REPORT

Hydropedological specialist study for the Integrated Water Use Licence Application for Belfast Expansion Project

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Executive Summary

The Belfast Mine of Exxaro Coal Mpumalanga Proprietary Limited (Exxaro) has an existing approved Integrated Water Use License (IWUL) for the Belfast Implementation Project (BIP) and is in the process of another IWUL Application for the Belfast Expansion Project (BEP).

Exxaro has appointed Golder Associates Africa (Pty) Ltd. (Golder) to provide assistance with the Integrated Water Use License Application (IWULA), Integrated Water and Waste management Plan (IWWMP) and associated specialist studies, including a hydropedological study, for the Exxaro BEP operation.

The aim of the hydropedology study is to explain how pedology, groundwater, surface water and wetlands feed into each other to conceptualise the hydrological processes spatially. The conceptual understanding of the baseline hydropedological conditions and the interaction between the surface and groundwater was used to assess the impacts on sensitive receptors such as rivers, wetlands, and groundwater.

This report details the study objectives, approach, results, and impact assessment for the hydropedological study for the Belfast expansion project.

The objectives of the hydropedology specialist study are as follows:

- Classify the hydropedological soil types of the project area and present a conceptual understanding of the baseline hydropedological conditions.
- Quantify the percentage loss of hydropedological recharge to the wetlands based on simple hydropedological principles.
- Determine the significance of the perceived impacts on the key drivers and receptors (hydrology, water quality, geomorphology, habitat and biota) of the wetlands associated with the study area.
- Recommend mitigation measures for perceived impacts, including the determination of a suitable buffer to ensure that appropriate consideration is given to the proposed mining activities and the perceived impacts thereof on the affected wetlands and the associated hydropedological drivers in the study area.

The mining area was divided into sub-catchments for the Leeubankspruit (western sub-catchment), Klein-Komati River (central sub-catchment) and the Driehoekspruit (eastern sub-catchment further separated into north and south).

All available information was used to develop a conceptual model for several cross sections through the area. The conceptual model cross sections indicate the flow direction, the hydrological soil type for pre-mining and operational periods to indicate how the receptor (wetland) will be affected by mining.

HYDRUS-1D models were developed for the soil zone to estimate the infiltration and these values were used as recharge into a FEFLOW groundwater flow model. This could be done, because all the wetlands are linked to and fed by groundwater (in addition to being fed from rainfall and interflow soils where present). Two groundwater flow scenarios were modelled:

- Model A: A single recharge value (39.3 mm/a or 5.5% of MAP) was applied to the entire modelling area.
- Model B: Recharge was applied only to the recharge soils using 175 mm/a (25% of MAP) as estimated from the HYDRUS model. Zero recharge was applied to interflow and responsive soils.

Results from the two groundwater models show that the highest impact will be on the wetlands of the central sub-catchment. This catchment will be extensively mined and the reduction in flow to the wetlands in this sub-

catchment is expected to be 34%. The reduction in flow to the wetlands in the western catchment is 10% - 20% and the flow reduction to the wetlands in the eastern sub-catchment is less than 5%.

The reduction in area compared to the model results is listed below:

- Western sub-catchment: The final reduction in area is 13% and the models simulated flow reductions of 11.4% and 19.7%.
- Central sub-catchment. The final reduction in area is 37% and the models simulated flow reductions of 34.4% and 34.0%.
- Eastern sub-catchment: The final reduction in area is 19% and the models simulated flow reductions of 3.6% and 0.2%.

The simulated reduction in flow is closely related to the reduction in area for the western and central catchments. However, the simulated flow reduction in the eastern catchment was much less than the percentage reduction in area. This can be explained by the position of the mining area in the catchment. All mining will be on the downstream part of the catchment and therefore the impact is much lower than expected when just considering the reduction in area.

It is however noted that reduction in the quaternary catchment area due to mining is 2% when all the mining is active at the same time. This reduction in area will be mitigated by shaping and covering after mining. If the shaping and covering can start as the mining is rolled out, the area reduction will be less than 2%. It is therefore anticipated that the flow reduction at catchment level will be negligible.

For the impact assessment, the wetlands were grouped together based on the following criteria:

- Wetlands that are completely removed by mining.
- Wetlands that are mostly removed (more than 70% of the wetland will be removed by mining).
- Wetlands that are partially removed by mining (more than 30 % of the wetland will remain).
- Wetlands that are impacted by upslope mining and removal of recharge soils.
- Wetlands that are impacted by upslope mining and removal of interflow soils.
- Wetlands where the upstream wetlands have been impacted. This is an indirect impact on the wetland where inflow from upstream may be compromised.

All the impacts are related to mining. After mining, rehabilitation will take place in the form of shaping to be free draining. It was assumed that a soil cover will be placed on the opencast areas and that the area will be re-vegetated.

It is recommended that the shaping should consider the pre-mined topography, specifically where wetlands were partially removed. The topography should at least be draining towards the remaining part of these wetlands. Where part of a wetland was removed by mining, the wetland should be rehabilitated by covering the wetland areas with responsive soils.

In the areas where interflow soils were removed by mining, all effort should be made to replace interflow soils in these areas and that the slope should resemble the slope prior to mining. In order to replace the interflow soils, they need to be stockpiled separately before mining. The interflow soils are the Avalon and Bainsvlei soil forms.

These recommendations are aimed to re-instate the hydropedological function of the wetlands.

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1.0 INTRODUCTION

Exxaro Coal Mpumalanga Proprietary Limited (Exxaro) is a mining company producing coal. The Belfast expansion project (BEP) area falls under the 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 eMakazeni (Belfast) on the farms Leeubank, Zoekop and Blyvooruitzicht. It is approximately 5819 ha in extent and mostly comprises undeveloped agricultural land and semi-natural and natural grassland.

The Exxaro projects department was tasked to evaluate the Belfast resource for potential scenarios to add additional export tonnages from the Belfast resource to the Exxaro portfolio. The exploitation analysis of the Belfast Resource outside the current BIP layout area revealed that there is potential for a 5 200 kcal/kg (kilocalorie/kilogram) open cast and underground mining scenario as well as a 5 800 kacl/kg (kilocalorie/kilogram) underground scenario. A potential of 39.7 Mt (million tonnes) of RoM can be additionally mined at a yield of 69% (sixty nine percent) resulting in 27.4 Mt of product.

Currently the Belfast Implementation Project (BIP) has an existing approved Integrated Water Use License (IWUL) number 05/X11D/ABCFGIJ/2613) and this IWUL Application will be an expansion of the BEP area.

Exxaro has appointed Golder Associates Africa (Pty) Ltd. (Golder) to provide assistance with the Integrated Water Use License Application (IWULA), Integrated Water and Waste management Plan (IWWMP) and associated specialist studies, including a hydropedological study, for the Exxaro BEP operation.

The aim of the hydropedology study is to explain how pedology, groundwater, surface water and wetlands feed into each other to conceptualise the hydrological processes spatially. The conceptual understanding of the baseline hydropedological conditions and the interaction between the surface and groundwater was used to assess the impacts on sensitive receptors such as rivers, wetlands, and groundwater.

This report details the study objectives, approach, results, and impact assessment for the hydropedological study for the Belfast expansion project.

2.0 PROJECT LIMITATIONS

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

This hydropedological study investigated the impact of opencast mining (BIP and BEP areas) on the wetlands. The following areas were excluded from this study:

- The development of the decline area will commence after mining and rehabilitation of the area. The initial impact of opencast mining represents the worst-case scenario and the impact of the decline on wetlands will not have an additional impact. Therefore, the decline was excluded from the hydropedological study.

Note that the hydropedological study was conducted in March 2020 and used the mine plans.

BIP: Wings_Scenario4b_November2019.shp.

BEP: BEP_Unconstrained OC Potential for Environmental Studies 2020-01-17.DXF.

Since then, more recent mine plans became available, they were:

BIP: BIP LOM 2020.shp.

BEP: BEP opencast schedule update 2020.shp.

All calculations based on the previous mine plans and conducted in March 2020 were not reworked. However, the impact assessment was based on the latest mine plans.

3.0 PROJECT DESCRIPTION

Hydropedology is an emerging field formed from the intertwining branches of soil science and hydrology.

Hydropedological studies aim to characterise the dominant surface and sub-surface flow of water through the landscape to wetlands and streams or to the groundwater. The Department of Water and Sanitation (DWS) guideline for hydropedological assessments (van Tol et al., 2021) gives two steps to follow for impact assessments that require a hydropedological survey, they are:

- Identification of dominant hillslopes.
- Conceptualising hillslope hydrological responses.

The Belfast Mine is currently mining the BIP opencast area and plans mining the BEP area. The BEP mining will consist of opencast and underground mining. The underground mining will not disturb soils, therefore only the opencast mining for the BIP and BEP areas have been considered in terms of hydropedology.

Opencast mining destroys the soil layers and therefore the hydropedological function of the soils are impacted. This study aims to assess the impact of mining on wetlands based on the loss of the hydropedological contribution to the wetlands.

4.0 OBJECTIVES

The objectives of the hydropedology specialist study are as follows:

- Classify the hydropedological soil types of the project area and present a conceptual understanding of the baseline hydropedological conditions.
- Quantify the percentage loss of hydropedological recharge to the wetlands based on simple hydropedological principles.
- Determine the significance of the perceived impacts on the key drivers and receptors (hydrology, water quality, geomorphology, habitat and biota) of the wetlands associated with the study area.
- Recommend mitigation measures for perceived impacts, including the determination of a suitable buffer to ensure that appropriate consideration is given to the proposed mining activities and the perceived impacts thereof on the affected wetlands and the associated hydropedological drivers in the study area.

5.0 METHODOLOGY

Hydropedology is an emerging discipline which integrates the principles of soil science and hydrology to understand how soil architecture and the distribution of soils within a landscape, control hydrologic processes and conversely, how hydrologic processes control soil genesis (Lin, 2012). Our approach to the hydropedology assessment includes an assessment of the soil characteristics and associated soil distribution map, wetland classification and consideration of basic climatic information and high-level hydrological cycle for the study area.

A conceptual model to describe the hydrological functioning of landscapes at catchment and hillslope scale as well as interactions with sensitive receptors such as wetlands, rivers and groundwater was then produced based on the soil, wetland and climate information reviewed. The baseline conceptual site model illustrates the baseline soil water flow dynamics for a representative catena (a catena is a series of soil types occurring down a slope, usually with similar parent material). The impact of the proposed activities was assessed in terms of the potential reduction in hydropedological wetland recharge. A conceptual site models illustrating the impact of the activities and proposed mitigation/control measures was also prepared.

5.1 Pedological classification

Viljoen & Associates (2009) conducted a pedological assessment and provided a soil map for the Belfast Mining areas. The available soil map, prepared by Viljoen & Associates, was used for the project area and Landtype map for the remainder of the groundwater model boundary to generate a combined soil map. This was needed so that the soil information could be incorporated in the FEFLOW numerical groundwater model to estimate the flows and potential changes in flows to wetlands within the project area. The soil map is shown in Figure 1 and the map legend is provided in the Table 1.

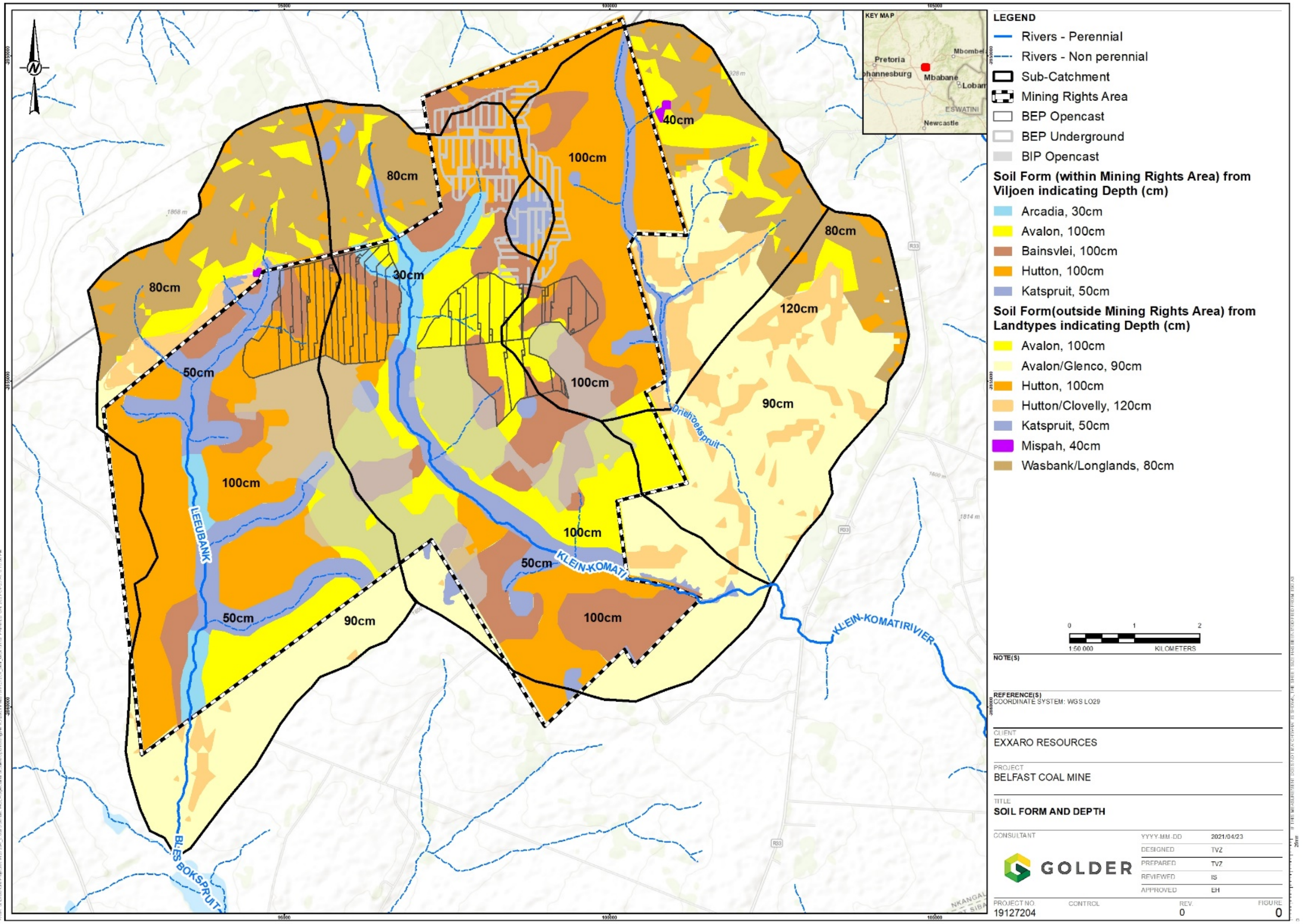

Figure 1: Soil form and depth

Table 1: Soil map legend

Simulations	Soil sequence (Catena) properties			
	Horizon	USDA Texture	Clay (%)	Effective depth(cm)
Hutton[1]	A	Medium Sandy clay loam	25	120
	B	Medium Sandy clay loam	25	
Clovelly[1]	A	Medium Sandy clay loam	25	120
	B	Medium Sandy clay loam	25	
Glencoe[1]	A	Medium Sandy clay loam	20	90
	B1	Medium Sandy clay loam	20	
	B2	Medium Sandy clay loam	34	
Avalon[1]	A	Medium Sandy clay loam	20	90
	B1	Medium Sandy clay loam	20	
	B2	Medium Sandy clay loam	34	
Bainsvlei[1]	A	Medium Sandy clay loam	20	100
	B1	Medium Sandy clay loam	20	
	B2	Medium Sandy clay loam	34	
Arcadia[2]	A	*	*	< 30
Katspruit[2]	A	*	*	< 30
	G	*	*	
Mispah[2]	A	*	*	< 30
Wasbank/Longlands[2]	A	*	*	> 30
	B	*	*	

Notes: * No detail provided on soil properties in soil report. 1) Soil information obtained from landtype memoir, 2) soil information obtained from soil report (Viljoen & Associates).

