerical model and are selected hydrogeologically to act as an early warning system. Five additional monitoring boreholes are proposed between the mine workings and rivers.

10.0 CONCLUSION

The main objective of the groundwater specialist study was to support Exxaro's BEP Integrated Water and Waste Management Plan (IWWMP) and Integrated Water Use Licence Application (IWULA) authorisations process.

This report contains a summary of previous geohydrological information and describes the conceptual model.

Based on the existing reports, drilling and aquifer testing results, three aquifer systems can be distinguished at the BEP area namely:

- Top weathered aquifer system; unconfined aquifer system with an average thickness of ~ 10 m.
- Fractured aquifer system; confined to semi confined aquifer system with an average thickness of ~20m below the weathered aquifer system and is characterised by secondary fractures resulting in preferential flow paths for the groundwater flow and possible contaminant migration.
- Deep fractured aquifer system; confined aquifer system with reported water strikes between 118 to 120 mbgl, and is present in the basement rocks below the fractured aquifer system.

The weathered and fractured aquifer systems are present in the Karoo Supergroup, whereas the deep fractured aquifer system is present in the Transvaal Supergroup.

The numerical model was conducted to simulate the inflows into the BEP opencast and underground mining areas. For the opencast mining, the pit recharge was removed to obtain lateral groundwater inflow into the pits. The opencast mining is scheduled from 2031 to 2039 and the highest simulated inflow occurs in 2032 with an expected lateral inflow rate of 4.4 L/s for the west pits and 9.9 L/s for the east pits. This is a total inflow of 14.3 L/s (1234 m^3/d). The underground mining is scheduled from 2037 to 2042 and the highest simulated inflow occurs in 2041 with an expected rate of 11.7 L/s (1014.2 m^3/d).

During the operational period, the contamination plume is contained in the mining areas. Post closure water levels recover until decanting starts. Nevertheless, the water level continues to recover, although in the higher topographical areas the water level does not recover to pre-mining levels after 100 years.

The following decant volumes were simulated after closure:

- No decant from the underground mining areas due to the water level that does not recover to the original levels in 100 years after closure.
- No decant from Pit 10 and 12 areas due to the water level that does not recover to the original levels in 100 years after closure.

- Pit 11 starts to decant 38 years after closure (in 2080). The decant rate gradually increases to 0.83 L/s 100 years after closure.
- Pit 8 starts to decant 17 years after closure (in 2059). The decant rate gradually increases to 6.6 L/s 100 years after closure.
- Pit 9 starts to decant 60 years after closure. The decant rate gradually increases to 1.2 L/s 100 years after closure in 2102.
- There are several decant points in the BIP opencast mining area with total decant rates of 15.8 L/s for the western BIP area and 15.7 L/s for the easter BIP area.

The sulphate and TDS plumes show the same pattern, moving to the south and south-west of the mining areas. The 100 mg/L concentration reaches the Klein Komati River and the upper reaches of the Leeubank River 20 years after closure.

The impact assessment considered the potential impacts from dewatering and groundwater. Table 34 gives a summary of the impacts and shows that the highest impact is associated baseflow reduction during the operational phase of BEP opencast mining.

Table 34: Summary of Impacts

Impact	Phase	Impact	Significance	Mitigation	Significance after mitigation
Dewatering	Operational	BEP underground mining impact on baseflow	21 (Low)	No mitigation	
		BEP underground mining impact on farmers	16 (Low)	Exxaro is the owner of the adjacent land. Mine to supply alternative source of water to affected users if necessary.	8 (Low)
		BEP opencast mining impact on baseflow	60 (Medium)	Operational rehabilitation of open pits to re-establish run-off and baseflow.	40 (Medium)
		BEP opencast mining impact on farmers	16 (Low)	Exxaro is the owner of the adjacent land. Mine to supply alternative source of water to affected users if necessary.	8 (Low)
	Post Closure	BEP underground mining impact on baseflow	30 (Low)	No mitigation	
		BEP underground mining impact on farmers	16 (Low)	Exxaro is the owner of the adjacent land. Mine to supply alternative source of water to affected users if necessary.	8 (Low)
		BEP opencast mining impact on baseflow	65 (High)	Operational rehabilitation of open pits to re-establish run-off and baseflow.	40 (Medium)
		BEP opencast mining impact on farmers	16 (Low)	Exxaro is the owner of the adjacent land. Mine to supply alternative source of water to affected users if necessary.	8 (Low)
Groundwater contamination	Operational	Stockpiles on BEP opencast mining areas: Decline infrastructure Option 1	0 (Low)	No mitigation	
		Stockpiles on unmined areas: Decline infrastructure Option 2 (preferred)	24 (Low)	Stormwater management, clean and dirty water separation to reduce contaminant migration to groundwater.	6 (Low)
		Conveyor Route - all options on opencast mining areas	0 (Low)	No mitigation	
		Conveyor Route D - where not on mining areas	12 (Low)	Comply to operational procedures.	0 (Low)
	Post Closure	Discard dump extension (MRF)	52 (Medium)	To add a soil cover and vegetate the area. Closure options to be evaluated and licensed at closure. Continue decant water management system in pit.	22 (Low)
		BEP underground mining	40 (Medium)	Open pit decant management and water treatment from mining voids	16 (Low)
		BEP opencast mining	40 (Medium)	Decant management and water treatment from mining voids	16 (Low)

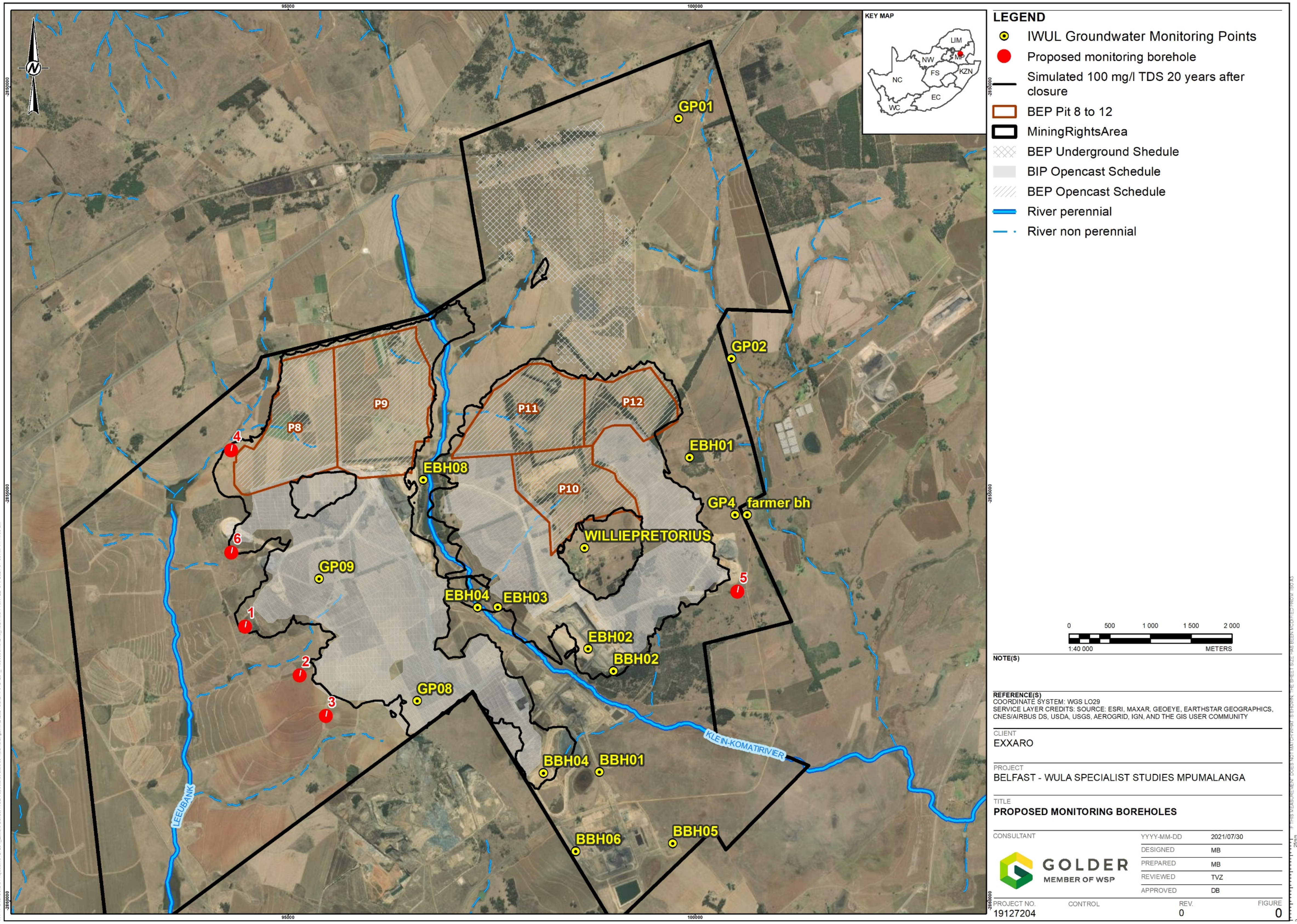


Figure 64: Proposed Additional Monitoring Boreholes

11.0 RECOMMENDATIONS

It is recommended that all mitigation measures mentioned in the impact assessment and summarised in Table 34 should be implemented.

To monitor future impacts and to monitor and contain the pollution plume to site, the monitoring network might need to be updated with additional monitoring boreholes. Five additional monitoring boreholes are proposed between the mine workings and rivers, the approximate locations are shown in Figure 64.

Aquifer testing of all new monitoring boreholes installed, to determine hydraulic parameters to improve hydraulic parameter accuracy for future groundwater model updates.

Groundwater monitoring of water levels and quality should continue as per WUL no. 5/X11D/ABCFGIJ/2613 on a quarterly frequency.

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Signature Page

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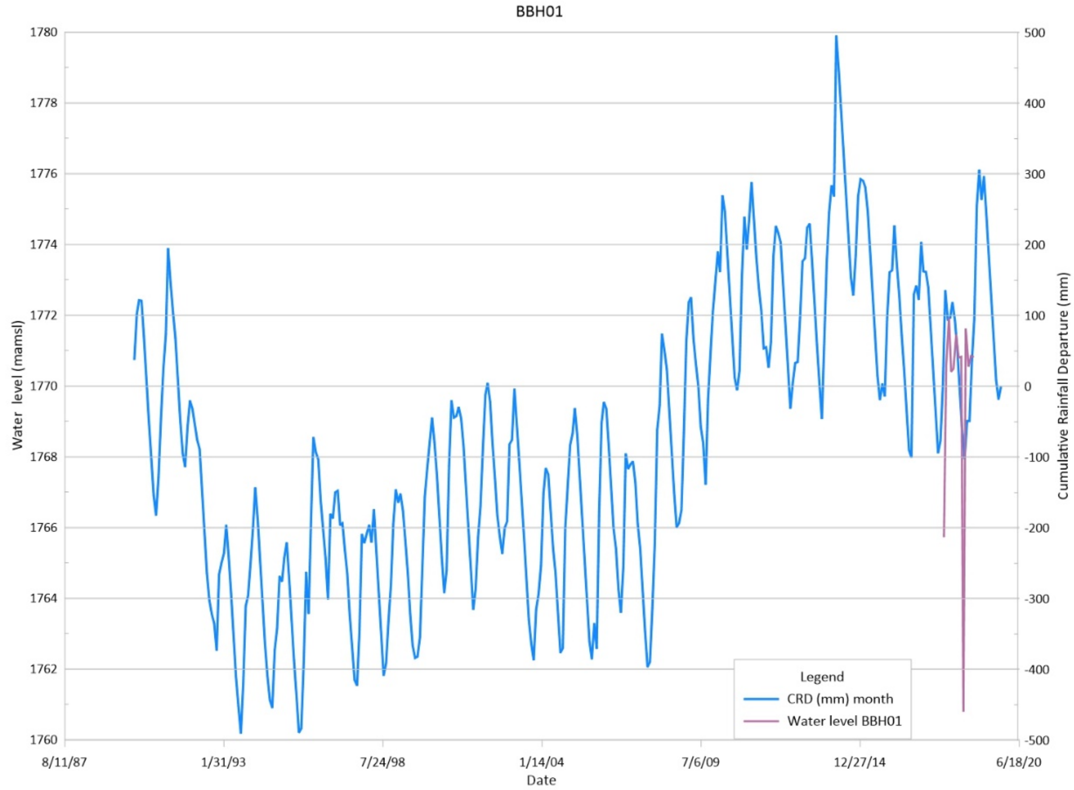
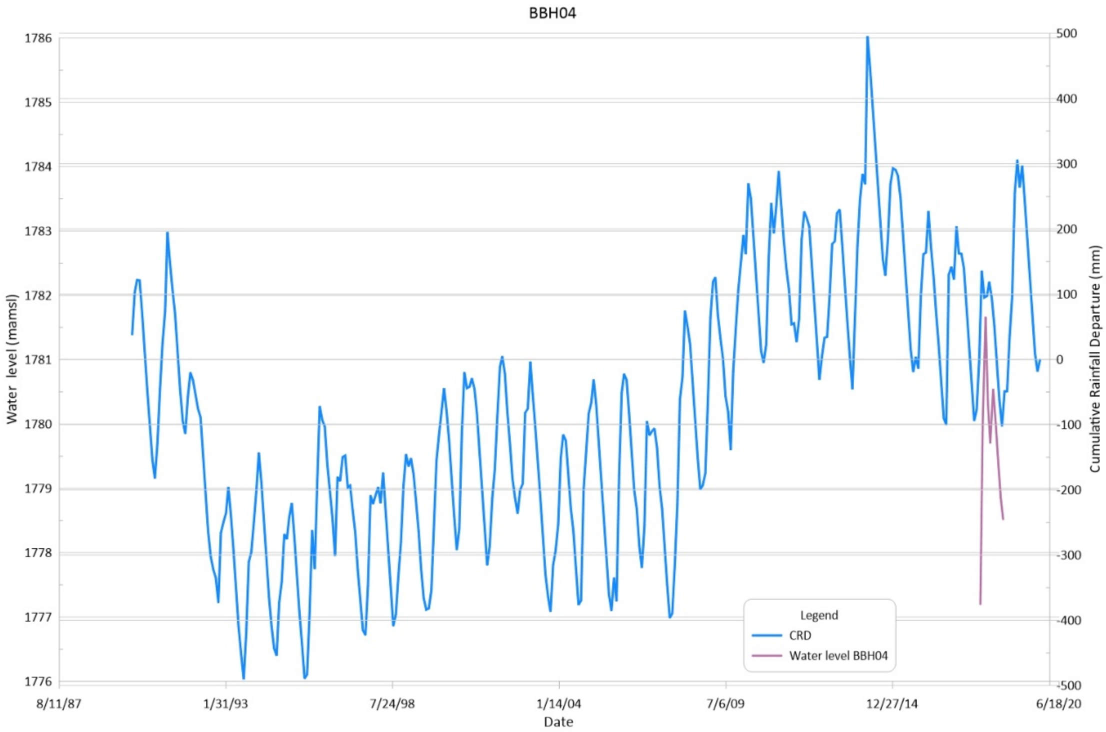
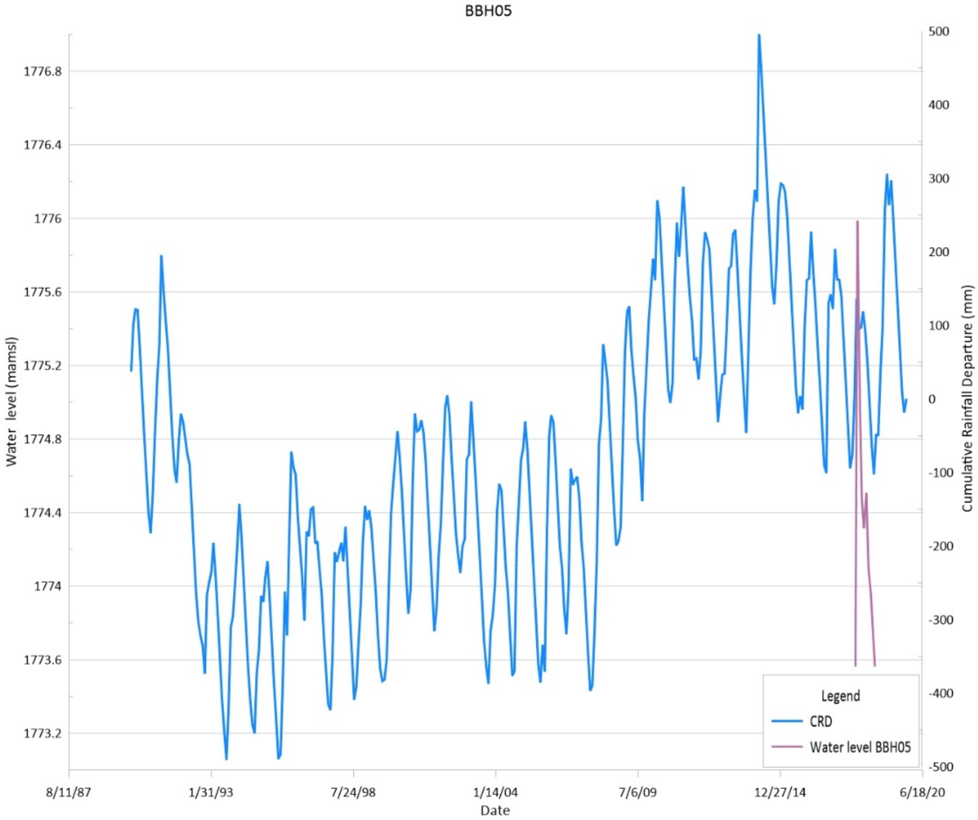
https://golderassociates.sharepoint.com/sites/112768/project files/6 deliverables/final client deliverables/19127204-329323-1 groundwater/19127204-329323-1_exxaro_bep_groundwater_final_rev2_23082021.docx

