HYDROPEDOLOGICAL ASSESSMENT: FOR THE PROPOSED SOUTH 3 OPENCAST MINE AND ASSOCIATED SUPPORT INFRASTRUCTURE WITHIN THE FETAKGOMO TUBATSE MUNICIPALITY, LIMPOPO, SOUTH AFRICA.

REF: HYDROPED_MPM SOUTH3_24

DATE OF FIRST DRAFT:

03 July 2024

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PREPARED FOR

Segope Water & Environmental Services

PREPARED BY

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DOCUMENT CONTROL

Report Name	Hydropedological Assessment: For The Proposed South 3 Opencast Mine and Associated Support Infrastructure Within The Fetakgomo Tubatse Municipality, Limpopo, South Africa.
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EXECUTIVE SUMMARY

Enviro-Solum Consulting was appointed to conduct a hydropedological assessment as part of the Environmental Impact Assessment (EIA) and Water Use License Application (WULA) for the proposed South 3 Opencast Mine and associated support infrastructure (hereafter referred to as study area). The area wherein the proposed development is to take place will is located approximately 2km north of the R555 road and approximately 5km west of the steelpoort town, within the Fetakgomo Tubatse Municipality, Limpopo, South Africa..

Modikwa Platinum Mine (MPM) has intended on developing another open pit on Winterveld which will follow the conventional Open Cast methods, which include the stripping at 40 to 60 ktpm with concurrent backfill. The ore from the open pit will be extracted by a combination of excavation and crushing activities. The ore will be transported by truck to the primary crusher stockpile. Waste is disposed to waste dumps on the surface.

The aim of the assessment was to conduct a hydropedological assessment of the focus area and identify the major drivers of the nearby wetlands and watercourses from a soil-water interaction point of view. The proposed development evokes this as it will likely involve bulk earthworks and excavation during construction. These activities may potentially alter some of the hydropedological processes, recharging the nearby watercourse in proximity to the proposed development, and thus, a provision of a hydropedology perspective on the functioning of the associated wetlands and watercourses is required.

The objective of this focus was to:

- Investigate the hydropedological drivers of the watercourse system in close proximity to the focus area;
- Determine the risk of the proposed activities on the watercourse system; and
- Define the developable areas from a hydropedological point of view taking into consideration the findings of other relevant studies;
- Quantify the hydropedological losses to the watercourse by means of SWAT+ Modelling.

The study area falls within the humid subtropical climate zone, characterised by hot and humid summers and cool to mild winters. A deep current of tropical air dominates the humid subtropics at the time of high sun, and daily intense (but brief) convective thundershowers are common but lack any predictability. The entire study area is characterised by rainfall ranging between 401 and 600 mm. The study area can, therefore, be described as water-stressed, and shallow lateral flows are not anticipated in such areas.

The study area is primarily characterised by soils of Mispah/Glenrosa, Coega and Rocky Outcrops formation in the crest and in the midslope positions the soils of Bonheim/Abbotspoort and along the valley bottom the soils of Inhoek/Dundee formation were identified

The crest position is primarily characterised by rocky outcrops, where miscellaneous soils are identified. Water either infiltrates via the preferential flow paths created by the tree roots or flows downslope as overland flow, as these areas can saturate quickly due to limited storage capacity. Towards the mid-slope and lower slope positions along the hillslope soils of Bonheim were identified, and thus, these soils are characterised by a vertical flow of water through and out of the profile. This is supported by the lack of any soil morphological features which typically indicate long-term saturation with water (e.g., mottling and gleying). However, the deeper layers of the B-horizons were characterised by lime precipitates, which may indicate periodic deep preferential flow paths within these soils. This is a result of water, which evaporates under great evaporative demand, and the lime concentrates and precipitates as calcium carbonate ($CaCO_3$), where the water evaporates, and the concentration exceeds the solubility product. Thus, the calcareous character may also indicate limited leaching due to the low rainfall in the area.

This hillslope is classified under Class 3 (Recharge to groundwater) hillslope class due to the nature of the expected water movement based on the hillslope classification devised by van Tol *et al*. (2013). The hillslope classification aims to categorise the contribution of different slopes to streamflow. It is doubtful that this hillslope contributes to the streamflow, apart from the preferential flowpaths in the form of erosion dongas created by high-intensive rainfall. The shallow rocky outcrops soils were observed on the hilltop positions and might generate overland flow. It is, however, hypothesised that the generated overland flow will re-infiltrate the freely drained soils. The absence of signs of saturation indicates either 1) evapotranspiration exceeds precipitation to such an extent that periodic saturation does not occur or 2) recharge of groundwater levels, not connected to the vadose zone in lower lying areas, is dominant (van Tol *et al.*,2013).

A modelling exercise using the SWAT+(v 1.2.3) model was undertaken in effort to quantify the losses with specific mention of the lateral flow which can be anticipated because of the proposed development. The quantification of losses was undertaken at three different scales namely the basin scale, landscape unit scale (LSU) and hydrological response unit scale (HRU), and these are discussed in detail in Section 6.3.

The LSU scale, equivalent to the hillslope scale, depicted an increase in streamflow and surface runoff by 13.2% and 13.44% while accounting for less than 2% of the water balance. This can be attributed to the removal of vegetation in preparation for construction and excavation activities, hardening of surfaces, and steeper slopes, which favour surface runoff generation. Due to the increase in surface water catchment yield, the separation of clean and dirty water and appropriate stormwater management are required to fulfil the GN704. The lateral flow and percolation components will decrease by 10.54% and 11.36%, respectively, while accounting for less than 1% of the water balance. This can be attributed to the discontinuity of subsurface flow processes (albeit in smaller quantities) in the vicinity of the footprint areas and the hardening of surface conditions, which reduces the infiltration rate. This impact at this scale is thus still considered minimal. The most significant loss of water at this scale is through evapotranspiration, which accounts for 98.12% of the water balance as modelled. The model also indicates that evapotranspiration processes consume rainfall in the hillslope, and little water from the impacted landscape units is exported to the greater catchment. The data thus indicates that rainfall in the area is important in driving the watercourse response in the landscape at this scale in the form of surface runoff. The profile water at scale decreases by 16.49%, and the hydropedological processes are anticipated to be slightly modified; the instream functionality impacted, as well as the present ecological state (PES), may be impacted at this scale, and this will have to be confirmed by the freshwater assessment.

The larger systems will experience the least impact, while the smaller watercourses, such as drainage lines downgradient of mining operations, will be impacted most significantly. Therefore, a stormwater and erosion management plan should be developed and implemented to minimise the potential impact on the watercourses during all phases of development. The PES/EIS and functionality of the watercourses will potentially remain unimpacted during all phases of development, provided that mitigation measures are implemented, such as the management of surface water and ensuring that the clean water is diverted and discharged back into the adjacent watercourses. Table A below depicts the summary results of the modelling exercise.

Table A: Summary of the water balance pre- and post-development at LSU scale.

