HYDROPEDOLOGICAL ASSESSMENT FOR THE PROPOSED GLENCORE KROONDAL MINE INFRASTRUCTURE ON PORTION 11 OF THE FARM RIETFONTEIN 338 JQ (WESTERN CHROME MINES)

Rustenburg Municipality, Bojanala Platinum District Municipality, North West Province, South Africa

18 June 2025

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Report Name	**HYDROPEDOLOGICAL ASSESSMENT FOR THE PROPOSED GLENCORE KROONDAL MINE INFRASTRUCTURE ON PORTION 11 OF THE FARM RIETFONTEIN 338 JQ (WESTERN CHROME MINES)**
Specialist Theme	Hydropedological Assessment
Project Reference	Glencore Kroondal Mine Infrastructure
Report Version	Draft 4 / 18 June 2025
Environmental Assessment Practitioner	EIMS – Environmental Impact Management Services
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Declaration	The Biodiversity Company and its associates operate as independent consultants under the auspice of the South African Council for Natural Scientific Professions. We declare that we have no affiliation with or vested financial interests in the proponent, other than for work performed under the Environmental Impact Assessment Regulations, 2017 (as amended). We have no conflicting interests in the undertaking of this activity and have no interests in secondary developments resulting from the authorisation of this project. We have no vested interest in the project, other than to provide a professional service within the constraints of the project (timing, time and budget) based on the principals of science.

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1 Introduction

1.1 Background

The Biodiversity Company was appointed to conduct a specialist hydropedological level two (2) assessment for the proposed Glencore Kroondal Mine Infrastructure on Portion 11 of the Farm Rietfontein 338 JQ (Western Chrome Mines) near Rustenburg, North West Province. The project site is located approximately 10 km east of Rustenburg in the North West Province. The site is located within the Rustenburg Local Municipality and the Bojanala Platinum District Municipality.

The hydropedological site assessment was conducted on the 2nd of August 2024. The hydropedological assessment was completed in fulfilment to obtain a Water Use Licence (WUL) authorisation for the project.

This report should be interpreted after taking into consideration the findings and recommendations provided by the specialist herein. Further, this report should inform and guide the Environmental Assessment Practitioner (EAP) and regulatory authorities, enabling informed decision making, as to the ecological viability of the proposed project.

1.2 Project Description

The following information pertaining to the overview and description of the project has been extracted from the Background Information Document (BID) for the Glencore WCM Kroondal Mine Infrastructure.

<u>Location</u>

The proposed project and related activities will be undertaken at the following location:

- Property Description - Portion 11 of the farm Rietfontein 338 JQ;
- Central Co-ordinates - approximately 25°43'33.74"S, 27°21'41.65"E;
- Regional Description:
    - District Municipality: Bojanala Platinum District Municipality;
    - Local Municipality: Rustenburg Local Municipality;
    - Province: North West Province; and
- Closest town or point of interest: the site is located approximately 5.3 km east of Kroondal.

Glencore Western Chrome Mines (WCM) is in the process of acquiring a portion of the mining and surface rights from the Clover Alloys Rustenburg Chrome Mine (RCM) to reduce the time taken to travel to the face at its Kroondal Mine and increase the mining facetime which will in turn increase productivity. In addition to utilizing the existing infrastructure at Clover Alloys RCM, the applicant wishes to develop additional facilities to use in the life of mine. The proposed new developments as well as existing infrastructure include (but are not limited to):

- A parking area for permanent employees;
- A parking area for visitors and contractors;
- Employee drop-off/pick-up zone;

- Salvage yard;
- Sewage plant;
- Shaft Laydown Area / Explosives Delivery Bay;
- Surface laydown area;
- Meeting venue hall (Lekgotla Hall);
- Access and escape roads;
- Two water storage dams;
- Compressor house;
- One 11kV Powerline;
- Administration Offices;
- Change houses;
- Engineering workshop;
- Stores; and
- Temporary laydown area (historic LanXess Chrome Mining village area).

Kroondal mining operations is situated approximately 10 km east of Rustenburg, North-West Province. Mining at Kroondal has historically consisted of both opencast and underground mining. Currently only underground mining is undertaken, and the old opencast areas have been closed and rehabilitated. The current underground mining is taking place in close proximity to the Clover Alloys RCM mining rights areas. Miners' underground travel time will be reduced by approximately 50% through Glencore WCM acquiring the surface rights on Portion 11 of the farm Rietfontein 338 JQ and mining right (MR336), which will in turn increase production and ensure the long-term survival of the business.

A detailed layout for the proposed project is provided in Figure 1-1 and a simplified layout with the Project Area is provided in Figure 1-2.

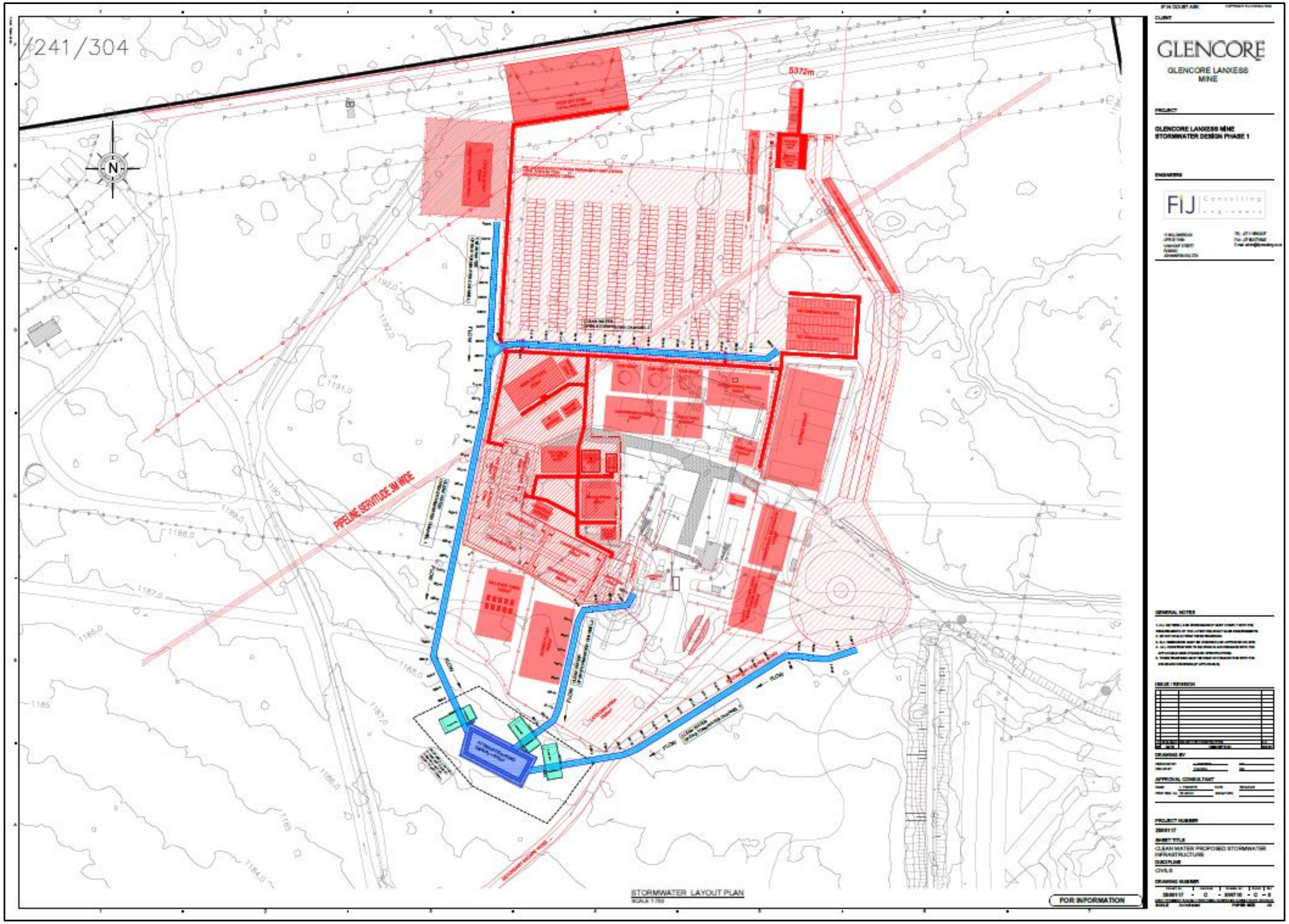


Figure 1-1 Detailed layout for the proposed project (EIMS BID, 2024)

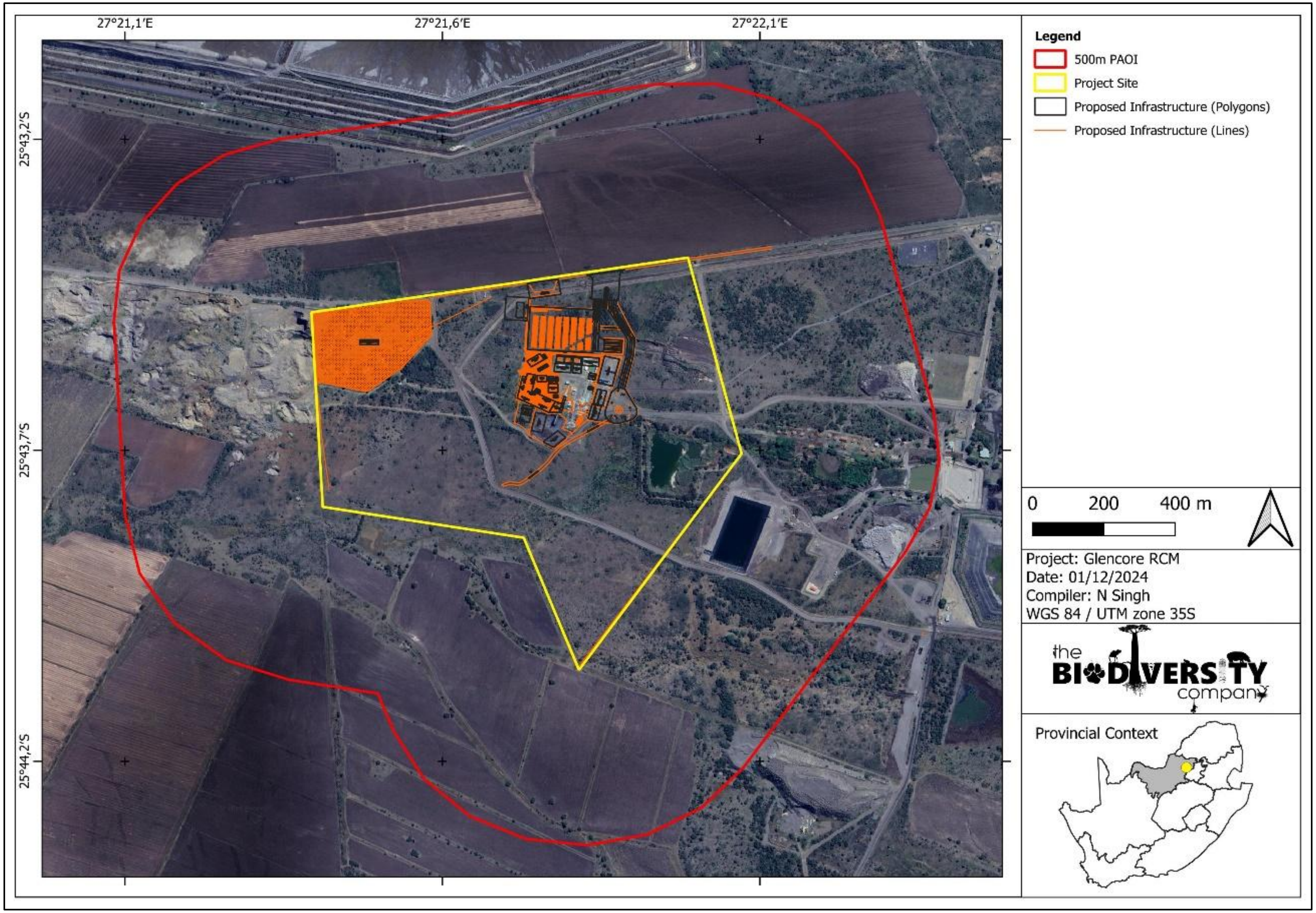


Figure 1-2 Map illustrating a simplified layout of the project and the Project Area of Influence

1.2.1 Project Area

The project area (see Figure 1-3) is located approximately 10 km east of Rustenburg within the Rustenburg Local Municipality and the Bojanala Platinum District Municipality, North West Province, South Africa (see Figure 1-3). The project area is also approximately 2.7 km north of the N4 national road, 3.8 km north of the R104 regional road and 14 km south east of the R510 regional road. The surrounding land uses include mining activities, chrome and platinum smelting and processing activities, watercourses, and agricultural practices.