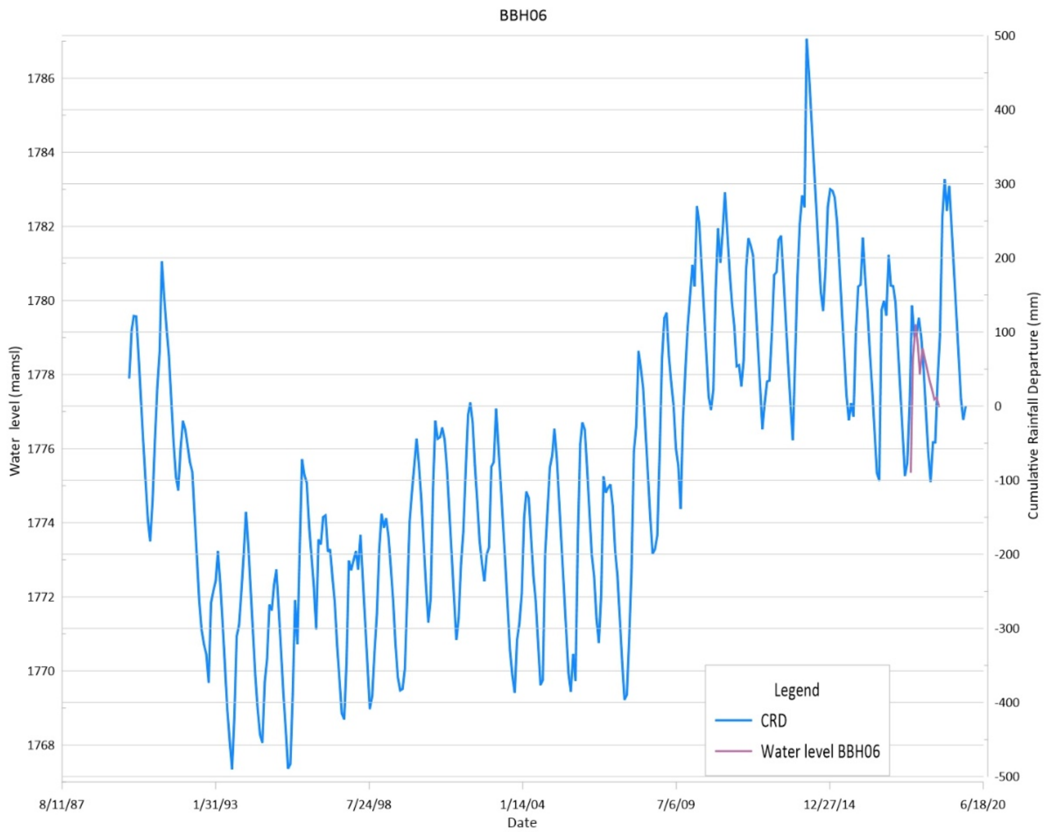
APPENDIX A

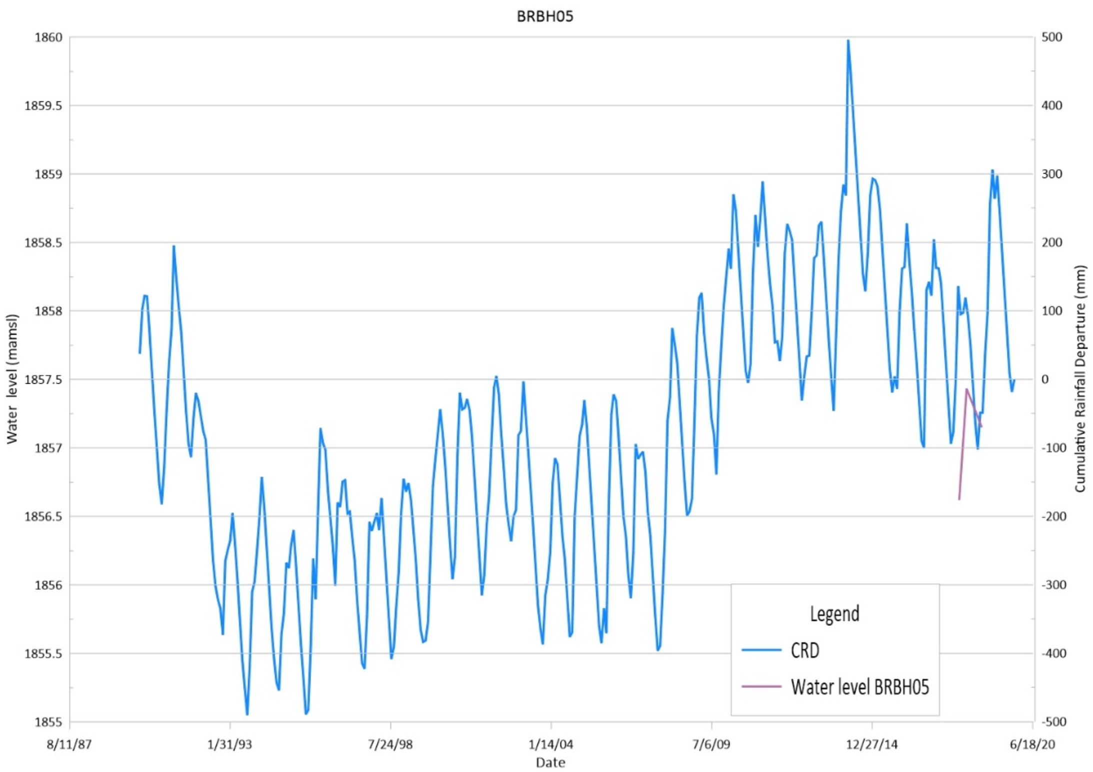
Measured water level and CRD


BBH01
Water level (mamsl)
Cumulative Rainfall Departure (mm)
Date
Legend
CRD (mm) month
Water level BBH01
1780
1778
1776
1774
1772
1770
1768
1766
1764
1762
1760
500
400
300
200
100
0
-100
-200
-300
-400
-500
8/11/87
1/31/93
7/24/98
1/14/04
7/6/09
12/27/14
6/18/20


BBH04
Water level (mamsl)
Cumulative Rainfall Departure (mm)
Date
Legend
CRD
Water level BBH04
1786
1785
1784
1783
1782
1781
1780
1779
1778
1777
1776
500
400
300
200
100
0
-100
-200
-300
-400
-500
8/11/87
1/31/93
7/24/98
1/14/04
7/6/09
12/27/14
6/18/20


BBH05
Water level (mamsl)
1776.8
1776.4
1776
1775.6
1775.2
1774.8
1774.4
1774
1773.6
1773.2
Cumulative Rainfall Departure (mm)
500
400
300
200
100
0
-100
-200
-300
-400
-500
8/11/87
1/31/93
7/24/98
1/14/04
7/6/09
12/27/14
6/18/20
Date
Legend
CRD
Water level BBH05


BBH06
Water level (mamsl)
1786
1784
1782
1780
1778
1776
1774
1772
1770
1768
Cumulative Rainfall Departure (mm)
500
400
300
200
100
0
-100
-200
-300
-400
-500
8/11/87
1/31/93
7/24/98
1/14/04
7/6/09
12/27/14
6/18/20
Date
Legend
CRD
Water level BBH06


BRBH05
Water level (mamsl)
Cumulative Rainfall Departure (mm)
Date
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1859
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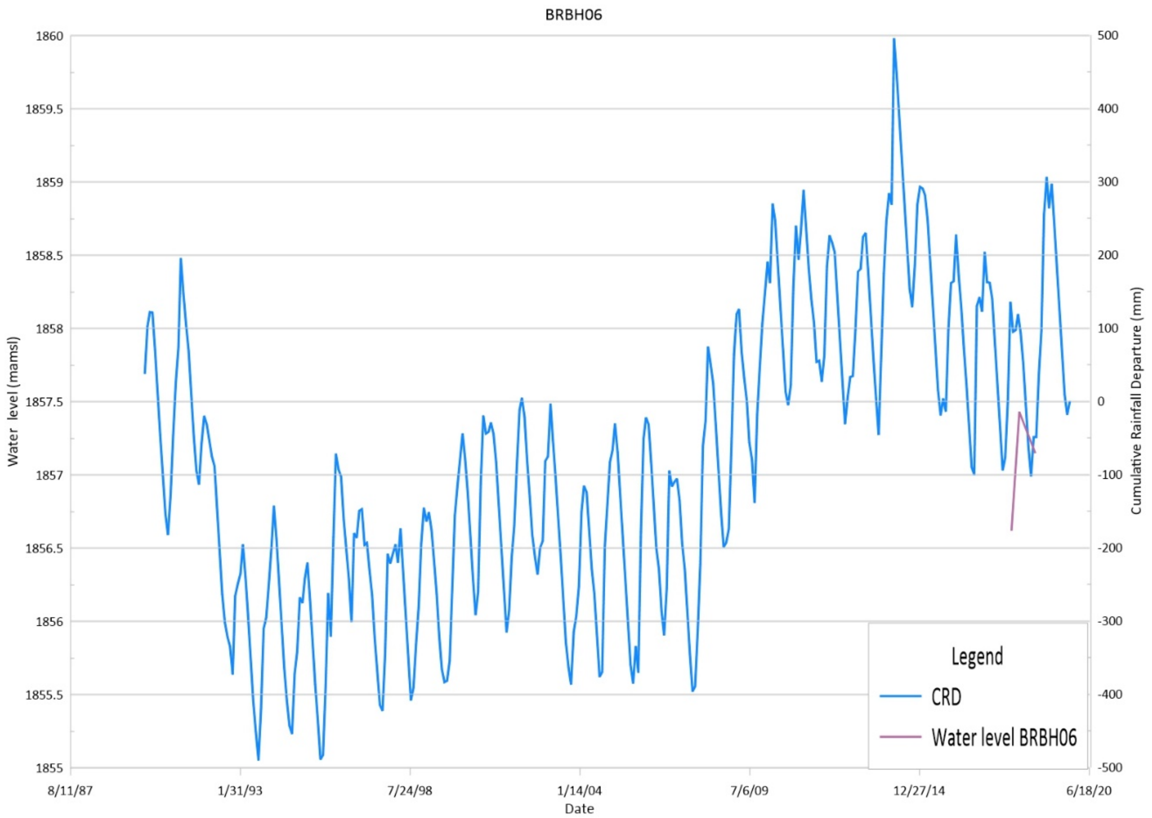
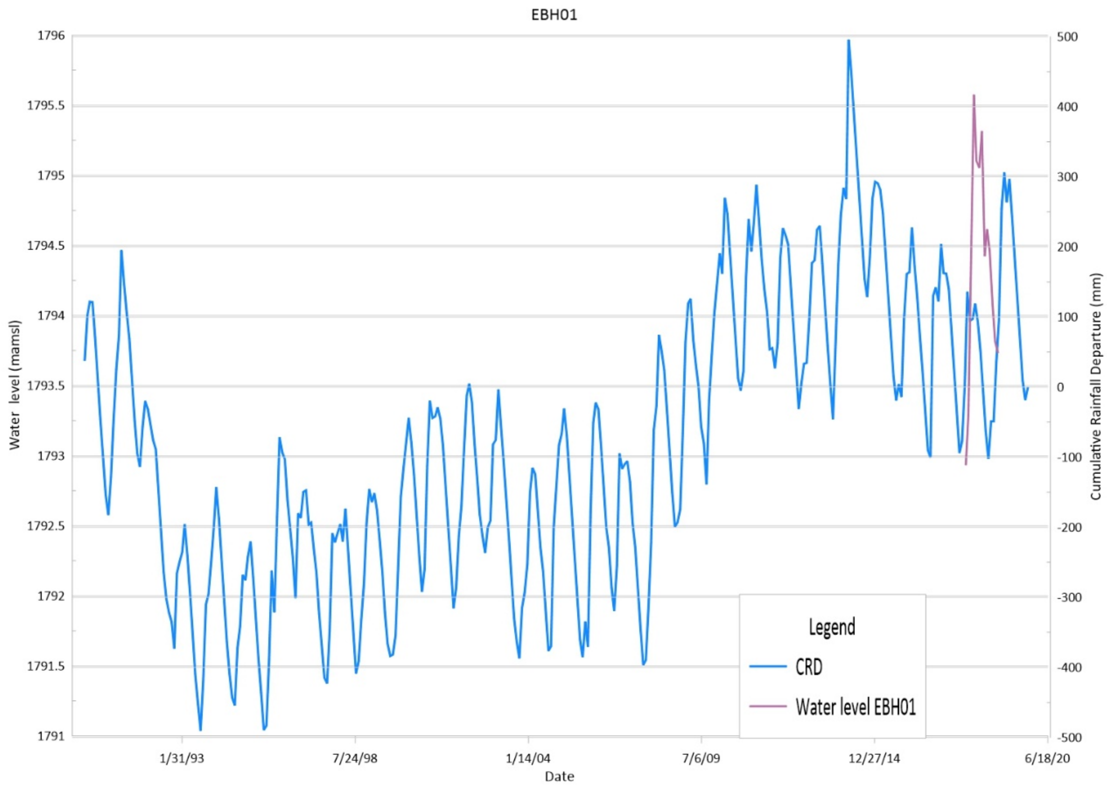
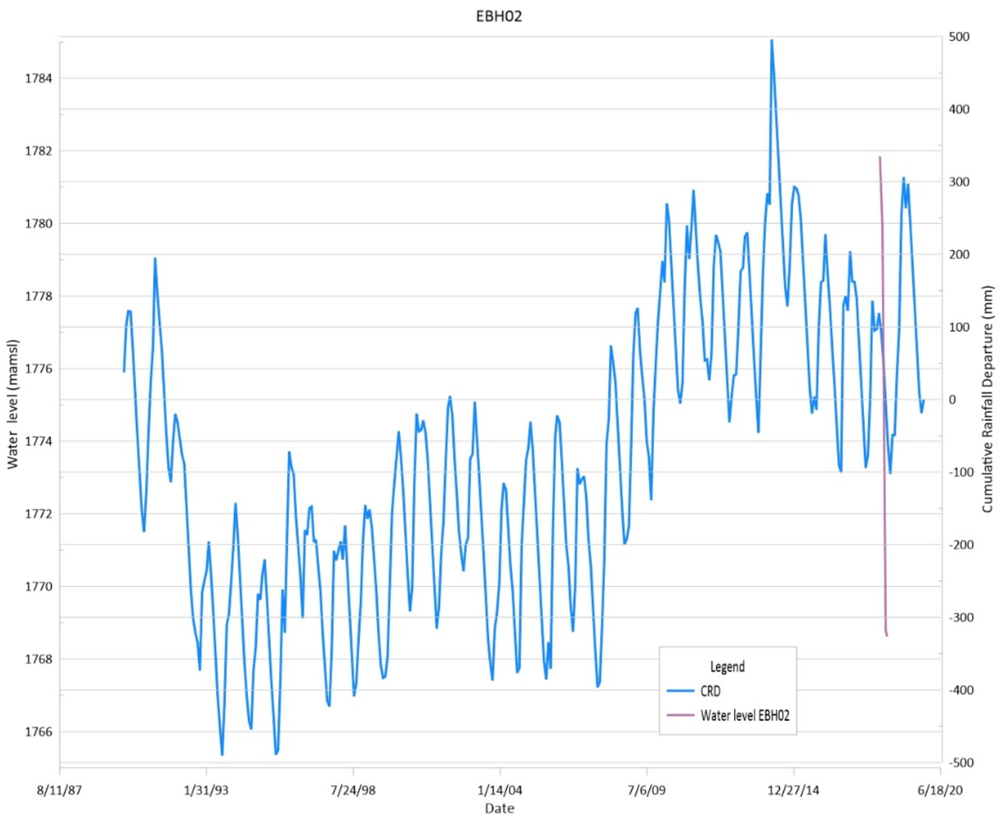
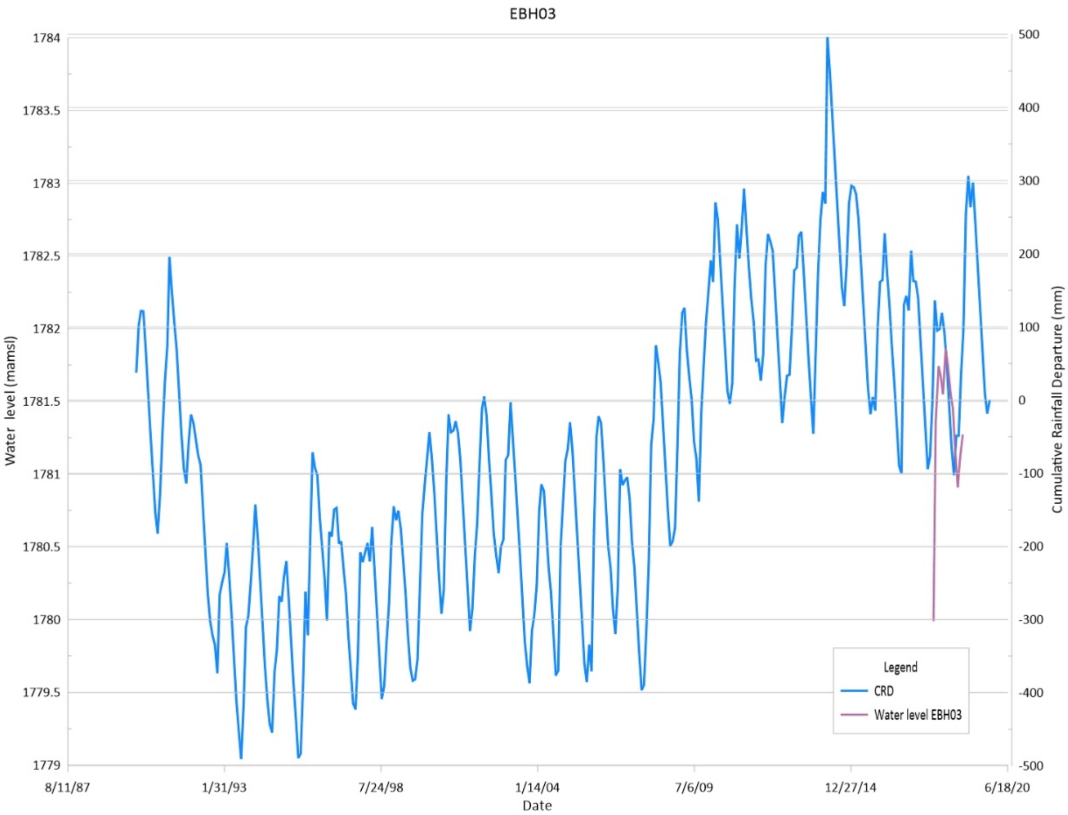
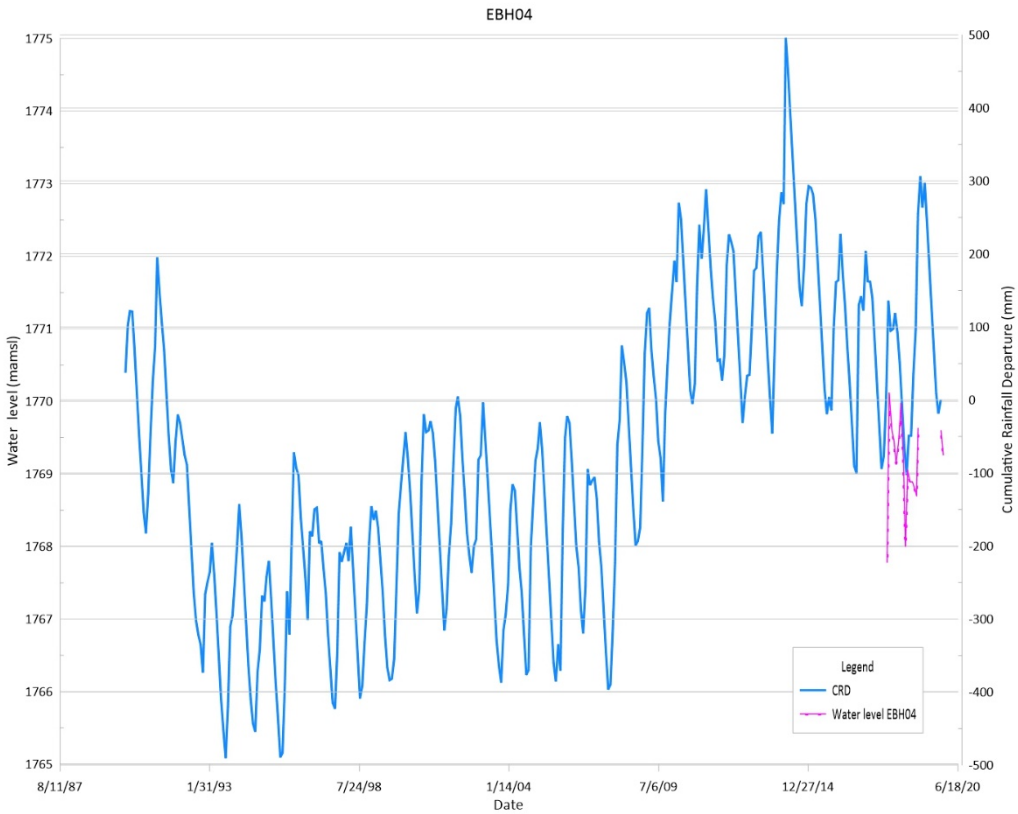
1857
1856.5
1856
1855.5
1855
500
400
300
200
100
0
-100
-200
-300
-400
-500
8/11/87
1/31/93
7/24/98
1/14/04
7/6/09
12/27/14
6/18/20
Legend
CRD
Water level BRBH05