	Before	% of WB	After	% of WB	Change
Rainfall	345,750		346,398		
Streamflow	5,495	1,589	6,220	1,796	13,202
Surface runoff	5,439	1,573	6,170	1,781	13,446
Lateral flow	0,056	0,016	0,050	0,014	-10,538
Percolation	0,296	0,086	0,263	0,076	-11,375
ET	339,591	98,219	339,915	98,129	0,095
ecanopy	0,036	0,647	0,027	0,442	-22,704
Transpiration	0,163	0,047	0,124	0,036	-23,725
Evaporation	339,393	98,161	339,764	98,085	0,109
ET0	1655,597		1655,597		
Profile available water	5,885		4,915		-16,485
Topsoil available water	1,777		1,720		-3,238

Water flowing through the catchment is increased when human intervention impact on the drainage systems, often at higher levels than before human impact. This can have severe impacts on the natural systems if not mitigated properly as these changes in water runoff volumes through the impervious surfaces and runoff timing considerations lead to increased wetness and spikes in water volumes in drainage features as predicted by the modelling. The sudy area is largely dominated by Responsive (shallow) soils and recharge deep soils highly likely prone to erosion and thus indicating a further increase in runoff volumes in the post development scenario. Henceforth, adequate stormwater mitigation measures should be adhered to at all phases of development, to manage the stormwater and channelised water effectively to prevent large pulses in storm water. As further increase in impervious surfaces may lead to changes in the hydrological flow regimes associated with the study area and may result in accelerated erosion and sedimentation of the lower lying areas if not properly attenuated and managed through proper landscaping in order to maintain functionality for downstream users. The proposed development does not pose a development constraint from an hydropedological perspective. This can be considered in conjunction with a freshwater assessment and which their findings can also be used to determine the current state of the associated watercourses and the ecoservices they provide.

The following recommendations which must be implemented with a suitably qualified engineer, horticulturalist (as a landscape planner) and in conjunction with other relevant specialists should the proposed project proceed:

- In terms of both the NWA (National Water Act) and NEMA (National Environmental Management Act) landowners have a duty to protect water resources, watercourses and wetlands. If not adequately managed can lead to criminal prosecution or disciplinary action from relevant authorities;
- Structures to trap silt and other sediments should be implemented at strategic locations to prevent further ingress of sediments into the watercourse;

- Ensure that water of different quality (i.e. clean and dirty water) is kept separate and managed separately, as far as possible. This will ensure that the contact between water of different quality and the potential for unnecessary water quality deterioration is minimised;
- Water from clean water structures should be discharged back into the watercourse in an attenuated manner;
- The runoff from the dirty areas must be captured, retained and managed within the mine water systems, through the use of diversion berms, channels and pollution control dams to manage the dirty water runoff.
- Ensure proper stormwater management designs are in place; stormwater management should allow for artificial recharge;
- An integrated stormwater management plan has to be drawn up by suitably qualified personnel that takes into account the stormwater generated upslope from the site as well as the stormwater generated on the specific site;
- Infiltration systems should be designed to collect stormwater from adjacent impervious areas and provide a pathway for water to infiltrate into the soil and subsurface areas, providing a natural recharge to groundwater systems; and
- Connectivity between the source (wetland/stormwater structures) and the stream channels should be prioritised.

Most of the study area is deemed developable from hydropedological point of view, provided that the above mitigatory measures are implemented.

DOCUMENT GUIDE

No.	Requirement from Section 2.7 of Protocol for the Specialist Assessment and Minimum Report Content Requirements for Assessments with no specific prescribed protocols (GN 320 of 20 March 2020)	Section
2.7.1.	Contact details of the specialist and their SACNASP registration number.	Appendix C
2.7.2	A signed statement of independence by the specialist.	Appendix A
2.7.3.	A statement on the duration, date and season of the site inspection and the relevance of the season to the outcome of the assessment.	Section 1.5 and 3
2.7.4.	The methodology used to undertake the site inspection and the specialist assessment, including equipment and modelling used, where relevant.	Section 3 and 4
2.7.6.	The location of areas not suitable for development, which are to be avoided during construction and operation, where relevant.	Section 6.4
2.7.5.	A description of the assumptions made, any uncertainties or gaps in knowledge or data.	Section 1.5
2.7.14.	A motivation whether the proposed development is deemed acceptable or not.	Sections 6.4 and 7
2.7.7.	Environmental impacts expected from the proposed Development.	Section 7
2.7.8.	Any direct, indirect and cumulative impacts of the proposed development on site.	Section 7
2.7.9.	The degree to which impacts and risks can be mitigated.	Section 8.1

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1. INTRODUCTION

Enviro-Solum Consulting was appointed to conduct a hydropedological assessment as part of the Environmental Impact Assessment (EIA) and Water Use License Application (WULA) for the proposed South 3 Opencast Mine and associated support infrastructure (hereafter referred to as study area). The area wherein the proposed development is to take place will is located approximately 2km north of the R555 road and approximately 5km west of the steelpoort town, within the Fetakgomo Tubatse Municipality, Limpopo, South Africa. Figure 1 below for the locality of the study area whereas, Figure 2 depicts the layout associated with the proposed development.

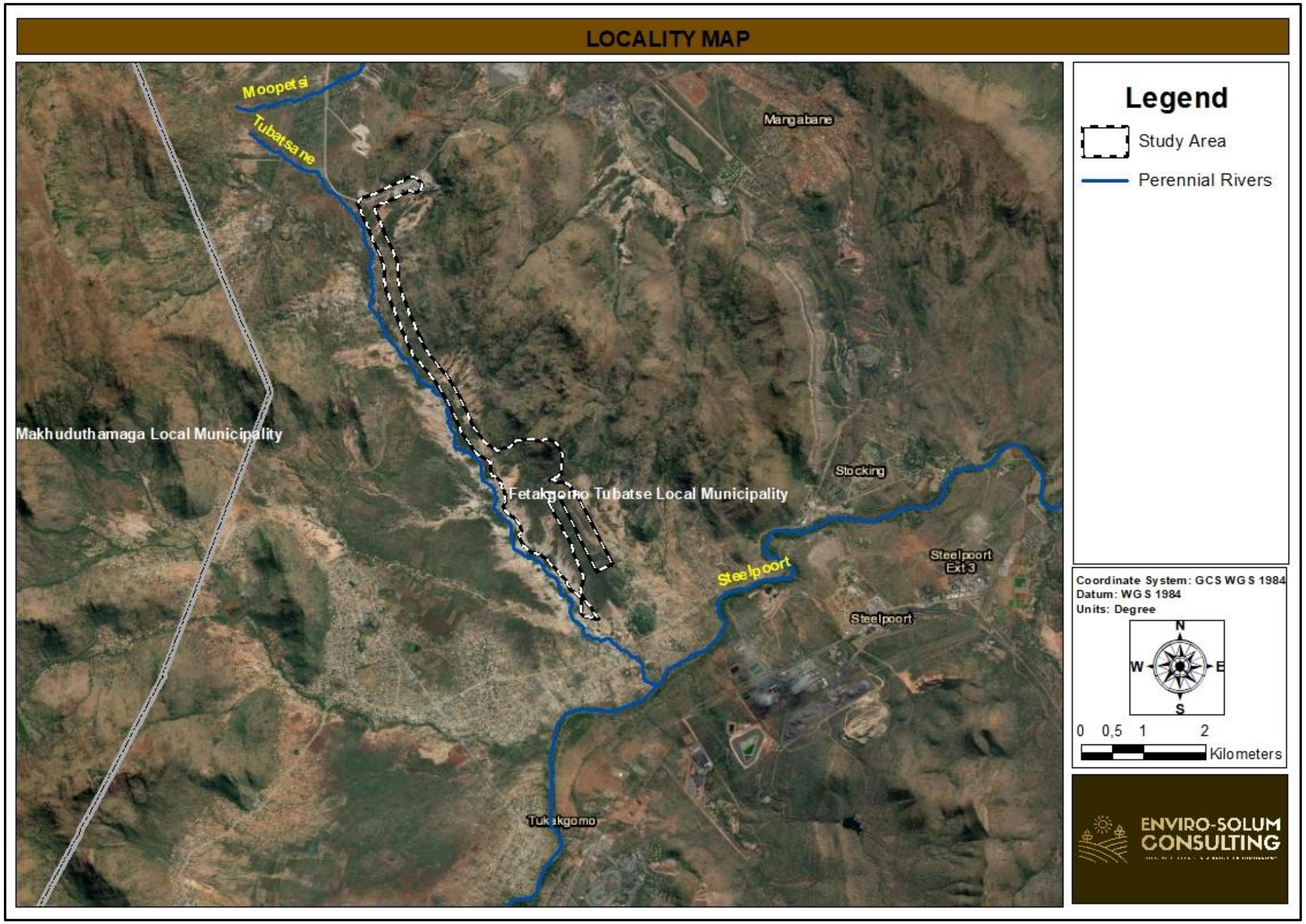

Figure 1: Locality of the study area in relation to the surrounding areas.