(including hydromorphic descriptions, physical properties)

5.2 Climate

The climate is typical of the Middelveld to Highveld and representative of the temperate, warm climatic zone. The area receives the majority of rainfall over the summer period, from October to March (Golder, 2011).

The Belfast Mine weather station (CR1000X) rainfall and evaporation data from November 2018 to March 2021 (2 years and 5 months). The average rainfall for this period was 889.1 mm/a and the average evaporation was 1344.8 mm/a. However, this was a wetter than average period.

The average Mean Annual Precipitation (MAP) for the 0516554 W weather station (~17 km from the study area), is 693 mm. The nearest weather station with a reliable evaporation dataset near the Belfast site is Station X1E003, located at the Nooitgedacht dam. The station is 16.6 km away from the Belfast Mine. The station's Mean Annual Evaporation (MAE) is 1807 mm/a (S-Pan) and the MAP is 734.9 mm/a. The length of record is from 1961 to 2020(58 years). The average monthly evaporation for X1E003 is presented in Figure 2. The figure also includes the average monthly rainfall from station 0516554 W.

A comparison of the rainfall and evaporation for the Belfast Mine weather station (CR1000X) and X1E003 is presented in Table 2.

Table 2: Comparison of rainfall and evaporation data

Date	Station	Rainfall (mm)	Evaporation (mm)
Annual average from 1961	X1E003	734.9	1807.2
Annual average from Nov 2018 to Jan 2020	X1E003	844.2	1957.9
	CR1000X	889.1	1344.8
Annual average from Nov 2018 to Mar 2021	CR1000X	943.2	1415.5

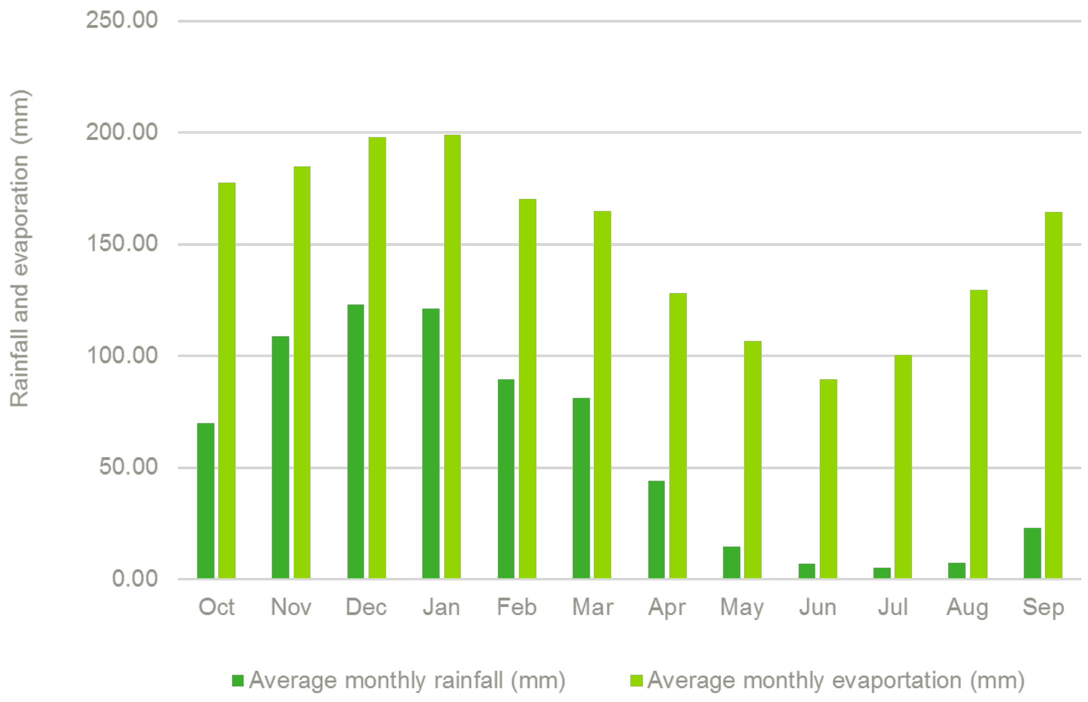

Figure 2: Comparison between the average monthly rainfall (Station 0516554 W) and evaporation (Station X2E002) in the area

5.3 Site Hydrology

This portion of the report provides a summary the surface water and groundwater hydrology of the site. Separate specialist surface water and groundwater studies have been conducted for the larger environmental assessment and the description below is extracted from the abovementioned reports.

5.3.1 Surface water hydrology

Regionally the area is located in the Komati River catchment of Drainage Region X. Locally the area falls over the X11C and the X11D quaternary catchment. The Belfast site is located on the south-western edge of the X11D catchment area, southward of the Klein-Komati River. The X11C quaternary catchment covers an area of 31 942 hectares while the X11D catchment areas has an area of 59 152 ha. The mean annual runoff (MAR) for the X11C and X11D catchments are 45 and 88 mm respectively. The surface water flow direction is determined by the local topography.

5.3.2 Topography and Drainage

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 elevation of the site ranges from 1750 to 1860 meters above mean sea level (mamsl).

The topography of the investigation area consists of slightly undulating topography of open grassland, typically found in the central Highveld. 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 elevation is at 1775 mamsl. The site was subdivided into sub-catchments for the Leeubankspruit (western sub-catchment), Klein-Komati River (central sub-catchment) and the Driehoekspruit (eastern sub-catchment further separated into north and south).

5.3.3 Aquifer Classification

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; 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; and
- Deep fractured aquifer system; confined aquifer system with reported water strikes between 118 to 120 mbgl (Table 3), 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.

Table 3: 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

5.3.3.1 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 (Groundwater Complete August 2014).

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).

5.3.3.2 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. It was reported by landowner, Mr. WP Pretorius that a 5.6 l/s borehole exists on his farm, Zoekop. No information confirming this statement could be obtained from the user and access to the borehole could not be obtained during both the hydrocensus surveys (Groundwater Complete August 2014).

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 4), the aquifer could be regarded as a minor, but often a sole aquifer system (Groundwater Complete 2014).

Table 4: Parsons Aquifer Classification (Parsons 1995)

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.

5.3.3.3 Deep Fractured Aquifer System

Based on the existing reports a third aquifer system – Deep fractured aquifer system (Table 4), fresh to fractured (confined) can also been identified. This aquifer system is present with in the Transvaal Supergroup with reported water strikes intersected between 118 to 120 mbgl.

5.4 Wetland Classification

Golder has assisted Exxaro with the monitoring of wetlands within the mine property. Three major Channelled valley bottom wetland systems flow through the project area, namely, the Leeubankspruit (LS system), Klein Komati River (KS system) and the Driehoekspruit (DS system) systems as shown in Figure 4. Other wetland systems identified within the project area include Unchannelled Valley Bottoms, Isolated Hillslope Seeps, Pans, Depressions and Hillslope Seeps.

5.4.1 Wetland Health Assessment – Present Ecological Status (PES)

The current health, or ecological integrity of each relevant wetland hydrogeomorphic unit was assessed as part of the wetland monitoring conducted by Golder. The Level 2 WET-Health assessment approach assesses wetlands using three modules; hydrology, geomorphology and vegetation. The wetland's health is inferred based on the analysis of catchment and/or on-site activities, as well as visible indicators of damage (e.g. erosion gullies) that have an impact on wetland hydrology, geomorphology and vegetation, resulting in the production of a health score for each component.

The scores for the hydrology, geomorphology and vegetation modules are then integrated based on a weighted average ratio of 3: 2: 2 (given that hydrology is considered to have the greatest contribution to health), to give an overall **Present Ecological State (PES) score**, enabling the placement of the wetland unit into a present state category, and identification of current impacts undermining the integrity of each unit. A description of the impact categories and scores and associated present state categories is provided in Table 5. The Present Ecological State for each monitoring site is shown in Figure 5.

Table 5: Impact scores and categories of Present State used by WET-Health for describing the integrity of wetlands (Macfarlane et al., 2007)

Impact Category	Description	Impact Score Range	Present State Category
None	Unmodified, or approximates natural condition	0 – 0.9	**A**
Small	Largely natural with few modifications, but with some loss of natural habitats	1 – 1.9	**B**
Moderate	Moderately modified, but with some loss of natural habitats	2 – 3.9	**C**
Large	Largely modified. A large loss of natural habitat and basic ecosystem function has occurred	4 – 5.9	**D**
Seriou	Seriously modified. The losses of natural habitat and ecosystem functions are extensive	6 – 7.9	**E**
Critical	Critically modified. Modification has reached a critical level and the system has been modified completely with almost complete loss of natural habitat	8 – 10.0	**F**

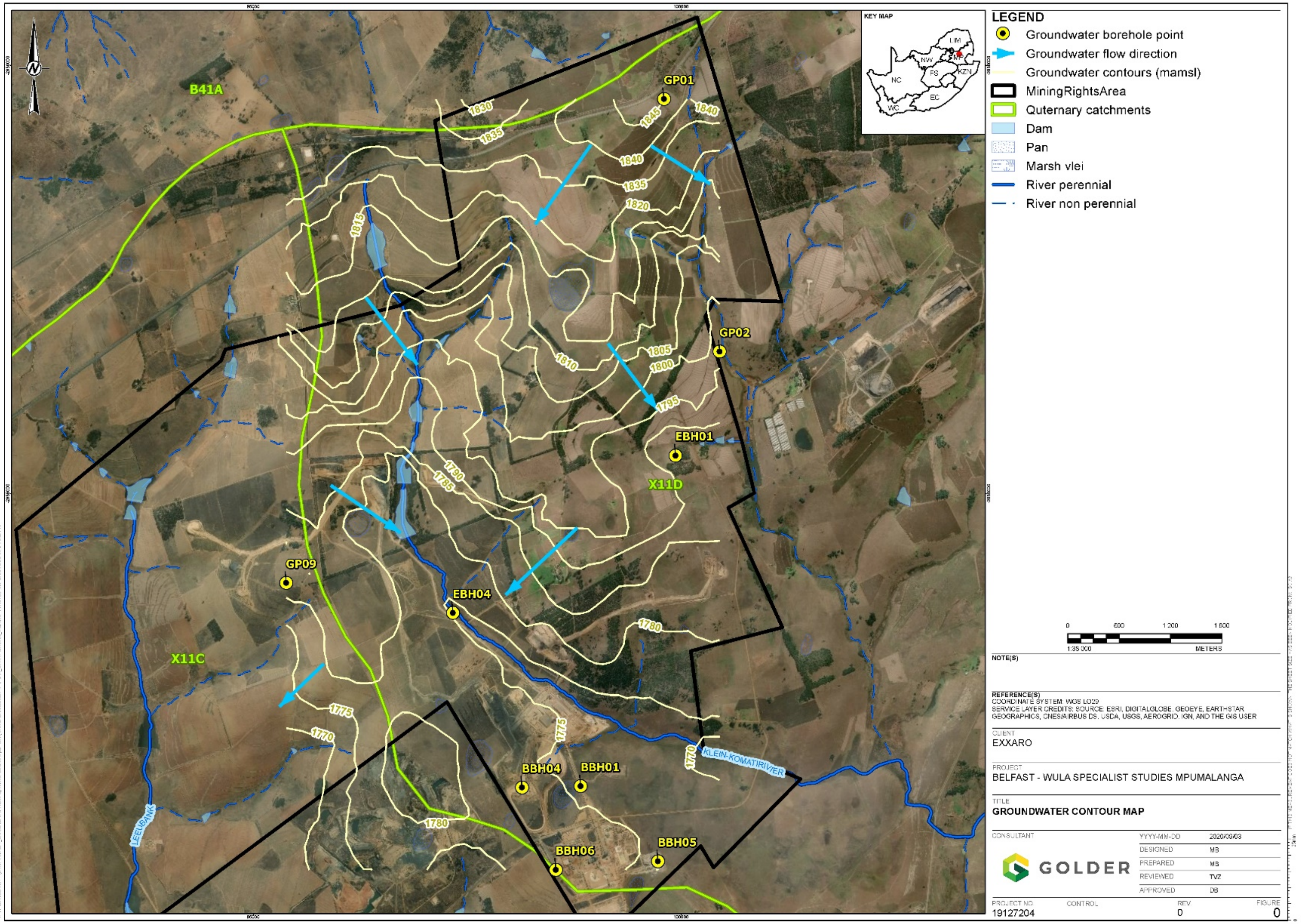

Figure 3: Groundwater Piezometric contour map

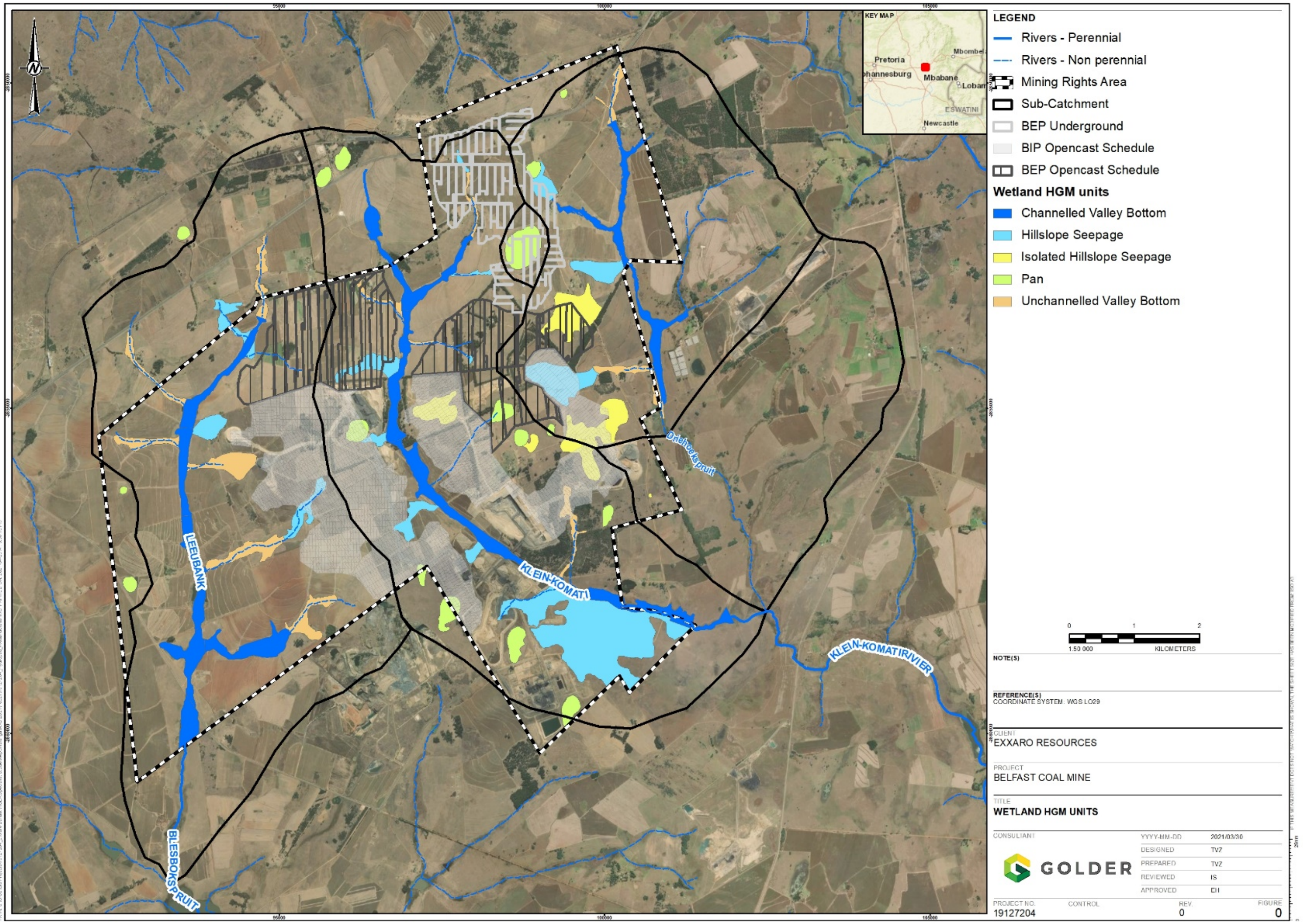

Figure 4: Wetland classification (HGM units)