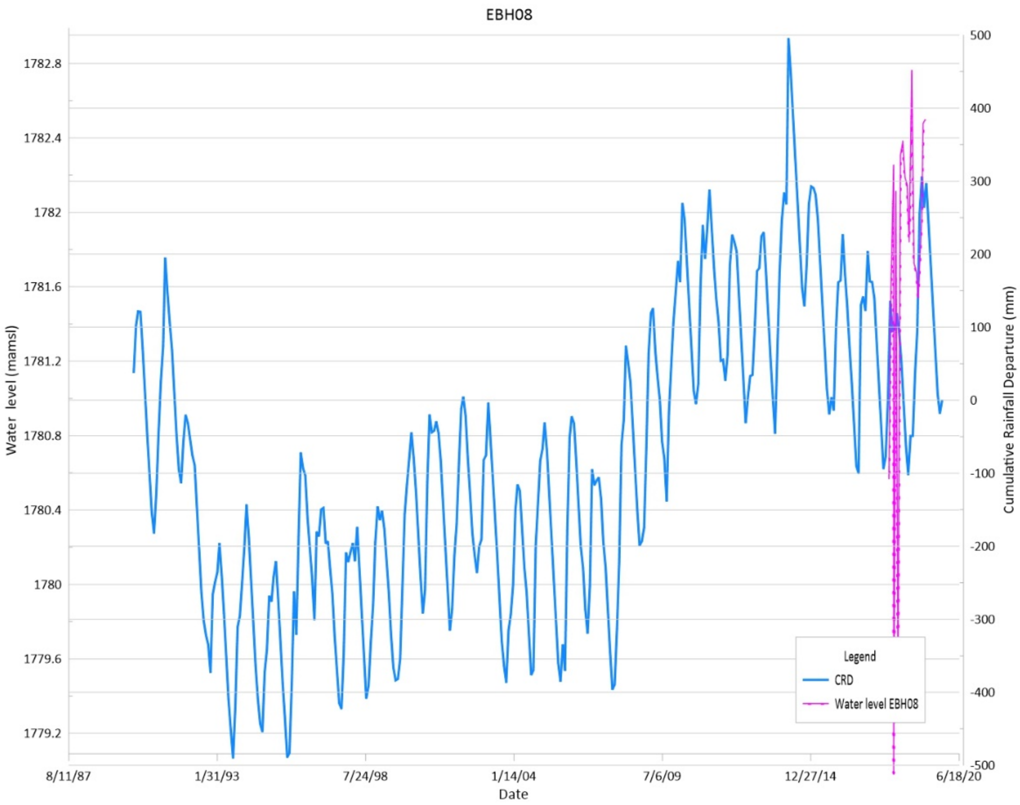

BRBH06
Water level (mamsl)
Cumulative Rainfall Departure (mm)
Date
1860
1859.5
1859
1858.5
1858
1857.5
1857
1856.5
1856
1855.5
1855
500
400
300
200
100
0
-100
-200
-300
-400
-500
8/11/87
1/31/93
7/24/98
1/14/04
7/6/09
12/27/14
6/18/20
Legend
CRD
Water level BRBH06

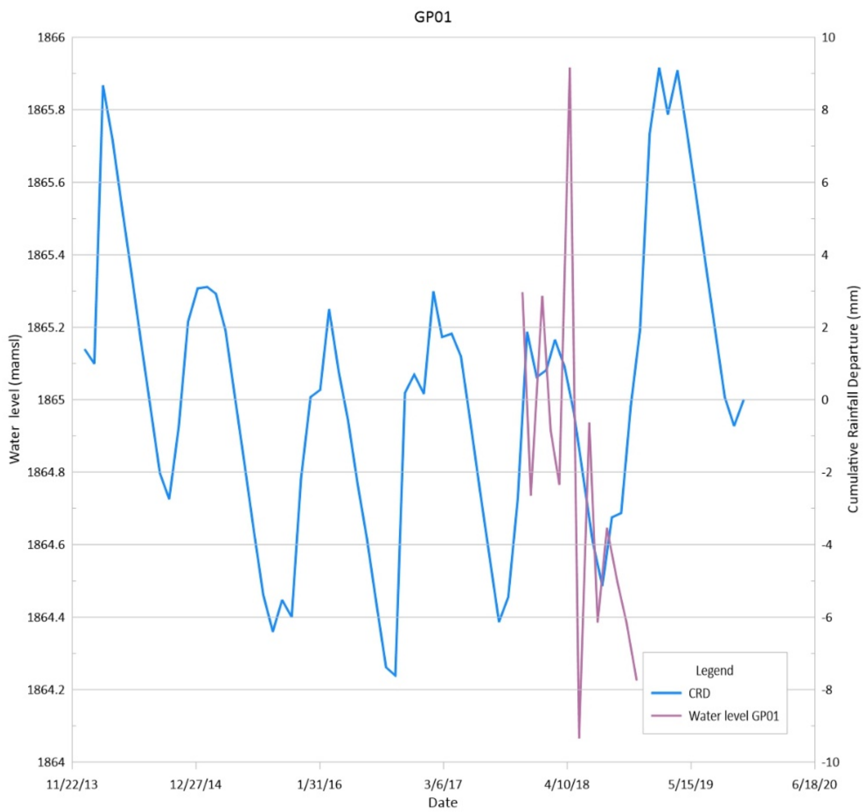

EBH01
Water level (mamsl)
Cumulative Rainfall Departure (mm)
Date
1796
1795.5
1795
1794.5
1794
1793.5
1793
1792.5
1792
1791.5
1791
500
400
300
200
100
0
-100
-200
-300
-400
-500
1/31/93
7/24/98
1/14/04
7/6/09
12/27/14
6/18/20
Legend
CRD
Water level EBH01

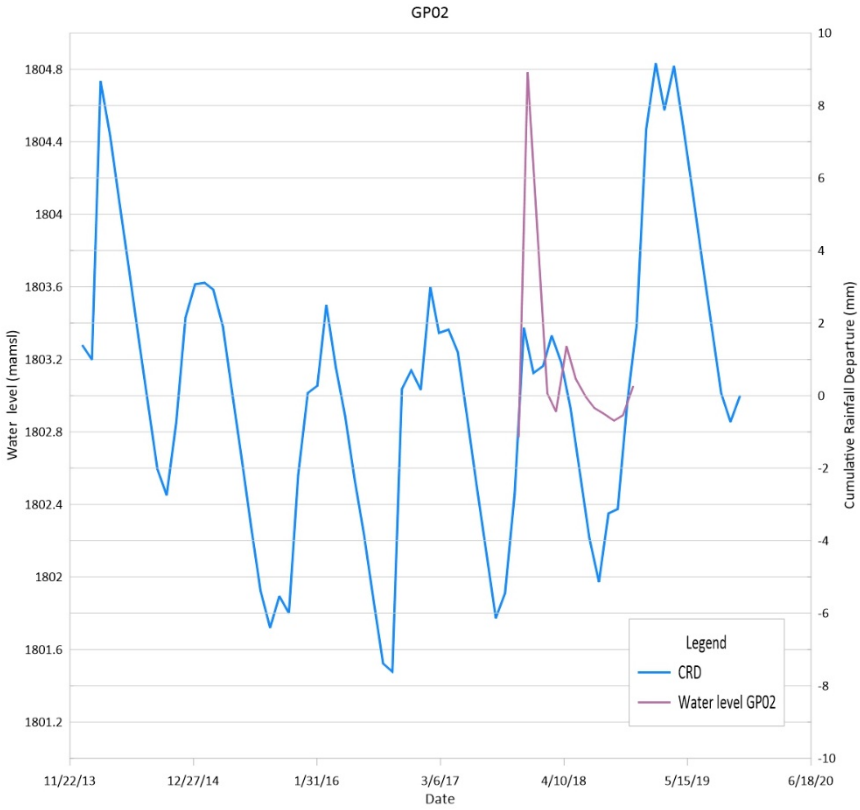

EBH02
Water level (mamsl)
Cumulative Rainfall Departure (mm)
Date
1784
1782
1780
1778
1776
1774
1772
1770
1768
1766
500
400
300
200
100
0
-100
-200
-300
-400
-500
8/11/87
1/31/93
7/24/98
1/14/04
7/6/09
12/27/14
6/18/20
Legend
CRD
Water level EBH02

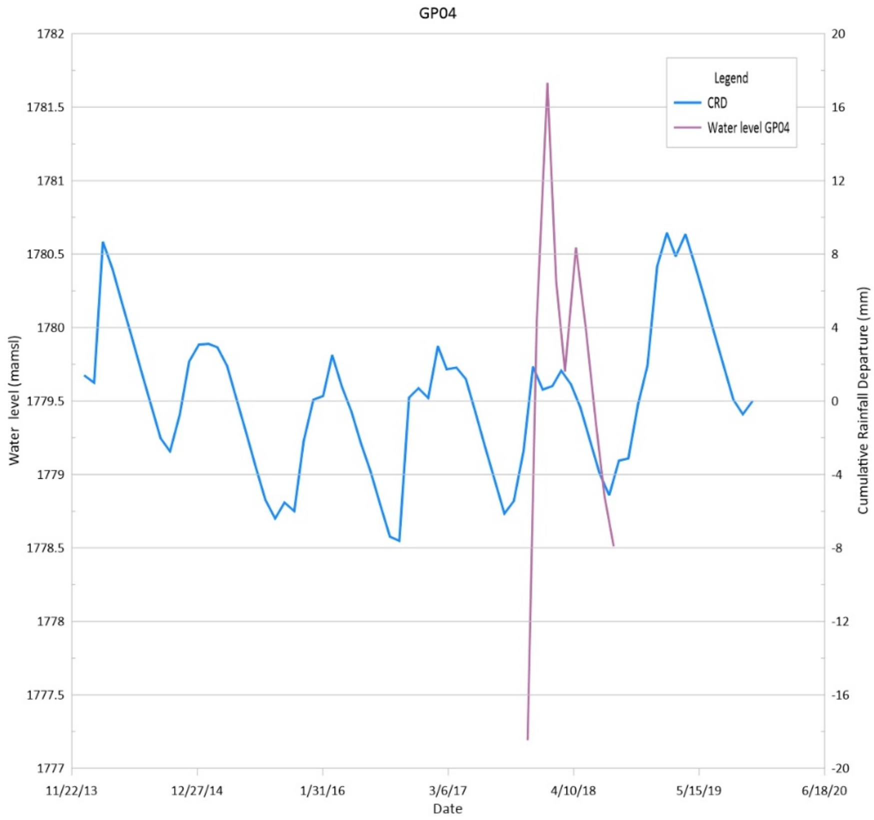

EBH03
Water level (mamsl)
Cumulative Rainfall Departure (mm)
Date
1784
1783.5
1783
1782.5
1782
1781.5
1781
1780.5
1780
1779.5
1779
500
400
300
200
100
0
-100
-200
-300
-400
-500
8/11/87
1/31/93
7/24/98
1/14/04
7/6/09
12/27/14
6/18/20
Legend
CRD
Water level EBH03

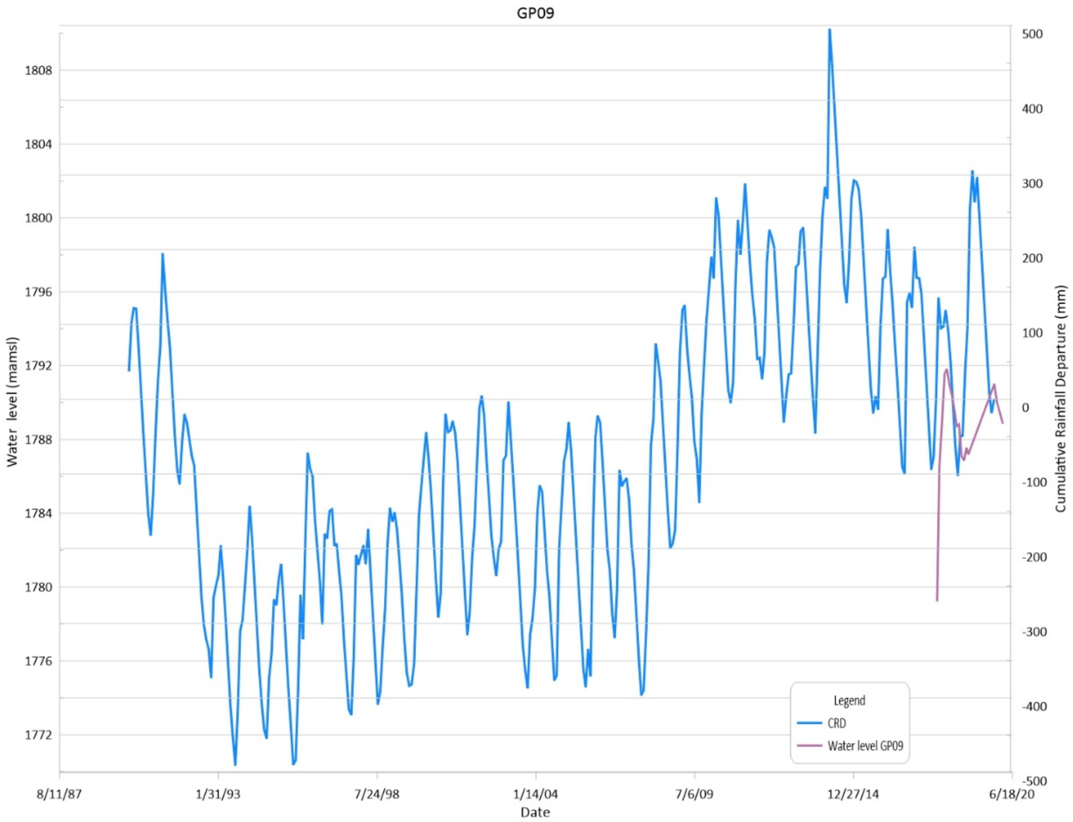

EBH04
Water level (mamsl)
Cumulative Rainfall Departure (mm)
Date
1775
1774
1773
1772
1771
1770
1769
1768
1767
1766
1765
500
400
300
200
100
0
-100
-200
-300
-400
-500
8/11/87
1/31/93
7/24/98
1/14/04
7/6/09
12/27/14
6/18/20
Legend
CRD
Water level EBH04

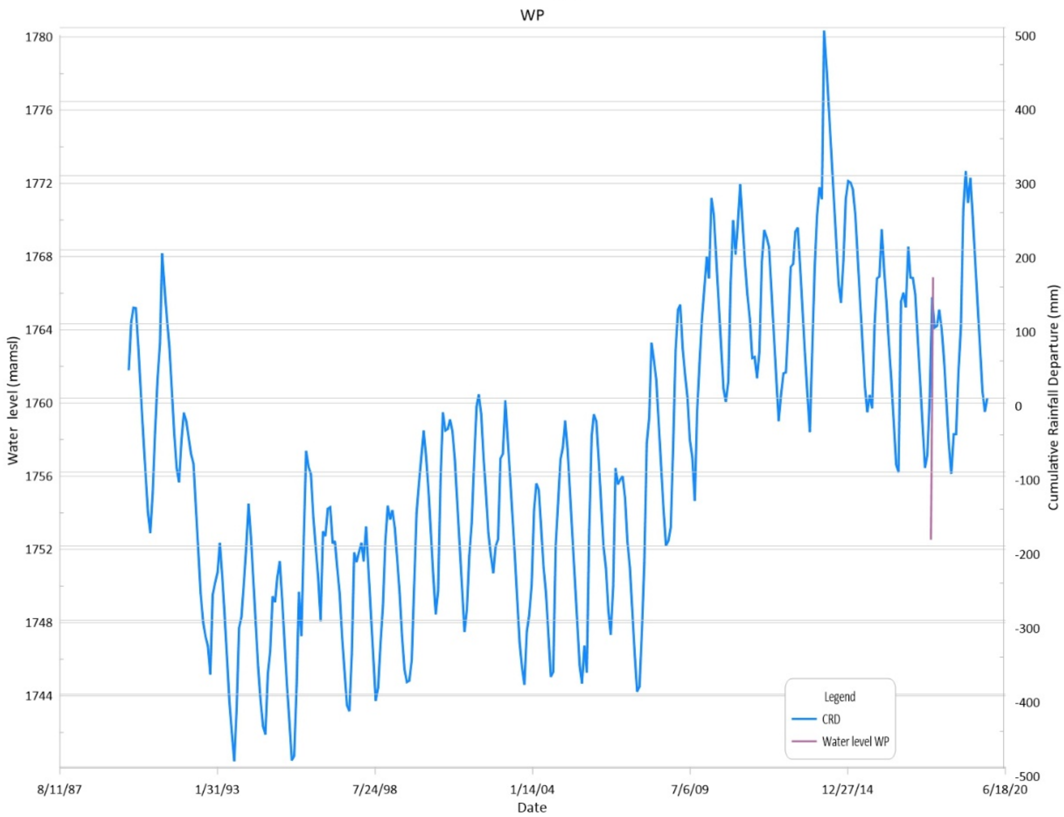

EBH08
Water level (mamsl)
Cumulative Rainfall Departure (mm)
Date
1782.8
1782.4
1782
1781.6
1781.2
1780.8
1780.4
1780
1779.6
1779.2
500
400
300
200
100
0
-100
-200
-300
-400
-500
8/11/87
1/31/93
7/24/98
1/14/04
7/6/09
12/27/14
6/18/20
Legend
CRD
Water level EBH08