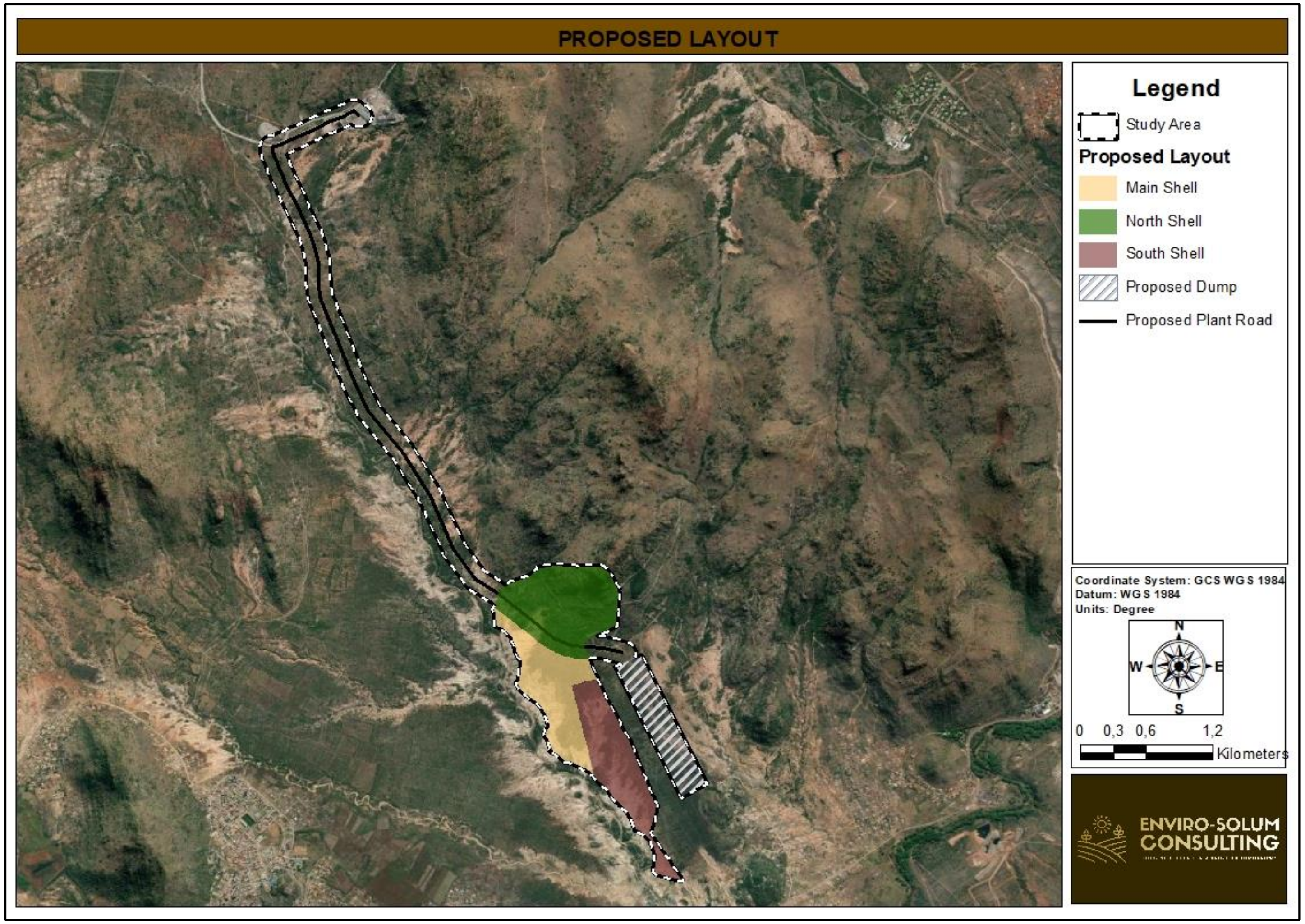

Figure 2: Proposed layout

1.1 PROJECT DESCRIPTION

Modikwa Platinum Mine (MPM) has intended on developing another open pit on Winterveld which will follow the conventional Open Cast methods, which include the stripping at 40 to 60 ktpm with concurrent backfill. The ore from the open pit will be extracted by a combination of excavation and crushing activities. The ore will be transported by truck to the primary crusher stockpile. Waste is disposed to waste dumps on the surface.

1.2 AIMS AND OBJECTIVES OF THE STUDY

The aim of the assessment was to conduct a hydropedological assessment of the study area and identify the major drivers of the nearby wetlands and watercourses from a soil-water interaction point of view. The proposed development evokes this as it will likely involve bulk earthworks and excavation during construction. These activities may potentially alter some of the hydropedological processes recharging the nearby watercourse in proximity to the proposed development and thus a provision of a hydropedology perspective on the functioning of the associated wetlands and watercourses is thus required.

The report is aimed at addressing specific site conditions in the context of current legislation, guidelines and best practice with the ultimate aim of ensuring the conservation and adequate management of the water resources identified within and in the vicinity of the study area.

1.3 APPLICABLE LEGISLATION

The legislative requirements and related policies are put in place to guide and direct the land user in terms of land use planning and manage the potential impacts of the proposed development on the environment and the natural resources. Applicable legislation to this effect includes but not limited to:

- The National Environmental Management Act. 1998 (Act 107 of 1998), requires that pollution and degradation of the environment be avoided, or, where it cannot be avoided, be minimised and remedied.
- National Water Act (Act No. 36 of 1998) (NWA).
- Environmental Conservation Act (Act 73 of 1989).

1.4 TERMS OF REFERENCE

The terms of reference applicable to the Hydropedological Assessment include the following:

- A review of available desktop information about the study area site and compile various maps illustrating the desktop data;
- Discussion of the relevant desktop literature;
- Conduct a hydropedological soil survey according to the DWS guidelines,
- Classify soils occurring within the study area according to the South African Soil Classification System: A Natural and Anthropogenic System for South Africa (Soil Classification Working Group, 2018);
- Investigate the hydropedological drivers of the identified watercourse and wetland systems in close proximity to the development footprint;
- Determine the risk of the proposed activities on the watercourse system;
- Define the developable areas from a hydropedological point of view taking into consideration the findings of other relevant studies;
- Quantify the hydropedological losses to the watercourse by means of SWAT+ Modelling; and
- Compile a hydropedological report based on the field-finding data under current on-site conditions.

1.5 ASSUMPTIONS, ASSUMPTIONS UNCERTAINTIES, LIMITATIONS, AND GAPS

The following assumptions, uncertainties, limitations, and gaps were applicable for the hydropedological assessment:

- It is assumed that the infrastructure components will remain as indicated on the layout and that the activities for the construction and operation of the infrastructure are limited to that typical for a project of this nature;
- While hydropedological investigations were confined to the study area, the surrounding areas were also examined for a holistic understanding of wetland recharge mechanisms.
- Wetland systems reflect the ecological boundary where water content and soil particles interact closely in the first 50 centimetres of the soil profile. The interaction between soil and water thus influences the presence of hydrophytic plants and soil morphology depicting signatures of saturation (i.e., gleying and mottling). A wetland boundary, based on vegetation species compositions and soil properties, can differ between years due to historical rainfall conditions as well as sampling periods (i.e., summer and winter assessments).