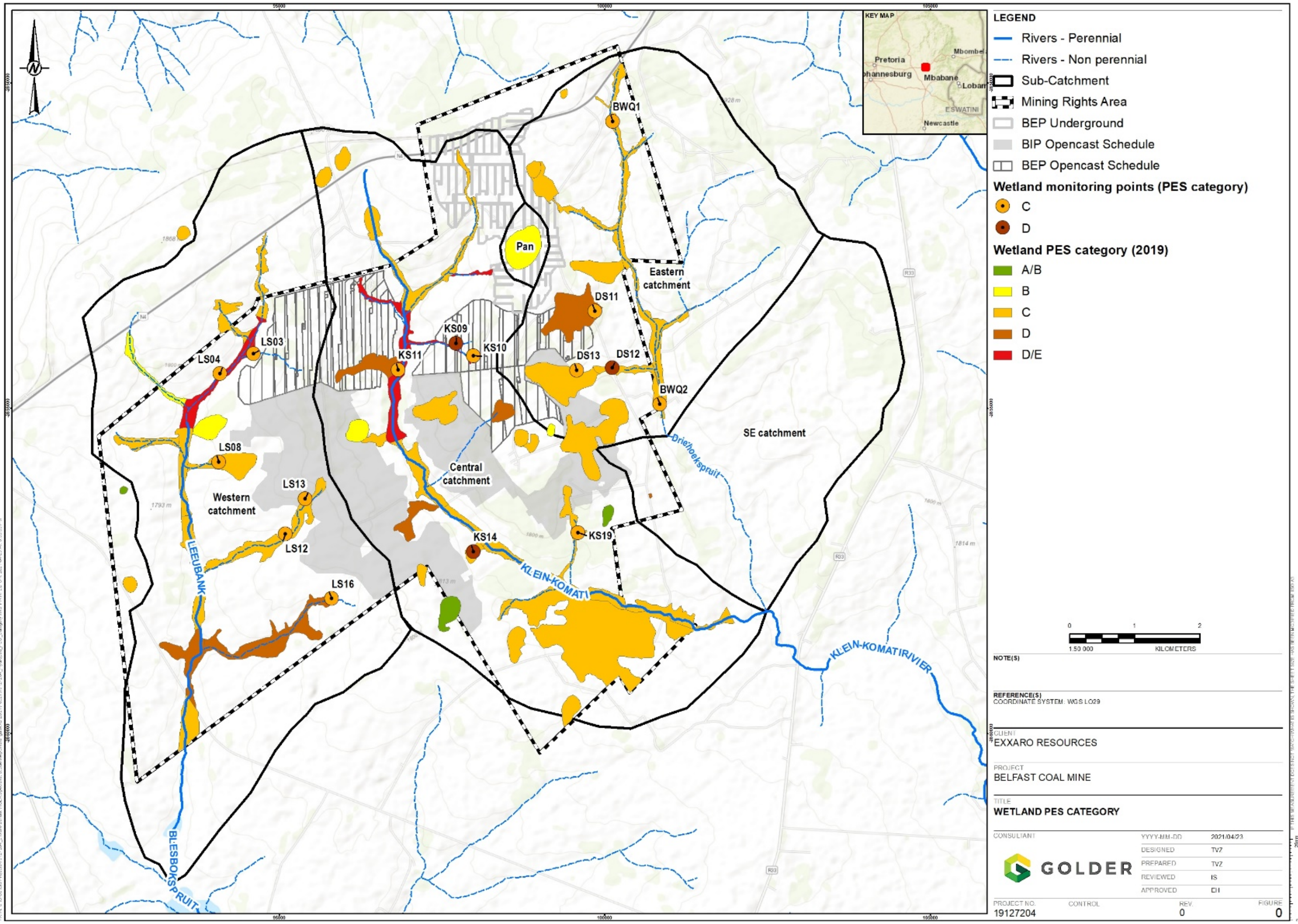

Figure 5: PES score for wetlands in 2019 monitoring network

5.5 Hydrological Soil Type Classification

In South Africa, hydropedological classification of soils are based on defining the hydrological function of soils within a hillslope (van Tol *et al*., 2013). The pedological soil forms are typically associated with soil water regimes. The soil form along with the soil hydromorphic signatures and can be used to infer soil water flow dynamics. In work by van Tol (2019) the pedological soil forms have categorised according to their hydropedological function in a hillslope. These categories were used to define the hydropedological classification of the project area. The hydrological soil types are presented in Table 6. The soil forms that are present in the study area are printed in bold in the table.

Table 6: Hydrological soil types (reproduced from van Tol *et al*., 2013, 2019)

Hydrological soil type	Description (van Tol et al., 2013)	Associated soil form (van Tol et al., 2019)
Recharge	Soils without any morphological indication of saturation. Vertical flow through and out of the profile into the underlying bedrock is the dominant flow direction. These soils can either be shallow on fractured rock with limited contribution to evapotranspiration or deep freely drained soils with significant contribution to evapotranspiration.	Kranskop, Magwa, Inanda, Lusiki, Sweetwater, Bonhein, Inhoek, Constantia, Tsitikamma, Concordia, Houwhoek, Griffin, Clovelly, **Hutton**, Shortlands, Pinegrove, Groenkop, Valsriver, Swartland, Dundee, Namib, Nomanci, Mayo, Milkwood, Jonkershoek, Glenrosa, Mispah, Witbank
Interflow (A/B)	Duplex soils where the textural discontinuity facilitates buildup of water in the topsoil. Duration of drainable water depends on rate of ET, position in the hillslope (lateral addition/release), and slope (discharge in a predominantly lateral direction).	Kroonstad, Longlands, Wasbank, Klapmuts, Vilafontes, Kinkelbos, Cartref
Interflow (soil/bedrock)	Soils overlying relatively impermeable bedrock. Hydromorphic properties signify temporal build of water on the soil/bedrock interface and slow discharge in a predominantly lateral direction.	Lamotte, Fernwood, Westleigh, **Avalon**, Pinedene, **Bainsvlei,** Bloemdal, Witfontein, Sepane, Tukulu, Montagu
Responsive (shallow)	Shallow soils overlying relatively impermeable bedrock. Limited storage capacity results in the generation of overland flow after rain events.	Nomanci, **Arcadia**, Mayo, Milkwood, Glenrosa, Mispah
Responsive (saturated)	Soils with morphological evidence of long periods of saturation. These soils are close to saturation during rainy seasons and promote the generation of overland flow due to saturation excess.	Champagne, Rensburg, Willowbrook, **Katspruit**
Stagnating	Soils where outflow of water is restricted or limited, and have morphological signatures which indicate that neither recharge or interflow are dominant.	Steendal, Immerpan, Dresden, Glencoe, Molopo, Askham, Kimberely, Plooysburg, Garries, Etosha, Gamoep, Oudtshoorn, Addo, Prieska, Trawal, Augrabies, Brandvlei, Coega, Knersvlakte

5.6 Wetland hydropedological recharge estimation

To assess the change in hydropedological recharge to the wetlands, the percentage occurrence of the hydrological soil types and their associated recharge rates, within the study area, was determined. The recharge (infiltration rate) of the representative hydrological soil profiles delineated for the project area was estimated using HYDRUS-1D software. HYDRUS-1D is a public domain Windows-based modelling environment for analysis of water flow and solute transport in variably saturated porous media. The software package includes a one-dimensional finite element model to simulate the movement of water, heat and multiple solutes. The model is supported by an interactive graphics-based interface for data pre-processing, discretization of the soil profile and graphic presentation of the results. The program numerically solves Richards' equation for variably saturated water flow. The HYDRUS-1D model code is widely accepted by the professional community for evaluating variably saturated flow and solute transport processes.

To gain a further conceptual understanding of the overall project impact, the pre- and post-intervention flows to the wetlands were simulated by incorporating the estimated soil recharge rates in the existing FEFLOW groundwater model. FEFLOW is a computer program for simulating groundwater flow, mass transfer and heat transfer in porous media and fractured media. The program uses finite element analysis to solve the groundwater flow equation of both saturated and unsaturated conditions. FEFLOW can also be used to understand the potential water fluxes to the wetlands because of the changes in hydropedological recharge and decant from groundwater.

A simplistic analytical model which considers the hillslope characteristics, hydrological soil type, soil textural class, soil hydraulic conductivity, mean annual precipitation, mean annual evaporation, transpiration and surface runoff was developed to estimate the percentage of recharge to the wetlands within the study area. The model is based on standard hydrological and pedological principles.

6.0 RESULTS

6.1 Hydropedological Soil Type Classification

The project area comprises 16% Recharge soils, 73% Interflow soils, 11% Responsive soils. The distribution of the hydropedological types within the project area is shown in Figure 6.

6.1.1 Recharge soils

The Hutton soil form is the dominant recharge soil type within the project area. These soils are characterised as structureless (apedal), red, mostly deep (> 120 cm), well-drained soils, typically occurring in the upslope landscape position. These soils are associated with oxidising conditions and formed under most climatic conditions and parent materials found in South Africa (SCWG, 1991). The Hutton soils occurring within the project area, are medium-fine textured sandy clay loam (SaClLm), with an estimated clay content of 15 – 25 % in the Orthic A horizon and 25 – 35 % clay in the Red Apedal B horizon. The higher clay content of these soils favours a degree soil water retention. However, due to the position in which these soils occur, i.e., upslope or crest, the soils tend to be well drained without signs of wetness. Most of the soils occurring in the project area are fine-medium SaClLm but based on their position in the landscape and differences in subsoil consistencies, have different soil hydraulic behaviours and subsequently different redoximorphic signatures. The Hutton soils water flow is expected to be mostly vertical and controlled by the soil texture, bulk density, and depth.

6.1.2 Interflow soils

Glencoe, Bainsvlei and Avalon soil forms occur in the midslope to footslope landscape position of the project area. These interflow soils consist of either red or yellow apedal B1 horizon overlying a soft or hard plinthic B2 horizon. The Yellow-Brown (YB) Apedal B, is similar to the Red Apedal B in terms of drainage and is also found widespread under varying climatic conditions. The YB colour is attributed to either the parent material with a lower ferrous iron reserve or a higher average moisture status of the horizon or both characteristics

(SCWG, 1991). Soft plinthic horizons have undergone localization and accumulation of iron and manganese oxides under conditions of a fluctuating water table. These conditions create the distinct reddish brown, yellowish brown and/or black mottles, with or within sesquioxide concretions as typical redoximorphic signatures of this material (SCGW, 1991). In the non-concretionary portions of the horizon, the soil matrix can also have grey colours, with a loose, friable, or slightly firm consistency. The horizon is non-indurated and can be cut with a spade when wet. The Hard Plinthic horizon consists of accumulation of iron and manganese, forming an indurated zone which cannot be cut with a spade, even when wet. The Hard Plinthic horizon is formed under the same conditions as the Soft Plinthic horizon, only for longer periods, with a resultant formation of the indurated zone. In the project area the Glencoe, Bainsvlei and Avalon soils indicate that a fluctuating water table may be present, with soil water flow being predominantly lateral flow and some degree vertical flow. For the infiltration rate estimate of the Interflow soils, a dense SaClLm was used to represent the Soft Plinthic horizon, and a hard SaClLm for the Hard Plinthic B horizon, was assumed for the simulations.

6.1.3 Responsive soils (shallow)

These are shallow soils overlying relatively impermeable bedrock with limited storage capacity resulting in the generation of overland flow after rain events (van Tol et al., 2019). The Arcadia soil form is an example of a shallow Responsive hydrological soil type which occurs in the project area. Arcadia soils are characterised by a smectitic clay-rich Vertic A horizon, dark brown or dark red in colour, and found in the valley bottom positions in the landscape. The smectite clay of the Vertic A horizon, swells and shrinks in response to changes in water content and is highly plastic when moist and sticky when wet (SCWG, 1991). This high clay content favours the soils water retention ability and are typically associated with vleis and wetlands. In the project area, the Arcadia soils are found in areas where wetlands have been delineated.

6.1.4 Responsive (saturated)

Saturated Responsive soils are those soils which exhibit morphological signs of prolonged periods of saturation and are close to saturation during the rainy seasons, where overland flow due to saturation excess typically occurs (van Tol et al., 2019). Redoximorphic signs of prolonged periods of wetness included grey and gleyed soil colours as dominant in G-horizons. In the project area, the Katspruit soil form also occurs in the valley bottom landscape positions and consists of an Orthic A horizon, overlying a G-horizon. G-horizons may also have blue or green tints, with or without mottling; randomly patterned sesquioxide mottles which may be yellowish brown, olive brown, red or black on the ped surfaces. The Katspruit soils have also been found in areas delineated as wetlands.