GP01
Water level (mamsl)
Cumulative Rainfall Departure (mm)
Date
1866
1865.8
1865.6
1865.4
1865.2
1865
1864.8
1864.6
1864.4
1864.2
1864
10
8
6
4
2
0
-2
-4
-6
-8
-10
11/22/13
12/27/14
1/31/16
3/6/17
4/10/18
5/15/19
6/18/20
Legend
CRD
Water level GP01


GP02
Water level (mamsl)
Cumulative Rainfall Departure (mm)
Date
11/22/13
12/27/14
1/31/16
3/6/17
4/10/18
5/15/19
6/18/20
Legend
CRD
Water level GP02

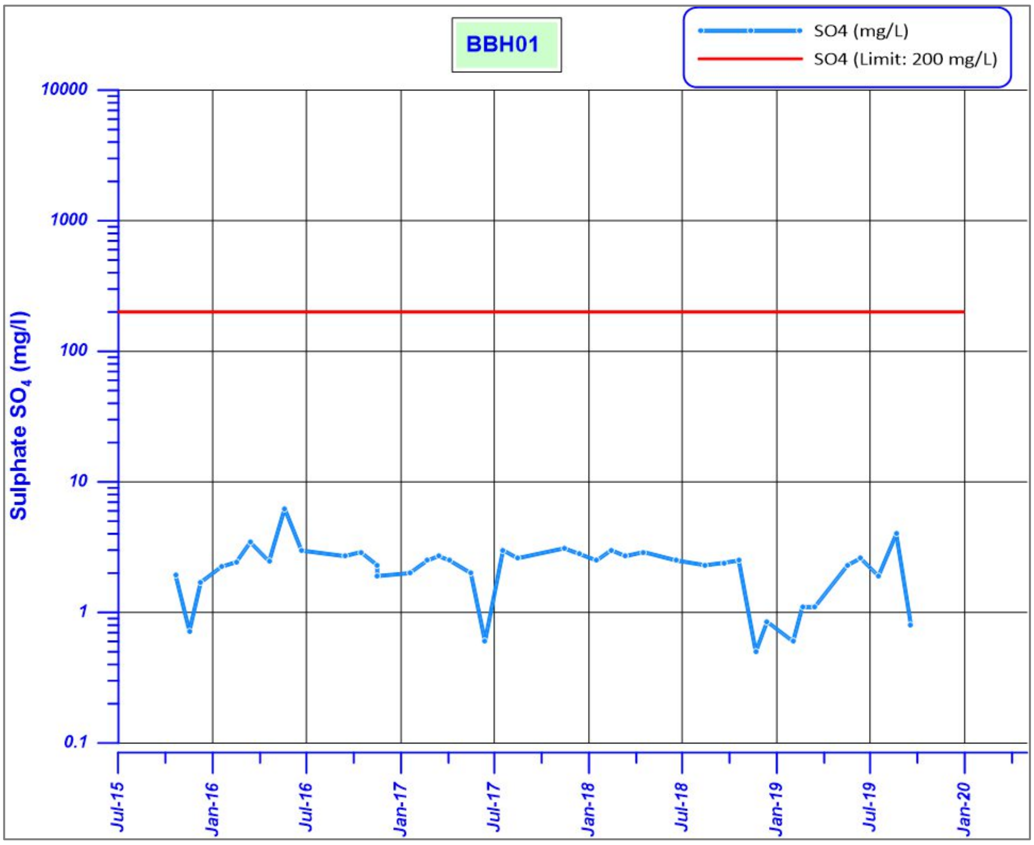

GP04
Water level (mamsl)
Cumulative Rainfall Departure (mm)
Date
11/22/13
12/27/14
1/31/16
3/6/17
4/10/18
5/15/19
6/18/20
Legend
CRD
Water level GP04

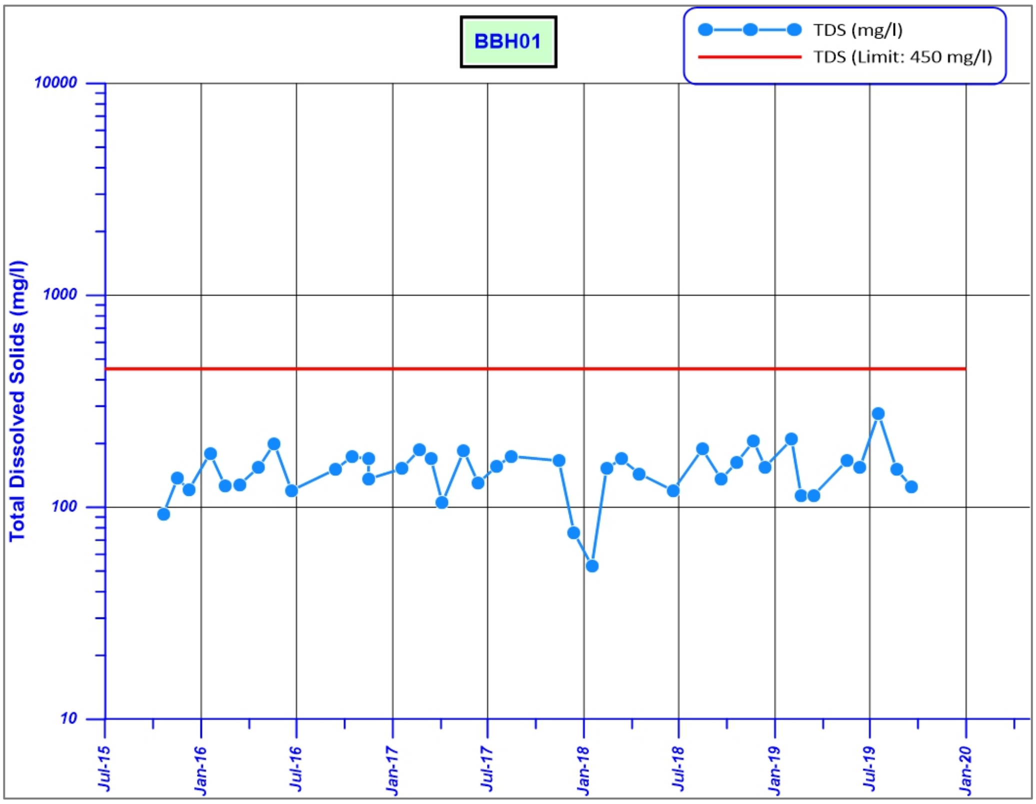

GP09
Water level (mamsl)
Cumulative Rainfall Departure (mm)
Date
Legend
CRD
Water level GP09
1808
1804
1800
1796
1792
1788
1784
1780
1776
1772
500
400
300
200
100
0
-100
-200
-300
-400
-500
8/11/87
1/31/93
7/24/98
1/14/04
7/6/09
12/27/14
6/18/20

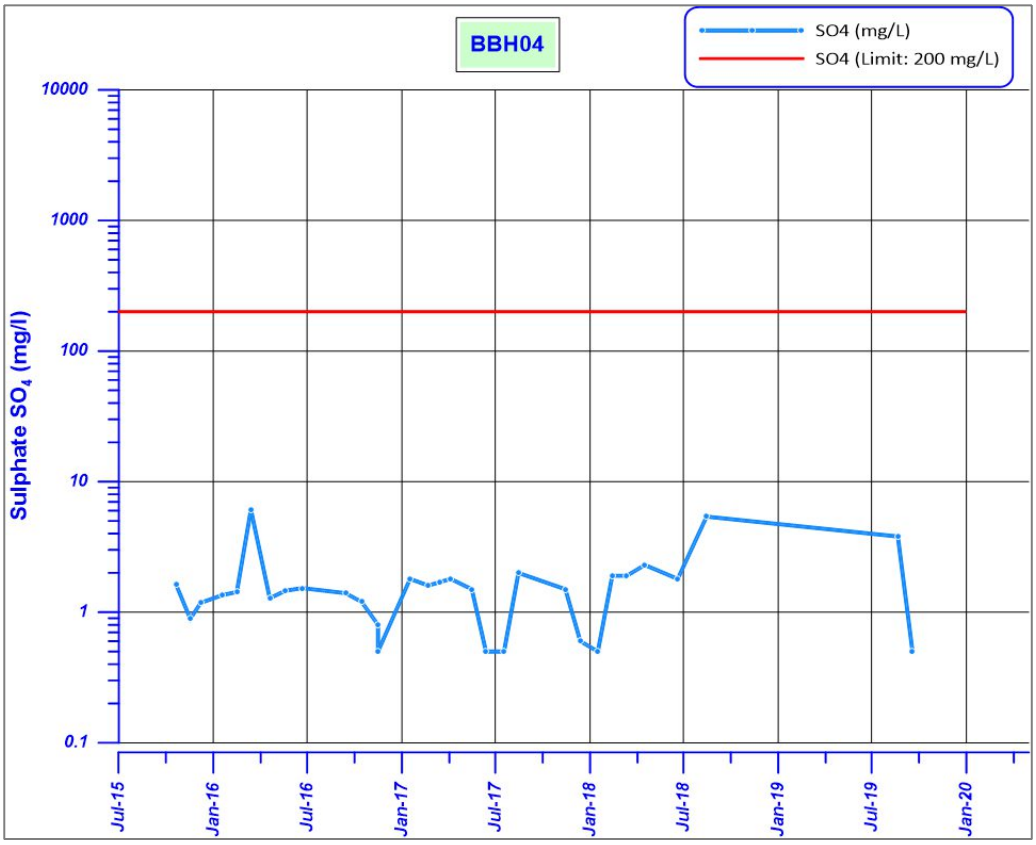

WP
Water level (mamsl)
Cumulative Rainfall Departure (mm)
Date
Legend
CRD
Water level WP
1780
1776
1772
1768
1764
1760
1756
1752
1748
1744
500
400
300
200
100
0
-100
-200
-300
-400
-500
8/11/87
1/31/93
7/24/98
1/14/04
7/6/09
12/27/14
6/18/20

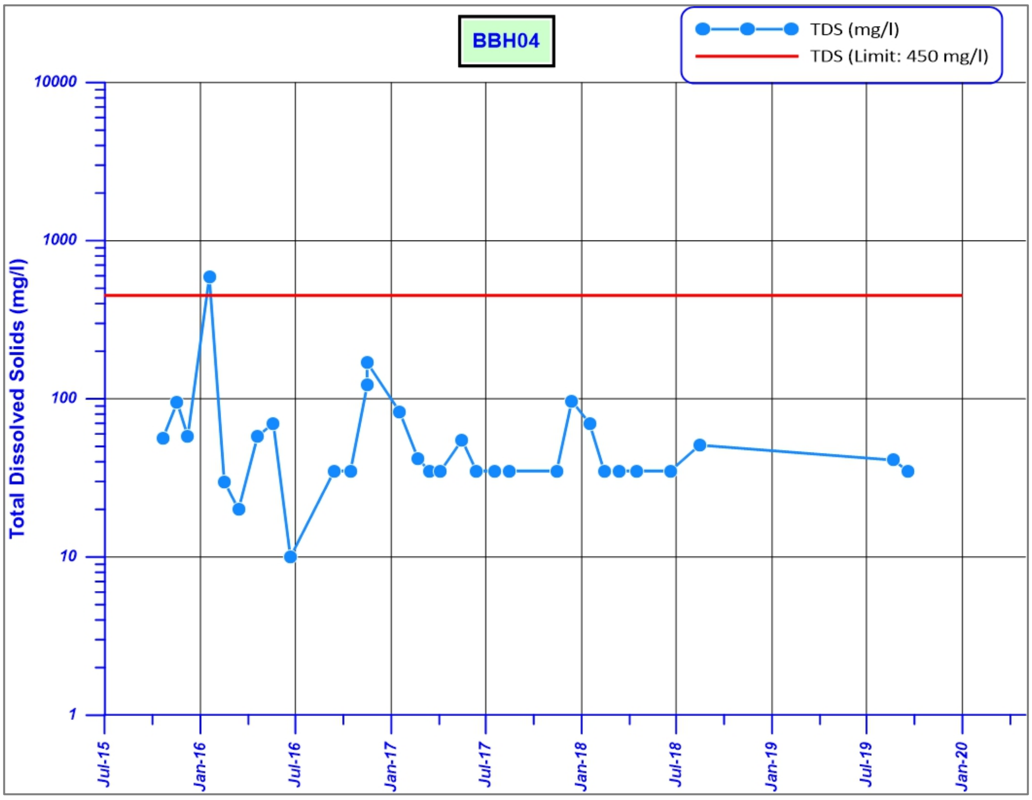
APPENDIX B

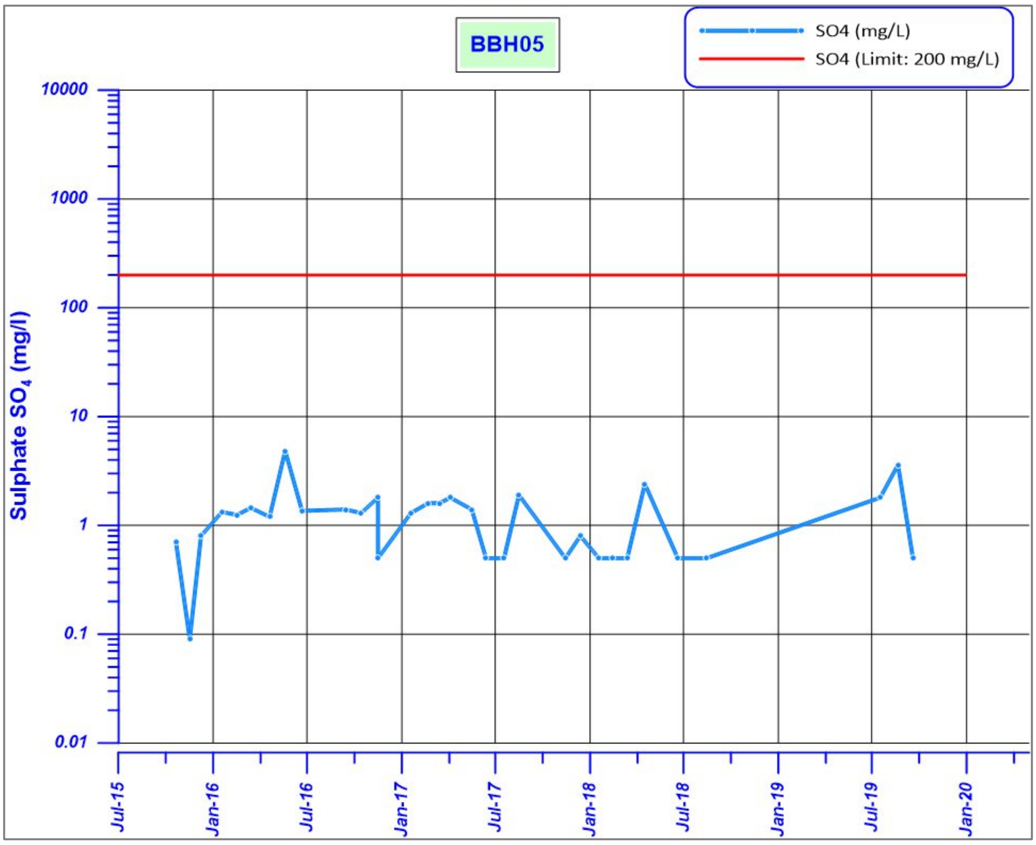
Measured Sulphate and Total Dissolved Solids

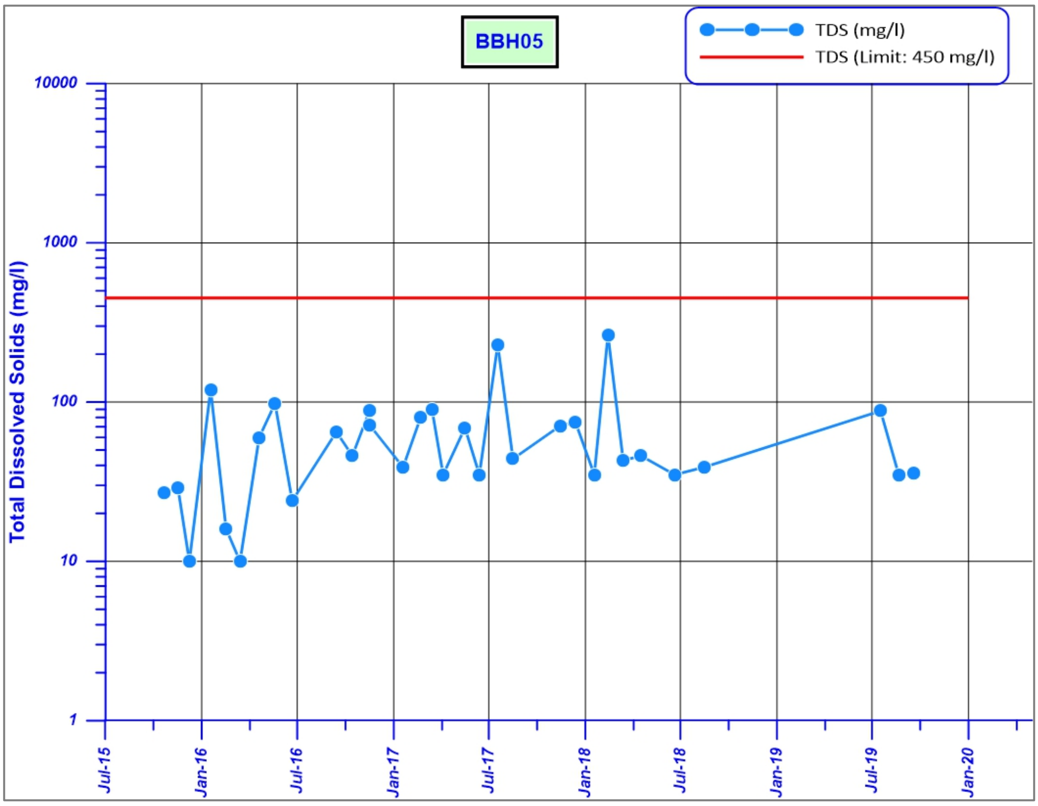

BBH01
SO4 (mg/L)
SO4 (Limit: 200 mg/L)
Sulphate SO4 (mg/l)
10000
1000
100
10
1
0.1
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20