- It can be challenging to classify soils as one specific form due to the infinite variations that exist in the soil continuum. Therefore, the classifications presented in this report are based on the "best fit" to South Africa's soil classification system.

2. WHAT IS HYDROPEDOLOGY

This intertwined study of soil science and hydrology is called 'hydropedology', which aims to promote the better understanding of soil-water interactions and landscape-soil-hydrological processes across space and time, aiming to understand pedologic controls on hydrologic processes and properties, and hydrologic impacts on soil formation, variability and functions (Lin *et al*., 2008).

Since hydropedology is a relatively new and advancing field of study, it was deemed necessary to include the background knowledge based of previously published document by Van Tol, Le Roux and Lorentz which appeared in the May/June 2017 issue of Water Wheel.

2.1 HYDROPEDOLOGY: LINKING SOIL MORPHOLOGY WITH HYDROLOGICAL PROCESSES

Hydropedology is the relatively new, interdisciplinary research field which focuses on the interactive relationship between soils and water (Figure 3). Soil physical properties, such as the hydraulic conductivity and porosity, have an important impact on the occurrence and rates of hydrological processes. In turn, hydrological processes play an important role on the formation of soil morphological properties such as colour, mottles, macropores and carbonate accumulations. Accurate mapping and the interpretation of these soil morphological properties can thus be used to conceptualise and characterise hydrological processes including water flowpaths, storage mechanisms and the connectivity between different flowpaths. Most of these hydrological mechanisms and processes are very difficult to observe (let alone measure!) in the field because they are dynamic in nature with strong temporal and spatial variation. Nevertheless, soil morphological properties are not dynamic in nature and their spatial variation is not random – making soil properties the ideal vehicle for predicting and conceptualising hydrological processes. One of the major contributions of hydropedology is the ability to conceptualise hydrological processes spatially i.e. not only 1-D mechanisms, but a more holistic understanding of the hydrological functioning of landscapes (catchments or hillslopes).

Hydropedological information is used in process-based landscape water resource management. This includes, for example:

- configuration and parameterization of distributed hydrological models;
- effective wetland delineation, protection and rehabilitation;
- understanding and controlling the fate of pollution in the subsurface;

- determining the impact of land use change (e.g. open pit mining) on water resources; and
- characterizing groundwater/surface-water interactions, including the important mechanism of low flow generation.

Hydropedological information generally assists with effective water resource management, as required by the National Water Act (1998), through improved understanding and characterization of hydrological processes.

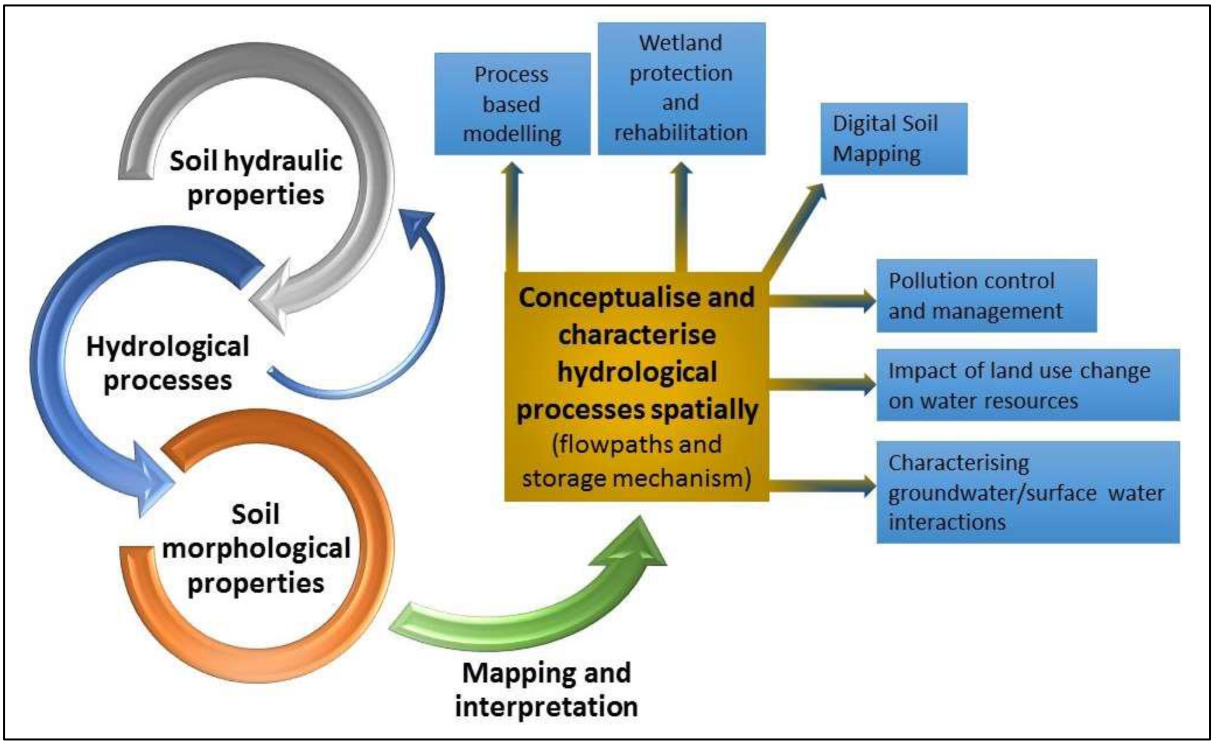

Figure 3: Hydropedology and some of the applications of hydropedological surveys.

2.2 Hydropedology of Soil Types

The hydropedological behaviour of different soils can differ significantly. For example, in Figure 4a the red colours of the top and subsoils of are typically associated with freely drained soils. Vertical flow into, through and out of the profile are the dominant hydrological pathway. These soils are termed recharge soils, as they are likely to recharge groundwater, or lower lying positions in the regolith, via the bedrock. In the second example (Figure 4b), lateral flow is likely to be dominant. These soils are termed interflow soils. Lateral flow occurs due to differences in the conductivity of horizons. In Figure 4b the 'sp' is restricting downward movement and lateral flow occurs at the A/B horizon interface. The lighter colour of the 'gs' horizon is further support that lateral flow dominates. Lateral flow frequently occurs on soil/bedrock interfaces due to the permeability of the rock. Mottles (red, yellow and grey colours) in the 'sp' horizon (magnified in Figure 4b-i) are the result of a fluctuating water table. In Figure 4c the grey colours of the 'gh' horizon and the dark colours of the topsoil horizon are indications that this profile is saturated for long periods of time. Because these soils are close to saturation, especially during peak rainy seasons, additional rainfall is unlikely to infiltrate the soils but will flow as overland flow (or surface runoff) downslope. These soils are termed responsive soils due to their rapid response to rain events. The same type of response can be expected on very shallow soils i.e. a small amount of rain can saturate the soil and additional rain will drain away as overland flow.