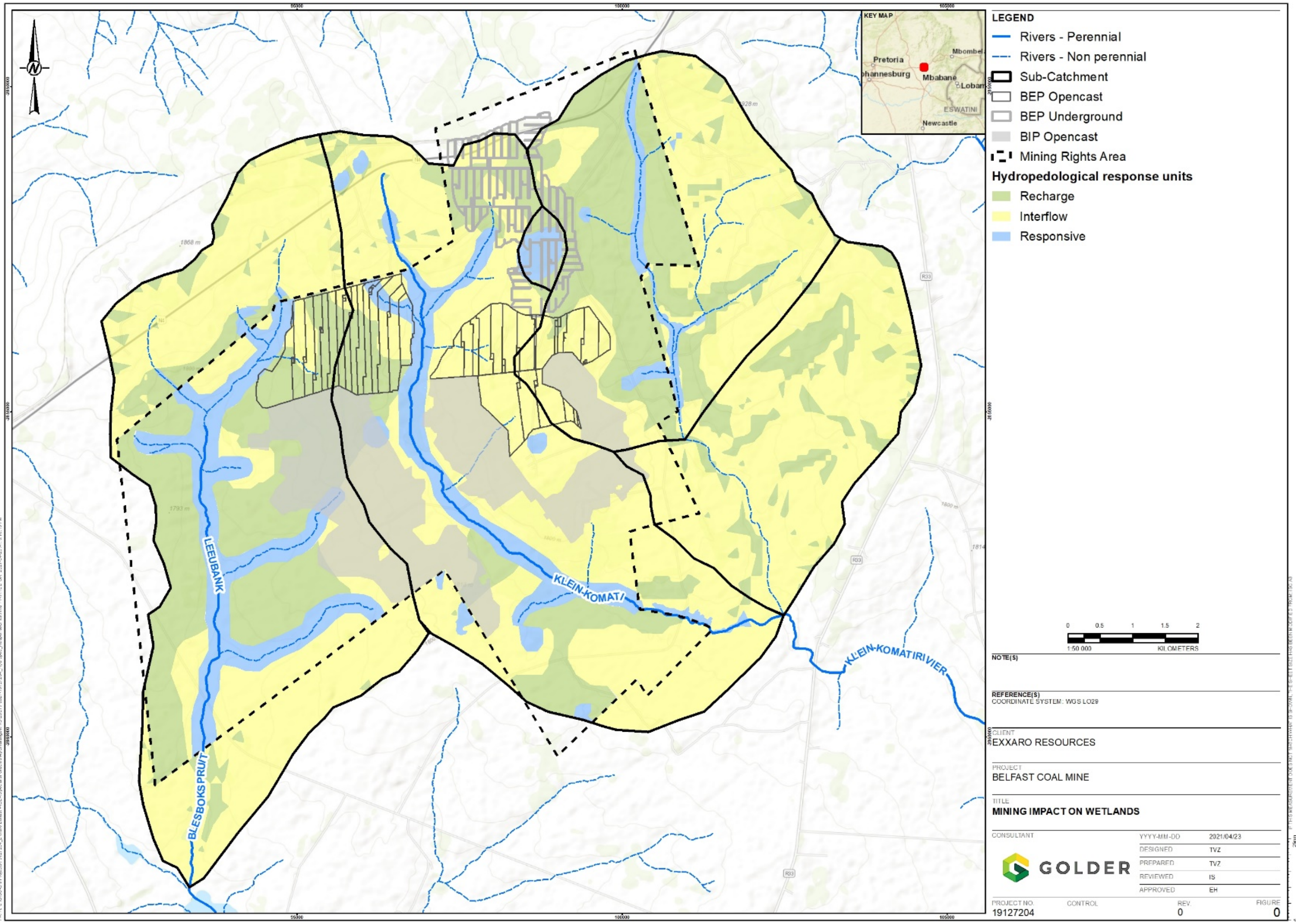

Figure 6: Distribution of hydropedological types within sub-catchments in project area

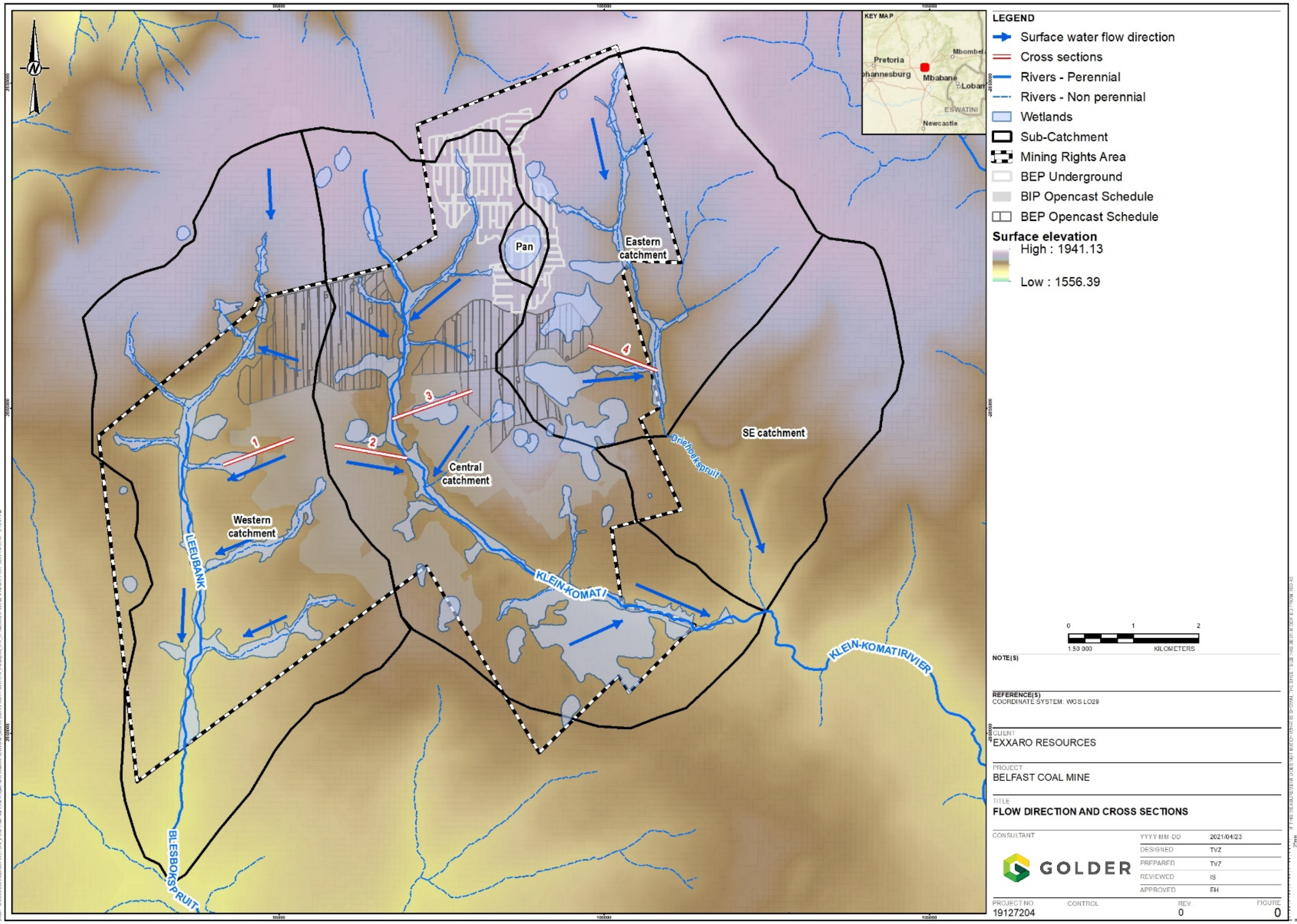

Figure 7: Flow direction and cross sections for conceptual model

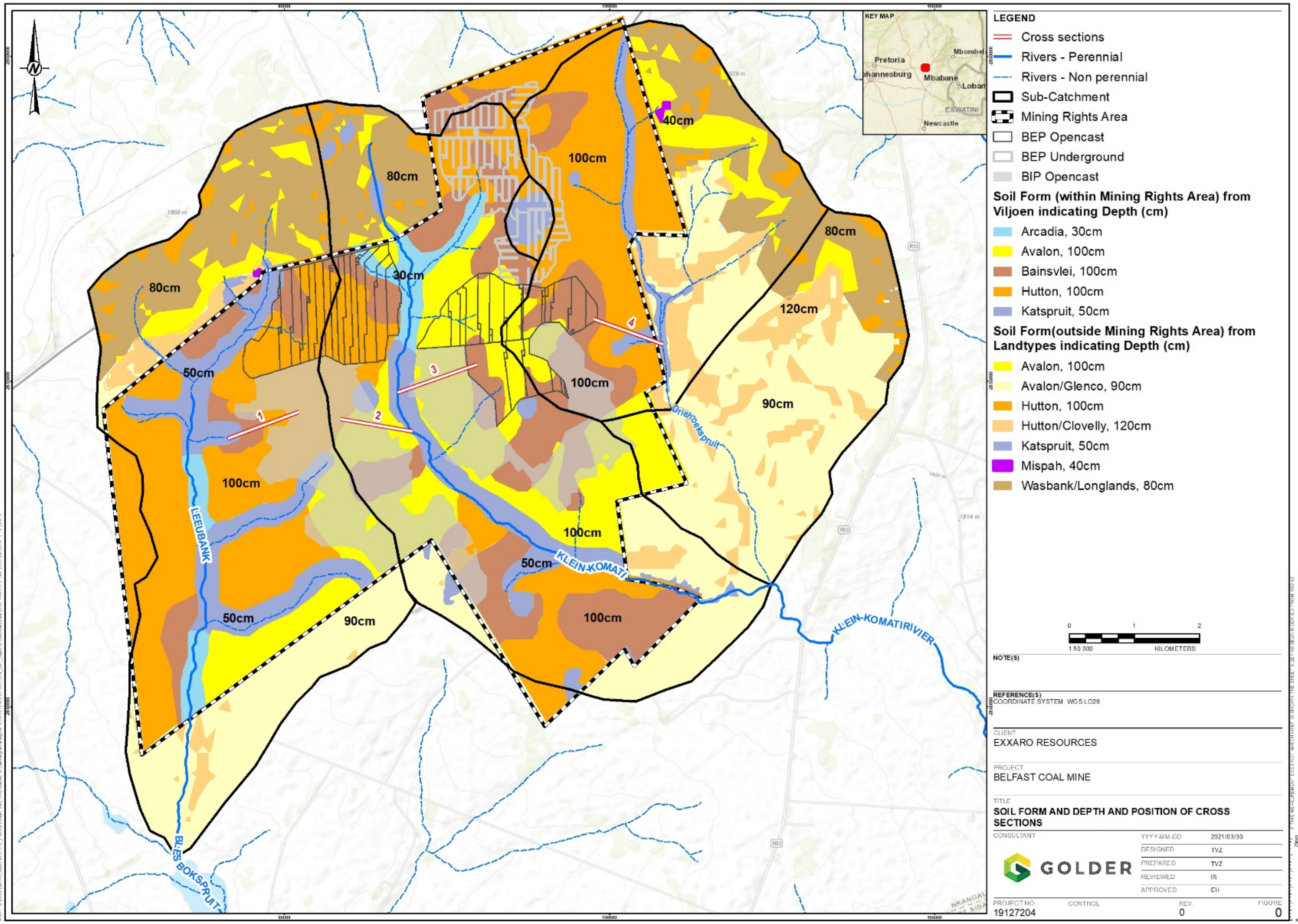

Figure 8: Cross sections indicated on soil forms

6.2 Conceptual Model

To understand the different wetland recharge mechanisms, the sub-catchment delineation along with the wetland classification was used. Conceptual site models of representative wetland systems and the associated hydropedological types for each sub-catchment was developed and used to demonstrate changes in the system due to the project activities. The surface water flow directions and positions of the cross sections are indicated in Figure 7 and Figure 8 shows the cross sections overlain on the soil form.

6.2.1 Western sub-catchment / Leeubankspruit System

Flow in the western sub-catchment is from north to south along the Leeubankspruit with tributaries flowing from the west and east towards the river. All mining activities will be to the east of the Leeubankspruit. A small part of the wetlands will be removed by mining. Cross section 1 was made through a representative hillslope that includes part of the BIP mining area. The cross section is shown prior to mining in Figure 9 and during mining in Figure 10.

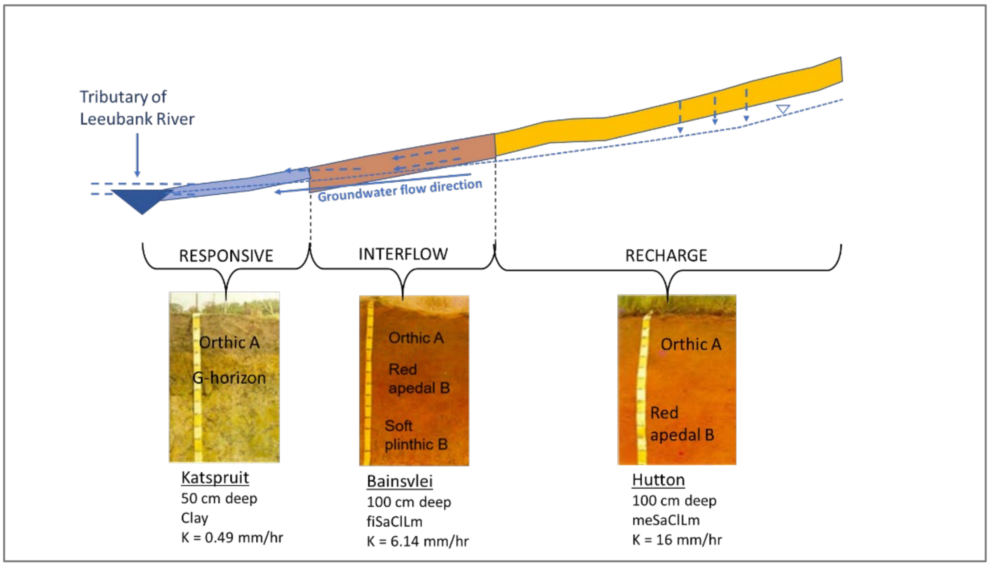

Figure 9: Cross section 1 prior to mining

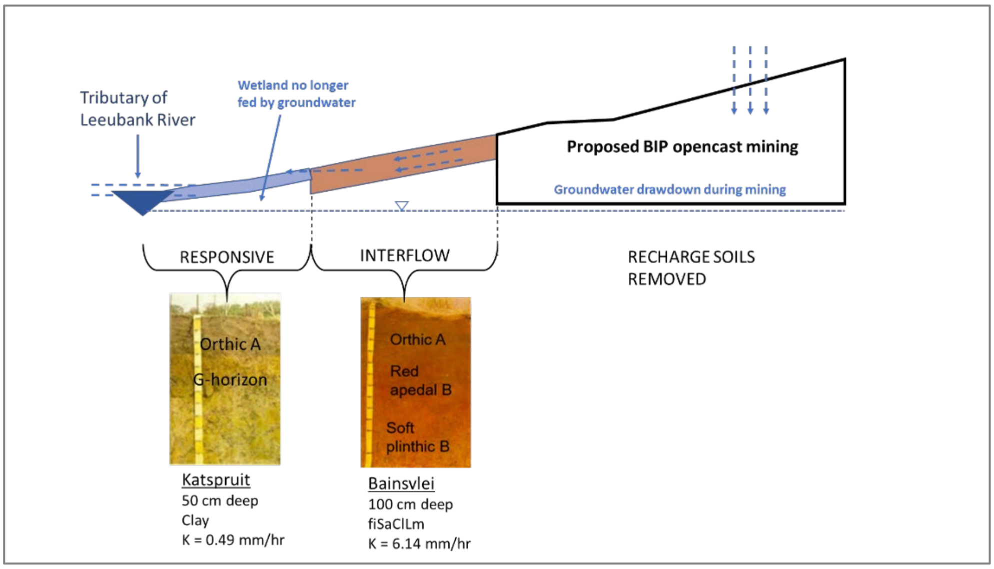

Figure 10: Cross section 1 during mining

In the selected cross section, only recharge soils are removed by mining. However, there are areas further south in the sub-catchment where interflow soils will be removed by mining (see Figure 8).

Cross section 1 (Figure 9 and Figure 10) indicates how the wetland (and river) will be impacted by the lowered water table. Groundwater will no longer feed the wetland. Nevertheless, the wetland is still being fed by the interflow soils. In the areas where interflow soils will be removed by mining, the impact on the wetlands will be amplified and the wetland may dry out completely and lose its function.

6.2.2 Central sub-catchment / Klein-Komati River System

Overall flow in catchment is north to south along the Klein-Komati River and then south-east in the lower catchment area. There will be extensive mining in this sub-catchment with mining activities planned for areas west and east of the Klein-Komati River. Some of the wetlands in this sub-catchment will be removed by mining, but the largest wetland in the south of the sub-catchment will remain.

Two cross sections were made in this sub-catchment to allow for flow from the west and from the east into the Klein-Komati River as stipulated by Van Tol *et.al.* (2021). Cross section 2 is flowing west to east and is presented in Figure 11 and Figure 12 for before and during mining. Cross section 3 is flowing east to west and is shown in Figure 13 and Figure 14 for before and during mining.