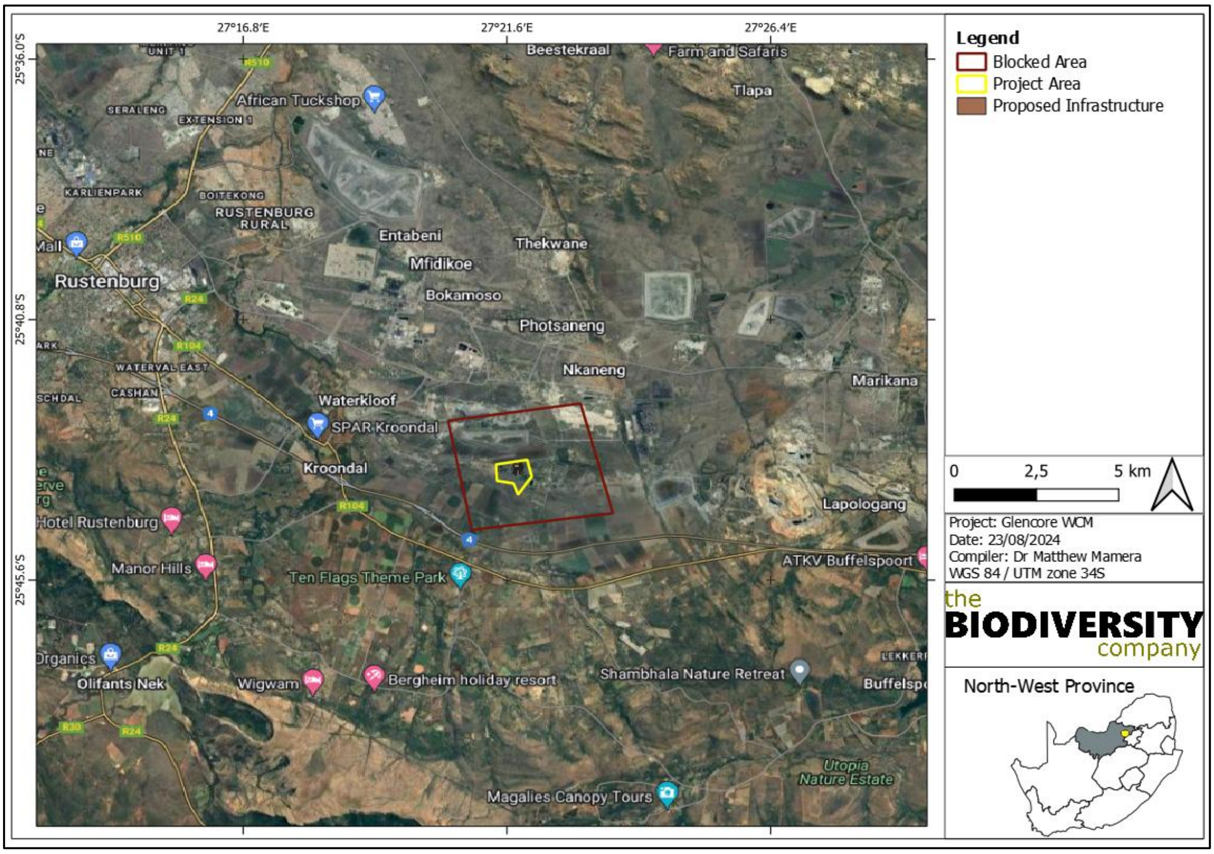


Figure 1-3 Spatial context of the proposed development

1.3 Scope of Work

The approach of this assessment is based on the protocols compiled by van Tol et al., (2021) and issued by the Department of Water and Sanitation (DWS). According to these protocols, the following two steps are required for this level of hydropedology assessment:

1. Identification of dominant hillslopes; and
2. Conceptualise hillslope hydrological responses.

For impact assessments associated with activities that pose significant threats on the interflow volumes of a landscape or activities that are expected to drastically change the dynamics of a landscape (i.e., open cast mining), four steps are required. For those activities that only include minor impacts (i.e., installation/upgrading of infrastructure pipelines or infrastructure mentioned in the project description), only the first two steps are required. Therefore, considering the intensity of some of the proposed activities, only the first two steps will be relevant to this assessment.

1.4 Assumptions and Limitations

The following aspects were considered as limitations;

- Only the slopes affected by the proposed development have been assessed;
- It has been assumed that the extent of the development area provided by the responsible party is accurate; and
- The GPS used for ground truthing is accurate to within five meters. Therefore, the wetland and the observation site's delineation plotted digitally may be offset by at up to five meters to either side.

2 Literature Review

2.1 Hydropedological Flow Paths

Given that hydropedology is a relatively new field, a short literature review has been added on this interdisciplinary research field. This literature is an excerpt from van Tol et al., (2017).

Soil physical properties and hydrology play significant roles in the fundamentals of hydropedology. Physical properties including porosity, hydraulic conductivity, infiltration etc. determine micro preferential flow paths through a soil profile. The hydrology in turn is responsible for the formation of various morphological processes in soil, including mottling, colouration and the accumulation of carbonate.

These processes are used to construct models illustrating sub-surface flow paths, storage and interconnection between these flow paths. Hydropedology can therefore be used for a variety of functions. These functions include process-based modelling, digital soil mapping, pollution control management, impact of land use change on water resources, wetland protection, characterising ground and sub-surface flows as well as wetland protection and rehabilitation, of which the latter will be the main focus during this report (see Figure 2-1). The latter mentioned enables effective water resource management regarding wetlands and sub-surface flows in general.

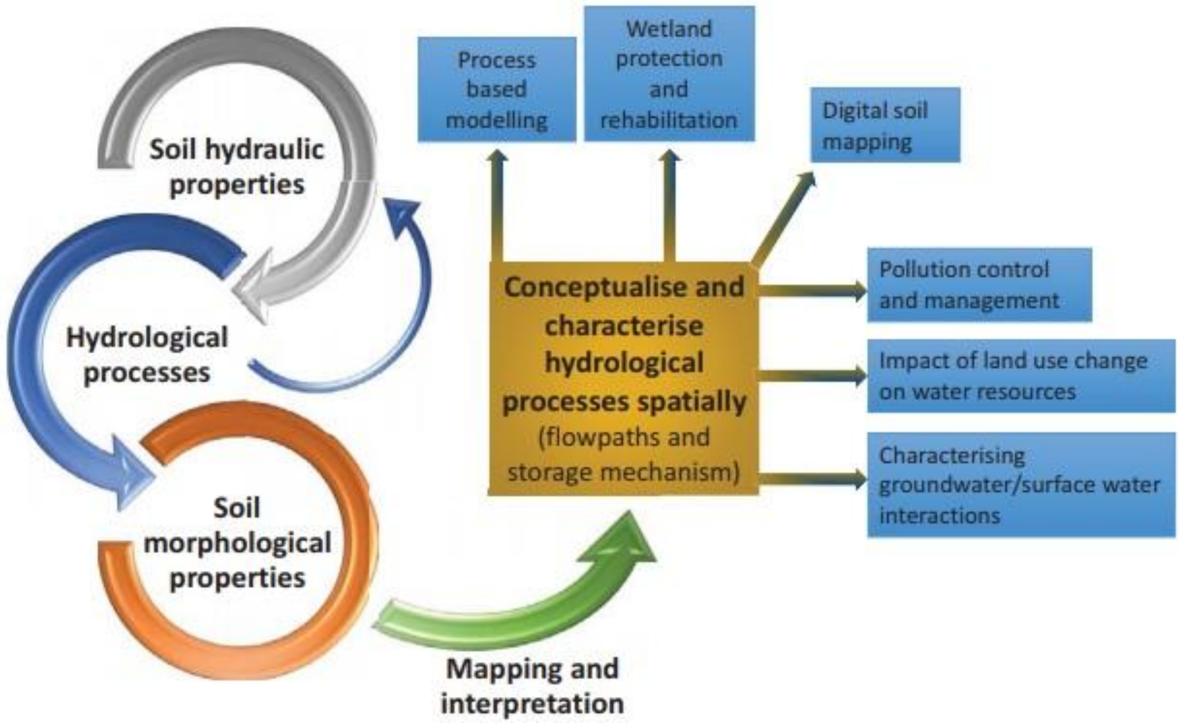


Figure 2-1 Illustration of the interactive nature of hydropedology and its potential applications (van Tol et al., 2017)

As can be seen in Figure 2-2, the hydropedological behaviour of soil types can differ significantly. Figure 2-2 (a) illustrates a typical red coloured soil (top- and sub-soil). This soil type will typically have a vertical flow path throughout the soil profile. Water will therefore infiltrate the topsoil and freely drain into the profile to such an extent that the water rapidly reaches the bedrock. After reaching this layer, water will penetrate the ground water source or be transported horizontally towards lower laying areas. This soil type is known as a recharge soil, given its ability to recharge ground and surface water sources.

Figure 2-2 (b) illustrates interflow soils. Lateral flows are dominant in this soil type and occurs due to differences in the hydraulic conductivity of soil horizons. The “sp” soil horizon restricts vertical movement and promotes lateral flows at the A/B interface. The lighter colour in this profile indicates leaching which is caused by lateral flows which often occurs on top of a bedrock layer due to the impermeable nature thereof. Mottles often occurs above this impermeable layer due to fluctuating water levels, see the magnified illustration in Figure 2-2 (b-i).

Figure 2-2 (c) illustrates responsive soil. This hydropedological soil type is characterised (in this case) by a dark top-soil and a grey coloured sub-soil. Other indicators include mottling and gleying. These soil types are saturated for very long periods. Therefore, rainfall is unlikely to infiltrate this layer and would likely be carried off via overland flow and are mostly fed by lateral sub-surface flows. Shallow soils are equally responsive in the sense that the soil profile will rapidly be saturated during precipitation, after which rainfall will be carried off by means of overland flows.

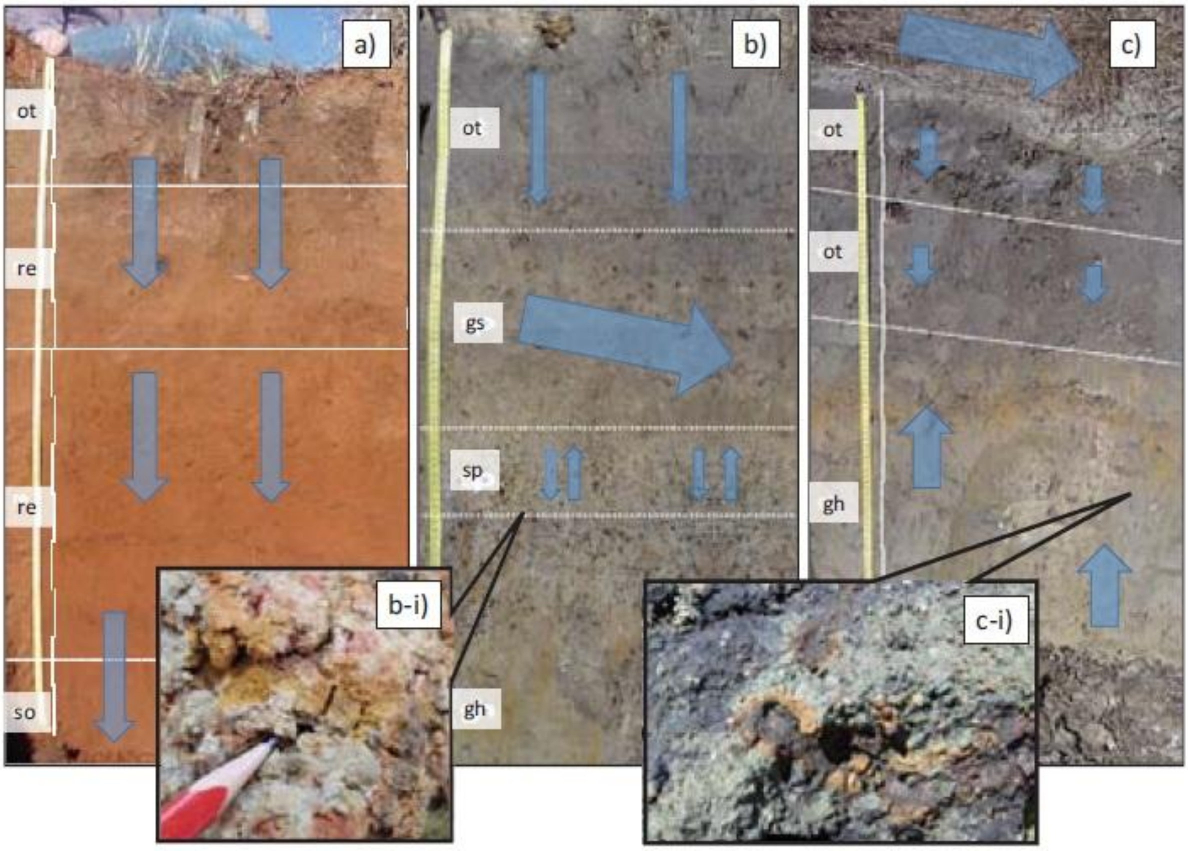


Figure 2-2 Illustration of different hydropedological soil types (van Tol et al., 2017)

A typical example of the hydropedological processes through a hillslope is illustrated in Figure 2-3. In this example, a recharge soil type is located at the upper reaches of the slope. Rainfall infiltrates this soil type and percolates vertically towards the bedrock. Water then, infiltrates into this bedrock given the permeability thereof and could now recharge groundwater or flow down-gradient towards soils in lower lying positions. The second soil type (the interflow zone) indicates lateral flows at the A/B interface and again at the soil/bedrock interface which feeds the responsive zone. The responsive zone is then simultaneously fed by lateral sub-surface flows and ground water recharge.