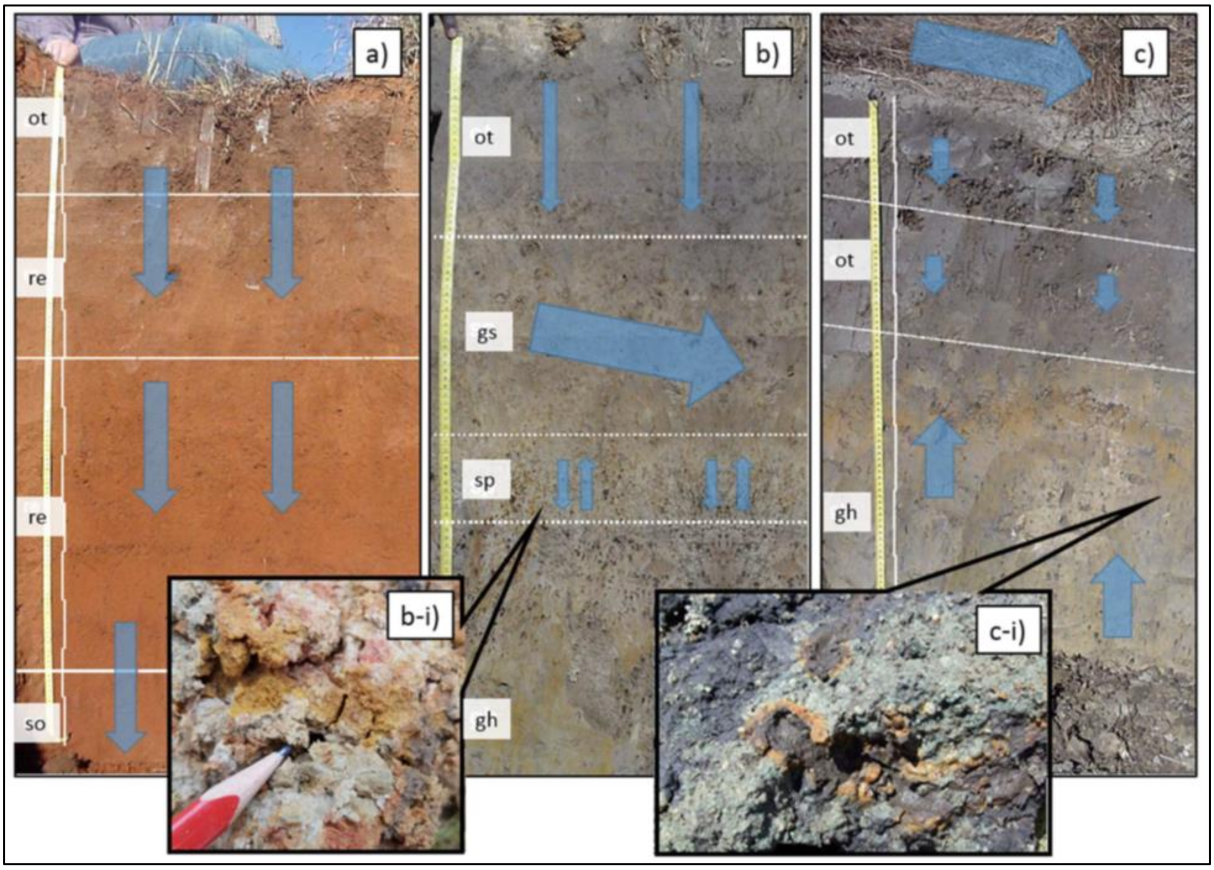

Figure 4: Different hydropedological soil types a) recharge soil, b) interflow soil and c) responsive.

2.3 HYDROPEDOLOGY OF HILLSLOPES

For effective water resource management, it is important to gain a holistic understanding of hydrological processes. Figure 5 presents a typical example of the hydropedological response of a hillslope. In the recharge zone, the dominant flow direction is vertical through the soil and into the fractured rock, from where it can recharge groundwater levels or downslope positions in the hillslope soils. Lateral flow at the A/B horizon interface or soil/bedrock interface dominates in the interflow zone. The responsive zone is fed by lateral flowing water from the interflow zone as well as via the bedrock from the recharge zone.

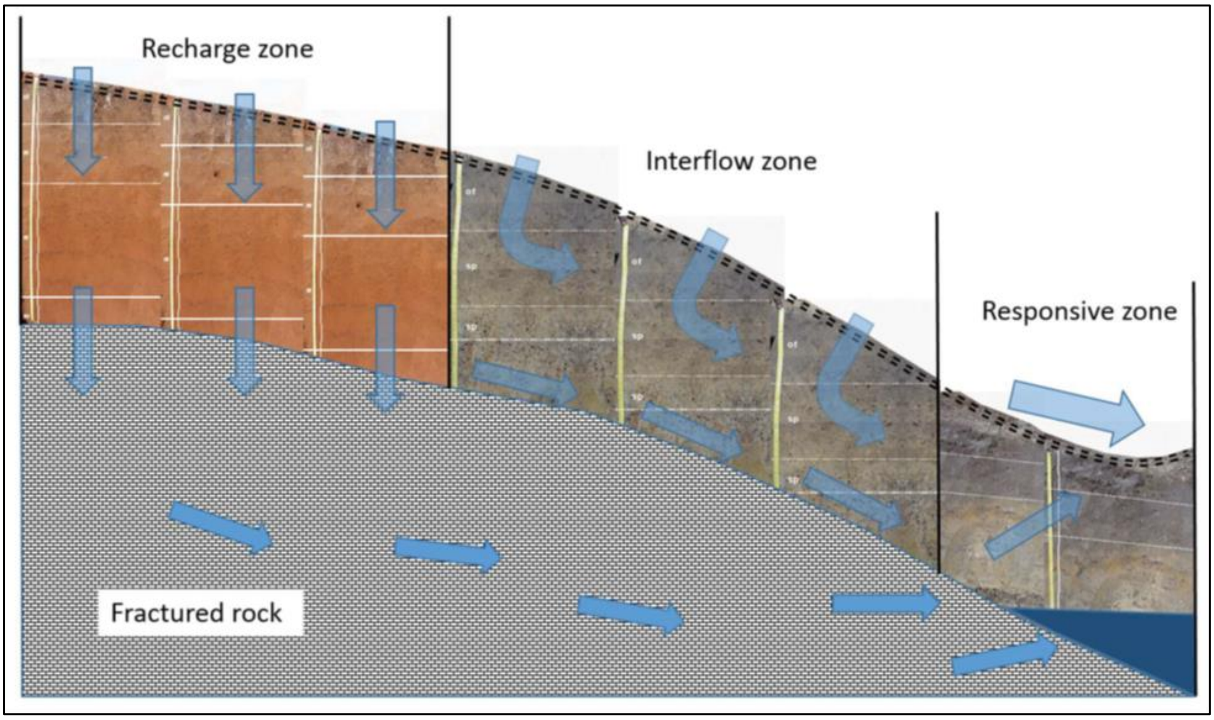

Figure 5: Hillslope hydropedological conceptual model.

Although Figure 5 represents an oversimplification of a fraction of the complex hydrological cycle, the application of this information can make important contributions to effective management. Four scenarios are presented to support this statement.

1. **Pollution:** The fate of pollution will differ depending whether it was spilled on recharge, interflow or responsive soils. A spill on recharge soils is likely to end up in the groundwater or might arrive in the stream several months after the spill via flow through the fractured rock. Pollutants spilled on interflow zones will migrate downslope through the soil. Because this downslope migration will be in contact with the soil, and hence abundance of microorganisms. It is possible that it may be transformed into non-toxic forms (depending on the pollutant). If a pollutant is spilled on the responsive zone it may travel quickly and unaltered to streams and other surface water bodies.
2. **Conserving wetlands:** Hydropedological information can aid in identifying the sources of water to preserve wetlands. If the recharge zone is the major source of water to the wetland i.e. the recharge zone is the hydrological driver of the wetland, care should be taken to restrict surface sealing (paving) of the recharge zone. If the wetland's water comes from an interflow zone, care should be taken to prevent obstruction of subsurface lateral flowpaths.
3. **Hydrological modelling:** Hydropedological information can assist in the correct configuration of distributed hydrological models. In many landscapes different landscape elements (or Hydrological Response Units – HRU's) are not connected in a simple cascading downslope way to one another. There might be areas which are disconnected from the stream or groundwater stores. In addition, deep infiltration from recharge soils at the crest of a hillslope, may re-appear as lateral flow water further down the slope. Hydropedological information can thus be used to ensure that the model configuration properly

reflects the hydrological processes. This can be critical in simulating low flows, where vegetation may have access to near-surface water and thus limit contributions to streamflow.