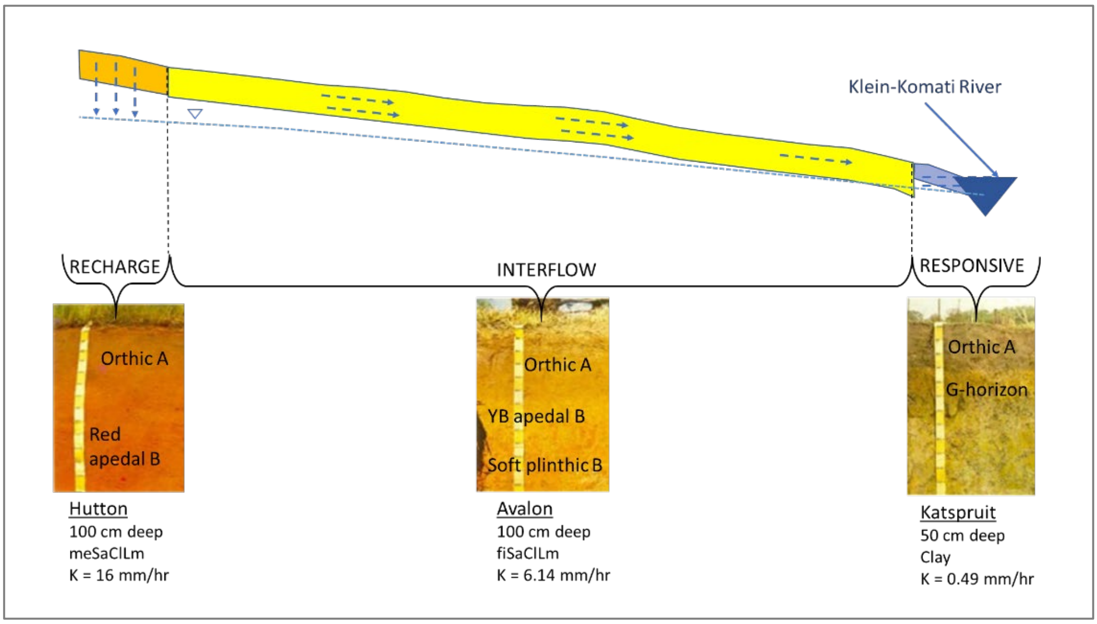

Figure 11: Cross section 2 prior to mining

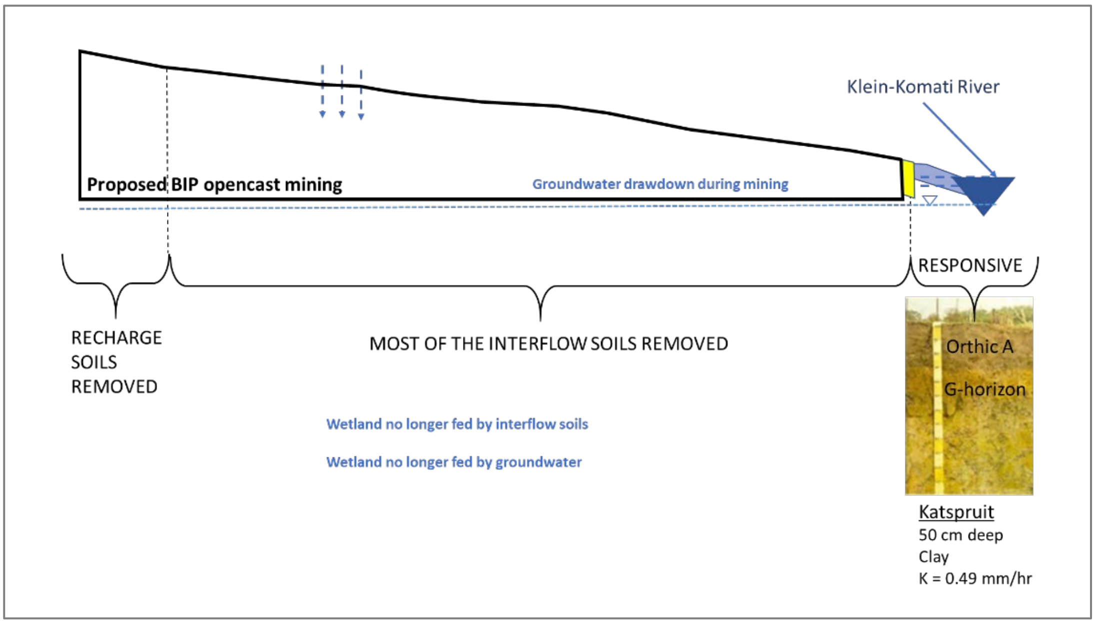

Figure 12: Cross section 2 during mining

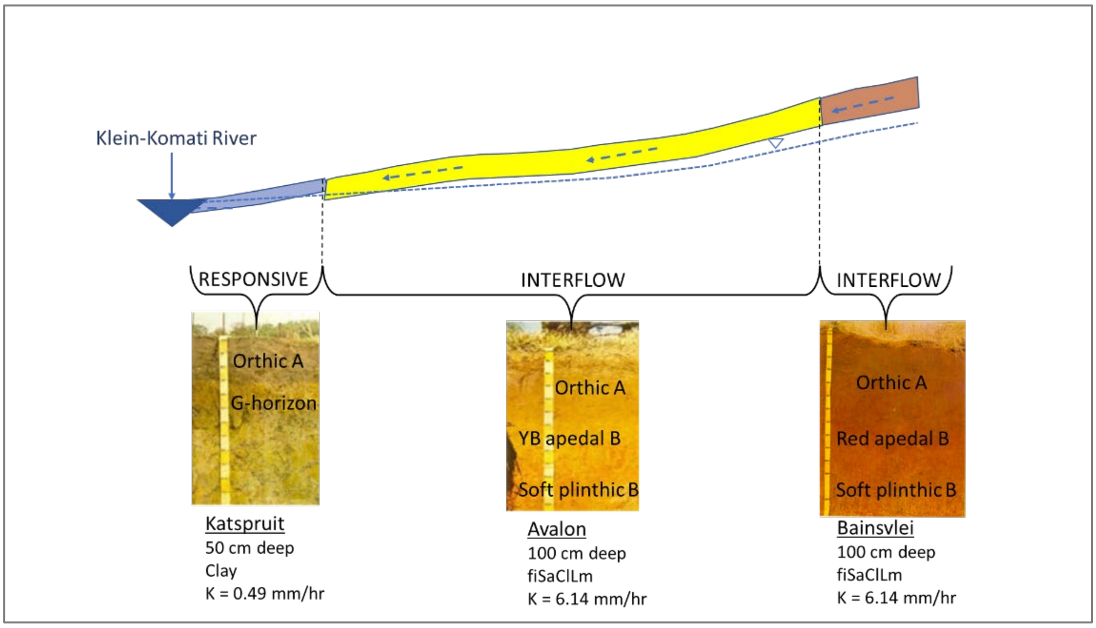

Figure 13: Cross section 3 prior to mining

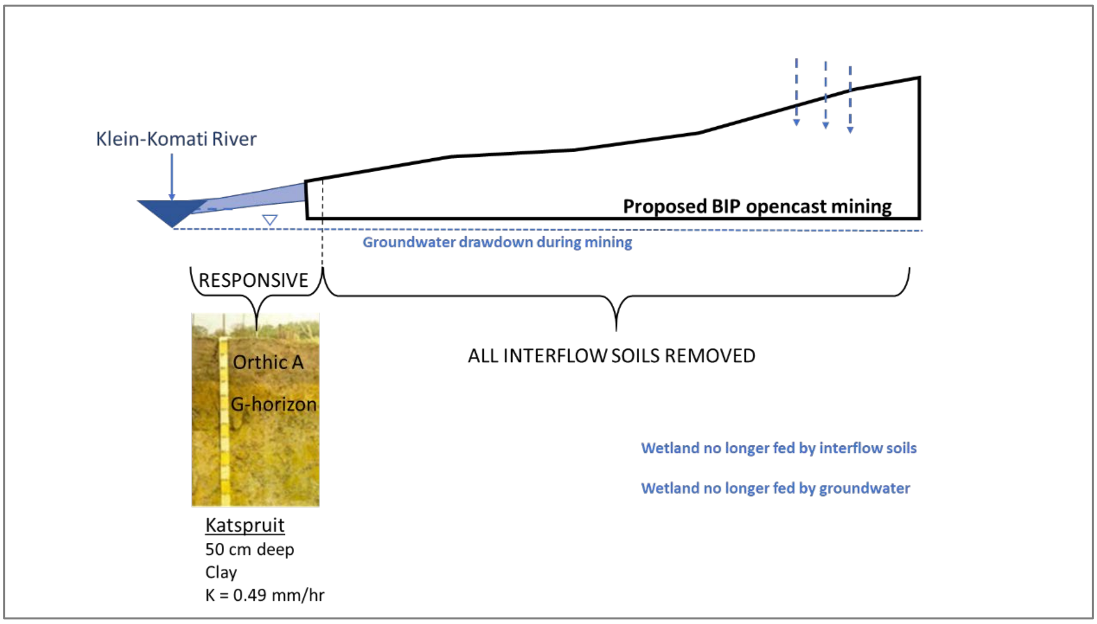

Figure 14: Cross section 3 during mining

Cross sections 2 and 3 show similar impacts in that large parts of the upper catchment areas and interflow soils feeding the wetlands will be removed by mining. The wetlands will be impacted by the removal of the interflow soils as well as the drawdown of the groundwater during mining.

6.2.3 North-East sub-catchment / Driehoekspruit System (North)

The north-east sub-catchment drains from north to south and mining is planned for the south-western part of this sub-catchment. Large wetland areas will be removed by mining. Cross section 4 was made in an area where mining will remove most of the wetland, but not all. The cross section is shown prior to mining in Figure 15 and during mining in Figure 16.

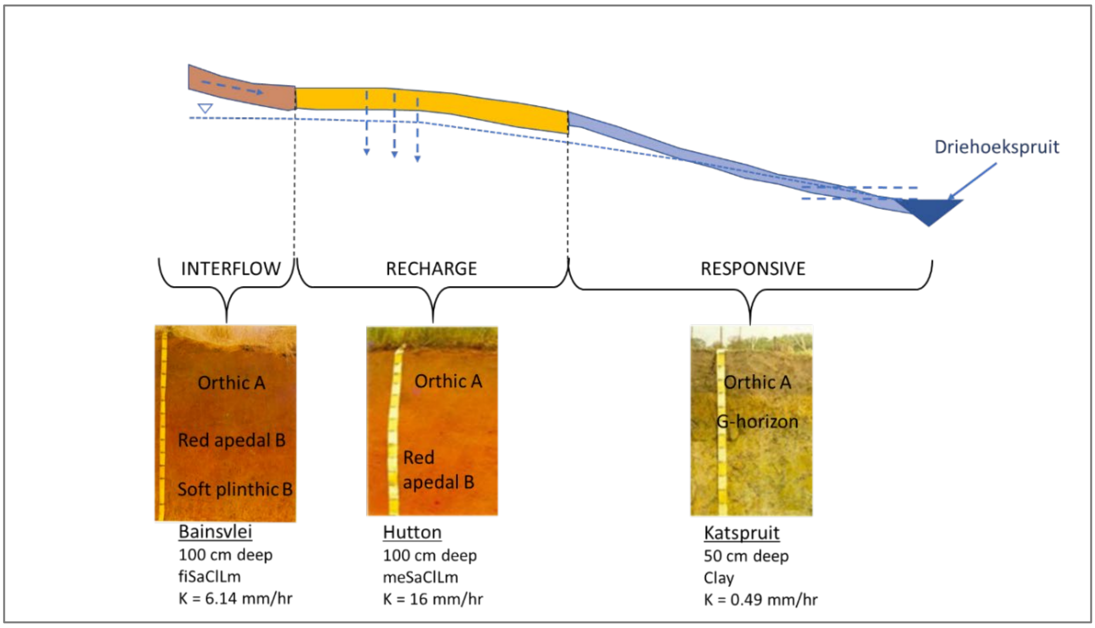

Figure 15: Cross section 4 prior to mining

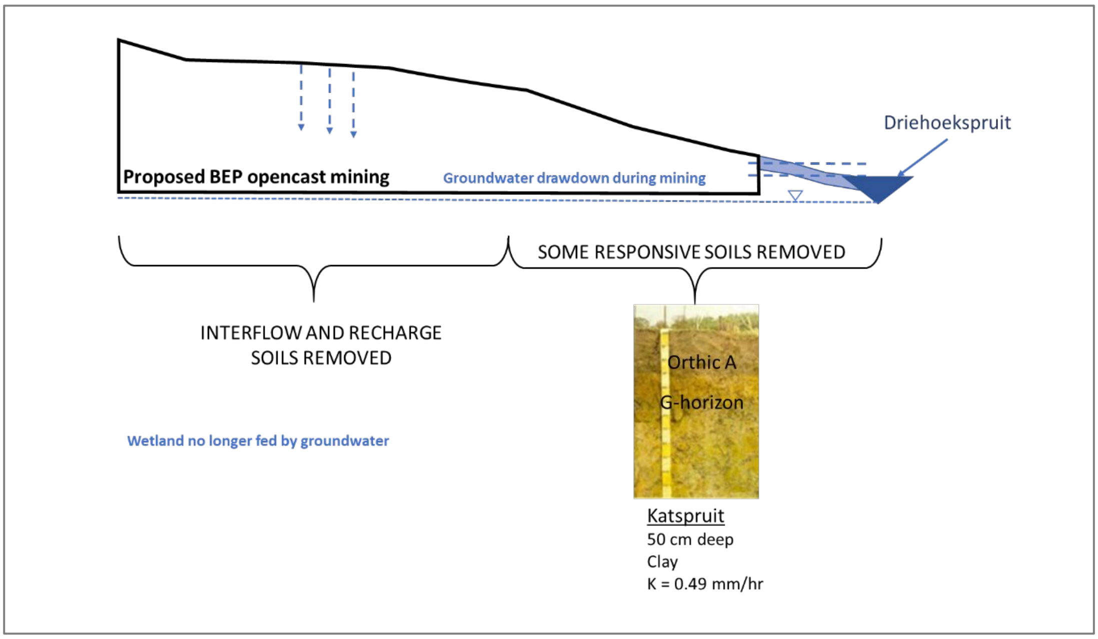

Figure 16: Cross section 4 during mining

Cross section 4 (Figure 15 and Figure 16) indicates how the wetland (and river) will be impacted by the lowered water table. The wetland is only fed by groundwater as there are no interflow soils directly feeding the wetland. The wetlands will be impacted by the removal of the interflow soils as well as the drawdown of the groundwater during mining.

6.2.4 South-East sub-catchment / Driehoekspruit System (South)

This sub-catchment has a tiny part in the upper catchment area that will be mined, and interflow soils will be removed. Most of the catchment interflow soils will however remain and it is not foreseen that it will have a significant impact on the Driehoekspruit. There are no wetlands in this sub-catchment.

6.3 Wetland hydropedological recharge

6.3.1 HYDRUS model

The recharge (infiltration rate) of the representative Recharge and Interflow soil profiles delineated for the project area was estimated using HYDRUS-1D software. HYDRUS-1D is a public domain Windows-based modelling environment for analysis of water flow and solute transport in variably saturated porous media. The software package includes a one-dimensional finite element model to simulate the movement of water, heat and multiple solutes. The model is supported by an interactive graphics-based interface for data pre-processing, discretization of the soil profile and graphic presentation of the results. The program numerically solves Richards' equation for variably saturated water flow. The HYDRUS-1D model code is widely accepted by the professional community for evaluating variably saturated flow and solute transport processes.