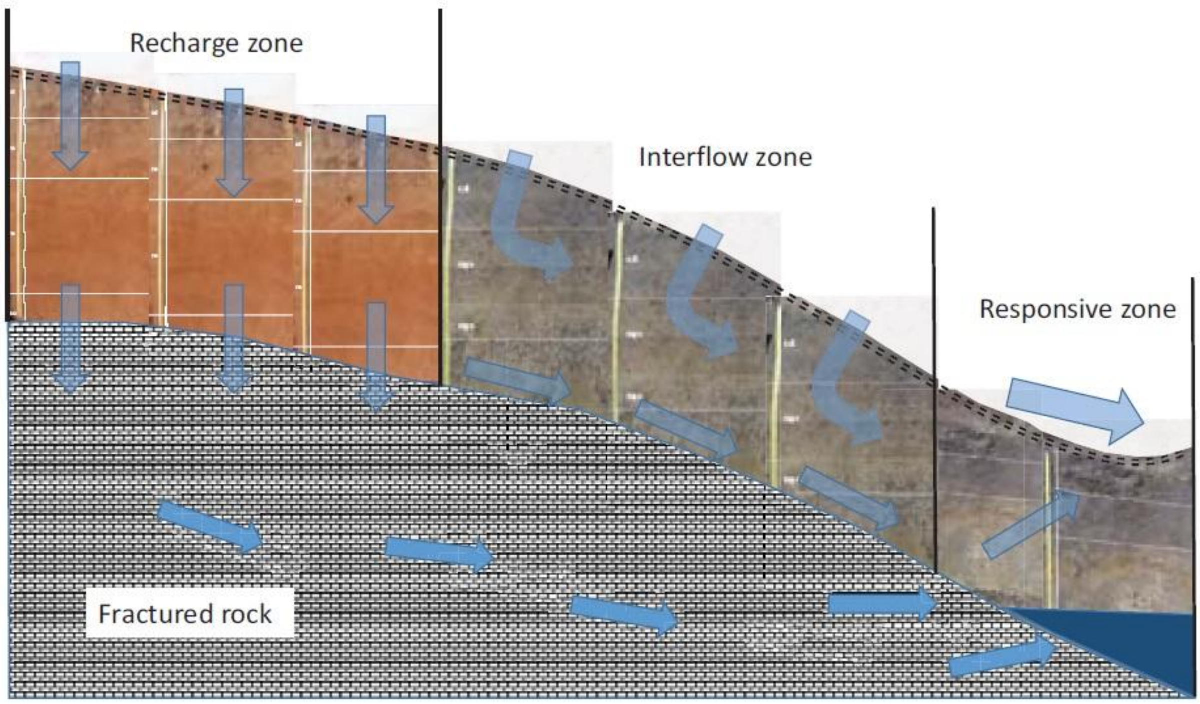


Figure 2-3 Illustration of different hydropedological soil types (van Tol et al., 2017)

The methodology of van Tol *et al.,* (2017) has since been updated to include a "stagnant" hydropedological type. According to van *Tol et al.,* (2019), four different hydropedological types exist, namely Recharge, Interflow, Responsive and Stagnating hydropedological types. These soil types are divided into seven subgroups depending on the morphology of the relevant soil form. The latest addition to this methodology, as mentioned, is known as a stagnating hydropedological type.

This soil type is characterised by restrictive movement of water through profiles (both laterally and vertically) and is dominated by evapotranspiration. The A- and B-horizon of such a soil type usually has a high permeability with morphological indicators indicating very little movement through the profile. Lime and iron concretions as well as cementation of silica are typical indicators of such a soil form.

3 Methodology

3.1 Desktop assessment

The following information sources were considered for the desktop assessment;

- Aerial imagery (Google Earth Pro);
- Land Type Data (Land Type Survey Staff, 1972 - 2006);
- Topographical river line data;
- Contour data (5 m); and
- Mucina & Rutherford (2006).

3.2 Field Procedure

The slopes within the project area have been assessed during the desktop assessment to identify possible transects (Figure 3-1) that will represent typical terrain and soil distribution patterns. These locations were then altered slightly during the survey depending on the extent of vegetation, slopes, access and any features that will improve the accuracy of data acquired.

3.2.1 Identification of Soil Types and Hydrological Soil Types

Soil types have been identified according to the South African soil classification system (Soil Classification Working Group, 2018) after which the link between soil forms and hydropedological response were established (van Tol & Le Roux, 2019), and the soils regrouped into various hydropedological soil types as shown in Table 3-1.

Table 3-1 Hydrological soil types of the studied hillslopes (van Tol et al., 2019)

Hydrological soil type	Description	Subgroup	Symbol
Recharge	Soils without any morphological indication of saturation. Vertical flow through and out 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.	Shallow	
		Deep	
Interflow (a/b)	Duplex soils where the textural discontinuity facilitates build-up 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).	A/B	
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.	Soil/Bedrock	
Responsive (shallow)	Shallow soils overlying relatively impermeable bedrock. Limited storage capacity results in the generation of overland flow after rain events.	Shallow	
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.	Saturated	
Stagnating	In these soils outflow of water is limited or restricted. The A and/or B horizons are permeable but morphological indicators suggest that recharge and interflow are not dominant. These includes soils with carbonate accumulations in the subsoil, accumulation and cementation by silica, and precipitation of iron as concretions and layers. These soils are frequently observed in climate regions with a very high evapotranspiration demand. Although infiltration occurs readily, the dominant hydrological flow path in the soil is upward, driven by evapotranspiration.		

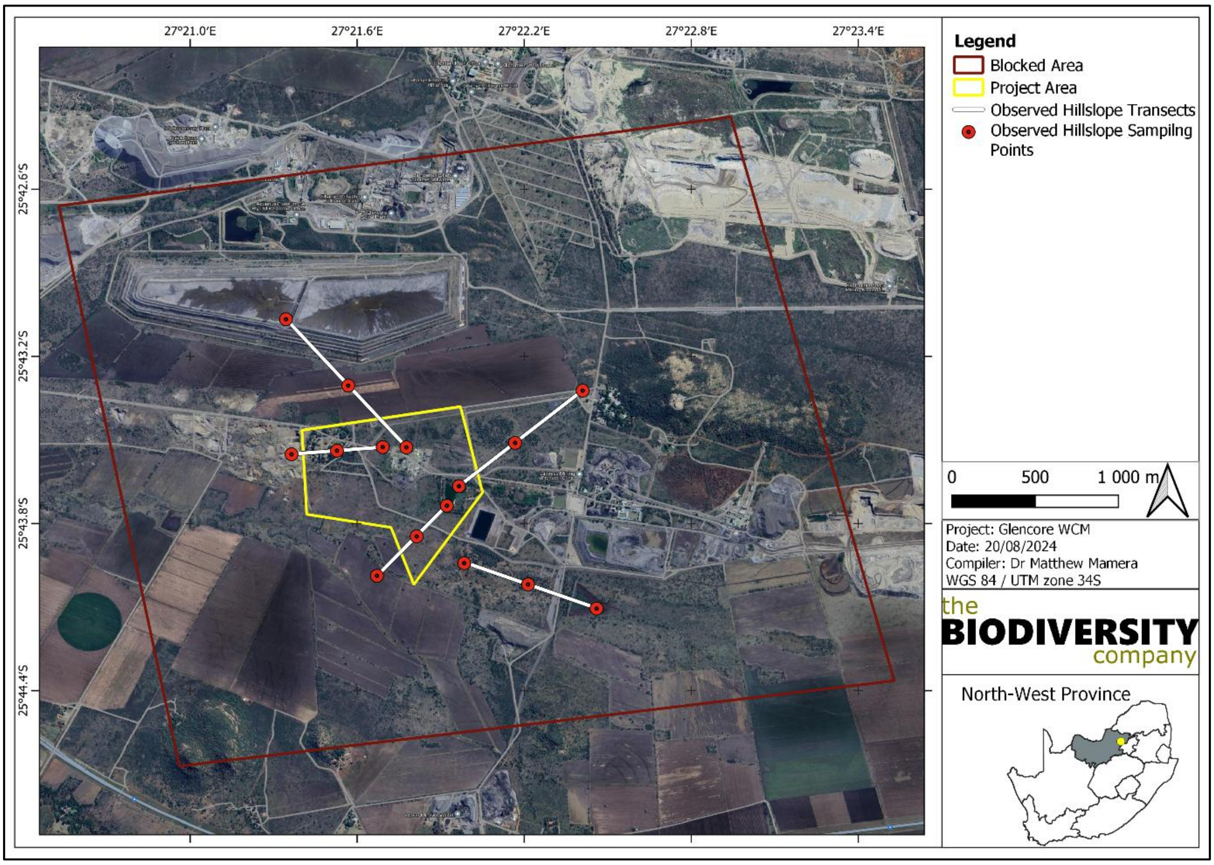


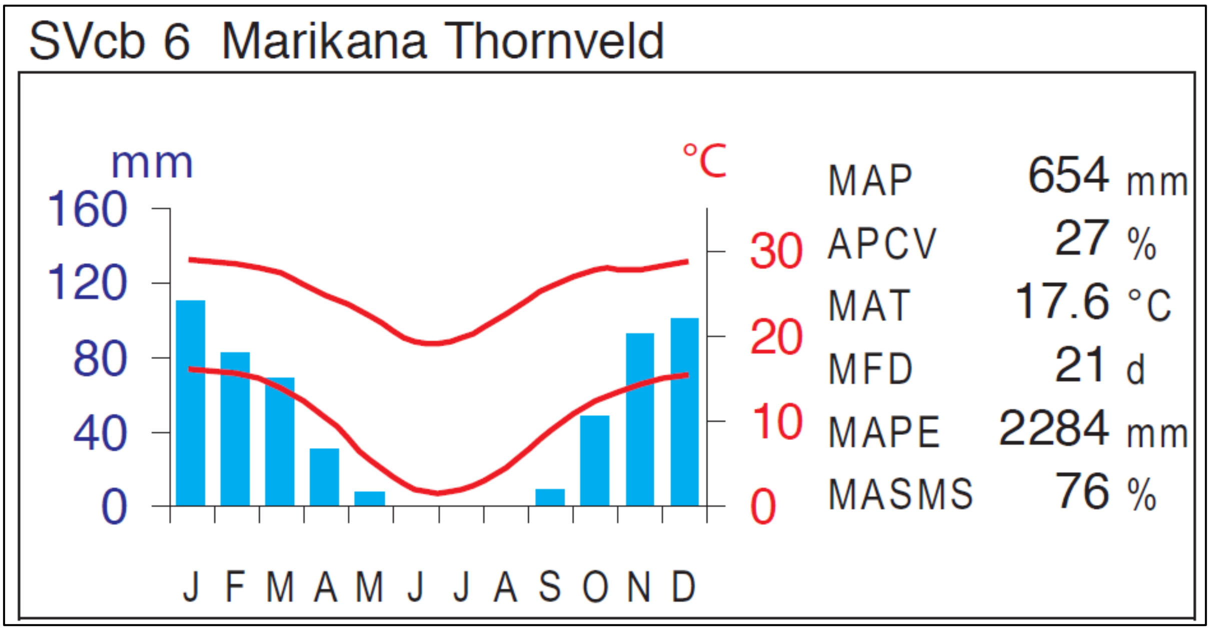
Figure 3-1 Transects and Observation Sites

4 Results and Discussions

4.1 Desktop Information

4.2 Climate

The project area falls within the Marikana Thornveld and Norite Koppies Bushveld vegetation. The area is characterised with a summer rainfall with dry winters. The overall mean average precipitation (MAP) of the proposed project area ranges from 600 - 700 mm. The monthly maximum and minimum temperature for Rustenburg are 35.3°C to -1.4°C in November and January respectively. The area experiences frost frequent in winter (see Figure 4-1).



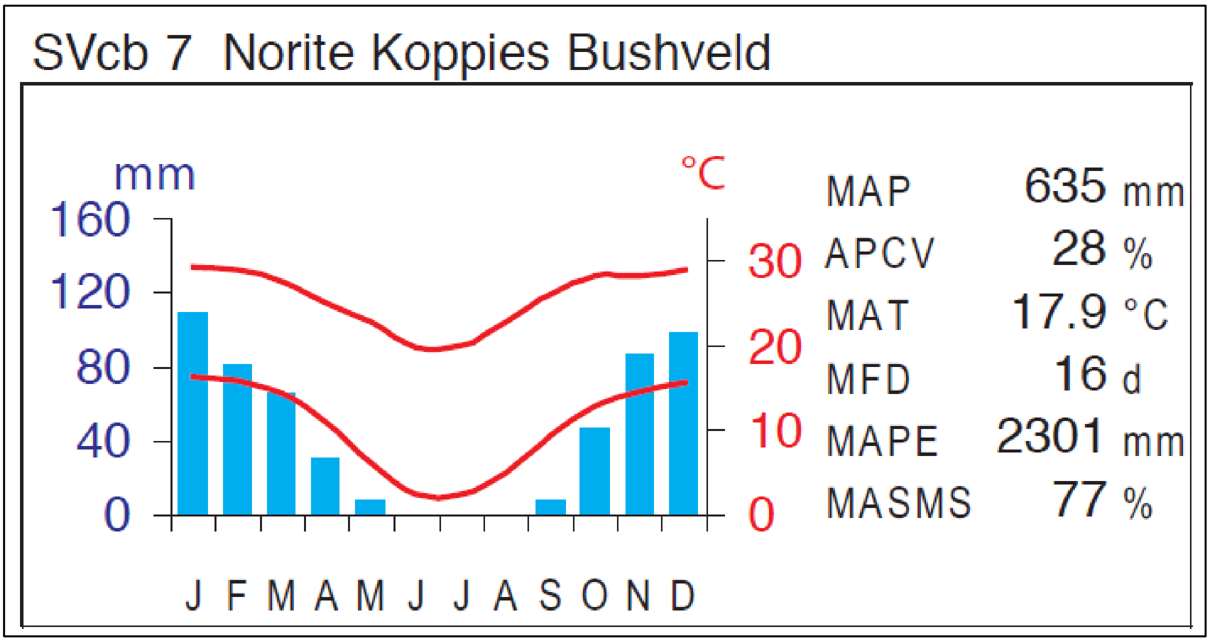


Figure 4-1 Summarised climate for the region (Mucina & Rutherford, 2006)

4.2.1 Vegetation

The Marikana Thornveld and Norite Koppies Bushveld vegetation Grassland vegetation is widely distributed in the North West and Gauteng province. The vegetation is found on plains from Rustenburg area in the west, through Marikana and Brits to the Pretoria area in the east. The altitude of this vegetation types is between 1 050 meters above sea level (masl) to 1 450 meters above sea level (Mucina & Rutherford, 2006).