4. **Land-use change:** Hydropedological information can support the understanding of the impact of land-use change on water resources. If, for example, the interflow zone is urbanised it may result in a build-up of water against foundations and the generation of return flow to the surface and overland flow which may cause erosion. Open pit mining close to responsive zones is likely to result in a draw-down of water levels and drying of wetlands. If such an open pit intersects lateral flowpaths it will break the connectivity of flowpaths and cut the source of water to wetlands. Although the impact of land-use change cannot always be avoided, hydropedological information might aid in managing and protecting the hydrologic drivers of the ecosystem and thereby minimise negative impacts.

2.4 Hydropedological Surveys

A hydropedological survey (in the context discussed above) is different from a conventional soil survey in the following aspects:

- **Observation depth:** the depth of observation in a conventional survey is 1.5 m, whereas the observation depth for the hydropedological survey is the depth to the soil bedrock interface.
- **Classification**: conventional soil surveys aim to classify soils in accordance with a specific classification system. In hydropedological surveys all morphological properties and all soil horizons are described, recorded and interpreted, with particular emphasis on the ambient and connected soil water environment. This includes saprolitic (weathering rock) horizons and horizons which are not necessarily included in the hierarchy of the classification system.
- **Observation density:** Conventional soil surveys aim to capture the distribution of different soils in a particular landscape. Hydropedological surveys focus on the hydrological response of dominant hillslopes/transects.

Important to note is that hydropedological surveys cannot be used as a surrogate for mapping the agricultural potential (as required during most EIA's) of an area. Conventional soil surveys (or other existing soil information) can also not always be used to infer the hydropedological response of an area, due to the differences between conventional and hydropedological surveys highlighted above.

Hydropedological surveys do not replace detailed soil physical or hydrometric measurements but rather serves as a vehicle to identify representative sites for such measurements and to extrapolate these measurements to larger areas. Hydropedological surveys are also not a surrogate for hydrological modelling but can contribute to the efficiency and accuracy of modelling exercises. Hydropedological surveys and the interpretation and application of hydropedological information can be a cost -and time effective approach to conceptualise and characterise hydrological behaviour of landscapes.

3. METHODOLOGY

A hydropedological transect survey and sampling activities were conducted in April 2024 to assess the hydropedological characteristics of the landscape associated with soils within the study area. This date was deemed acceptable since seasonality has no bearing on the hydropedological characteristics. During the hydropedological transect survey the soil morphology was described up to the bedrock with respect to colour, structure, mottles, lime, interpedal macropores and other macropores, including the type of coatings on these pores. At selected representative points soil augers were taken used to describe the soils in detail and obtain samples for the modelling of hydropedological losses in order to identify and quantify the impact of the proposed development on wetland recharge mechanisms.

The hydropedological survey was conducted in accordance with the new DWS guidelines for hydropedological assessments. The guidelines are divided into 4 steps:

1. Identification of dominant hillslopes.
2. Conceptualising hillslope hydropedological responses.
3. Quantification of hydraulic properties and flowrates.
4. Quantification of hydropedological fluxes.

The first two steps should be conducted for any impact assessment requiring a hydropedological survey. Step 3 and 4 will typically be required where drastic land-use change or planned e.g. open-pit mining or large developments which will obstruct lateral flowpaths.

<u>Step 1: Identification of the representative hillslope/s</u>

Prior to the site visit a desk-based exercise was undertaken which included the following:

- Identification of land types (Land Type Survey Staff, 1972 – 2006) within the study area; and
- Identification of dominant hillslopes (from crest to stream) of the study area using terrain analysis.

<u>Step 2: Conceptualize hillslope hydropedological responses</u>

- Transect soil survey was conducted on each of the identified hillslope (Le Roux et al., 2011);
- Soil observations were made at regular intervals, not exceeding 100 m, on the transect;
- Analysis of soil was made by means of a hand augur as well as analysis of exposed profile areas which depict the diagnostic horizon sequence; and
- soils observations were made until the layer of refusal.

Field assessment data included description of physical soil properties including the following parameters, in order to characterise the various recharge mechanisms of the investigated wetlands:

- Diagnostic soil horizon sequence;
- Landscape position in relation to the investigated wetlands (recorded on GPS); and
- Depth to saturation (water table), if encountered;

Conceptual hillslope hydropedological response

The occurrence, sequence, and coverage of the different hydropedological groups on a transect was used to describe the hydrological behaviour of the hillslope (van Tol *et al*., 2013). This includes a graphical representation of the dominant and sub-dominant flowpaths at hillslope scale prior to development (as presented in Section 5.3). This will include:

- Overland flow;
- Subsurface lateral flow;
- Bedrock flow;
- Return flow; and
- Storage mechanisms.

Step 3: Quantification of hydraulic properties and flowrates

- Identify the representative soil forms and horizons from the transect survey.
- Collect selected verification samples for textural analysis, bulk density and conductivity at a SANAS accredited analytical laboratory.
- Relate the measurements to the conceptualised hydropedological response model to provide a quantitative description of flowrates and storage.

Step 4: Quantification of hydropedological fluxes

- Identify the potential impacts of the propose development on the unsaturated flow processes and wetlands.
- Recommend suitable mitigation and management measures to alleviate the identified impacts on the wetland hydropedological drivers.
- Based on the outcome of the hydropedological assessment and taking into consideration the results of the geohydrological assessment, a scientifically determined buffer will be generated around the affected wetlands.
- Compile a specialist report on the conceptual hydropedological regime of the investigated wetlands based on the identified soil types under current conditions.

4. SWAT+ MODELLING APPROACH

SWAT is the acronym for Soil and Water Assessment Tool developed to predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex watershed with varying soils, land use and management conditions over long periods of time. This is a physical model as it requires specific information pertaining to weather, soil properties, topography, vegetation, and land management practices occurring in the watershed.

The hydrological model SWAT+ (v 2.1.4) was used for the modelling with QSWAT+ (v. 3.28) to set up the watershed. SWAT+ is a revised version and an effective and comprehensive tool for simulating streamflow and pollutant transport across a wide range of spatial and temporal scales, environmental conditions, land management practices, and land use and climate change scenarios (Arnold and Fohrer, 2005).

SWAT+ divides the catchment into landscape units (LSUs), which comprise of a number of similar hydrological response units (HRUs). An HRU is a homogenous area in terms of soils, land use, and slope. The model then calculates various components of the water balance, such as infiltration, overland flow, lateral flow, percolation, evapotranspiration, as well as discharge to the stream for each LSU and HRU. Figure 6 illustrates the conceptual water balance used in SWAT+. Hydraulic processes are the major driving force behind any process in SWAT (Neitsch *et al.*, 2011). Components of the water balance such as precipitation (rainfall), surface runoff, infiltration, evapotranspiration, soil water and channel processes are key components of the hydraulic process definition. The water balance equation used by SWAT+ is as follows:

$$SWt = SWo\sum_{i=0}^{t}(\mathrm{Rday} - \mathrm{Qsurf} - \mathrm{Ea} - \mathrm{Wseep} - \mathrm{Qgw})$$

Where:

SWt–final soil water content;

$SW0$–initial soil water content;

$Rday$–precipitation;

$Qsurf$–surface runoff;

Ea–evapotranspiration;

$wseep$–the amount of percolation flow exiting the soil profile at the bottom;

Qgw–groundwater flow enters the channel (return flow);

Units –mm H_2O; and

t–is the time span to apply the equation.