The soil map and the Ba21 and Ad1 Landtype memoirs were used to understand the hydraulic behaviour of the representative soil profiles. The daily precipitation and daily evaporation of weather station X1E003 for the September 1980 – January 2020 period of record was used for the model simulations.

Based on the available soil map and Landtype memoirs, the dominant soil sequence (and terrain position) for the study area is as follows:

Hutton(1)-Bainsvlei (3)-Avalon (4)-Katspruit/Arcadia(5) (Wetland)

or

Hutton (1)-Glencoe (3)-Avalon (4)-Katspruit (5)(Wetland)

Depending on the wetland recharge mechanism, the recharge to a particular wetland system, was assumed as the estimated recharge rates of the hydrological soils adjacent to the wetland in a sub-catchment. The reduction in wetland recharge was calculated by removing the recharge contribution of the impacted soil type. To gain a further conceptual understanding of the overall project impact, the pre- and post-mining flow to the wetlands was simulated using FEFLOW modelling software. FEFLOW is a finite-element subsurface flow and transport simulation software package. The simulation results were used to understand the potential water drawdown in the wetlands as a result of the reduction in hydropedological recharge.

Table 7: Soil properties used to estimate recharge for dominant hydrological soil types contributing to wetland recharge

Simulations	Soil sequence (Catena) properties							Net Infiltration	Runoff
	Horizon	Material	BD (g/cm³)	Clay (%)	Thickness (cm)	USDA Texture	K_{sat} (cm/day)	% of MAP	% of MAP
Hutton (Recharge zone)	A	meSaClLm	1.6	25	30	SaClLm	31.44	25.00	0
	B	meSaClLm	1.6	25	60	SaClLm	31.44		
Glencoe (Interflow zone)	A	meSaClLm	1.6	20	30	SaClLm	31.44	10.00	2
	B1	meSaClLm	1.6	20	30	SaClLm	31.44		
	B2	meSaClLm	1.9	34	30	SaClLm	0.36		
Avalon (interflow zone)	A	meSaClLm	1.6	20	30	SaClLm	31.44	14.70	1
	B1	meSaClLm	1.6	20	30	SaClLm	31.44		
	B2	meSaClLm	1.7	34	30	SaClLm	1.10		
Bainsvlei (Interflow zone)	A	meSaClLm	1.6	20	30	SaClLm	31.44	14.70	1
	B1	meSaClLm	1.6	20	30	SaClLm	31.44		
	B2	meSaClLm	1.7	34	30	SaClLm	1.10		
Bainsvlei (from Golder database)						Sandy Loam	63.24	6.2	9

6.3.2 FEFLOW model

The FEFLOW model was setup for the groundwater regime with the addition of the topsoil layer. During calibration, recharge relating to the hydropedological soil types were adjusted. The best calibration for the groundwater model (Model A) was obtained by using a single recharge value (39.3 mm/a or 5.5% of MAP) for the entire modelling area. Although this is a good estimate for a groundwater model, it is not ideal to explore the contribution of the soils to wetland recharge. Therefore, another option (Model B) was also used to investigate the contribution of the soils to wetland recharge. For Model B the estimated recharge from the HYDRUS model was applied to the recharge soils and no recharge was applied to the rest of the model area.

To Summarise:

- Model A: A single recharge value (39.3 mm/a or 5.5% of MAP) was applied to the entire modelling area.
- Model B: Recharge was applied only to the recharge soils using 175 mm/a (25% of MAP) as estimated from the HYDRUS model. Zero recharge was applied to interflow and responsive soils.

Figure 17 shows the catchment areas, the recharge soils, and the mining areas.

- The western sub-catchment has large areas where the recharge soils will be removed by mining, therefore a significant impact is expected on the wetlands.
- The central sub-catchment has smaller areas where the recharge soils will be removed by mining, but most of the sub-catchment will be mined. Therefore, a significant impact is expected on the wetlands of the central sub-catchment.
- The eastern sub-catchment has small areas of mining on recharge soils and thus a limited impact is expected on the wetlands of this sub-catchment.

Please note that these models used zero recharge for the mining areas. This is a worst case as there will still be recharge to the groundwater although recharge soils are removed by mining.

Results from Model A (Table 8) indicate that the highest impact is on the central remaining wetlands. This is expected because the central sub-catchment has the largest mining area (37% of the central sub-catchment will be mined). The inflows in the remaining wetlands of the central sub-catchment are reduced by 34.4% after all (BIP & BEP) opencast mining. This is expected due to the large amount of mining in the sub-catchment.

Table 8: Results from Model A

	Inflow into wetland (l/s)			Percentage reduction in inflow	
Wetland	**Unimpacted**	**BIP only**	**BIP & BEP**	**BIP only**	**BIP & BEP**
Western catchment	28.6	26.23	25.34	8.3%	11.4%
Central catchment – remaining wetlands in mining area	19.8	15.54	12.98	21.5%	34.4%
Eastern catchment – remaining wetlands	9.8	9.67	9.45	1.3%	3.6%
Southern part of Central Catchment	6.8	6.62	6.6	2.6%	2.9%

The results from Model B (Table 9) are comparable to the Model A results. However, after BIP mining and before BEP mining, the impact on the western sub-catchment is highest at 11.8% reduction in flow. At the end of BEP mining the impact on the western sub-catchment is substantially higher than for Model A. This is due to the large amount of recharge soils in the sub-catchment that will be removed by mining.

The impact on the wetlands of the eastern sub-catchment is lower due to the small amount of recharge soils that will be removed by mining.

For the central sub-catchment the results of the two models are similar which is expected because mainly interflow soils will be removed in this sub-catchment.

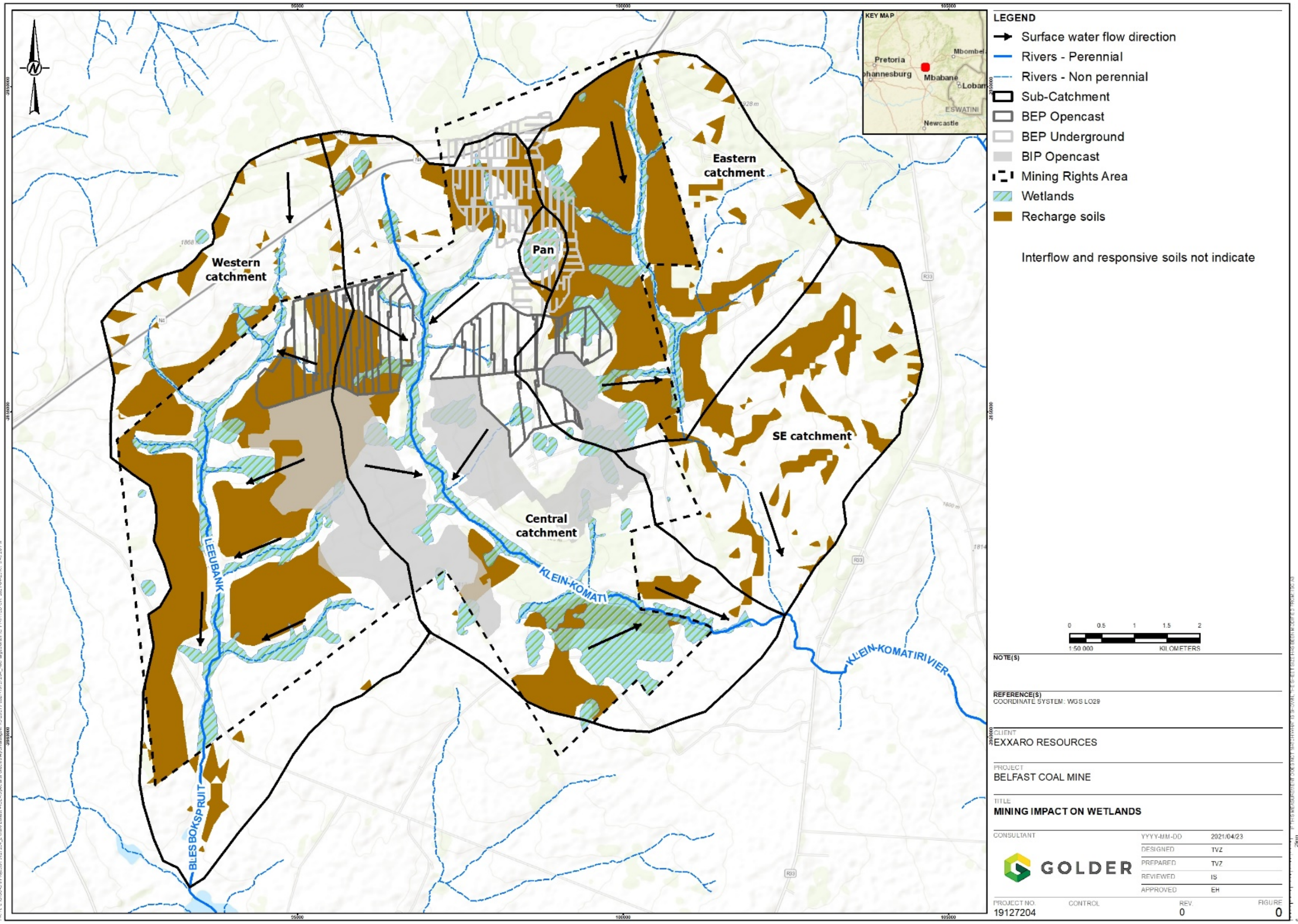

Figure 17: Recharge soils

Table 9: Results from Model B

	Inflow into wetland (l/s)			Percentage reduction in inflow	
Wetland	**Unimpacted**	**BIP only**	**BIP & BEP**	**BIP only**	**BIP & BEP**
Western catchment	37.6	33.18	30.2	11.8%	19.7%
Central catchment – remaining wetlands in mining area	9.95	9.09	6.57	8.6%	34.0%
Eastern catchment – remaining wetlands	13.42	13.42	13.39	0.0%	0.2%
Southern part of Central Catchment	4.6	4.5	4.5	2.2%	2.2%

Cross sections from Model A (Figure 18) show how the water level drops after mining and thereby reducing the inflows into the wetlands. Similar patterns are seen for Model B.

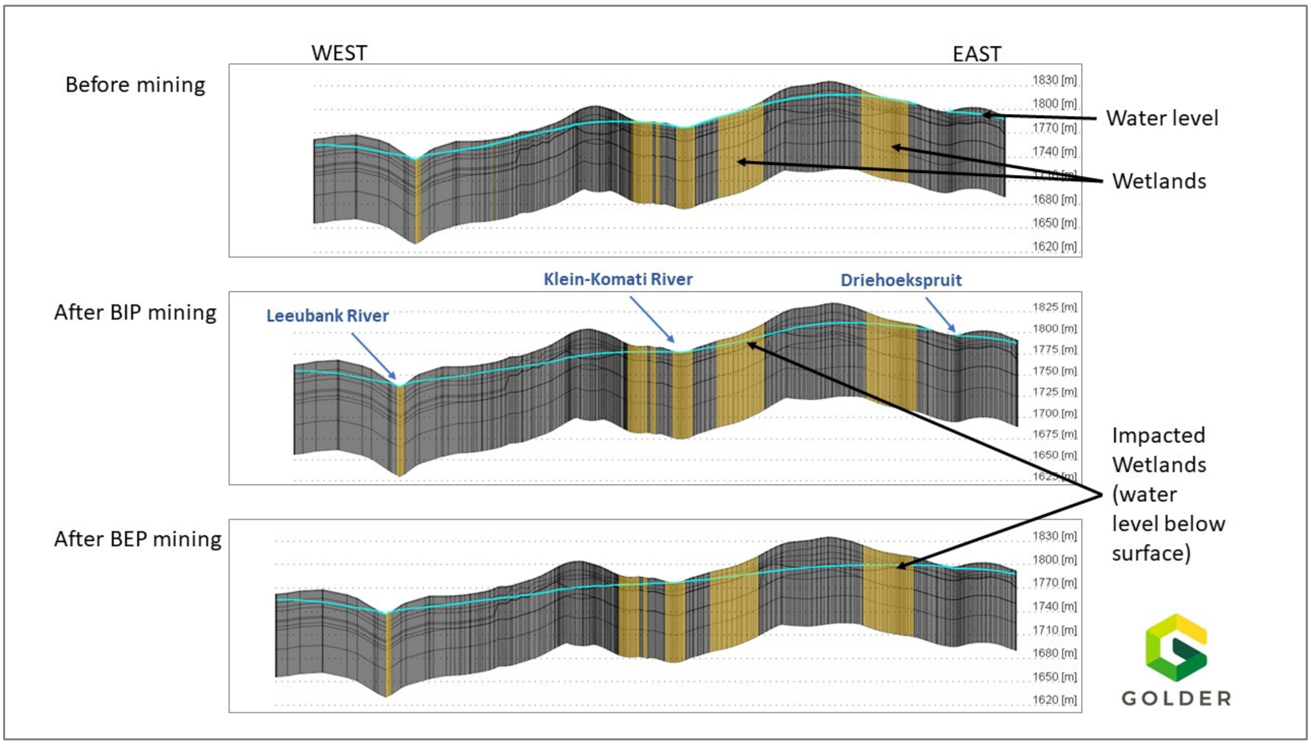

Figure 18: Cross sections showing how the groundwater level is impacted by mining

6.3.3 Reduction in Surface Area

For comparison, the surface area reduction was calculated and is shown in Table 10. The reduction in area is expressed as % of the sub-catchment as well as percentage of the quaternary catchment to put it into perspective. The relative size of the mining areas to the quaternary catchments are shown in Figure 19.

Table 10: Reduction in surface area

	Area (ha)			Percentage of sub-catchment		
Area of interest	**West**	**Central**	**East**	**West**	**Central**	**East**
Sub-catchment	3216	3263	1983			
BIP mining	239	684	111	7%	21%	6%
BEP mining	170	518	260	5%	16%	13%
Total mining	409	1202	371	13%	37%	19%
	Area (ha)			**Percentage of quaternary catchment**		
Area of interest	**X11C**	**X11D**		**X11C**	**X11D**	
Quaternary catchment	31887	59055				
BIP mining	239	684		0.7%	1.2%	
BEP mining	170	518		0.5%	0.9%	
Total mining	409	1202		1.3%	2.0%	

Reduction in the quaternary catchment area due to mining is 2% when all the mining is active at the same time. This reduction in area will be mitigated by shaping and covering after mining. If the shaping and covering can start as the mining is rolled out, the area reduction will be less than 2%. It is therefore anticipated that the flow reduction at catchment level will be negligible.

The reduction in area compared to the model results is listed below:

- Western sub-catchment: The final reduction in area is 13% and the models simulated flow reductions of 11.4% and 19.7%.
- Central sub-catchment. The final reduction in area is 37% and the models simulated flow reductions of 34.4% and 34.0%.
- Eastern sub-catchment: The final reduction in area is 19% and the models simulated flow reductions of 3.6% and 0.2%.

The simulated reduction in flow is closely related to the reduction in area for the western and central catchments. However, the simulated flow reduction in the eastern catchment was much less than the percentage reduction in area. This can be explained by the position of the mining area in the catchment. All mining will be on the downstream part of the catchment and therefore the impact is much lower than expected when just considering the reduction in area.

Reduction of the total flow in the catchment is 2% or less.

6.4 Buffer determination

In 2017, the Water Research Commission (WRC) published a set of guidelines for the determination of buffer zones for wetlands, rivers and estuaries (Macfarlane and Bredin, 2017). A buffer zone is a strip of land designed to protect one area of land against impacts from another.

The minimum recommended buffer zone width for the Mining sector with a moderate to high-risk mining operations is 25 m as indicated in Figure 20.