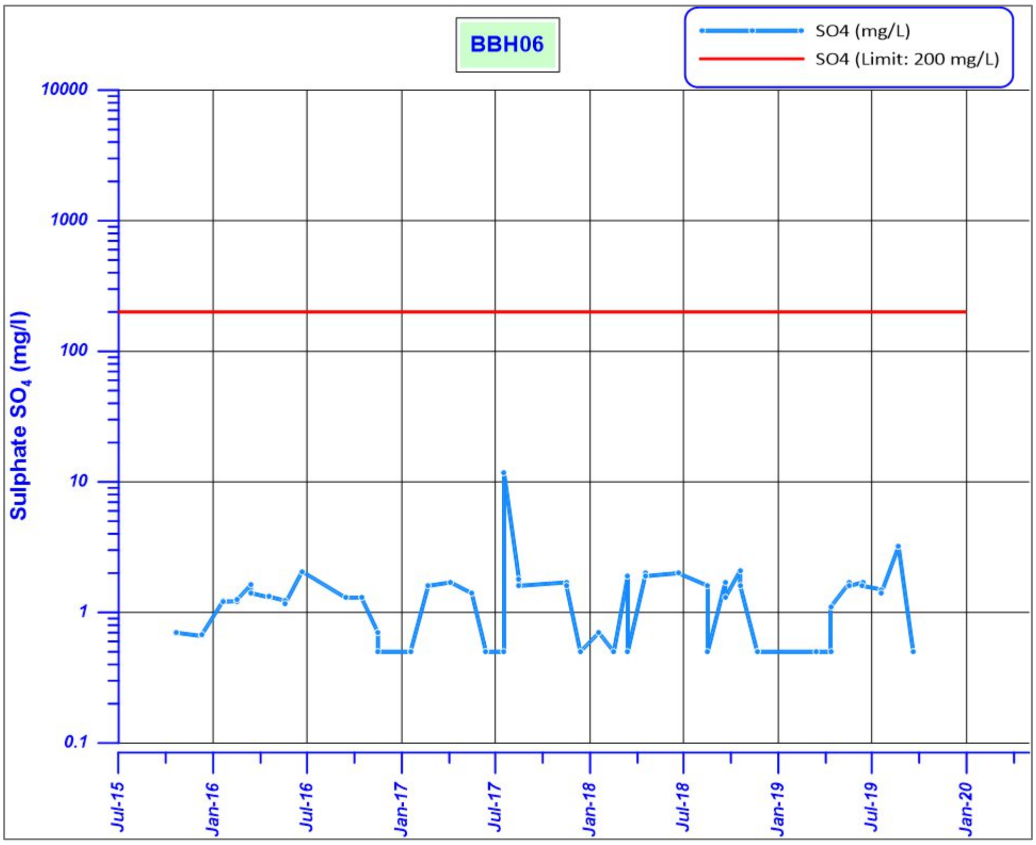

BBH01
TDS (mg/l)
TDS (Limit: 450 mg/l)
Total Dissolved Solids (mg/l)
10000
1000
100
10
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20

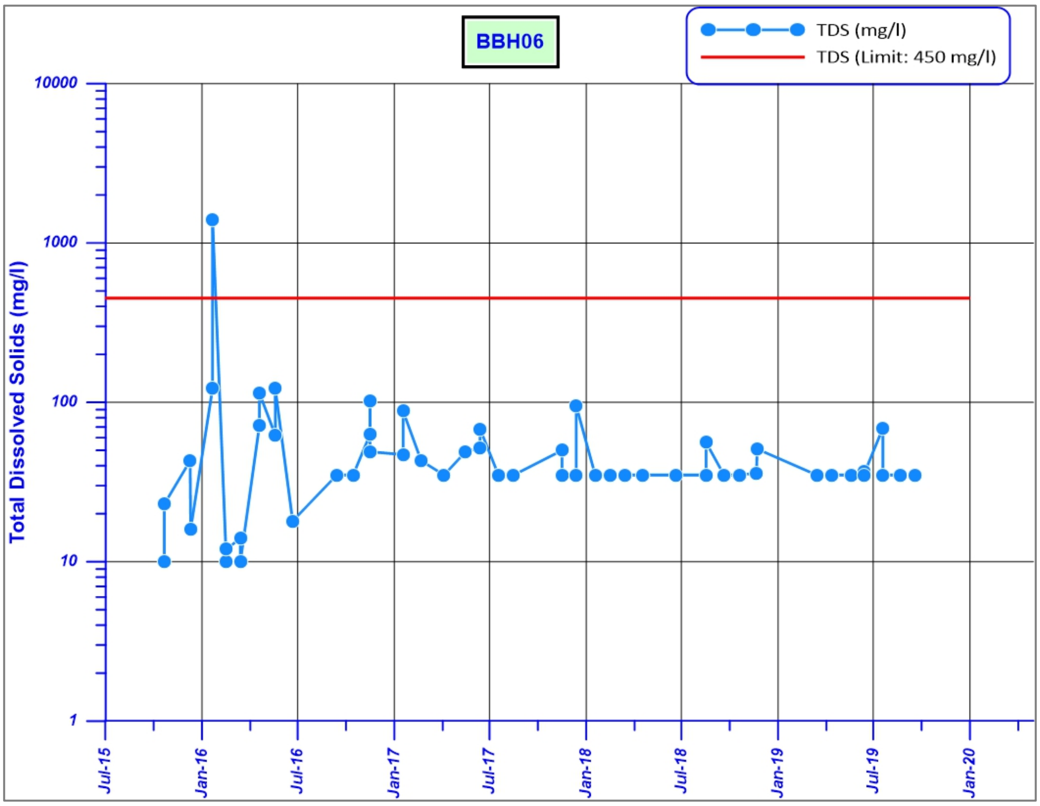

BBH04
SO4 (mg/L)
SO4 (Limit: 200 mg/L)
Sulphate SO_4 (mg/l)
10000
1000
100
10
1
0.1
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20

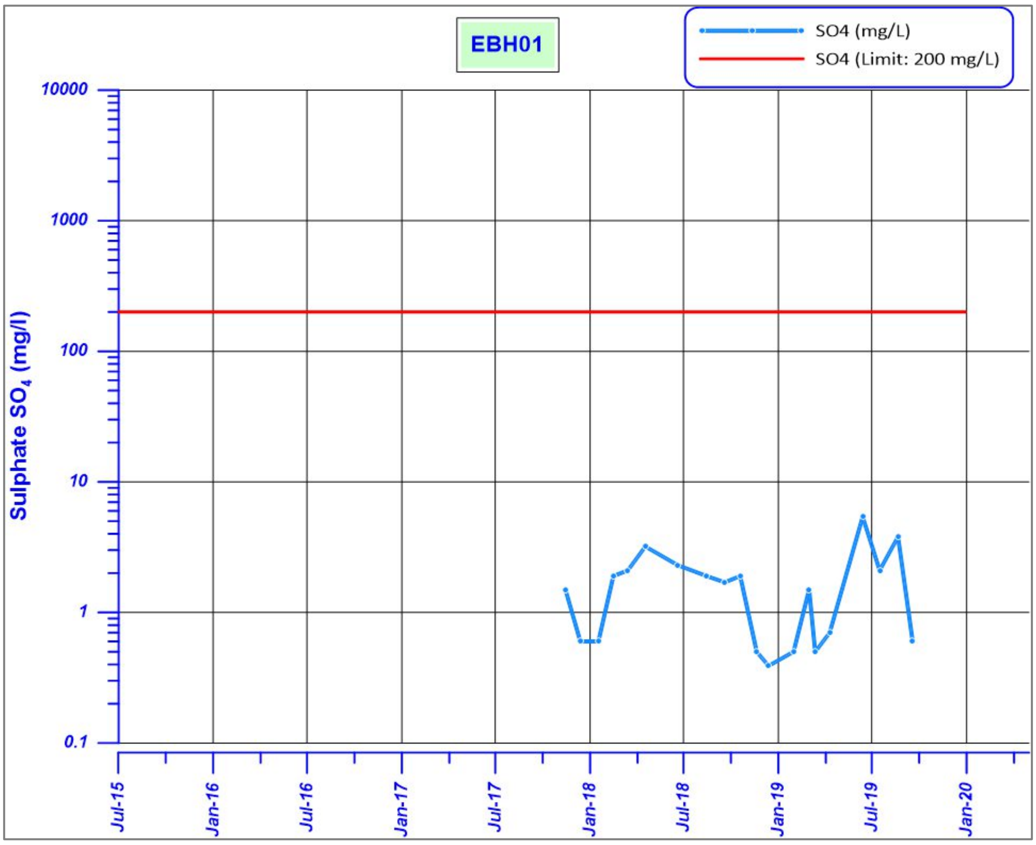

BBH04
TDS (mg/l)
TDS (Limit: 450 mg/l)
Total Dissolved Solids (mg/l)
10000
1000
100
10
1
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20

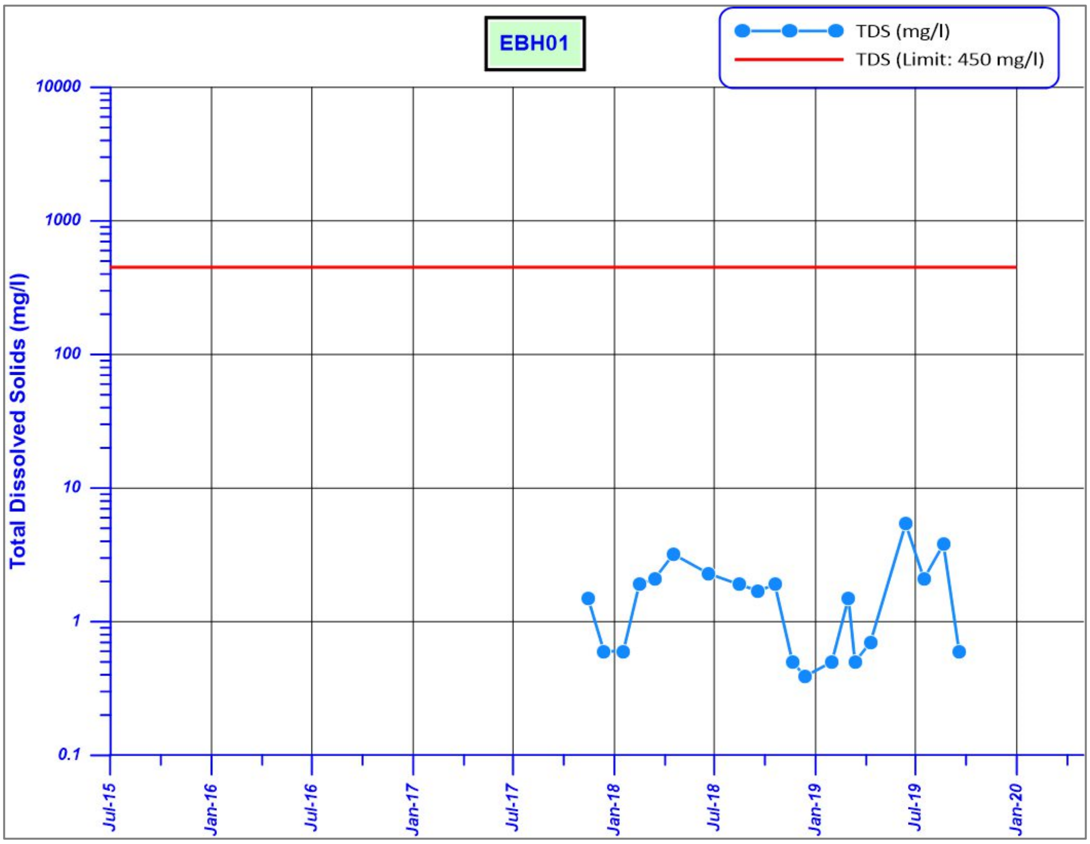

BBH05
SO4 (mg/L)
SO4 (Limit: 200 mg/L)
Sulphate SO_4 (mg/l)
10000
1000
100
10
1
0.1
0.01
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20

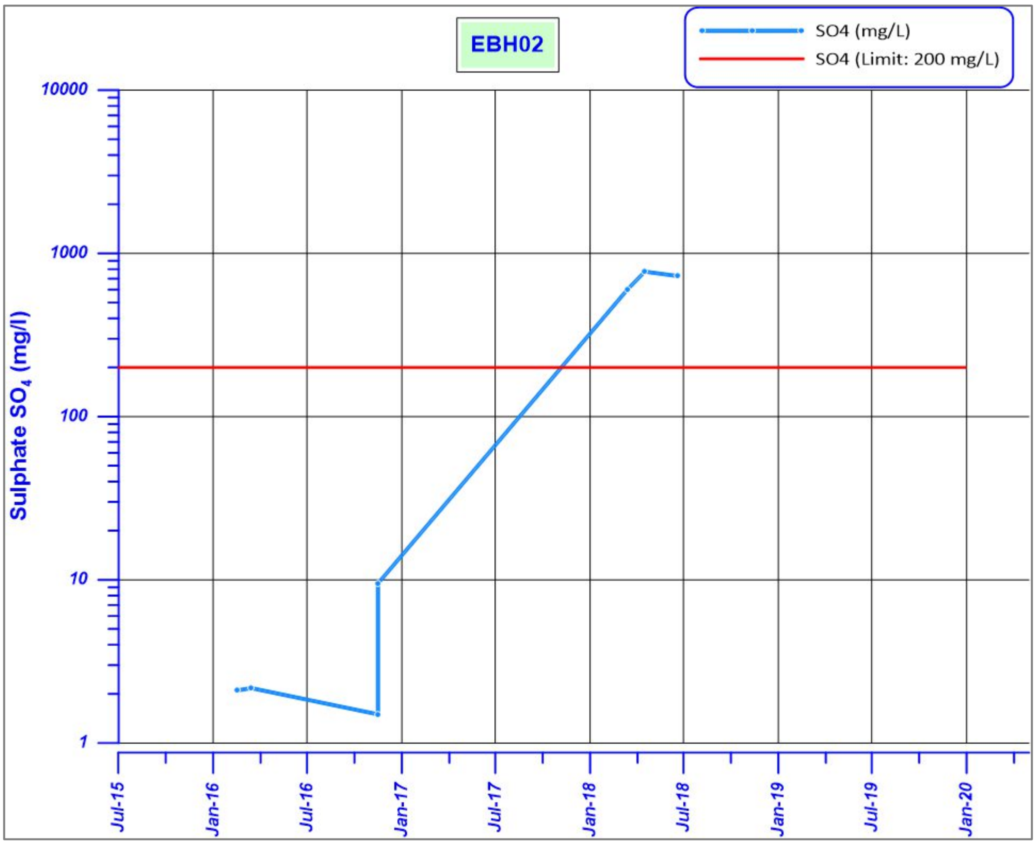

BBH05
TDS (mg/l)
TDS (Limit: 450 mg/l)
Total Dissolved Solids (mg/l)
10000
1000
100
10
1
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20

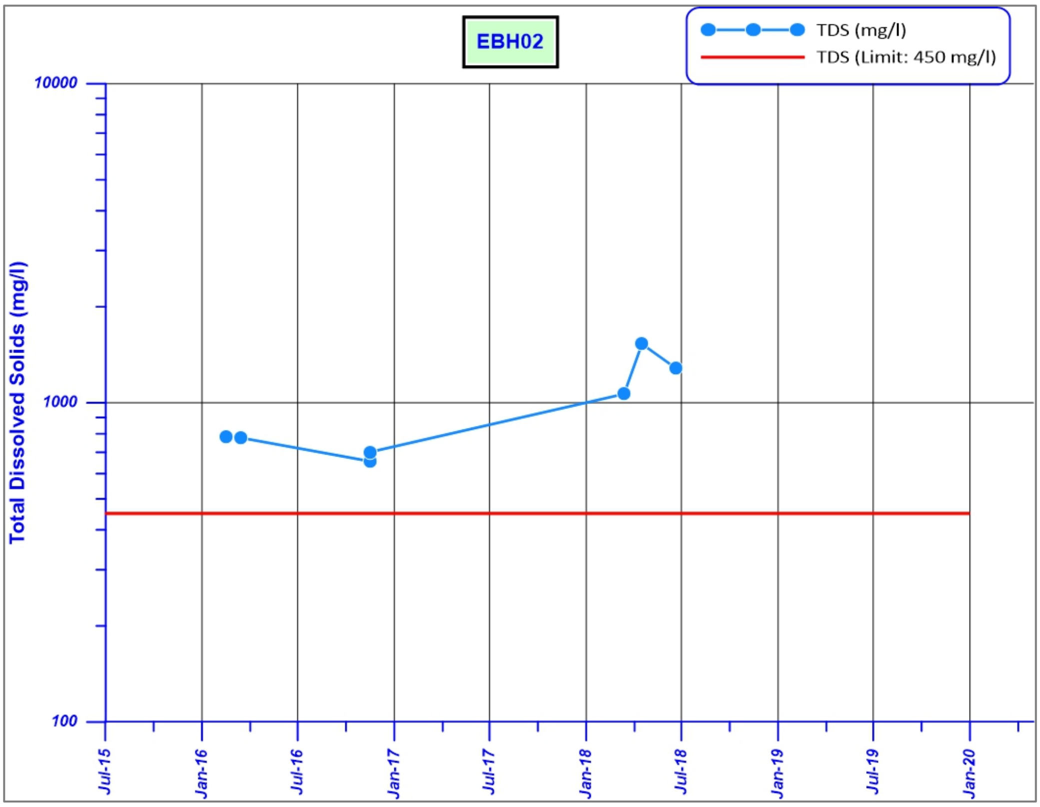

BBH06
SO4 (mg/L)
SO4 (Limit: 200 mg/L)
Sulphate SO_4 (mg/l)
10000
1000
100
10
1
0.1
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20