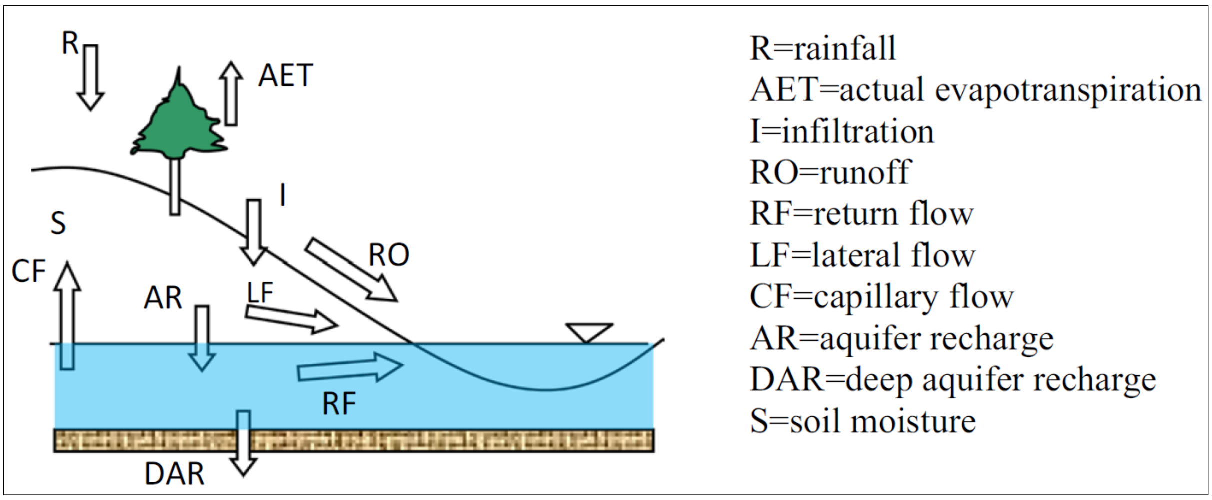

Figure 6: Schematic illustration of the conceptual water balance model in SWAT.

The hydrological modelling aimed to quantify the dominant hydrological processes and the impact of the proposed development and all its existing water uses. The catchment area was determined from a 30m DEM and subdivided into 6 sub-basins, with 74 Landscape Units (LSUs) and 437 Hydrological Response Units (HRU's). The proposed development area (study area) is limited to LSUs 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, 120, 130, 260, 360, 400 and 590 only. This LSU was, consequently, the focus of this modelling. Figure 6 depicts the affected LSUs within the proposed development study area.

The current land use was obtained from the South African National Land-Cover Database (2013 – 2014) with predefined parameters for each use. In the post-development modelling scenario, the area under the development footprint was assigned a "mining bare" class for the open cast footprint area and the waste rock dump to simulate the impact of the development.

Table 1: Data used in the modelling process.

Data	Scale	Source
Topography	30 m	The Shuttle Radar Topography Mission (SRTM)
Soil	30 m	In-situ and Land Type Data (Sorter Database).
Landuse/Land Cover	30 m	South African National Land-Cover Database (2013 – 2014).
Climate	2 stations	Climate Forecast System Reanalysis (CFSR, 1979 – 2014).

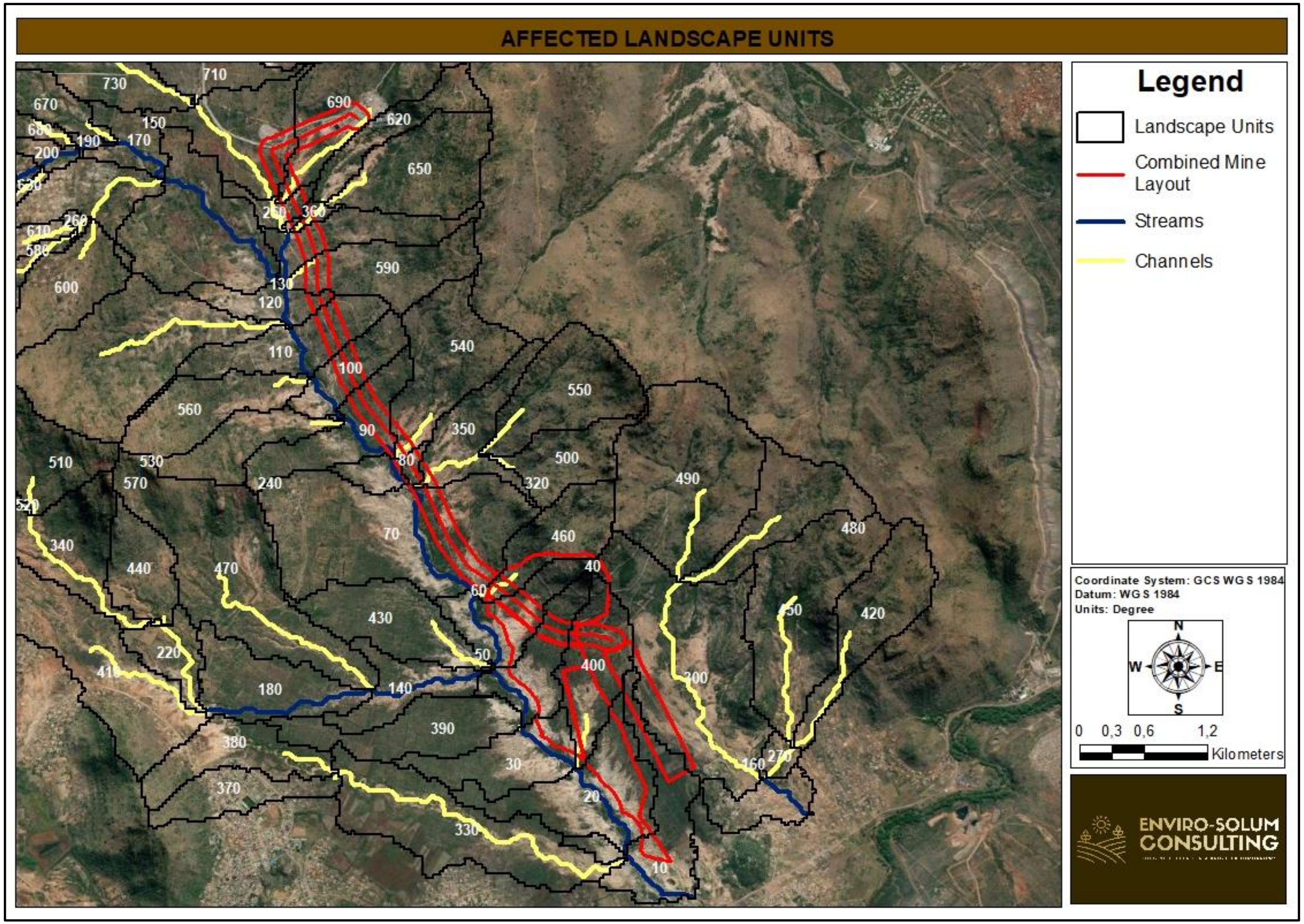

Figure 7: Affected landscape units associated with the catchment area.

The soils identified from the soil survey were reclassified and regrouped into hydropedological classes namely according to Van Tol & Le Roux, 2019; Recharge (deep), Responsive (shallow) and Responsive (saturated). The soils were further extrapolated to cover the areas outside the study area using the Land Type soil information and thus enabling the modelling to take place at a larger catchment scale (Basin-scale). Soil physical parameters such as bulk density, particle size distribution affecting the water content and the hydraulic conductivity were determined under laboratory conditions. The hydraulic properties of the dominant horizons used as inputs into the SWAT+ model are presented in Table 2.

Table 2: Hydraulic Properties of identified soils.