The landscape features include Open *Acacia karoo* woodland, occurring in valleys and slightly undulating plains, and some lowland hills. Shrubs are denser along drainage lines, on termitaria and rocky outcrops or in other habitat protected from fire (Mucina & Rutherford, 2006).

4.2.2 Geology & Soils

The geology of the area includes mafic intrusive rocks of the Rustenburg layered suite of the Bushveld Igneous Complex, gabbro, norite, pyroxenite, anorthosite, shales and quartzites. According to the land type database (Land Type Survey Staff, 1972 - 2006) the transects relevant to the project is located in the Ea 3 and Ib 116 land types (see Figure 4-2 to Figure 4-3 below). The Ea 3 land type mainly consists of Arcadia, Oakleaf soil forms and rocky areas, according to the Soil classification working group (1991), with the occurrence of other soils within the landscape. The Ib 116 land type mainly consists of Arcadia and Rensburg soil forms, with rocky areas, associated with the occurrence of other soils in the landscape.

The Ea land type is characterised by vertic, melanic, red-structured diagnostic horizons and undifferentiated soils. The Ib land types have miscellaneous land classes and soils with rocky areas being dominant in the terrain. The relevant terrain units for the land types are illustrated below in the respective figures and tables.

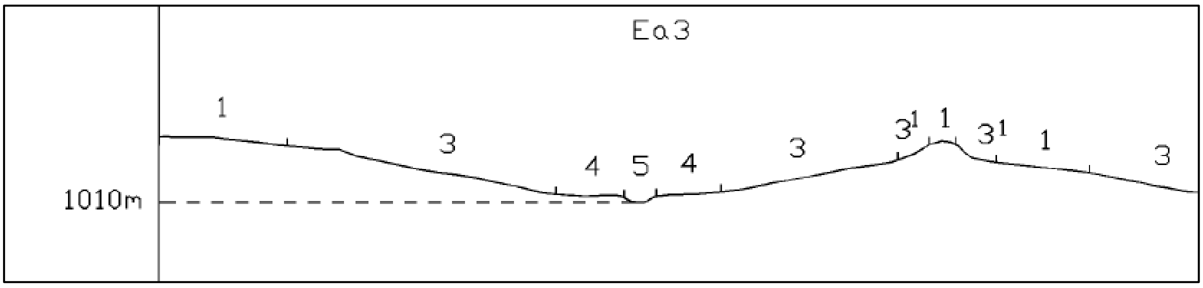


Figure 4-2 Illustration of land type Ea 3 terrain units (Land Type Survey Staff, 1972 - 2006)

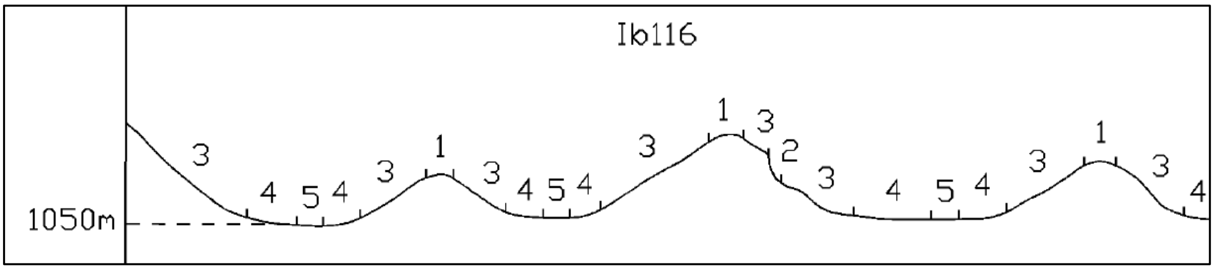


Figure 4-3 Illustration of land type Ib 116 terrain units (Land Type Survey Staff, 1972 - 2006)

Table 4-1 Soils expected at the respective terrain units within the Ea 3 land type (Land Type Survey Staff, 1972 - 2006)

Terrain Units									
1 (30%)		1 (0.5%)		3 (44.5%)		4 (15%)		5 (9%)	
Arcadia	70%	Bare Rocks	80%	Arcadia	76%	Arcadia	89%	Oakleaf	67%
Bare rock	14%	Mispah	20%	Bare Rocks	10%	Hutton	3%	Arcadia	22%
Mispah	9%			Mispah	6%	Shortlands	3%	Shortlands	6%
Hutton	4%			Hutton	4%	Swartland	3%	Hutton	5%
Shortlands	3%			Shortlands	3%	Bare Rocks	2%		
				Swartland	1%				

Table 4-2 Soils expected at the respective terrain units within the Ib 116 land type (Land Type Survey Staff, 1972 - 2006)

Terrain Units									
1 (5%)		2 (1%)		3 (50%)		4 (39%)		5 (5%)	
Bare Rock	60%	Bare Rocks	100%	Bare Rocks	86%	Bare Rocks	45%	Rensburg	40%
Mispah	40%			Mispah	14%	Arcadia	39%	Arcadia	40%
						Mispah	16%	Mispah	12%
								Bare Rocks	8%

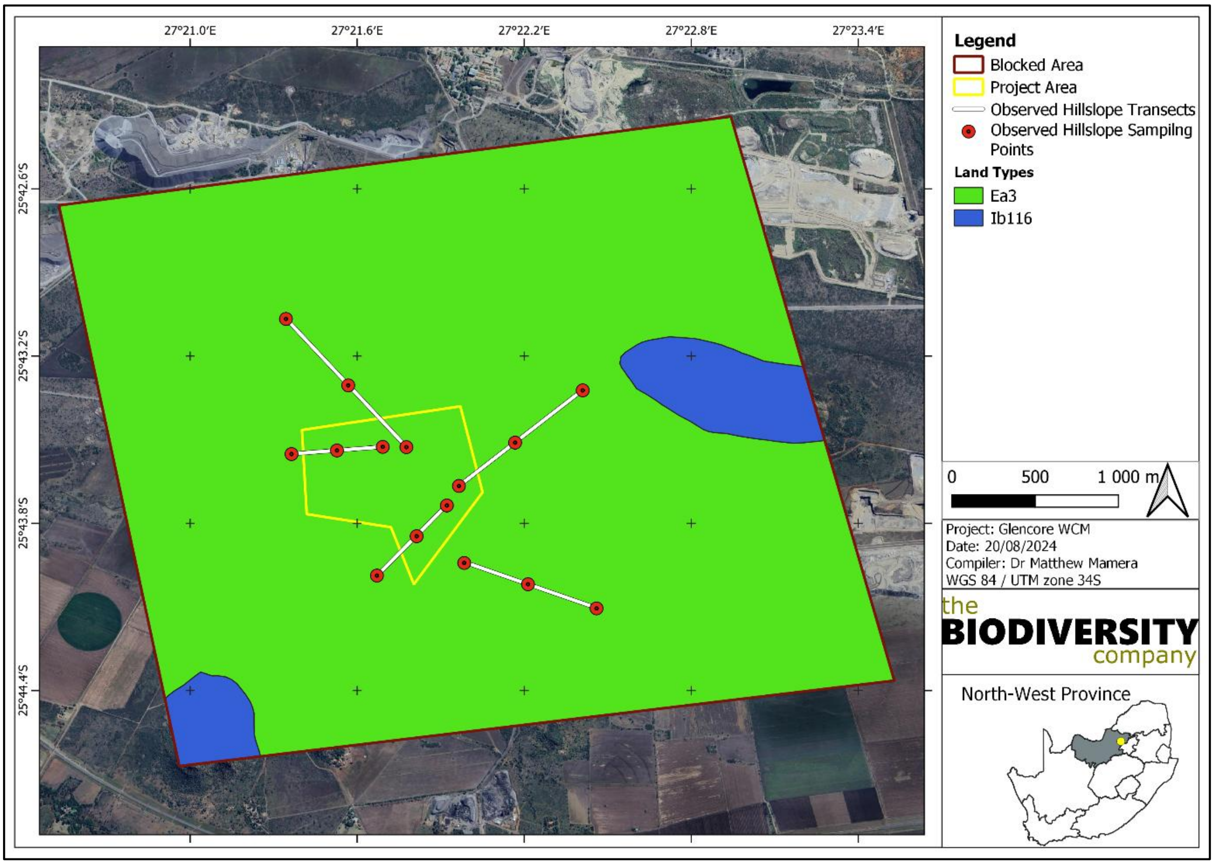


Figure 4-4 Land types present within the proposed Glencore Kroondal Mine Infrastructure Project`s surroundings

4.3 Identified Soil Forms

The following soil forms were identified on-site whilst surveying the relevant transects;

- Arcadia (Vertic topsoil on top of a lithic horizon below);
- Rustenburg (Vertic topsoil on top of a Hardrock substratum below);
- Rensburg (Vertic topsoil on top of a Gley horizon below);
- Mispah (Orthic topsoil on top of a hard rock layer below); and
- Witbank (Transported anthropogenic material from mining activities with some evidence of the original diagnostic horizons or partially processed saprolithic material).