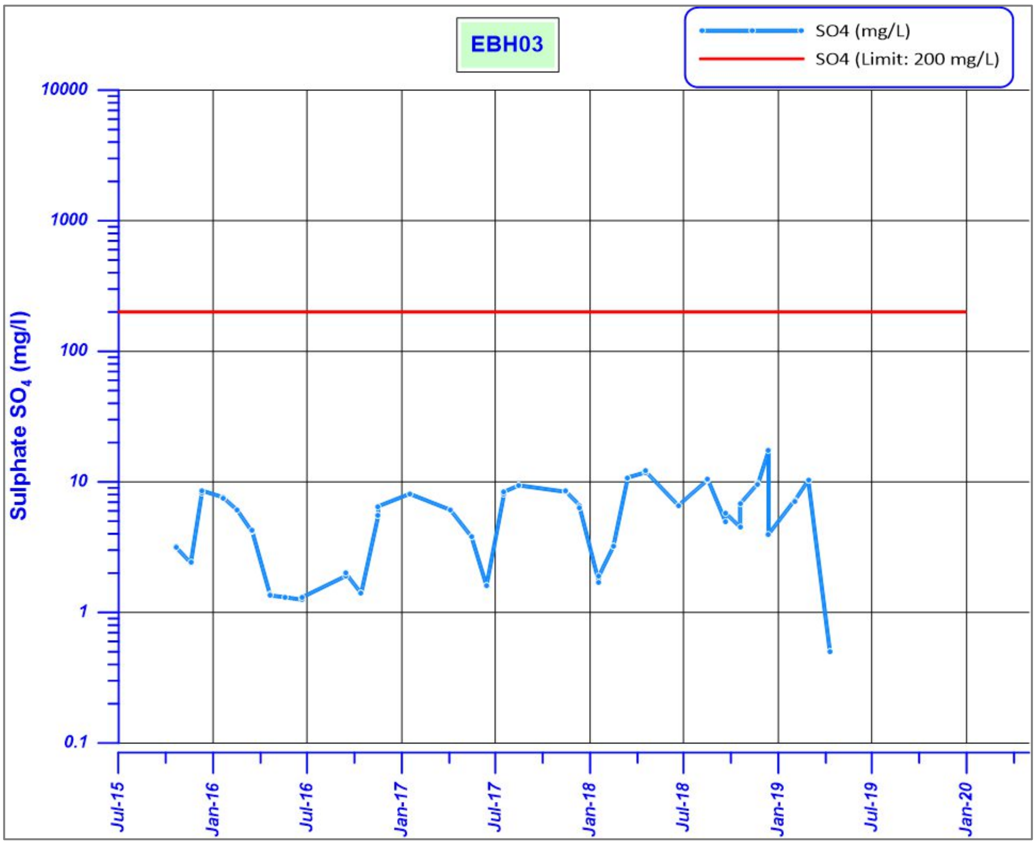

BBH06
TDS (mg/l)
TDS (Limit: 450 mg/l)
Total Dissolved Solids (mg/l)
10000
1000
100
10
1
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20

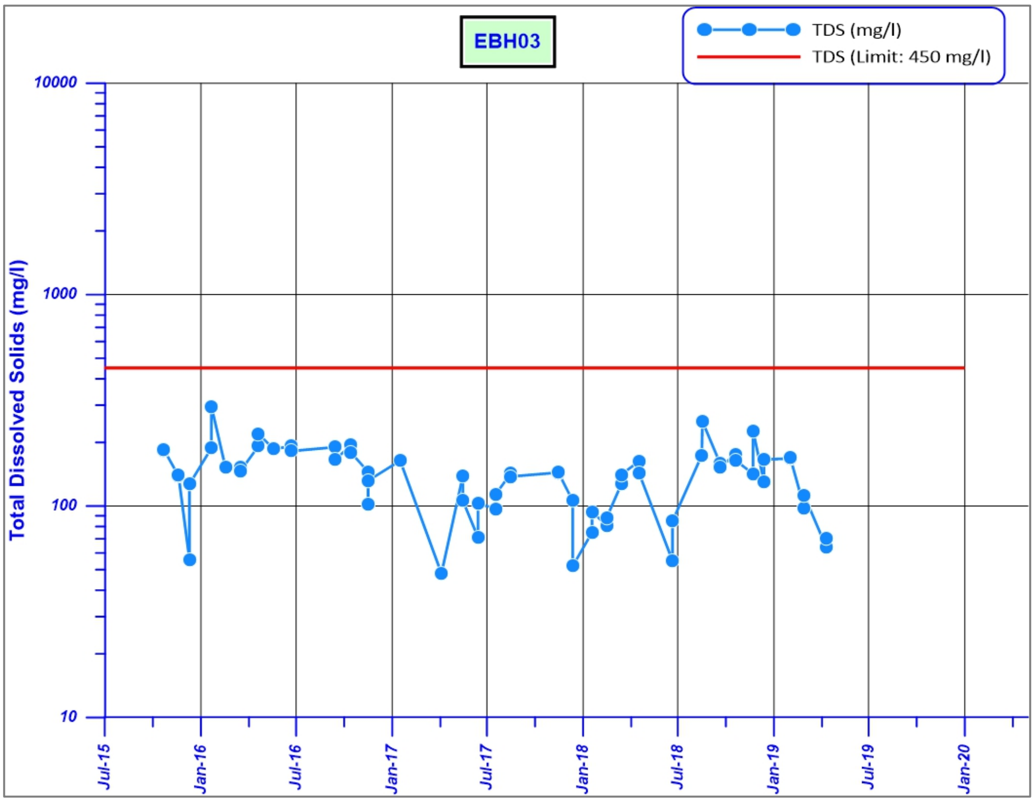

EBH01
SO4 (mg/L)
SO4 (Limit: 200 mg/L)
Sulphate SO_4 (mg/l)
10000
1000
100
10
1
0.1
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20

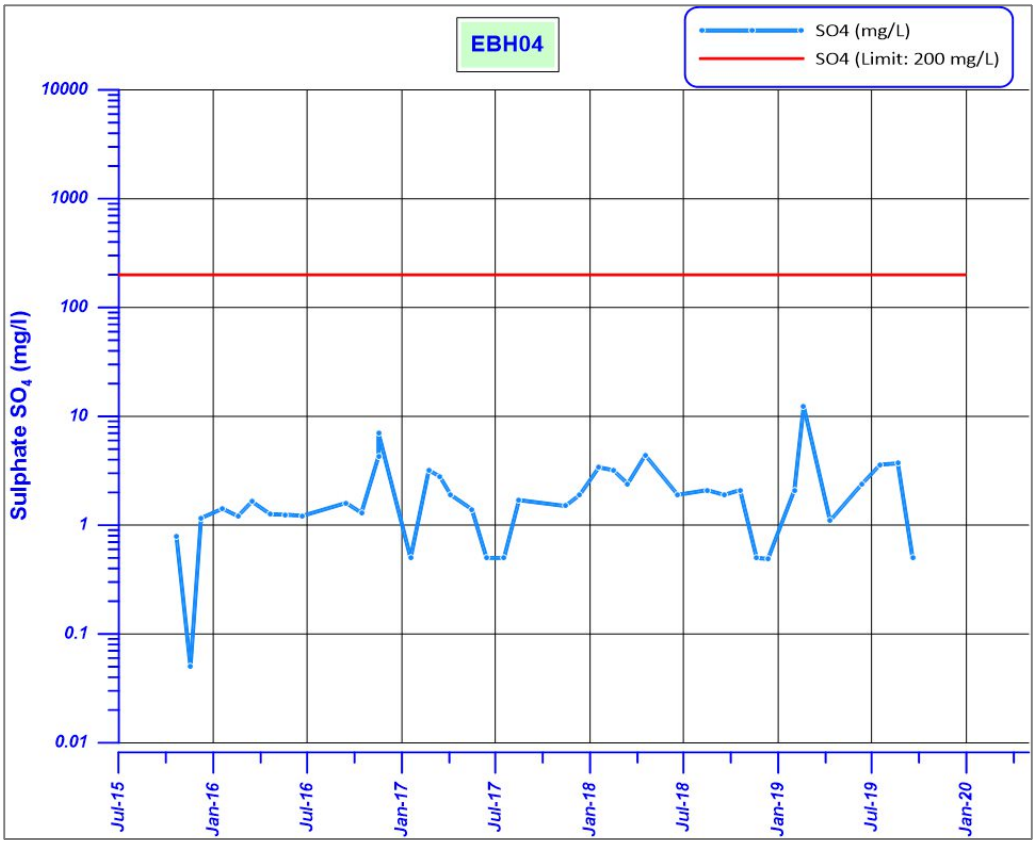

EBH01
TDS (mg/l)
TDS (Limit: 450 mg/l)
Total Dissolved Solids (mg/l)
10000
1000
100
10
1
0.1
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20

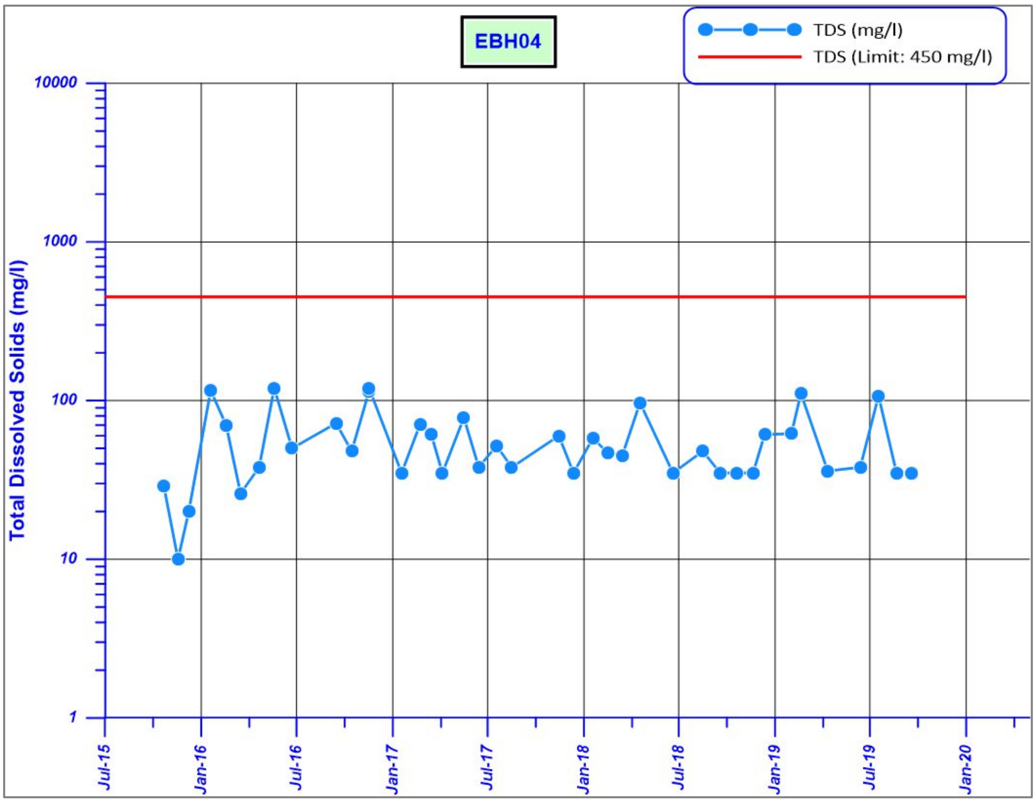

EBH02
SO4 (mg/L)
SO4 (Limit: 200 mg/L)
Sulphate SO_4 (mg/l)
10000
1000
100
10
1
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20

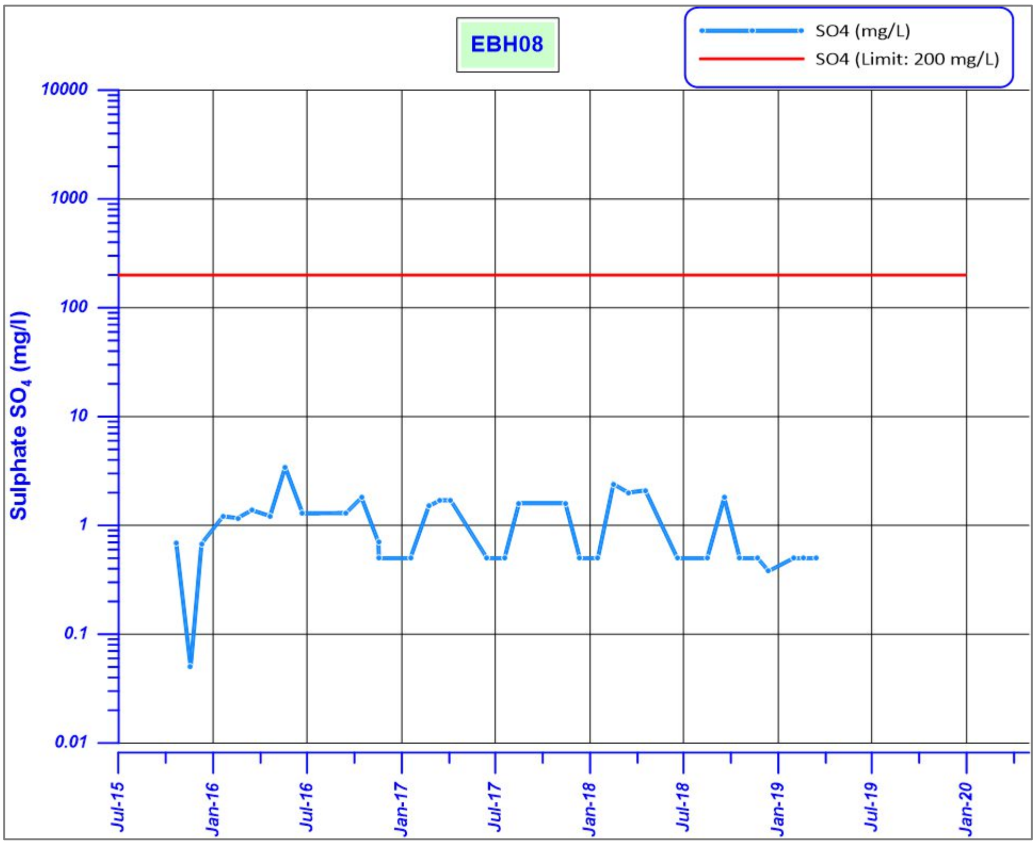

EBH02
TDS (mg/l)
TDS (Limit: 450 mg/l)
Total Dissolved Solids (mg/l)
10000
1000
100
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20

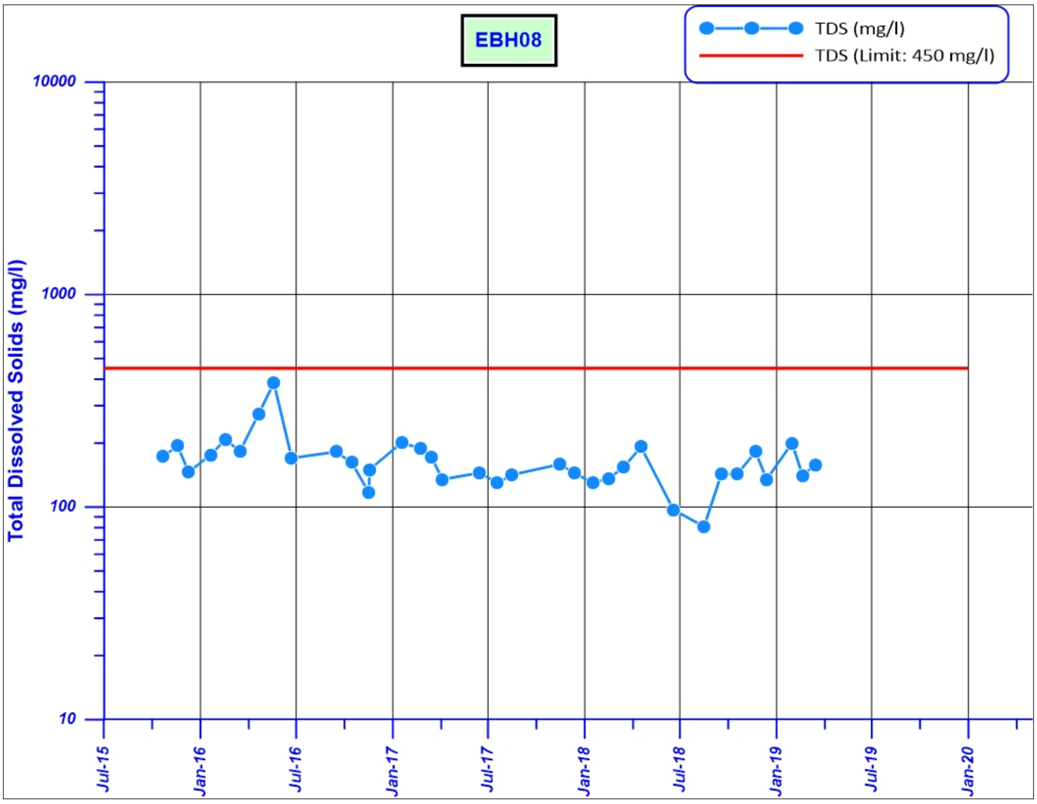

EBH03
SO4 (mg/L)
SO4 (Limit: 200 mg/L)
Sulphate SO_4 (mg/l)
10000
1000
100
10
1
0.1
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20