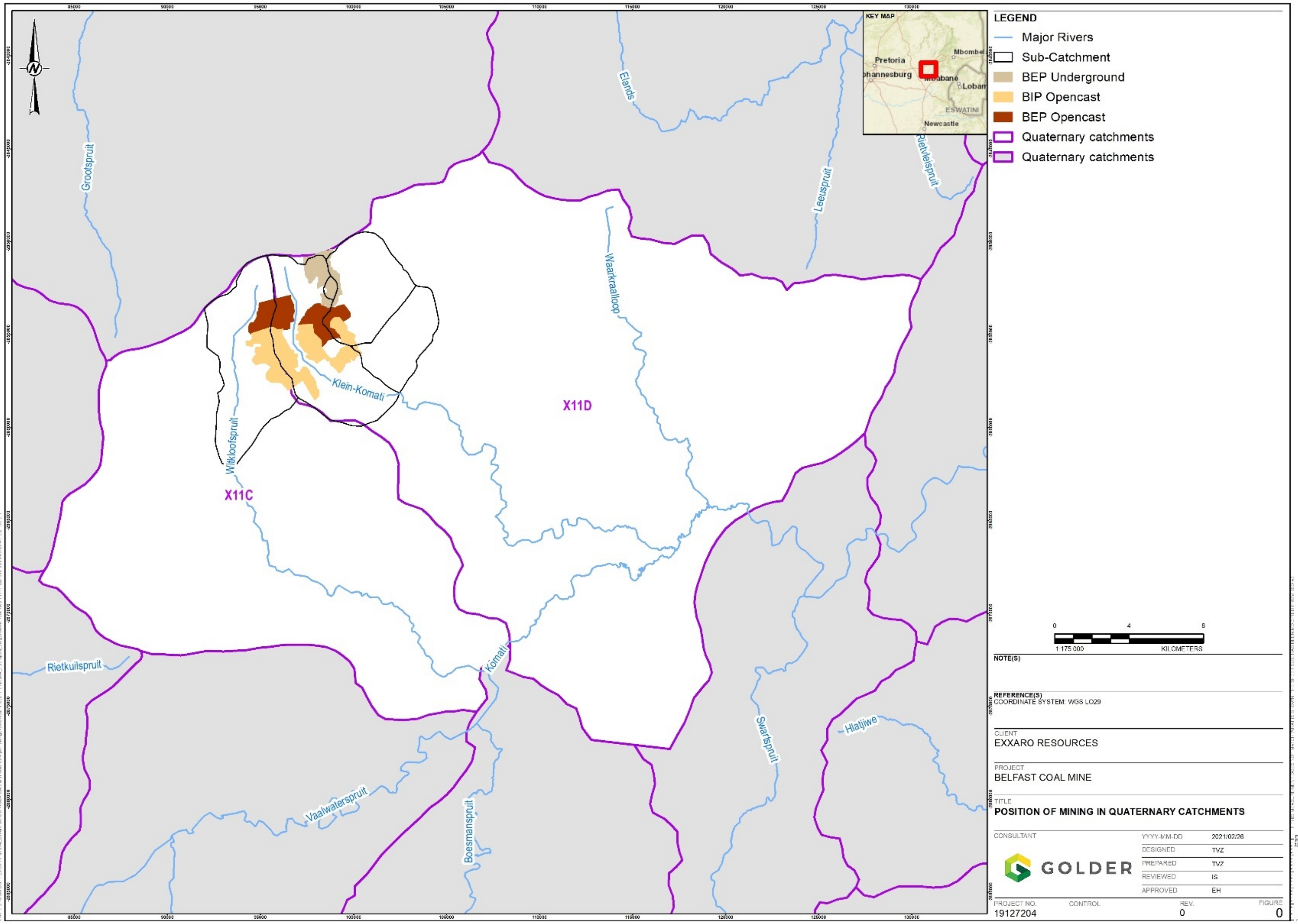

Figure 19: Relative size of mining areas in Quaternary Catchment

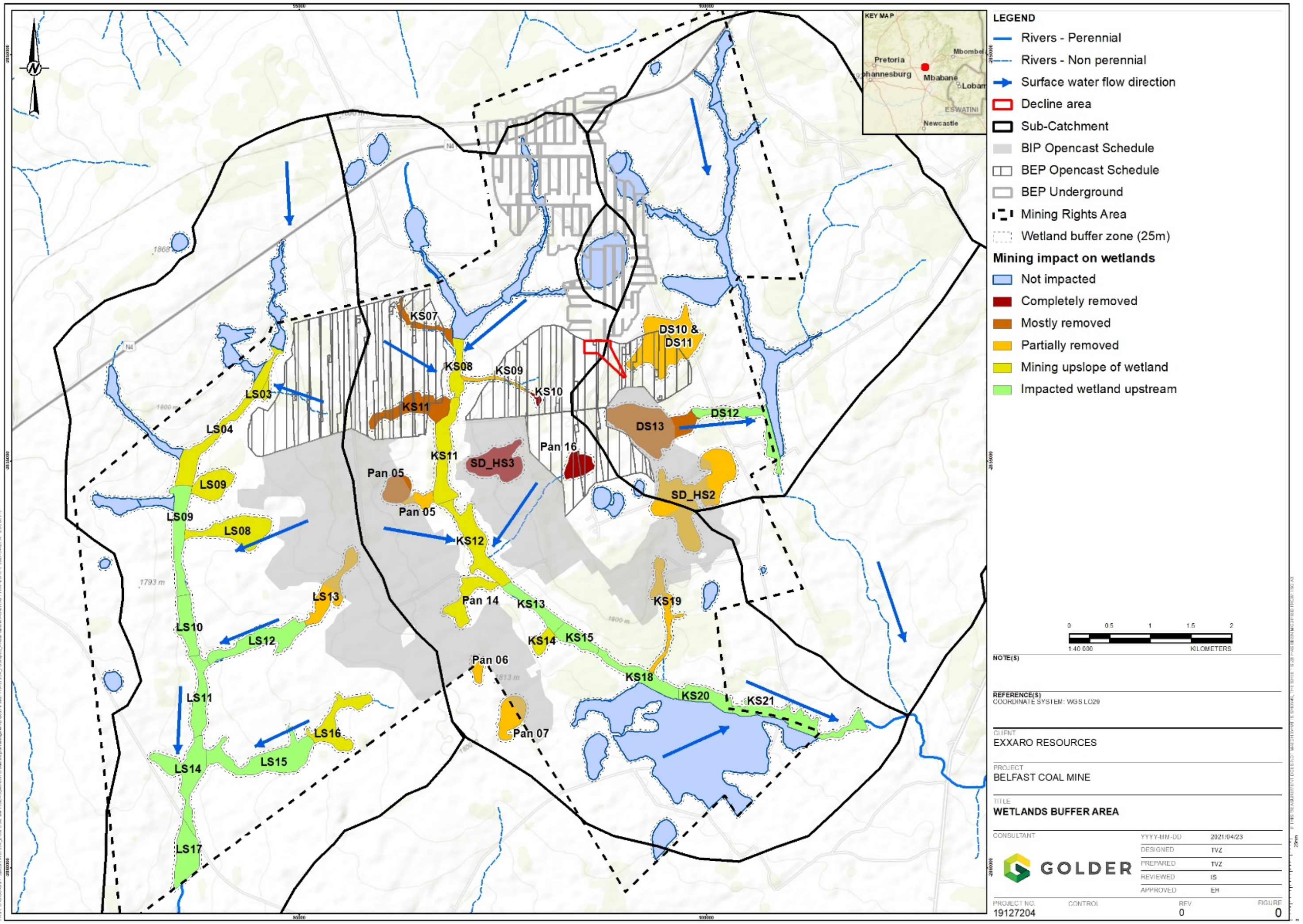

Figure 20: 25 m buffer around wetlands

6.5 Hydropedological risk rating

The assessment of impacts on the hydropedology, aligns with the impact assessment guidelines, published by the Water Research Commission, for wetland condition assessment. The guidelines use the "*hydropedological classification of South African soil forms, along with information on the soil forms in the wetland's catchment to determine the relative extent of different hydrological response types in the catchment and within specific hillslopes contained within the catchment"* (Job et al., 2019).

The risk assessment matrix in Table 11 has been used for the hydropedological impact assessment. The project site mostly consists of recharge and interflow areas which will be impacted. From a hydropedological perspective the risk of the project activities such as soil disturbance and surface sealing impacting on the hydropedological functioning is high. For this study, however, surface sealing is not an action. Only the shaded cells apply to the Belfast study area and it applies to cross sections 1, 2 and 3. These cross sections are representative for the western and central sub-catchments where a moderate hydropedological risk is expected according to Table 11. Although cross section 4 also has a slope of higher than 2%, it does not have the soft plinthic B horizon. The wetland illustrated in cross section 4 has recharge soils adjacent to the wetland and the wetland is mainly groundwater fed. There is no hydropedological risk rating for these conditions stipulated.

Table 11: Risk of local activities impacting on the functions of hydrological soil classes (reproduced from Job et al., 2019)

Hydropedological area	Soil feature	Flow process affected	Impact on hydrological response	Risk level
Recharge areas	Recharge soil	Recharge of soil, fractured rock and groundwater	Surface sealing convert recharge into peak flow and runoff.	High
	Fractured rock outcrops	Recharge fractured rock and groundwater	Surface sealing convert recharge into peak flow and runoff.	High
Interflow areas	Midslope E horizon or bleached A horizon not overlying interflow subsoils	Evapotranspiration, hillslope geophysical properties	Local losses, foreign gains (translocating soils' space-time continuum on the interaction with water, i.e. from midslope interflow to wetland recharge).	Low
	Footslope E horizon, bleach A horizon not on interflow subsoils	Shallow flow path returning to soil	Event and post-event flow.	Moderate
	Soft plinthic B horizon	Slope 0-1% following from steep slope	Flow from rain recharge.	Low
			Mainly local. Post-event.	
		Slope 2% and higher	Possible return flow	Moderate
	Hard plinthic B horizon	Interflow in deep subsoil or return flow to subsoil, topsoil or even soil surface	Post-event and post-seasonal in wet years.	Moderate
	Reducing morphology below 500 mm	Return or recharge flow to subsoil	Seasonal to permanent	High
	Reducing morphology below 500 mm	Rainfall or return flow to subsoil	Post-event to seasonal	High

7.0 ENVIRONMENTAL IMPACT ASSESSMENT

The impact assessment on the effect of opencast mining on the wetlands in the study area must be read from a hydropedological viewpoint. Other impacts, specifically wetland impacts, will be addressed in other studies.

7.1 Methodology for Assessing Impact Significance

The significance of identified impacts was determined using the approach outlined below (terminology from the Department of Environmental Affairs and Tourism Guideline document on Environmental Impact Significance Regulations, 2002). This approach incorporates two aspects for assessing the potential significance of impacts, namely occurrence and severity, which are further sub-divided as follows:

- Occurrence:
  - Probability of occurrence.
  - Duration of occurrence.
- Severity:
  - Scale/extent of impact.
  - Magnitude of impact.

Four ranking scales are used to assess these factors for each impact, and they are listed in Table 12. After ranking each of the impacts, the Significance Points are calculated, and the significance is determined based on the points as shown in Table 13.

Table 12: Impact assessment scoring methodology

Magnitude	Duration	Scale	Probability
10- Very high/unknown	5- Permanent (>10 years)	5- International	5- Definite/Unknown
8- High	4- Long term (7 - 10 years, impact ceases after site closure has been obtained)	4- National	4- Highly Probable
6- Moderate	3- Medium-term (3 months- 7 years, impact ceases after the operational life of the activity)	3- Regional	3- Medium Probability
4- Low	2- Short-term (0 - 3 months, impact ceases after the construction phase)	2- Local	2- Low Probability
2- Minor	1- Immediate	1- Site Only	1- Improbable
		0- None	0- None

Significance Points= (Magnitude + Duration + Scale) x Probability.

Table 13: Significance of impact based on point allocation

Points	Significance	Description
SP>60	High environmental significance	An impact which could influence the decision about whether or not to proceed with the project regardless of any possible mitigation.
SP 30 - 60	Moderate environmental significance	An impact or benefit which is sufficiently important to require management and which could have an influence on the decision unless it is mitigated.
SP<30	Low environmental significance	Impacts with little real effect and which will not have an influence on or require modification of the project design.
+	Positive impact	An impact that is likely to result in positive consequences/effects.

For the methodology outlined above, the following definitions were used:

- Magnitude is a measure of the degree of change in a measurement or analysis (e.g., the area of pasture, or the concentration of a metal in water compared to the water quality guideline value for the metal), and is classified as none/negligible, low, moderate or high. The categorization of the impact magnitude may be based on a set of criteria (e.g. health risk levels, ecological concepts and/or professional judgment) pertinent to each of the discipline areas and key questions analysed. The specialist study must attempt to quantify the magnitude and outline the rationale used. Appropriate, widely recognised standards are to be used as a measure of the level of impact.
- Scale/Geographic extent refers to the area that could be affected by the impact and is classified as site, local, regional, national, or international.
- Duration refers to the length of time over which an environmental impact may occur: i.e., immediate/transient, short-term (0 to 7 years), medium term (8 to 15 years), long-term (greater than 15 years with impact ceasing after closure of the project), or permanent.
- Probability of occurrence is a description of the probability of the impact actually occurring as improbable (less than 5% chance), low probability (5% to 40% chance), medium probability (40% to 60% chance), highly probable (most likely, 60% to 90% chance) or definite (impact will definitely occur).

7.2 Impact description

The impacts are based on the impacted wetlands in each of the sub-catchments. All these impacts are related to mining. After mining, rehabilitation will take place in the form of shaping to be free draining. It was assumed that a soil cover will be placed on the opencast areas and that area will be re-vegetated.

Wetlands were grouped together (Figure 21) based on the following criteria:

- (A1) Wetlands that are completely removed by mining. These wetlands include KS10, Pan16 and SD_HS3.
- (A2) Wetlands that are mostly removed (more than 70% of the wetland will be removed by mining). These are wetlands KS07, KS11 (western limb), Pan05 (western part of pan) and DS13.

- (B) Wetlands that are partially removed by mining (more than 30 % of the wetland will remain). Wetlands LS13, Pan05 (eastern part), Pan06, KS09, KS19, SD_HS2 and DS10 & DS11.
- (C) Wetlands that are impacted by upslope mining and removal of recharge soils. Wetlands LS03, LS04, LS08, LS09 and KS14.
- (D) Wetlands that are impacted by upslope mining and removal of interflow soils. Wetlands KS08, KS11 (downstream section), KS12 and Pan14. These wetlands (excluding Pan14) are further affected by impacted upstream wetlands.
- (E) Wetlands where the upstream wetlands have been impacted. This is an indirect impact on the wetland where inflow from upstream may be compromised. LS09 to LS15, LS17, KS13, KS15, KS18, KS20, KS21 and DS12.

The Impact assessment scoring is presented in Table 14 and described in the sections below the table.