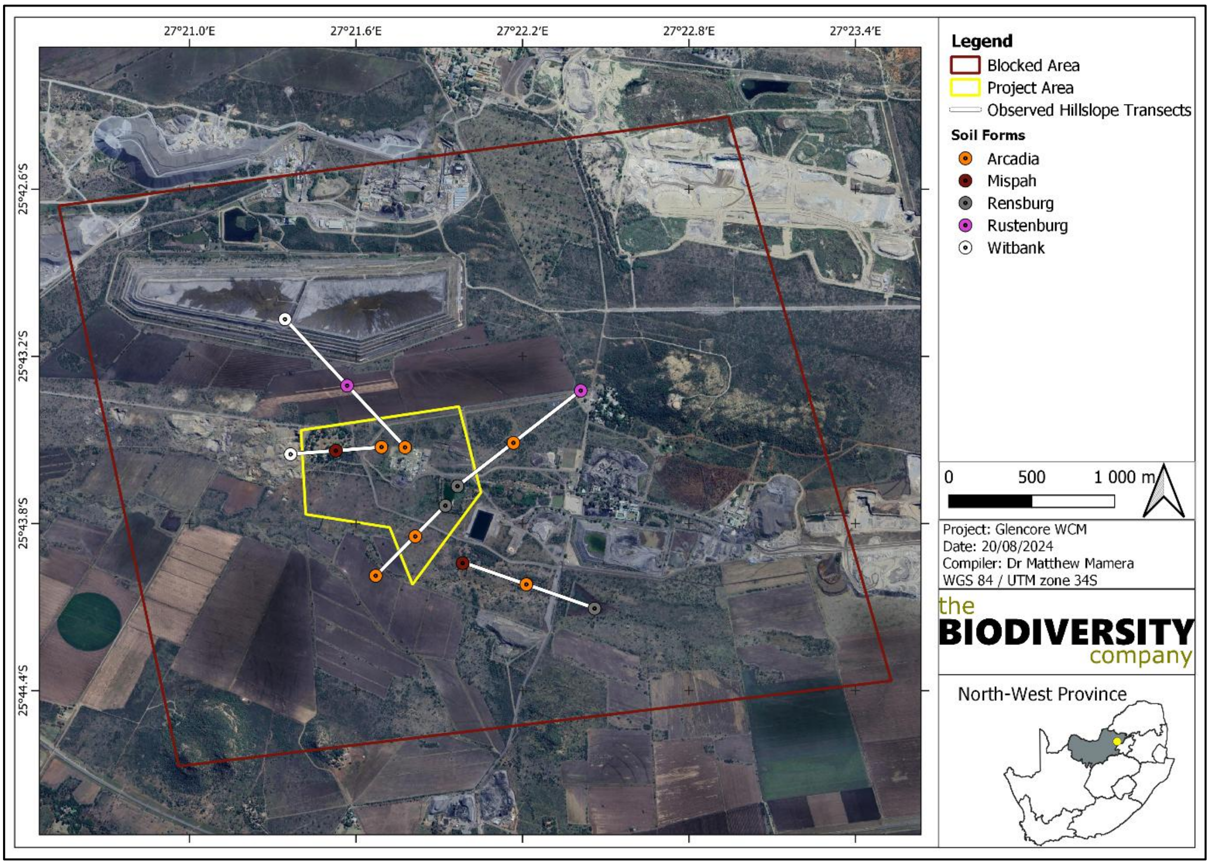


Figure 4-5 Soil forms identified within representative hillslope transects

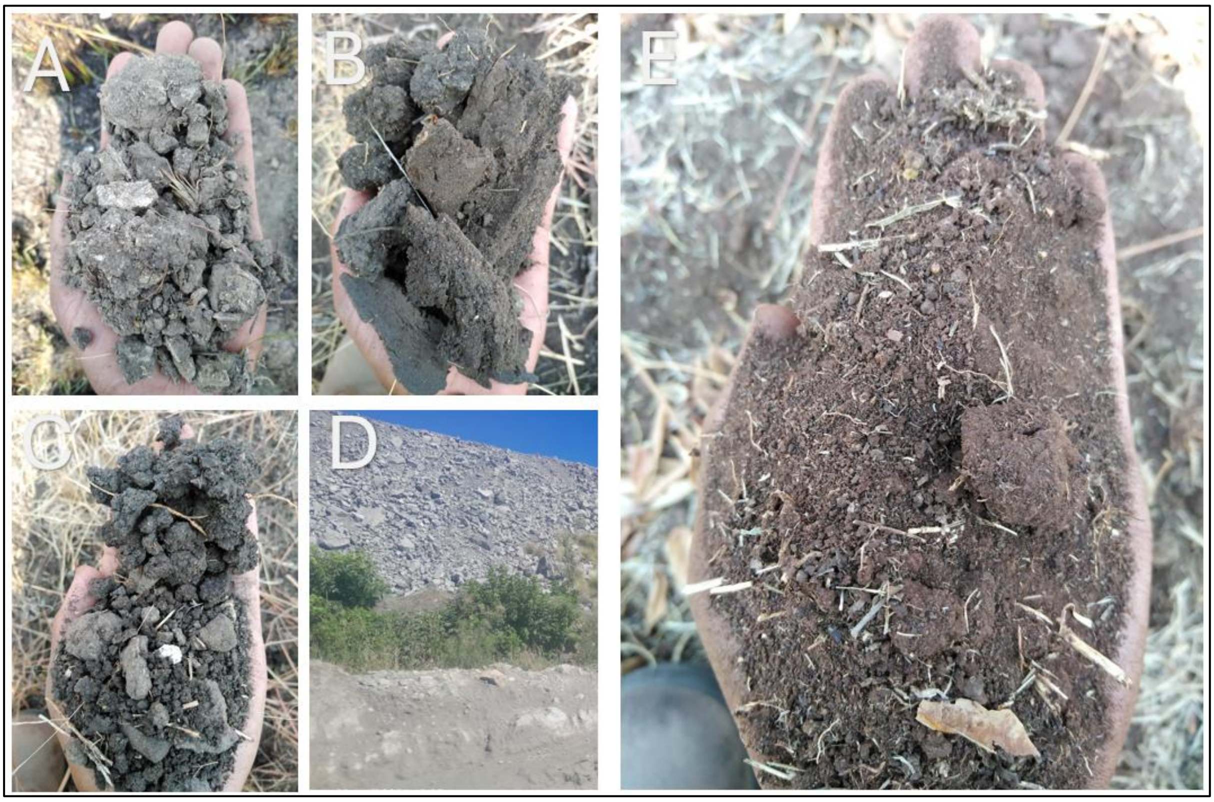


Figure 4-6 Diagnostic soil horizons identified on-site: A-C) Vertic horizons. D) Transported material. E) Orthic topsoil horizon with a hard rock layer

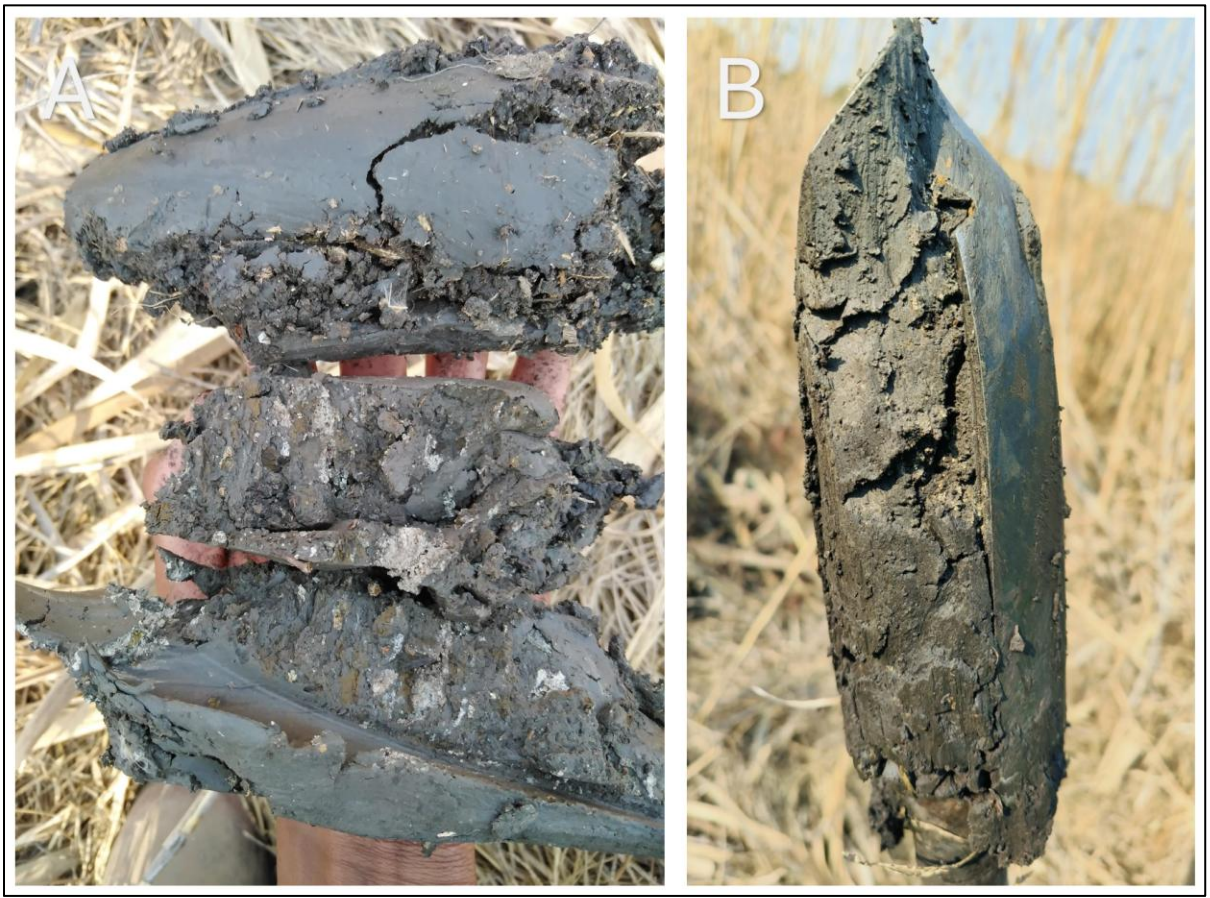


Figure 4-7 Diagnostic soil horizons identified on-site: A- B) Vertic horizon over gley horizon below

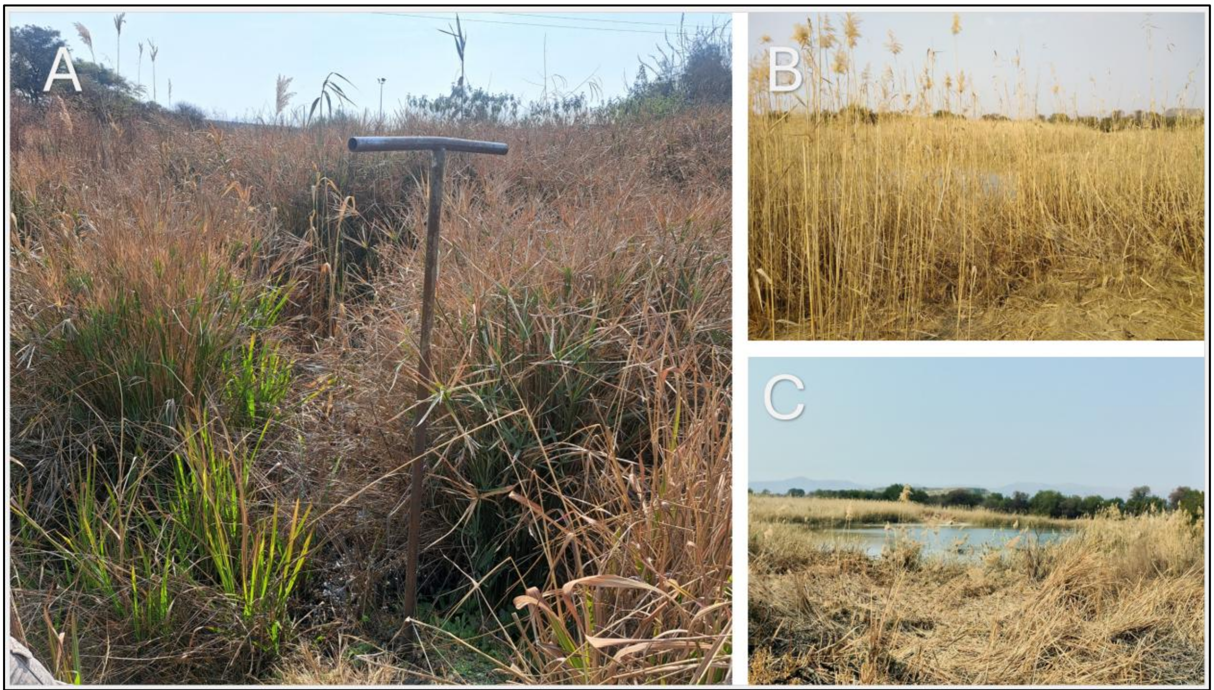


Figure 4-8 Diagnostic soil horizons identified on-site: A-C) Examples of surface return/overland flows and lateral flows pathways

4.4 Hillslope Hydrology

The survey was conducted to obtain information regarding the soil morphology and hydropedological flow paths relevant to the hillslope by means of several representative transects (see Table 4-3). The hillslope hydrology of slopes intersected by the proposed Glencore Kroondal Mine and associated infrastructure components development are characterised by their distinct hydropedological patterns. The majority of the slopes for the first distinctive hydropedological patterns are characterised by recharge (Deep and Shallow) (see Figure 4-9) hydropedological types. These patterns occur from the crest to the mid-slope transecting into interflow (A/B) towards the valley bottom merging to a watercourse.

The second to fourth distinctive hydropedological pattern is characterised with recharge (Shallow) or interflow (A/B) hydropedological soil types (Figure 4-10 to Figure 4-11) from the crest to lower mid-slope section, which transects to a responsive saturated hydropedological type at the valley bottom section. Restrictions in the water flow occurs within the responsive soils due to the presence of a high clay content and partially or unfractured parent material (see Figure 4-11 to Figure 4-12).

Table 4-3 Identified hillslope dominant soil forms and hydropedological groups

Terrain Morphological Unit (TMU)							
1&2		3		4		5	
Soil form	Hydroped	Soil form	Hydroped	Soil form	Hydroped	Soil form	Hydroped
Witbank	Recharge (deep)	Rustenburg	Interflow (A/B)	Acardia	Interflow (A/B)	Acardia	Interflow (A/B)
Witbank	Recharge (deep)	Mispah	Recharge (shallow)	Acardia	Interflow (A/B)	Acardia	Interflow (A/B)
Acardia	Interflow (A/B)	Acardia	Interflow (A/B)	Acardia	Interflow (A/B)	Rensburg	Responsive (Saturated)
Mispah	Recharge (shallow)	Acardia	Interflow (A/B)	Acardia	Interflow (A/B)	Rensburg	Responsive (Saturated)
Rustenburg	Interflow (A/B)	Acardia	Interflow (A/B)	Acardia	Interflow (A/B)	Rensburg	Responsive (Saturated)

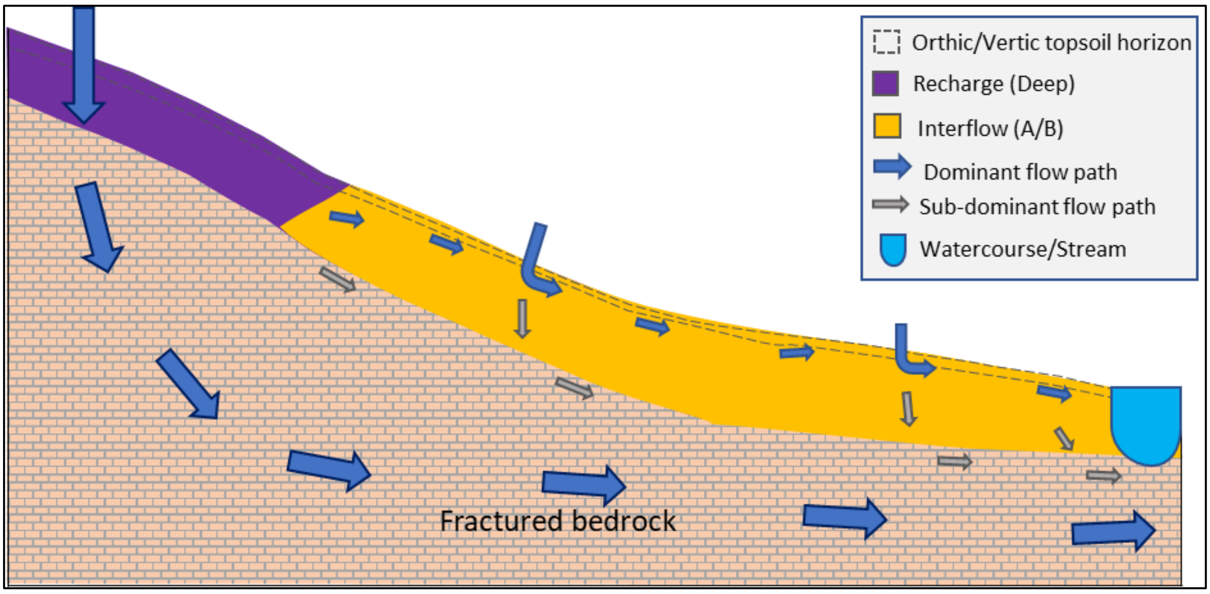


Figure 4-9 Hillslope hydrology one of four of the distinct hydropedological patterns prior to construction of the proposed Glencore Kroondal Mine Project and associated infrastructure.