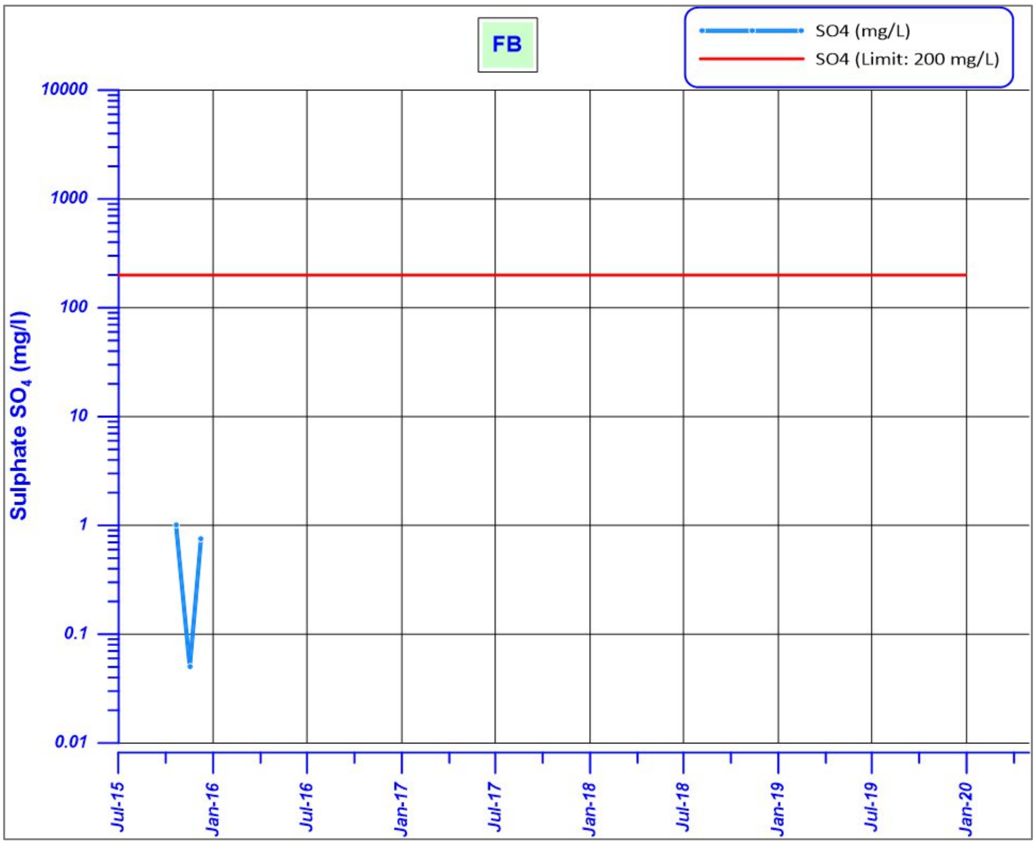

EBH03
TDS (mg/l)
TDS (Limit: 450 mg/l)
Total Dissolved Solids (mg/l)
10000
1000
100
10
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20

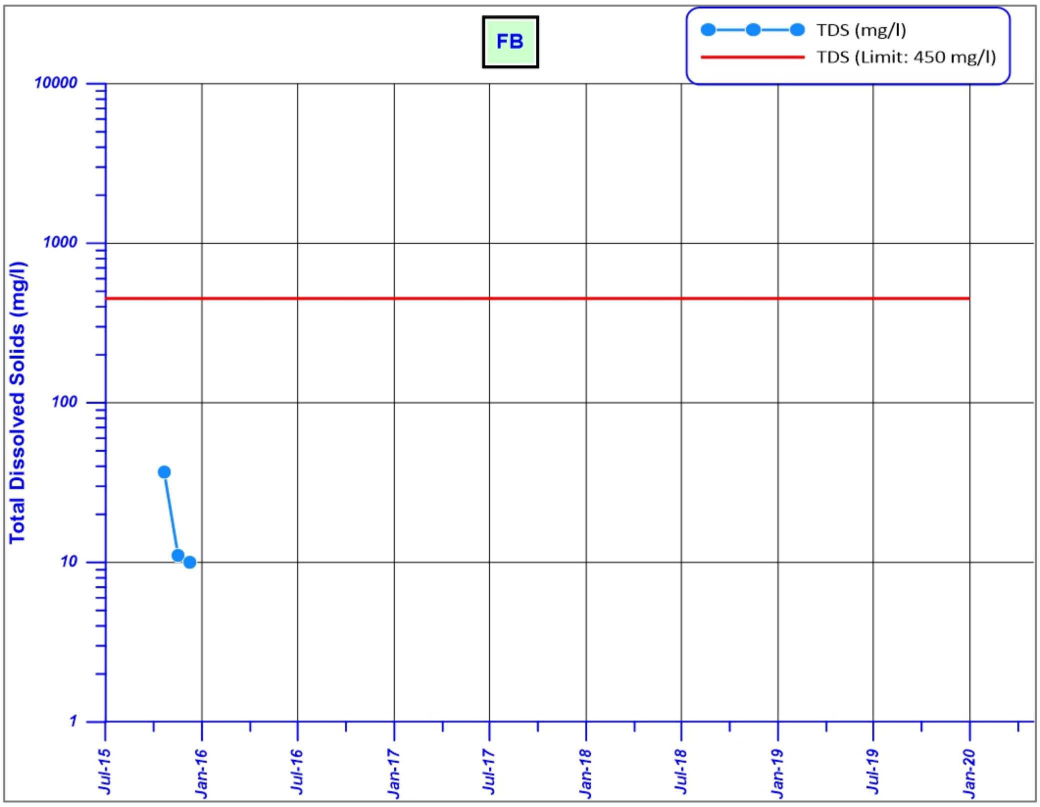

EBH04
SO4 (mg/L)
SO4 (Limit: 200 mg/L)
Sulphate SO_4 (mg/l)
10000
1000
100
10
1
0.1
0.01
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20

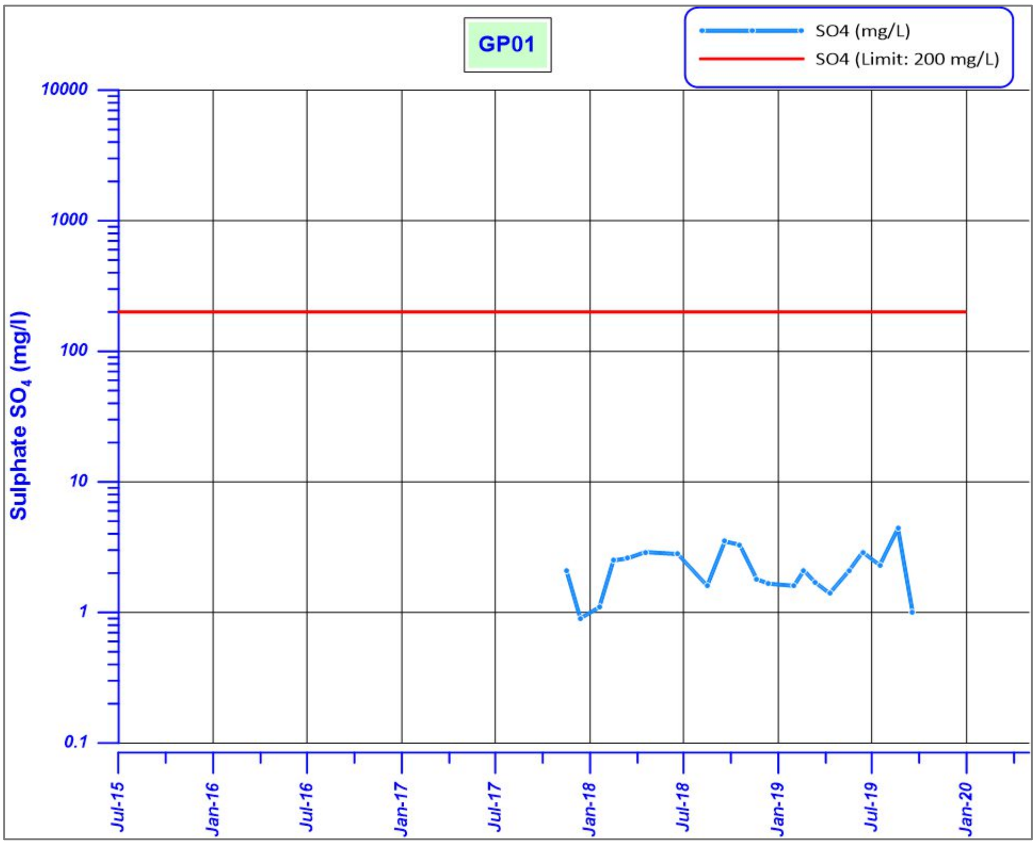

EBH04
TDS (mg/l)
TDS (Limit: 450 mg/l)
Total Dissolved Solids (mg/l)
10000
1000
100
10
1
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20

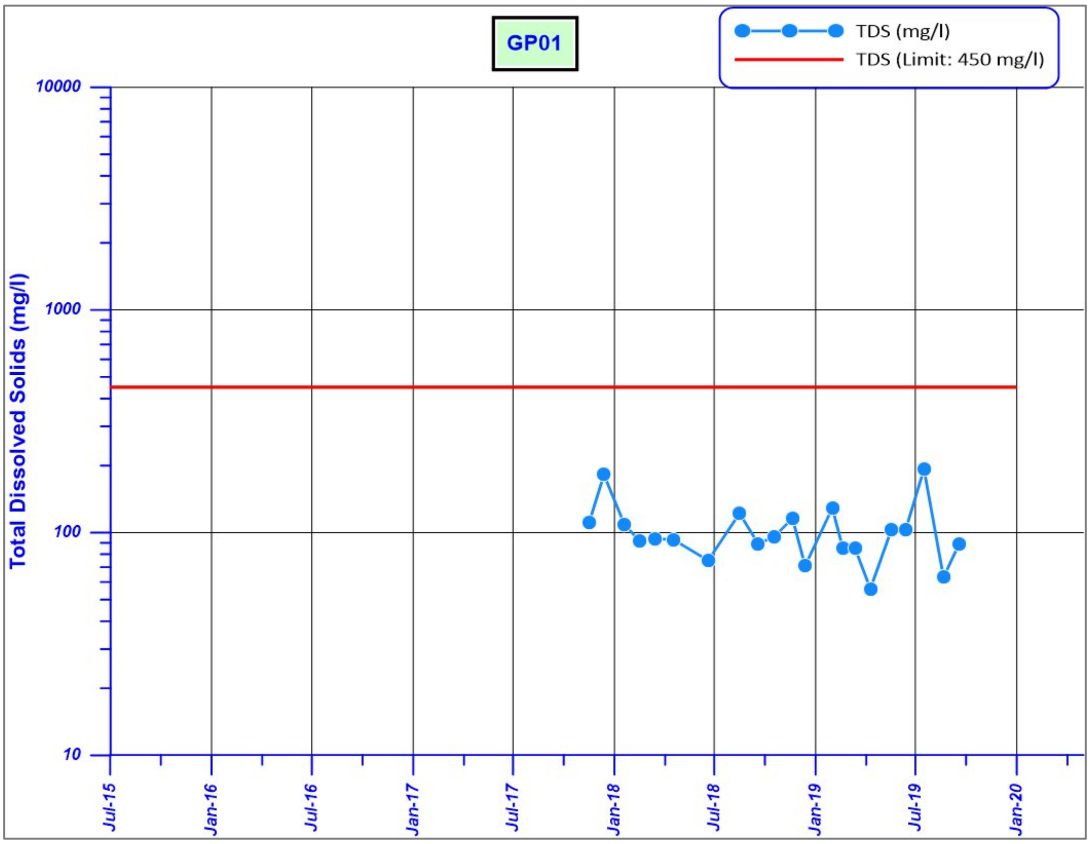

EBH08
SO4 (mg/L)
SO4 (Limit: 200 mg/L)
Sulphate SO_4 (mg/l)
10000
1000
100
10
1
0.1
0.01
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20

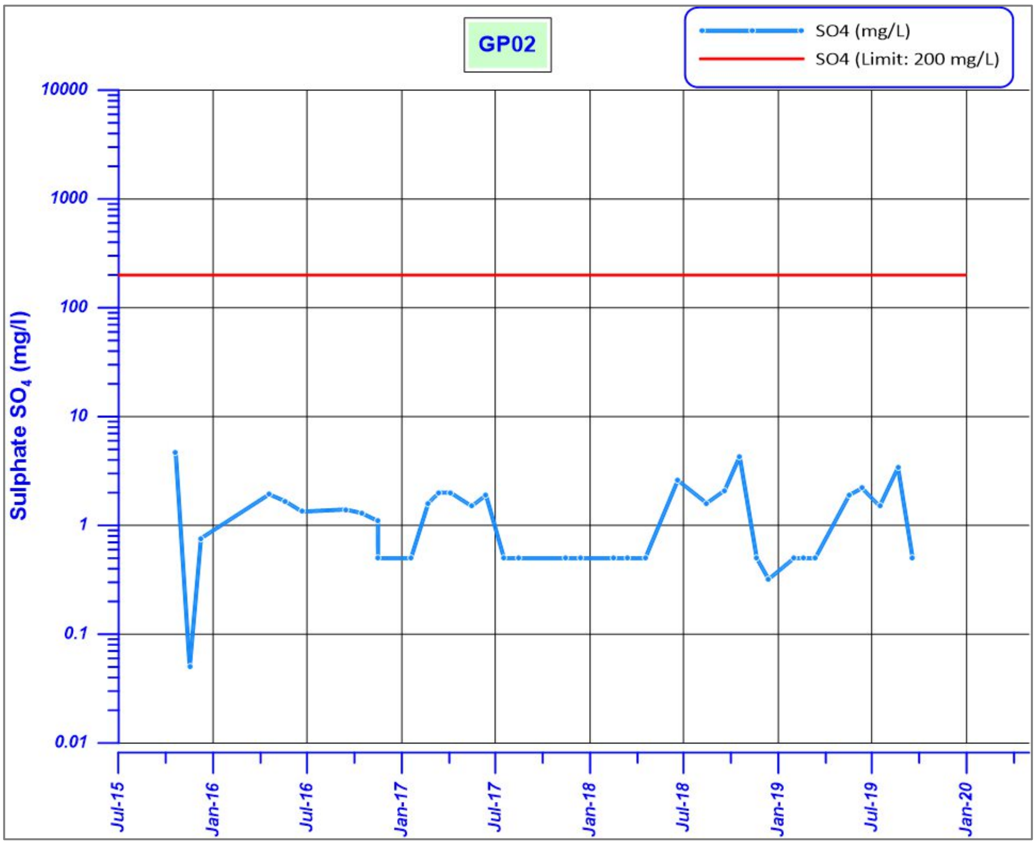

EBH08
TDS (mg/l)
TDS (Limit: 450 mg/l)
Total Dissolved Solids (mg/l)
10000
1000
100
10
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20


FB
SO4 (mg/L)
SO4 (Limit: 200 mg/L)
Sulphate SO4 (mg/l)
10000
1000
100
10
1
0.1
0.01
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20


FB
TDS (mg/l)
TDS (Limit: 450 mg/l)
Total Dissolved Solids (mg/l)
10000
1000
100
10
1
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20


GP01
SO4 (mg/L)
SO4 (Limit: 200 mg/L)
Sulphate SO4 (mg/l)
10000
1000
100
10
1
0.1
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20


GP01
TDS (mg/l)
TDS (Limit: 450 mg/l)
Total Dissolved Solids (mg/l)
10000
1000
100
10
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20