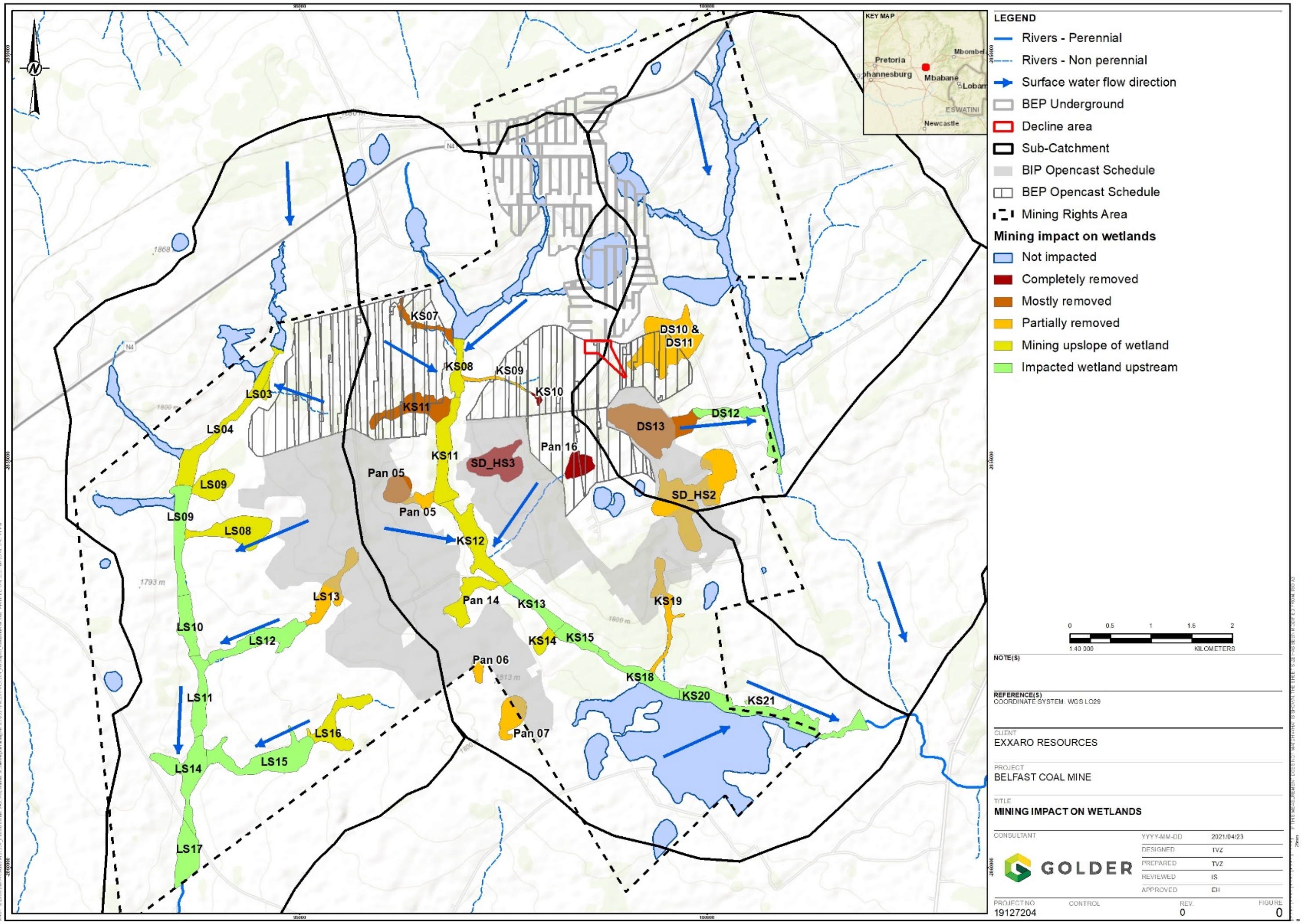

Figure 21: Wetland groups for impact assessment

Table 14: Impact assessment scoring

Phase	PRE- MITIGATION IMPACT	Magnitude	Duration	Scale	Probability	Total	Significance Rating	Overall risk score	MITIGATION	Magnitude	Duration	Scale	Probability	Total	Significance Rating	Overall risk score
Operational	(A) Wetlands mostly or completely removed	10	5	2	5	85	HIGH	Negative	Offset wetland					0		Neutral
	(B) Wetlands partially removed	8	5	2	4	60	MODERATE	Negative	Shape to drain towards remaining wetland & rehabilitate wetland	8	3	2	3	39	MODERATE	Negative
	(C) Wetland impacted by upslope mining - Recharge soils removed	4	5	2	3	33	MODERATE	Negative	Shape to free draining	4	3	2	3	27	LOW	Negative
	(D) Wetland impacted by upslope mining - Interflow soils removed	6	5	2	4	52	MODERATE	Negative	Shape to free draining	4	3	2	4	36	MODERATE	Negative
	(E) Wetlands where the upstream wetlands are impacted	4	5	2	3	33	MODERATE	Negative	Shape to free draining	2	3	2	3	21	LOW	Negative
Closure	(B) Wetlands partially removed & then rehabilitated	8	3	2	3	39	MODERATE	Negative	Cover and vegetate	6	3	2	3	33	MODERATE	Negative
	(C) Wetland impacted by upslope mining - Recharge soils removed	4	3	2	3	27	LOW	Negative	Cover and vegetate	2	3	2	2	14	LOW	Negative
	(D) Wetland impacted by upslope mining - Interflow soils removed	4	3	2	4	36	MODERATE	Negative	Cover with interflow soils and vegetate.	4	3	2	4	36	MODERATE	Negative
	(E) Wetlands where the upstream wetlands are impacted	2	3	2	3	21	LOW	Negative	Cover and vegetate	2	3	2	2	14	LOW	Negative

7.2.1 Operational phase

The following scores were assigned for the operational phase.

- (A) Wetlands mostly or completely removed:
  - Pre-mitigation: The magnitude of the impact is very high, the duration permanent, the scale is local and the probability definite, giving a significance point of 85 which is a **high** significance rating.
  - By offsetting these wetlands, the post-mitigation is a **neutral** score.
- (B) Wetlands partially removed:
  - Pre-mitigation: The magnitude of the impact is high, the duration permanent, the scale is local, and the impact is highly probable, giving a significance point of 60 which is a **moderate** significance rating.
  - The mitigation action is to shape the areas where the wetland has been removed so that the area will drain toward the remaining part of the wetland. Additional actions should be considered to rehabilitate the impacted areas to function as a wetland.
  - Post-mitigation: The magnitude of the impact is high; the duration of the impact is medium-term. This can be up to seven years, after which the wetland should be rehabilitated. The scale of the impact is local, and the impact is of medium probability, giving a significance point of 39 which is a **moderate** significance rating.
- (C) Wetlands impacted by upslope mining – Recharge soils removed:
  - Pre-mitigation: The magnitude of the impact is low, the duration permanent, the scale is local, and the impact is of medium probability, giving a significance point of 33 which is a **moderate** significance rating.
  - The mitigation action is to shape the mining areas so that they will be free draining.
  - Post-mitigation: The magnitude of the impact is low, the duration medium-term, the scale is local, and the impact is of medium probability, giving a significance point of 27 which is a **low** significance rating.
- (D) Wetlands impacted by upslope mining – Interflow soils removed:
  - Pre-mitigation: The magnitude of the impact is moderate, the duration permanent, the scale is local, and the impact is highly probable, giving a significance point of 52 which is a **moderate** significance rating.
  - The mitigation action is to shape the mining areas so that they will be free draining.
  - Post-mitigation: The magnitude of the impact is low, the duration medium-term, the scale is local, and the impact is highly probable, giving a significance point of 36 which is a **moderate** significance rating.
- (E) Wetlands where the upstream wetlands are impacted:
  - It is assumed that the flow from upstream has been impacted and potentially reduced which will have a further impact on these (E)-type wetlands.

- Pre-mitigation: The magnitude of the impact is low, the duration permanent, the scale is local, and the impact is of medium probability, giving a significance point of 33 which is a **moderate** significance rating.
- The mitigation action is to shape the mining areas so that they will be free draining and thereby reducing the impact on the upstream wetlands.
- Post-mitigation: The magnitude of the impact is low, the duration medium-term, the scale is local, and the impact is of medium probability, giving a significance point of 21which is a **low** significance rating.

7.2.2 Closure phase

For the purpose of the impact assessment, it was assumed that the closure phase will start after shaping and that the mitigation action will be to cover the mining areas with a soil cover and vegetation.

- (B) Wetlands partially removed:
  - Pre-mitigation: The magnitude of the impact is high; the duration of the impact is medium-term. This can be up to seven years, after which the wetland should be rehabilitated. The scale of the impact is local, and the impact is of medium probability, giving a significance point of 39 which is a **moderate** significance rating.
  - The mitigation action is to cover the mining areas with soil and the previous wetland areas with suitable soils such as Arcadia or Katspruit that are commonly found in areas of semi-permanent wetness.
  - Post-mitigation: The magnitude of the impact is moderate; the duration of the impact is medium-term. This can be up to seven years, after which the wetland should be rehabilitated. The scale of the impact is local, and the impact is of medium probability, giving a significance point of 33 which is a **moderate** significance rating.
- (C) Wetlands impacted by upslope mining – Recharge soils removed:
  - Pre-mitigation: The magnitude of the impact is low, the duration medium-term, the scale is local, and the impact is of medium probability, giving a significance point of 27 which is a **low** significance rating.
  - The mitigation action is to cover the mining areas with soil and to vegetate the area.
  - Post-mitigation: The magnitude of the impact is minor, the duration medium-term, the scale is local, and the impact is of low probability, giving a significance point of 14 which is a **low** significance rating.
- (D) Wetlands impacted by upslope mining – Interflow soils removed:
  - Pre-mitigation: The magnitude of the impact is low, the duration medium-term, the scale is local, and the impact is highly probable, giving a significance point of 36 which is a **moderate** significance rating.
- The mitigation action is to cover the mining areas with soil and to vegetate the area. The areas where interflow soils occurred prior to mining should be covered with interflow soils so that lateral flow in these cover soils can reach the wetlands. In order to replace the interflow soils, they need to be stockpiled separately before mining. The interflow soils are the Avalon and Bainsvlei soil forms.
  - Post-mitigation: The magnitude of the impact is low, the duration medium-term, the scale is local, and the impact is highly probable, giving a significance point of 36 which is a **moderate** significance

rating. This scoring is the same as pre-mitigation because of the placement and function of interflow soils may not be possible and/or effective.

- (E) Wetlands where the upstream wetlands are impacted:
  - Pre-mitigation: The magnitude of the impact is low, the duration medium-term, the scale is local, and the impact is of medium probability, giving a significance point of 21which is a **low** significance rating.
  - The mitigation action is to cover the mining areas with soil and to vegetate the area.
  - Post-mitigation: The magnitude of the impact is low, the duration medium-term, the scale is local, and the impact is of low probability, giving a significance point of 14 which is a **low** significance rating.

8.0 CONCLUSIONS AND RECOMMENDATIONS

The hydropedology of the Belfast BIP and BEP opencast mining areas was undertaken to support the Water Use License Application. The objectives of the hydropedology specialist study are as follows:

- Classify the hydropedological soil types of the project area and present a conceptual understanding of the baseline hydropedological conditions.
- Quantify the percentage loss of hydropedological recharge to the wetlands based on simple hydropedological principles.
- Determine the significance of the perceived impacts on the key drivers and receptors (hydrology, water quality, geomorphology, habitat and biota) of the wetlands associated with the study area.
- Recommend mitigation measures for perceived impacts, including the determination of a suitable buffer to ensure that appropriate consideration is given to the proposed mining activities and the perceived impacts thereof on the affected wetlands and the associated hydropedological drivers in the study area.

The mining area was divided into sub-catchments for the Leeubankspruit (western sub-catchment), Klein-Komati River (central sub-catchment) and the Driehoekspruit (eastern sub-catchment further separated into north and south).

All available information was used to develop a conceptual model for several cross sections through the area. The conceptual model cross sections indicate the flow direction, the hydrological soil type for pre-mining and operational periods to indicate how the receptor (wetland) will be affected by mining.

HYDRUS-1D models were developed for the soil zone to estimate the infiltration and these values were used as recharge into a FEFLOW groundwater flow model. This could be done, because all the wetlands are linked to and fed by groundwater (in addition to being fed from rainfall and interflow soils where present). Two groundwater flow scenarios were modelled:

- Model A: A single recharge value (39.3 mm/a or 5.5% of MAP) was applied to the entire modelling area.
- Model B: Recharge was applied only to the recharge soils using 175 mm/a (25% of MAP) as estimated from the HYDRUS model. Zero recharge was applied to interflow and responsive soils.

Results from the two groundwater models show that the highest impact will be on the wetlands of the central sub-catchment. This catchment will be extensively mined and the reduction in flow to the wetlands in this sub-catchment is expected to be 34%. The reduction in flow to the wetlands in the western catchment is 10% - 20% and the flow reduction to the wetlands in the eastern sub-catchment is less than 5%.

The reduction in area compared to the model results is listed below:

- Western sub-catchment: The final reduction in area is 13% and the models simulated flow reductions of 11.4% and 19.7%.
- Central sub-catchment. The final reduction in area is 37% and the models simulated flow reductions of 34.4% and 34.0%.
- Eastern sub-catchment: The final reduction in area is 19% and the models simulated flow reductions of 3.6% and 0.2%.

The simulated reduction in flow is closely related to the reduction in area for the western and central catchments. However, the simulated flow reduction in the eastern catchment was much less than the percentage reduction in area. This can be explained by the position of the mining area in the catchment. All mining will be on the downstream part of the catchment and therefore the impact is much lower than expected when just considering the reduction in area.

It is however noted that reduction in the quaternary catchment area due to mining is 2% when all the mining is active at the same time. This reduction in area will be mitigated by shaping and covering after mining. If the shaping and covering can start as the mining is rolled out, the area reduction will be less than 2%. It is therefore anticipated that the flow reduction at catchment level will be negligible.

The project area comprises predominantly recharge and interflow soils, with responsive soils typically representing the wetland areas. The wetlands are linked with the shallow groundwater aquifer with other drivers such as rainfall and runoff as well as interflow in some cases where interflow soils are present adjacent to the wetland. The proposed mining will have an impact on the wetlands:

- By lowering the water table in the operational sections, thereby reducing groundwater inflows into the downslope wetlands.
- By removing large areas of interflow soils which feeds subsurface water into the wetlands.
- By removing large areas of recharge soils that feeds the groundwater. However, recharge will continue to feed the groundwater directly through the opencast and backfilled areas. This may have a detrimental effect on the water quality.
- Removal of wetlands. There are several wetlands that will be completely or mostly lost due to mining. They include Pan 05, Pan16, SD-HS3, DS13, KS07, KS10 and KS11. The total area covered by these wetlands is 106.5 ha and offset areas should be found for these wetlands.
- Partial removal of wetlands. These include LS13, KS19, Pan6, SD_HS2 and DS 10&11. For all these wetlands the upstream part of the wetland will be removed which will have an impact on the remaining downstream part of the wetland.
- Indirect impacts on downstream wetlands due the impact on upstream wetlands.

To mitigate the potential impacts, it is recommended that:

- The extent of soil disturbance should be restricted to approved mining areas.
- A minimum buffer of at least 25 m around the remaining wetlands be preserved where possible.
- Wetlands offsets should be established for all the wetlands that will be completely or partially removed by mining.

After mining, rehabilitation will take place in the form of shaping to be free draining. It is recommended that the shaping should consider the pre-mined topography, specifically where wetlands were partially removed. The topography should at least be draining towards the remaining part of these wetlands. Where part of a wetland was removed by mining, the wetland should be rehabilitated by covering the wetland areas with responsive soils.

In the areas where interflow soils were removed by mining, all effort should be made to replace interflow soils in these areas and that the slope should resemble the slope prior to mining. . In order to replace the interflow soils, they need to be stockpiled separately before mining. The interflow soils are the Avalon and Bainsvlei soil forms.

These recommendations are aimed to re-instate the hydropedological function of the wetlands.

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APPENDIX A

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