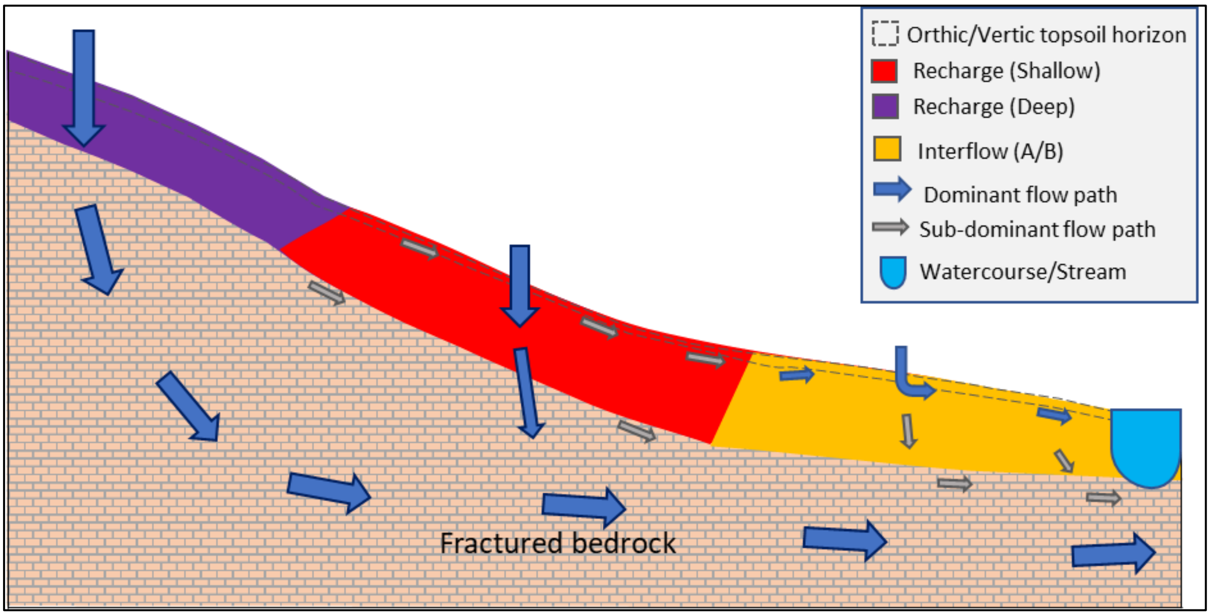


Figure 4-10 ***Hillslope hydrology two of four of the distinct hydropedological patterns prior to construction of the proposed Glencore Kroondal Mine Project and associated infrastructure.***

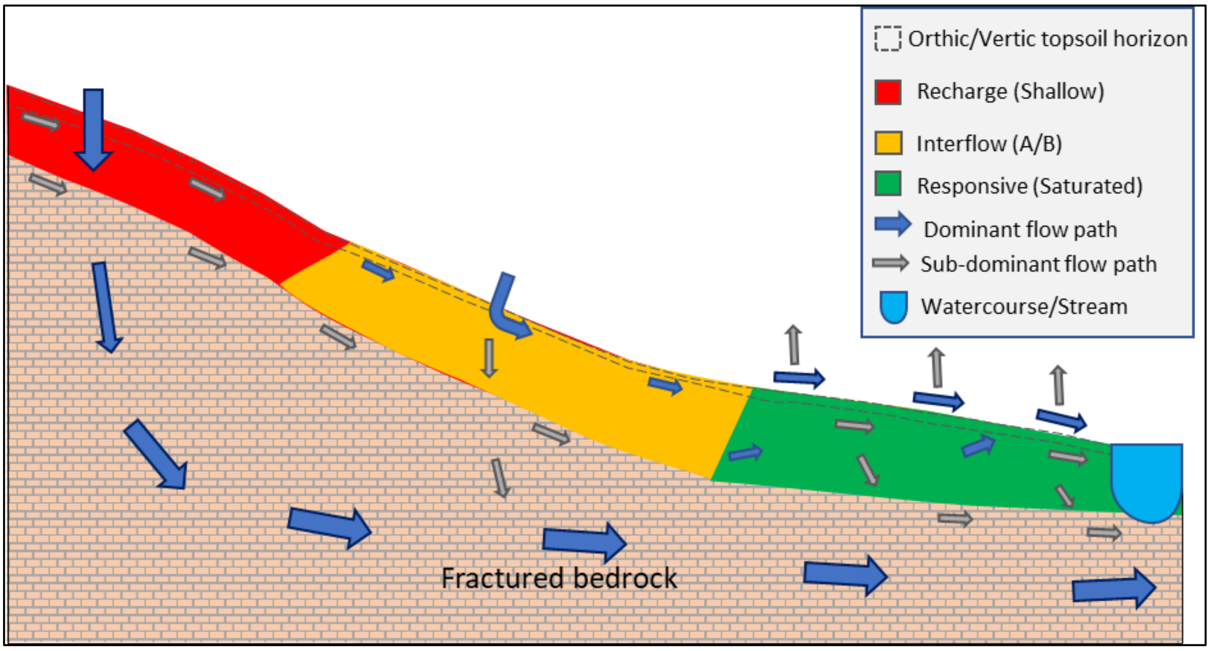


Figure 4-11 ***Hillslope hydrology three of four of the distinct hydropedological patterns prior to construction of the proposed Glencore Kroondal Mine Project and associated infrastructure.***

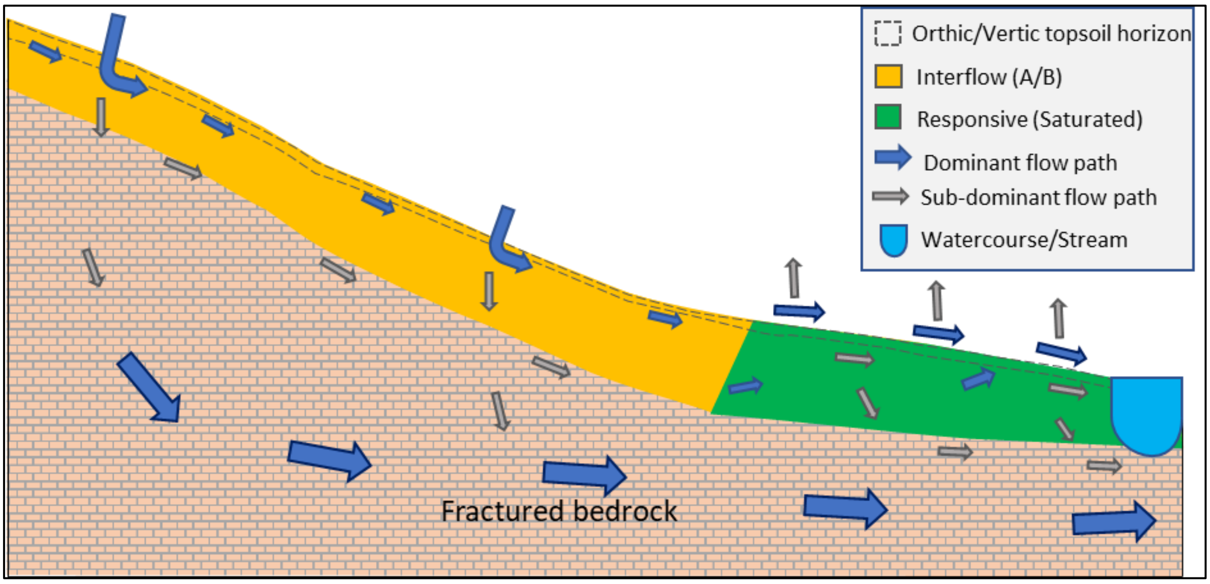


Figure 4-12 Hillslope hydrology four of four of the distinct hydropedological patterns prior to construction of the proposed Glencore Kroondal Mine Project and associated infrastructure.

The shallow Mispah soil forms and deep Witbank soil forms identified on-site are characterised with well drained profiles. The Mispah soil forms consist of an orthic topsoil with a hard rock layer below. The Witbank soil forms consist of anthropogenic transported material from the mining activities, with evidence of the inherent diagnostic horizons. Clear horizons of red and yellow apedal horizons were evident and visible in the profile. These profiles are characterised by extremely high permeability soil hydraulic conductivity (Ks) rates, including the lower lithic horizon which can also be available below the B1 subsurface horizon in most cases.

No signs of leaching or oxidation/reduction processes were identified throughout the soil profiles, which, together with the high Ks emphasises rapid vertical recharge of the groundwater storage as being the dominant flow path.

The soil form relevant to some of the mid-slope to foot slope areas has been classified as an interflow (A/B) hydropedological types. These soil forms are characterised by vertic horizons. The interflow (A/B) between the soil and or bedrock, is an indicative of lateral sub-surface flows between the topsoil, subsurface soils and bedrock layer. The subsurface layer or bedrock layer displays a very low Ks, which has limited percolation into the bedrock, which can ultimately result in interflow.

Vertic horizons are often characterised by strongly structured, dark clay horizons, with a high smectite clay content that gives rise to pronounced swell-shrink processes. Sometimes, red or gley variants occur. Thicker vertic horizons exhibits slickensides and wedge-shaped structural aggregates at some depth. They may also exhibit self-mulching properties at the surface. Mechanical disturbances of vertic horizons may give rise to massive or altered surface structural aggregates. Vertic horizons crack strongly when dry and sticky when wet. Some vertic horizons have a strong tendency to invert, depositing calcium carbonate nodules, and/or stones and rocks on the surface. Vertic soils may also exhibit gilgai microrelief (Soil Classification Working Group (2018).

The valley bottom regions are characterised by responsive (wet) hydropedological types. The soil form relevant to this observation point is that of the Rensburg soil forms. The Rensburg soil forms are characterised by a gley horizon as the subsoil, which is indicative of prolonged/permanently saturated soils which result in the formation of “responsive soils.” Responsive soils will be subject to overland/return flow during precipitation events (due to the naturally high-water content which will ensure rapid saturation). Between rainfall events, these soil forms will steadily feed watercourses and will lose moisture by means of Evapotranspiration (ET).

Gley horizons that are well developed and have homogenous dark to light grey colours with smooth transitions. Stagnant and reduced water over long periods is the main factor responsible for the formation of a gley horizon and could be characterised by green or blue tinges due to the presence of a mineral called Fougerite which includes sulphate and carbonate complexes. Even though grey colours are dominant, yellow and/or red striations can be noticed throughout a gley horizon. The structure of a gley horizon mostly is characterised as strong pedal, with low hydraulic conductivities due to high clay content (clayey texture), although sandy gley horizons are also known to occur. The gley soil form commonly occurs at the toe of hillslopes (or benches) where lateral water inputs (sub-surface) are dominant and the underlaying geology is characterised by a low hydraulic conductivity. The gley horizon usually is second in diagnostic sequence in shallow profiles yet is known to be lower down in sequence and at greater depths (Soil Classification Working Group, 2018).

4.5 Conceptual Impact Prediction

The proposed Glencore Kroondal Mine and associated infrastructure components development will have acceptable impacts on the hydropedology of some of the relevant hillslopes, due to the position of the development area and associated infrastructure like offices, buildings, parking, storage dams, infrastructure pipelines, administration office, houses and stores (crest lower and mid-slope). For recharge soils, recharge won't be affected at all given the fact that infiltration will only be impeded for the width of concrete areas or buildings and their associated pipelines, which has been deemed insignificant in the catchment as the dominant flow paths will remain vertical recharging groundwater storages (see Figure 4-13 to Figure 4-15 for a conceptual example of interferences via the proposed concrete building foundations, reclaiming equipment, infrastructure pipelines and associated infrastructure).

As for the interflow (A/B) responses at the soil rock interface (merging into an impermeable substratum), lateral flow changes between the transition from recharge to lateral pathways will be impeded upon due to the fact that recharge from the crest will pass underneath the building foundations and associated infrastructure pipelines (see Figure 4-13 to Figure 4-16). It has also been assumed that a fraction of the lateral flows associated with the soils is from seepage and return flows out of the shallow available substratum, which minimises impacts in the catchment flows due to the most infrastructure like the building concrete formations or and or infrastructure pipelines to such seepage phenomena. The lateral flow zones tend usually to be between 100 cm and 300 cm deeper, which ultimately allows for flows to pass underneath concrete layers or pipelines in most cases and recharge groundwater. It is worth noting that some of the lateral flow will be impeded with impermeable layers like the underground tunnels, impermeable sealed areas, concretes and infrastructure pipeline, and this can result in return flows and overland flows occurring. Existing or expansion of the tunnels can also result in draw-backs effects of lateral flows due the discontinuity of this flow paths. Measures which promote infiltration and percolation of the return flow surface water can minimise this effect as the flows will gradually change to vertical flows, and continue to sufficiently recharge the aquifer and ground water reserves.

The responsive (saturated) hydropedological types, are typically associated with wetlands and not commonly recommended for most development activities as their interface can affect the total streamflow and ground water stores of sensitive receptors (e.g., the lower valley bottoms in Figure 4-15 to Figure 4-16). Moreover, these soils have a tendance to promote migration of inorganic (hydrocarbon spills), chemical elements (metal alloys processing) and organic (bacteria) contaminants towards water resources from a pollution source.