GP02
SO4 (mg/L)
SO4 (Limit: 200 mg/L)
Sulphate SO_4 (mg/l)
10000
1000
100
10
1
0.1
0.01
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
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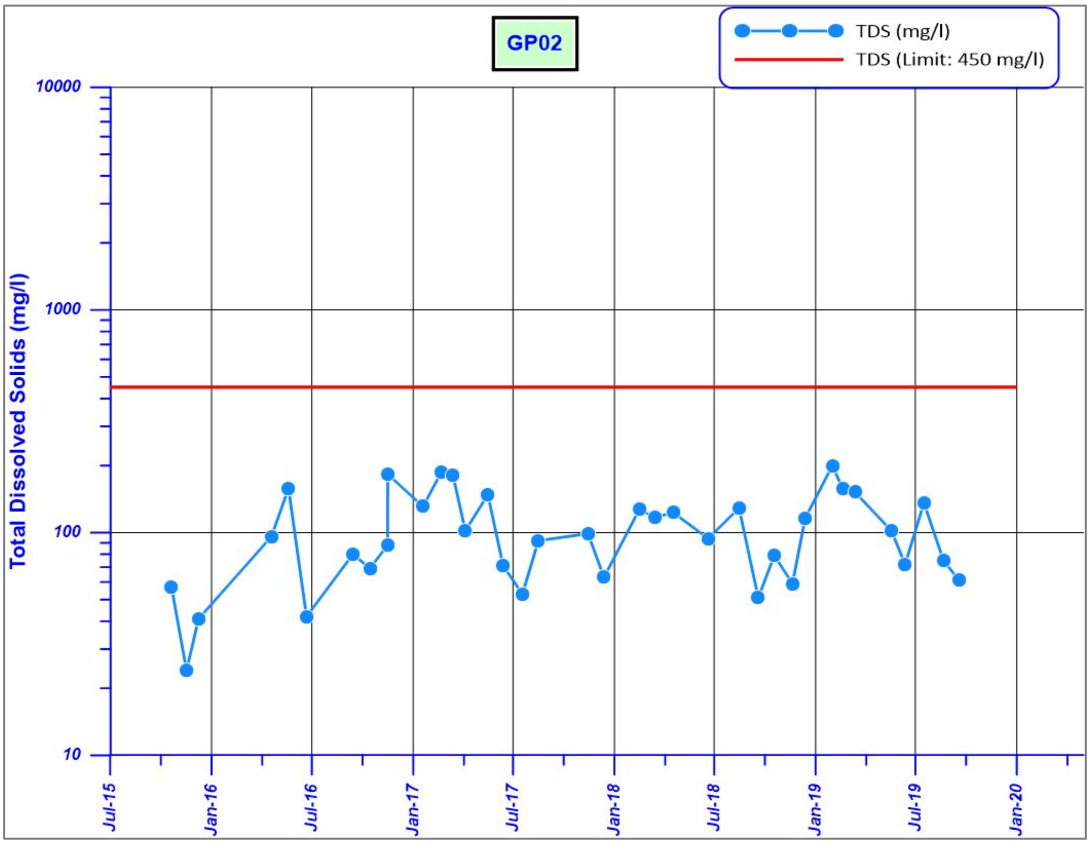
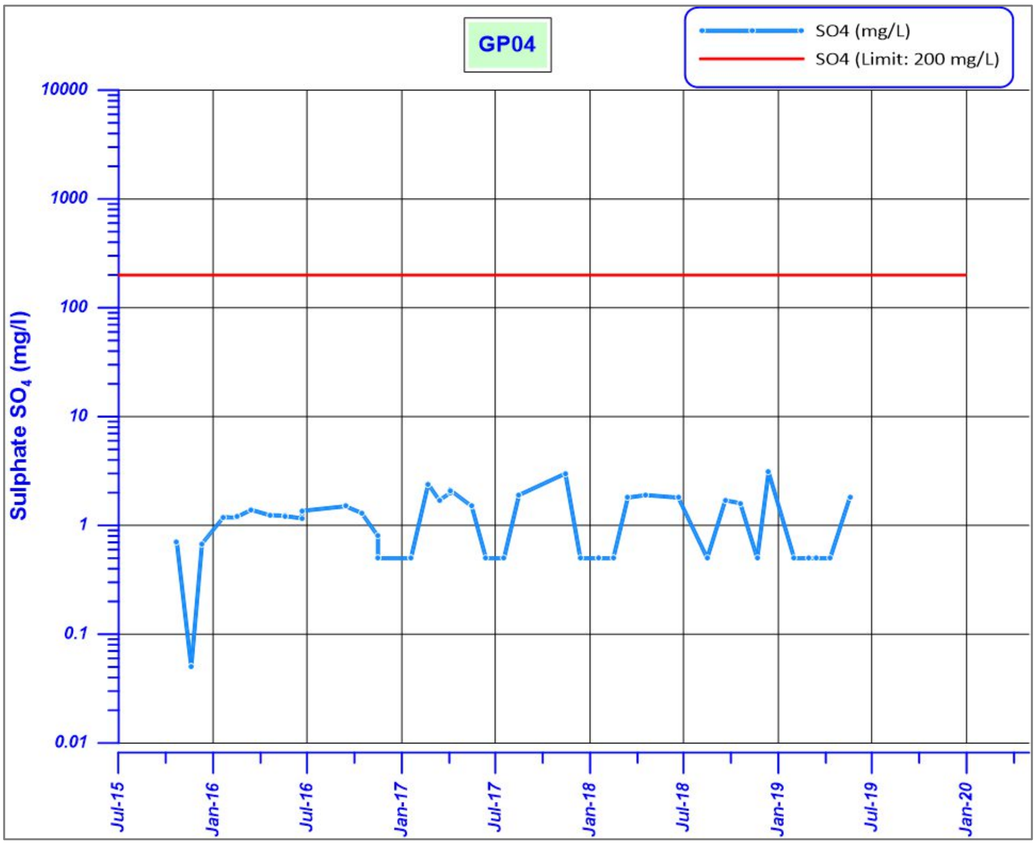
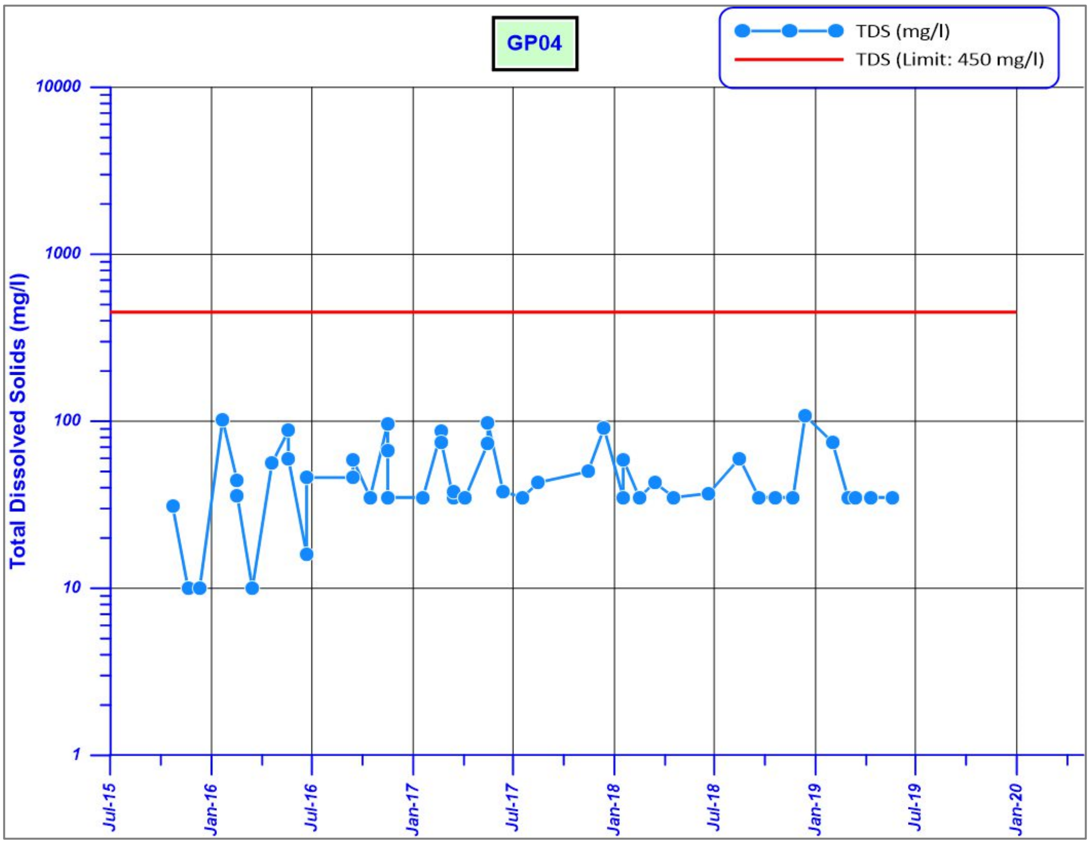
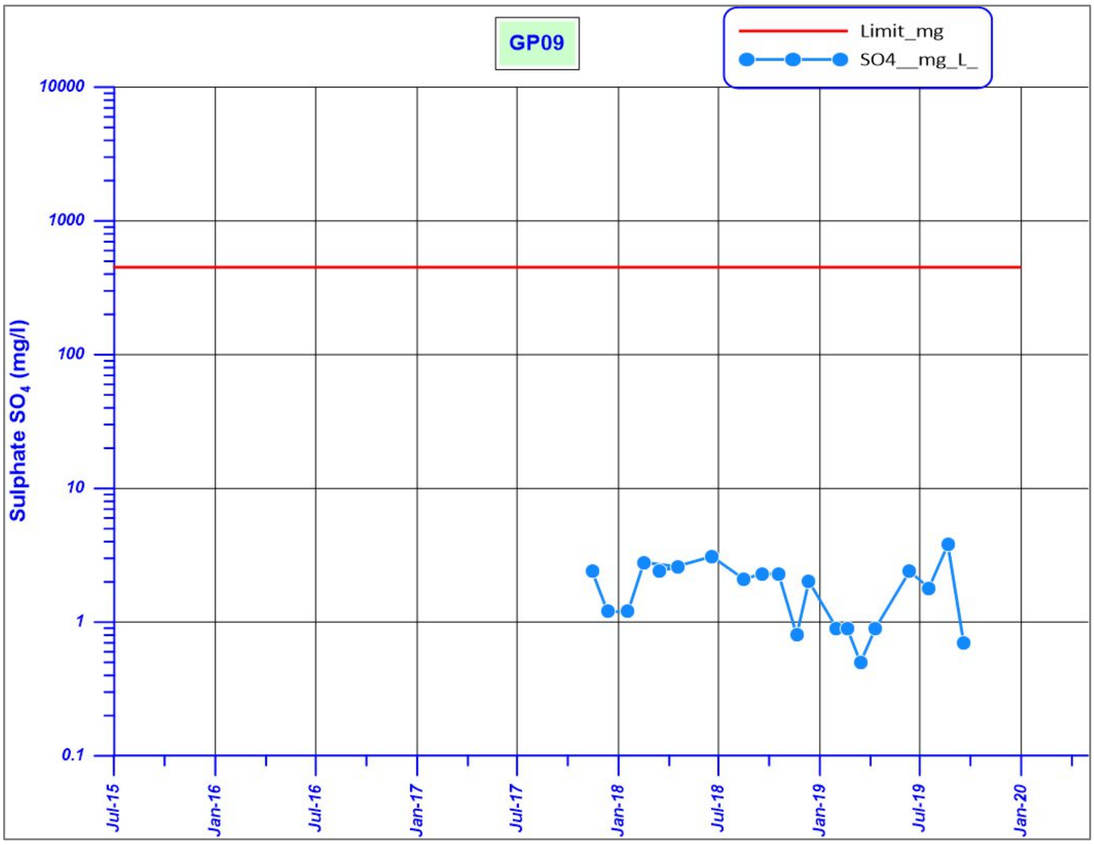
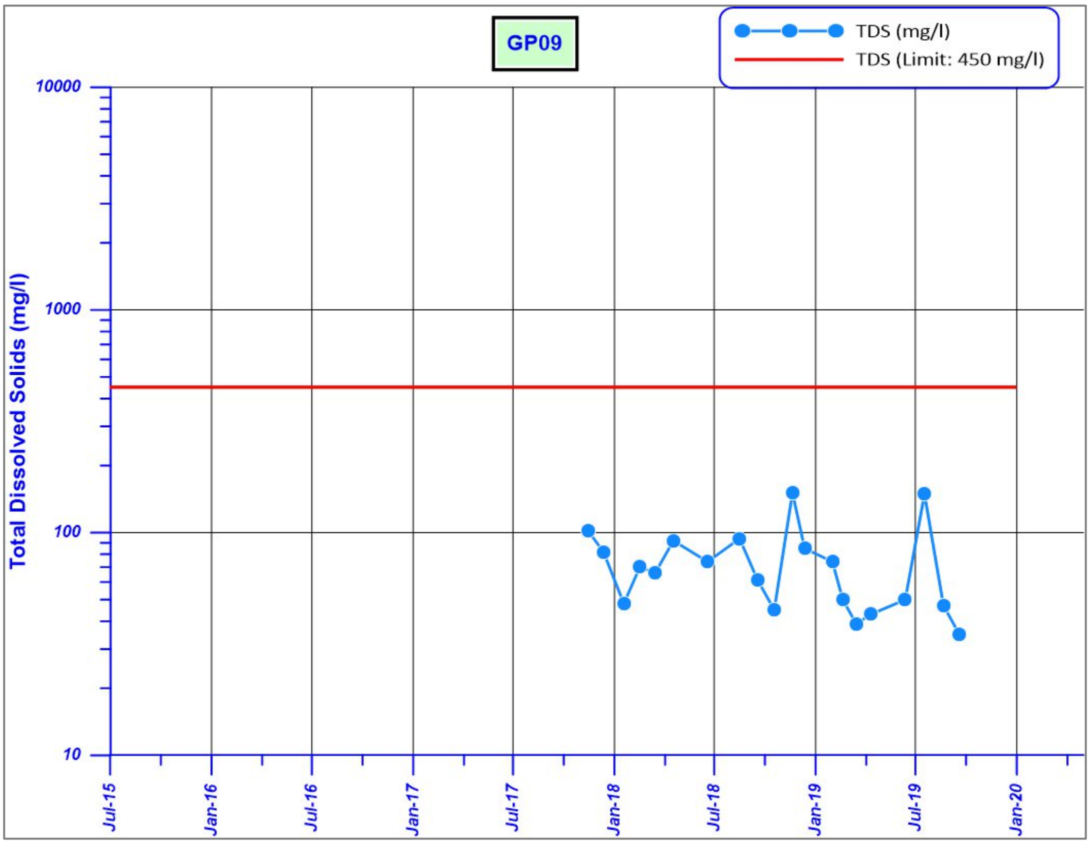
Jan-19
Jul-19
Jan-20

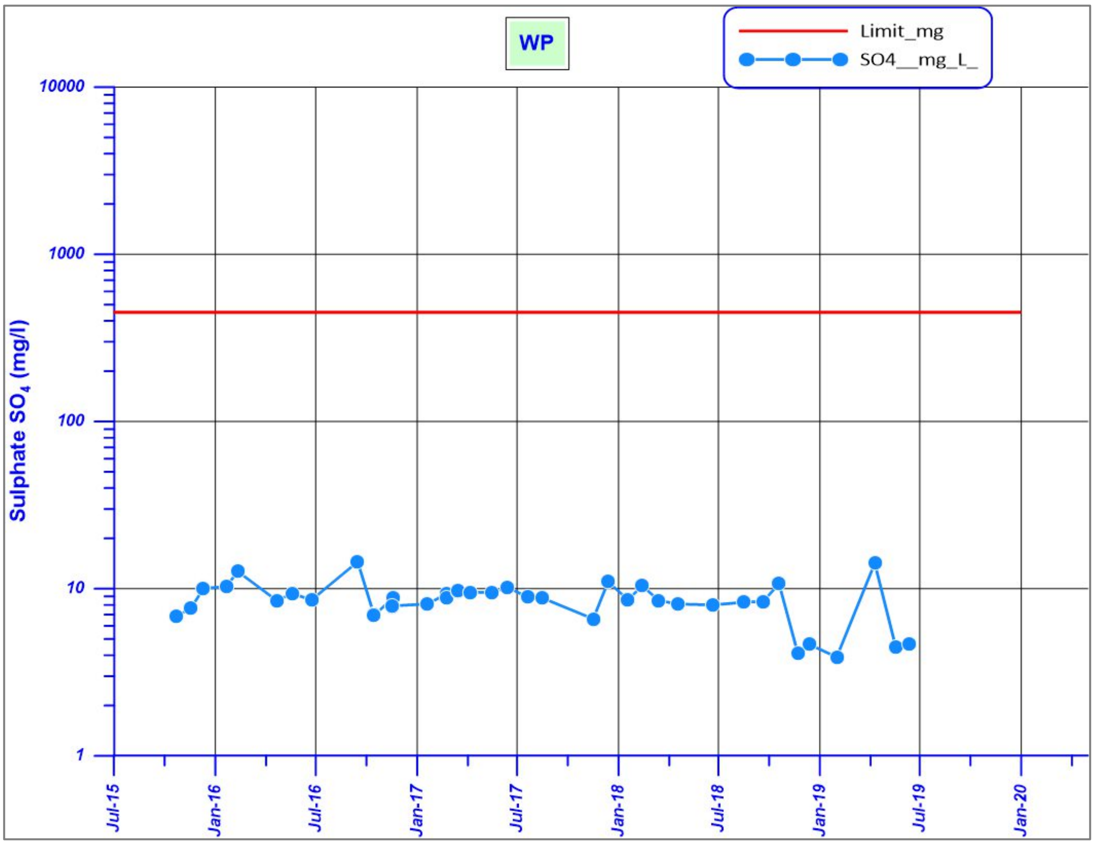

GP02
TDS (mg/l)
TDS (Limit: 450 mg/l)
Total Dissolved Solids (mg/l)
10000
1000
100
10
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20

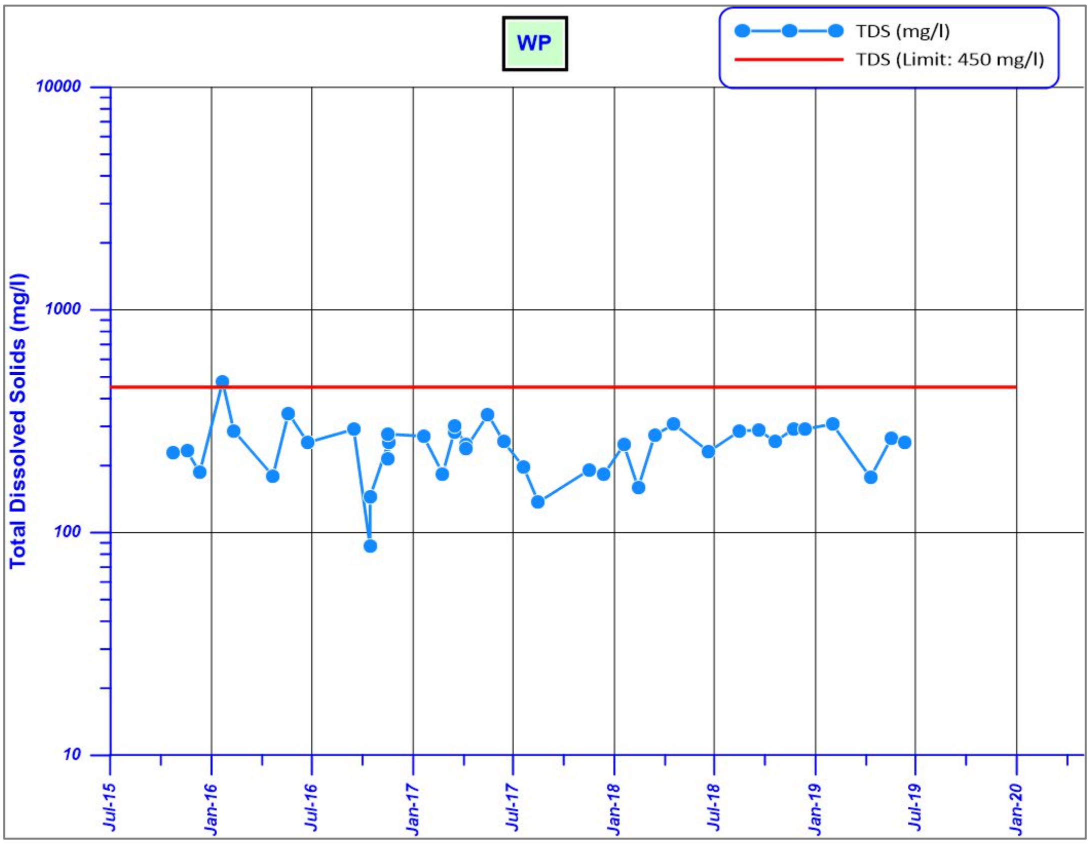

GP04
SO4 (mg/L)
SO4 (Limit: 200 mg/L)
Sulphate SO_4 (mg/l)
10000
1000
100
10
1
0.1
0.01
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20


GP04
TDS (mg/l)
TDS (Limit: 450 mg/l)
Total Dissolved Solids (mg/l)
10000
1000
100
10
1
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20


GP09
Limit_mg
SO4__mg_L_
Sulphate SO4 (mg/l)
10000
1000
100
10
1
0.1
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20


GP09
TDS (mg/l)
TDS (Limit: 450 mg/l)
Total Dissolved Solids (mg/l)
10000
1000
100
10
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20


WP
Limit_mg
SO4__mg_L_
Sulphate SO_4 (mg/l)
10000
1000
100
10
1
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20


WP
TDS (mg/l)
TDS (Limit: 450 mg/l)
Total Dissolved Solids (mg/l)
10000
1000
100
10
Jul-15
Jan-16
Jul-16
Jan-17
Jul-17
Jan-18
Jul-18
Jan-19
Jul-19
Jan-20

APPENDIX C

Document Limitations

DOCUMENT LIMITATIONS

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