The proposed Glencore Kroondal Mine and associated infrastructure Project located within the available recharge hydropedological type is not expected to affect the hillslope hydrology in any manner. Flow changes can occur in the lateral flows due to increased water regimes and underlying restrictive impermeable layers which can disconnect these lateral flows. These effects are however expected to have acceptable impact significance towards the total streamflow or total deductible water regime losses of sensitive receptors (downstream rivers and wetlands) and groundwater storage.

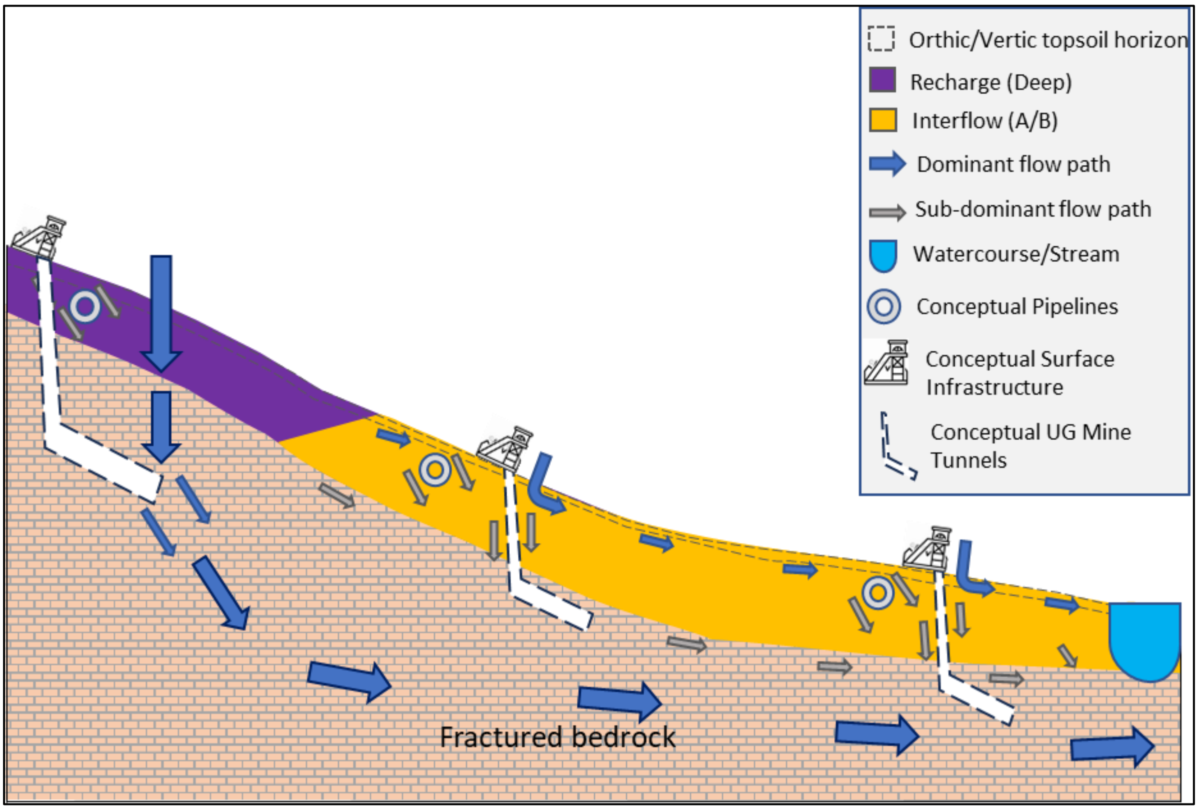


Figure 4-13 ***Hillslope hydrology one of four of the distinct hydropedological patterns after the construction of the proposed Glencore Kroondal Mine Project and associated infrastructure***

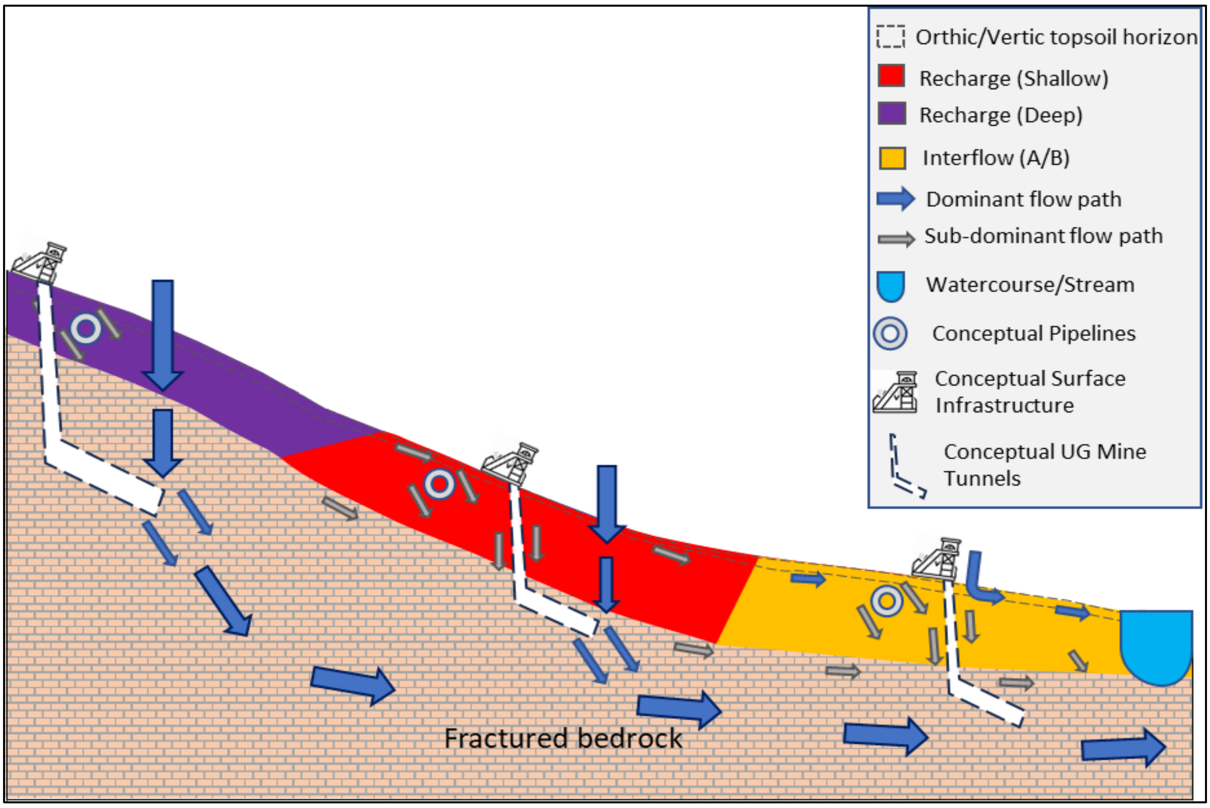


Figure 4-14 ***Hillslope hydrology two of four of the distinct hydropedological patterns after the construction of the proposed Glencore Kroondal Mine Project and associated infrastructure***

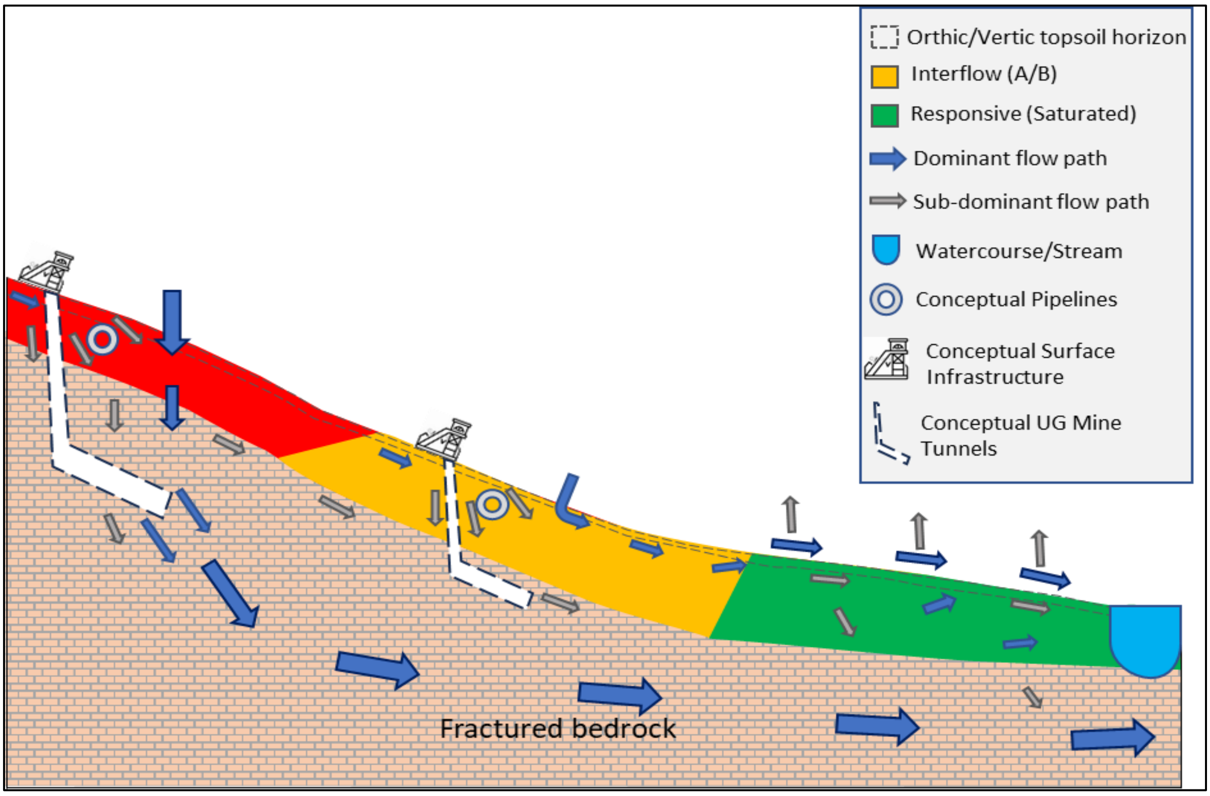


Figure 4-15 ***Hillslope hydrology three of four of the distinct hydropedological patterns after the construction of the proposed Glencore Kroondal Mine Project and associated infrastructure***

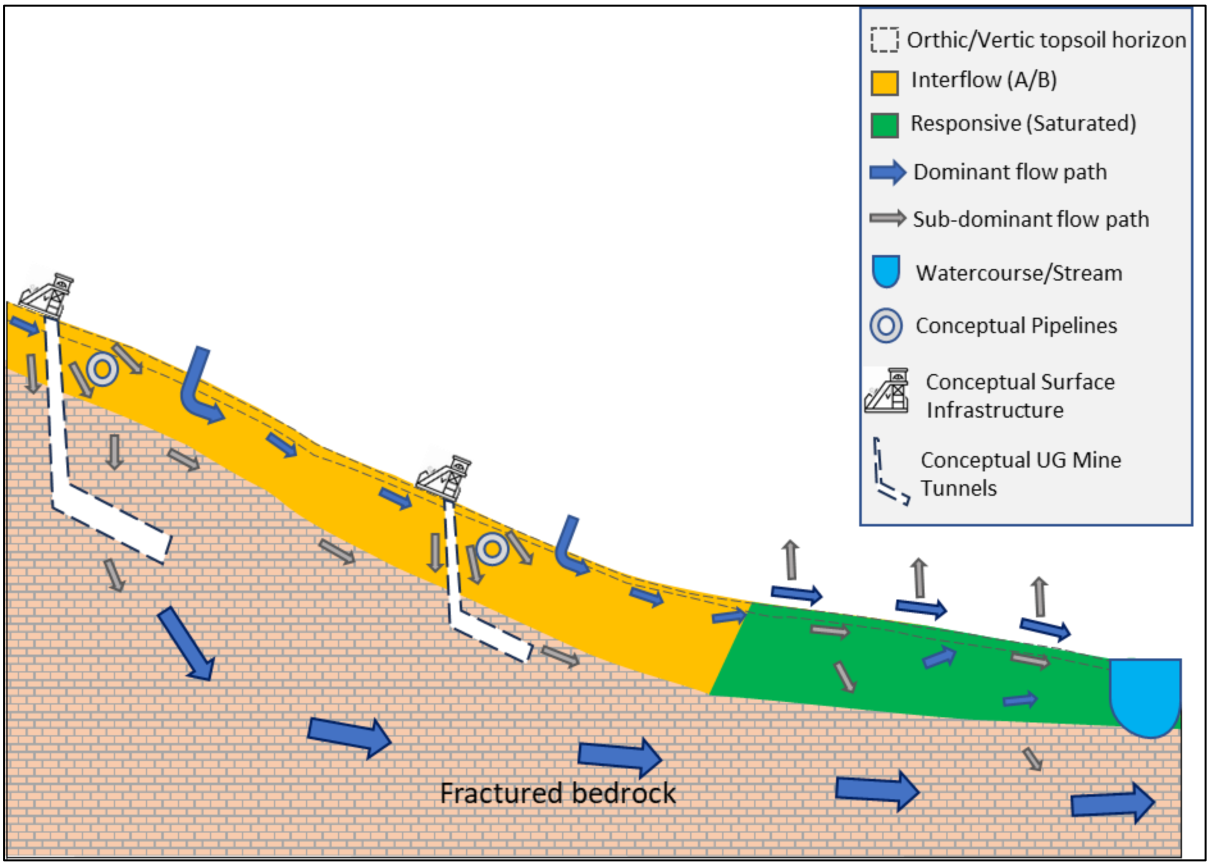


Figure 4-16 Hillslope hydrology four of four of the distinct hydropedological patterns after the construction of the proposed Glencore Kroondal Mine Project and associated infrastructure

4.6 Impact Assessment

4.6.1 Construction and Operation phase

The expected impacts on the catchment water regimes were assessed following an impact matrix methodology. Soil erosion, sedimentation or overland flows can occur due to increased traffic on the surface during the construction phase which can also result in compaction and surface sealing. Overland flow and potential erosion of terrestrial and wetlands soils can occur which can lead to loss of fertile topsoil. Soil erosion can also contribute to water pollution and siltation of rivers. Surface sealing will also promote head cutting instreams and loss of fertile topsoil. Existing sealed areas can intercept lateral flow paths and remove connectivity between recharge zones and lateral flow zones. Alteration of this flow path will likely change the water regimes negatively, even though the impact should be acceptable. The draw-down effect on the water flows can also occur impacting the water regimes as well. These effects are manageable as the post mitigation has been scored low.

Table 4-4 Impact assessment of erosion due to increased overland flow on the environment.

	Without Mitigation	With Mitigation
Magnitude	High (8)	Low (4)
Extent	Local (2)	Local (2)
Duration	Long-term (4)	Short-term (2)
Probability	Probable (4)	Possible (3)
Significance	47	24

Status (positive or negative)	Negative	Negative

Table 4-5 Impact assessment of potential decrease in subsurface lateral flow and return flow on the environment.

	Without Mitigation	With Mitigation
Magnitude	High (8)	Moderate (6)
Extent	Regional (4)	Local (2)
Duration	Long-term (4)	Short-term (2)
Probability	Highly Probable (4)	Probable (3)
Significance	55	30
Status (positive or negative)	Negative	Negative

4.6.2 Decommissioning and Closure Phase

The phase will include closure and ceasing of the chair lift. Some of the infrastructure will be removed from the site for decommissioning, this will be done with specialist on the site. Increased traffic will occur on-site, though the effects are expected to be minimal and manageable and mitigation measures will already be implemented. These effects are manageable as the post mitigation has been scored low.

Table 4-6 Impact assessment of erosion due to increased overland flow on the environment..

	Without Mitigation	With Mitigation
Magnitude	Low (4)	Minor (2)
Extent	Local (2)	Site (1)
Duration	Moderate-term (4)	Short-term (2)
Probability	Probable (4)	Very Improbable (1)
Significance	27	5
Status (positive or negative)	Negative	Negative

Table 4-7 Impact assessment of potential decrease in subsurface lateral flow and return flow on the environment.

	Without Mitigation	With Mitigation
Magnitude	Low (4)	Minor (2)
Extent	Local (2)	Site (1)
Duration	Short-term (2)	Short-term (2)
Probability	Probable (4)	Very Improbable (1)
Significance	24	5
Status (positive or negative)	Negative	Negative

4.6.3 Mitigation Measures

Subsurface drainage on associated infrastructure like the buildings or offices should be included in the water management plan for stormwater which can minimise overland flow from paved surfaces. This can also allow the roof water from the associated infrastructure like parking lots or offices to percolate and re-infiltrate. Pipe leakages need to be fixed and ensure measures are in place to prevent future leakages. Measures like contacting the responsible authorities immediately for sewage or faecal sludge pipelines associated with sanitation systems and having response guidelines.

The following measures can promote infiltration, and percolation flows during the construction, operation and closure phases:

The following measures can promote infiltration and percolation flows:

- Minimise soil compaction and keep the soil covered with mulching residue (plant or gravel) and vegetative cover;
- Infiltration basin or trench only where necessary can minimise surface overflows or runoffs and allow water that runs off from roofs to settle and re-infiltrate;
- Installation of pre-treatment stormwater practices which remove large sediment and other solids upstream of infiltration practice; and
- Adhering to the recommended footprint buffers and wetland buffers (15 m minimal) or wetland rehabilitation measures if encroaching within this buffer as proposed with the wetland specialist for the proposed project area should be sufficient to reduce the deductible water losses in the catchment. Also prevent any discharge of untreated potential wastewater into the catchment as responsive saturated soils (mostly associated with the valley bottoms or along water channels) have a high tendency to promote contaminant (i.e., Bacteria and inorganic elements) migrations towards water resources.

5 Conclusion

The four hillslope types which were identified, includes the presence of recharge (shallow and deep), interflow (A/B) and responsive saturated hydropedological types. The Glencore Kroondal Project and associated infrastructure will have an acceptable effect on the hillslope hydrology due to the extent of the underground mining tunnels, building concrete foundations, or associated water and drainage or infrastructure pipelines and other infrastructures. Most of the hillslopes with recharge (deep) dominating throughout as well as the size of the greater catchment have minimal impacts. Lateral flow from interflow (A/B) changes can occur in the hillslopes which may increase surface run-offs, surface return flows and overland flows or draw-backs into the mine tunnels. However, their effects will have acceptable impacts on the total streamflow or total deductible water regime losses of watercourses in the larger catchment as both lateral and vertical flow paths will occur in response to the flow impediment.

The Glencore Kroondal Project and associated infrastructure activities will require some mitigation measures being implemented due to impacts expected on some of the identified hillslopes in the assessment area. Measures can be set on soils which experienced some changes in flow paths following the development and associated infrastructure construction. Flow impediment can be managed well to minimise saturation conditions and surface return flows to promote subsurface groundwater recharge and storage. Valley bottom soils are responsive hydromorphic soils due to long periods of saturation. Usually, development should avoid areas with responsive (saturated) hydropedological soil types mostly associated to, and found in areas like wetlands which act as water regime receptors for the water balance in the hillslopes` catchment. These soils also have a high tendency to promote migration of inorganic (chemical elements) and organic (faecal bacteria) from a pollution source towards water resources.

5.1 Impact Statement

The project has an overall low residual impact, and this is acceptable. The following aspects must be considered for the development to reduce overland flows and surface return flows:

- Prevent flood damage or concentration of run-off;
- Divert stormwater and surface run-off from buildings, roads and parking areas into an attenuation pond;
- Preserve the natural and beneficial functions of the natural drainage system downstream;
- Preserve and enhance stormwater quality;
- Attenuate the difference between pre and post-development flows; and
- Prevent disposal of untreated wastewater into the catchment system or surrounding areas.

Such measures for these systems will ensure that adequate water deducted from the catchment as run-off will be re-applied into the system which can minimise losses from the total deductible regimes as most of the hillslopes have recharge soils. Application of good quality water will promote lateral flows associated with these hydropedological groups. Improved water quality in the area is important to minimise pollutes migrations. From a hydropedological perspective, the proposed monitoring will be sufficient for water flows and groundwater recharge receptors.

5.2 Specialist Opinion

From a hydropedological perspective, the impact of the development on hydropedological flow paths would be acceptable and the impacts can be managed sustainably.

5.3 Layout Approval

Following refinement and further specialist input a SWMP was developed after the completion of the specialist report and therefore this section aims to provide consideration by the specialist of the new clean water dam infrastructure in the context of the overall study. The remaining clean water dam will now incorporate a constructed wetland system, designed to enhance passive treatment, water quality improvement, and ecological function. Figure 5-1 presents the updated layout.

The siting, design, and scale of this dam have been informed by specialist findings, ecological sensitivities, and site conditions. This change does not represent a significant deviation from the original project scope; rather, it results in a net improvement in environmental outcomes introducing a multifunctional, ecologically beneficial wetland system.

These updates are detailed in the stormwater management plan drawing (Drawing No. P2501017-SW-ST2-710). Minor adjustments to infrastructure layout, are considered acceptable and do not affect the conclusions of the original specialist assessment. The revised design is supported by the specialist and is regarded as favourable for environmental authorisation.

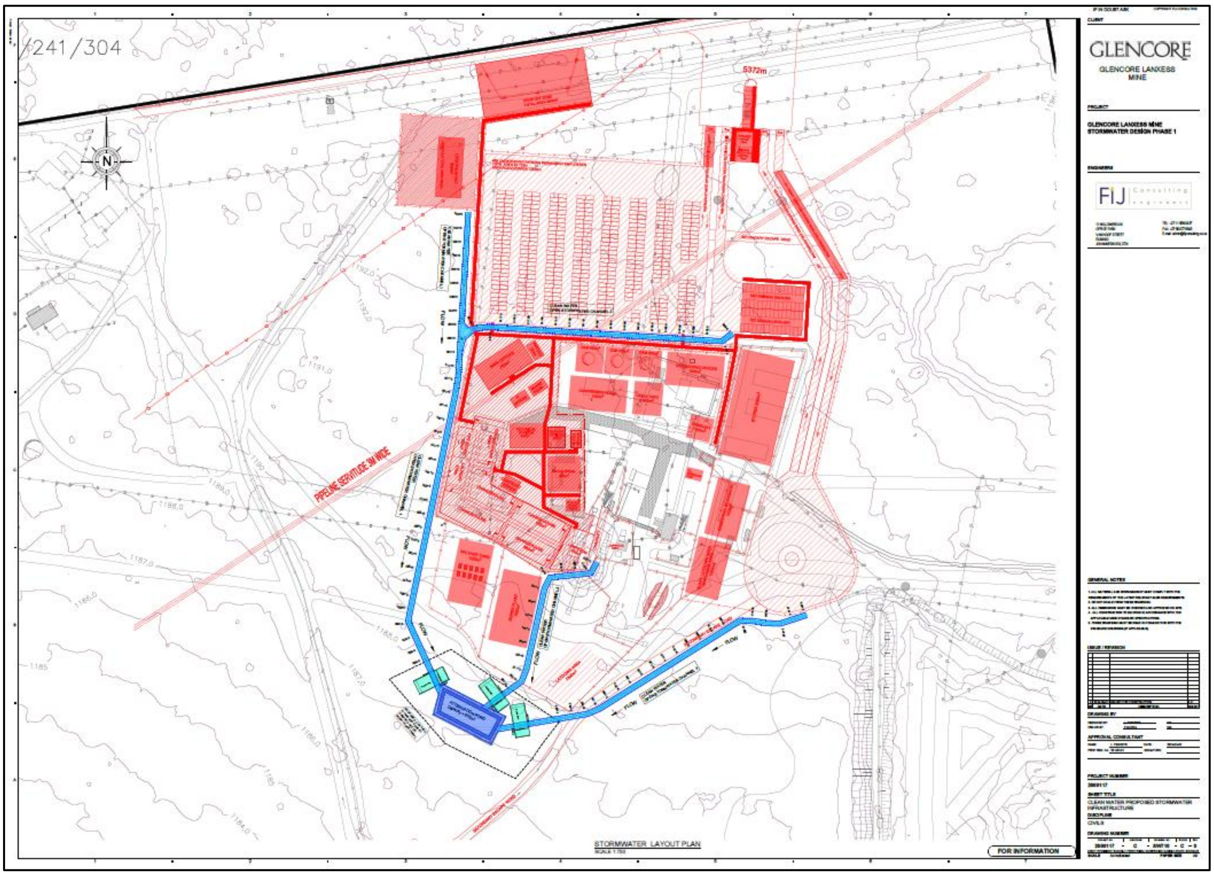


Figure 5-1 The updated layout

From a hydropedological standpoint, the integration of a constructed wetland within the clean water dam system, enhances the hydrological integrity of the site. The wetland system promotes passive recharge and preserves subsurface lateral flow patterns, which is favourable for maintaining hillslope hydrological processes. The inclusion of a clean water dam (functioning as an artificial wetland) remain within the scope of previously assessed flow regimes and do not introduce additional hydropedological risks.

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7 Appendix

7.1 Erosion due to increased overland flow on the environment

		Pre-Mitigation							**Post Mitigation**								**Priority Factor Criteria**			
Impact	Phase	Nature	Extent	Duration	Magnitude	Reversibility	Probability	Pre-mitigation ER	Nature	Extent	Duration	Magnitude	Reversibility	Probability	Post-mitigation ER	Confidence	Cumulative Impact	Irreplaceable loss	Priority Factor	Final score
Soil compaction, Soil erosion, Land degradation	Construction	-1	3	4	4	3	3	-10,5	-1	3	2	2	3	2	-5	High	2	3	1,38	-6,88
	Operation	-1	2	3	2	3	2	-5	-1	2	2	2	2	2	-4	High	2	3	1,38	-5,5
	Decommissioning	-1	2	2	2	2	3	-6	-1	2	2	1	2	2	-3,5	Low	2	2	1,25	-4,38
	Rehab and closure	-1	2	2	2	2	2	-4	-1	2	2	1	2	1	-1,75	Low	1	2	1,13	-1,97

7.2 Decrease in subsurface lateral flow and return flow impacts

		Pre-Mitigation							Post Mitigation								Priority Factor Criteria			
Impact	Phase	Nature	Extent	Duration	Magnitude	Reversibility	Probability	Pre-mitigation ER	Nature	Extent	Duration	Magnitude	Reversibility	Probability	Post-mitigation ER	Confidence	Cumulative Impact	Irreplaceable loss	Priority Factor	Final score
Decrease in subsurface lateral flow and return flow	Construction	-1	4	4	4	3	4	-15	-1	2	2	3	3	2	-5	High	2	3	1,38	-6,875
	Operation	-1	2	3	2	3	2	-5	-1	2	2	2	2	2	-4	High	2	3	1,38	-5,5
	Decommissioning	-1	2	2	2	2	3	-6	-1	2	2	1	2	2	-3,5	Low	2	2	1,25	-4,375
	Rehab and closure	-1	2	2	2	2	2	-4	-1	2	2	1	2	1	-1,75	Low	1	2	1,13	-1,9688