Hydropedological class	Horizon	Depth (mm)	Db	Clay	Silt	Sand	AWC	Ks	OC (%)
RECD	Orthic/Melanic A	300	1.17	31.57	19.18	49.56	0.7	38.71	0.69
	Pedocutanic	2000	0.98	52.75	31.45	16.33	1.2	15.21	0.71
	Hard Rock/Lithic	2000+	-	-	-	-	-	-	
RESS	Orthic A	300	1.22	32.9	10.16	56.99	0.04	32.72	0.69
	Hard Rock/Lithic	-	-	-	-	-	-	-	-
RESW (watercourse)	Stratified Alluvial	700	1.1	18.75	11.7	69.49	0.3	115.38	0.50
Ea88	Topsoil	800	1.17	31.57	19.18	49.56	0.7	38.71	0.69
Ib239	Topsoil	800	2.5	30	30	40	0.7	15	0.47
Ae115	Topsoil	800	1.25	24.96	9.91	65.52	0.07	68.43	0.64

*** RECD – Recharge (Deep); RESS – Responsive (Shallow); RESW – Responsive (Saturated); Db – bulk density; C; AWC – available water content; Ks – saturated hydraulic conductivity; Ea88 Landtype – Dark and red coloured structured and high base status; Ib239 – Miscellaneous young land classes that include alluvial depressions and rock dominated landscapes; Ae115 Landtype – Red and yellow structureless soils without water tables within the observable soil profile.**

Based on the latest climatic data available, a 23-year simulation period was selected (1st January 2000 – 31st December 2023). Climatic data for this period was obtained from the Climate Forecast System Reanalysis (CFSR, 1979 – 2014) project done by the National Centers for Environmental Prediction (NCEP) (Saha *et al.*, 2010). WeatherGen in SWAT+ Editor used daily precipitation, temperature (minimum and maximum, wind speed, solar radiation and relative humidity from selected stations to generate daily climatic variables for the simulations. Only years with full data ranges were selected, leaving a 21-year evaluation period. Results are reported only as yearly averages for the affected HRUS, LSUs and the basin before and after the proposed development.

5. DESKTOP RESULTS AND DISCUSSIONS

As part of the desktop site assessment, background information related to the study area and literature reviews were gathered from various databases including Landtype Survey Staff (1972 – 2002) and SOTER (Soil and Terrain). Even though desktop results are not field verified, the data presented may contain inaccuracies. Nevertheless, the data provide valuable information regarding the soils within the study area.

3.1 CLIMATIC DATA

The study area falls within the humid subtropical climate zone, characterised by hot and humid summers and cool to mild winters. A deep current of tropical air dominates the humid subtropics at the time of high sun, and daily intense (but brief) convective thundershowers are common but lack any predictability. The entire study area is characterised by rainfall ranging between 401 and 600 mm. The study area can, therefore, be described as water-stressed, and shallow lateral flows are not anticipated in such areas.

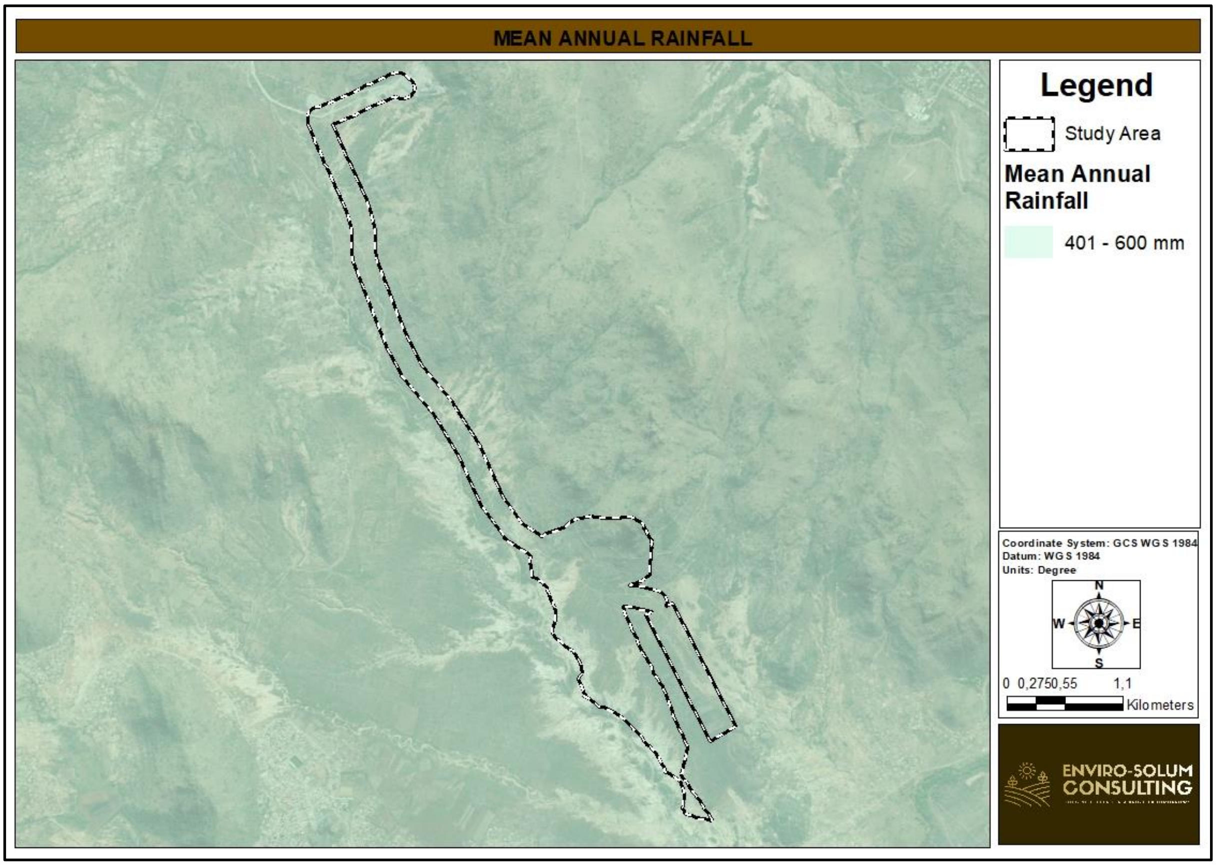

Figure 8: Mean Annual Rainfall associated with the study area.

3.2 LANDTYPE CLASSES

A land type is an area with similar climate, geology and soil distribution patterns, giving a good spatial representation of homogenous areas. The land type information, together with terrain attributes, were used to identify observation locations. The location of the observations was chosen to capture the soil distribution pattern of the study area.

According to the land type survey staff (1972–2006), the majority of the study area is dominated by the Ea88 landtype and to a lesser extent, dominated by the Ib31. The Ea landtype is characterised by dark and red coloured structured and high base status. The dominant soil moisture regime in these soils varies largely in line with the area of formation. with the area of formation. In relatively flat landscapes the moisture regime is one of rapid infiltration of water following dry periods and the localised accumulation of water in subsoil horizons under high matrix suction forces due to the high clay content and hence the high base status indicating limited leaching. not indicate extensive wetland areas. In the event of no internal drainage impediments these soils may allow percolation of water downward through the profile to weathering rock and lime rich subsoil horizons. The Ib landtype is characterised by miscellaneous young land classes that include alluvial depressions and rock dominated landscapes. In general the moisture regime of the Ialand types is dominated by surface flows of water with infiltration and subsequent lime and gypsum translocation. As these land types occur more readily in dry to arid environments the dominance of lime in the soil will mask most redox morphology features due to alkaline condition. the dominant Fe minerals in alkaline soil solution conditions). Additionally, the youthful nature of the soils lead to limited expression of mottling.

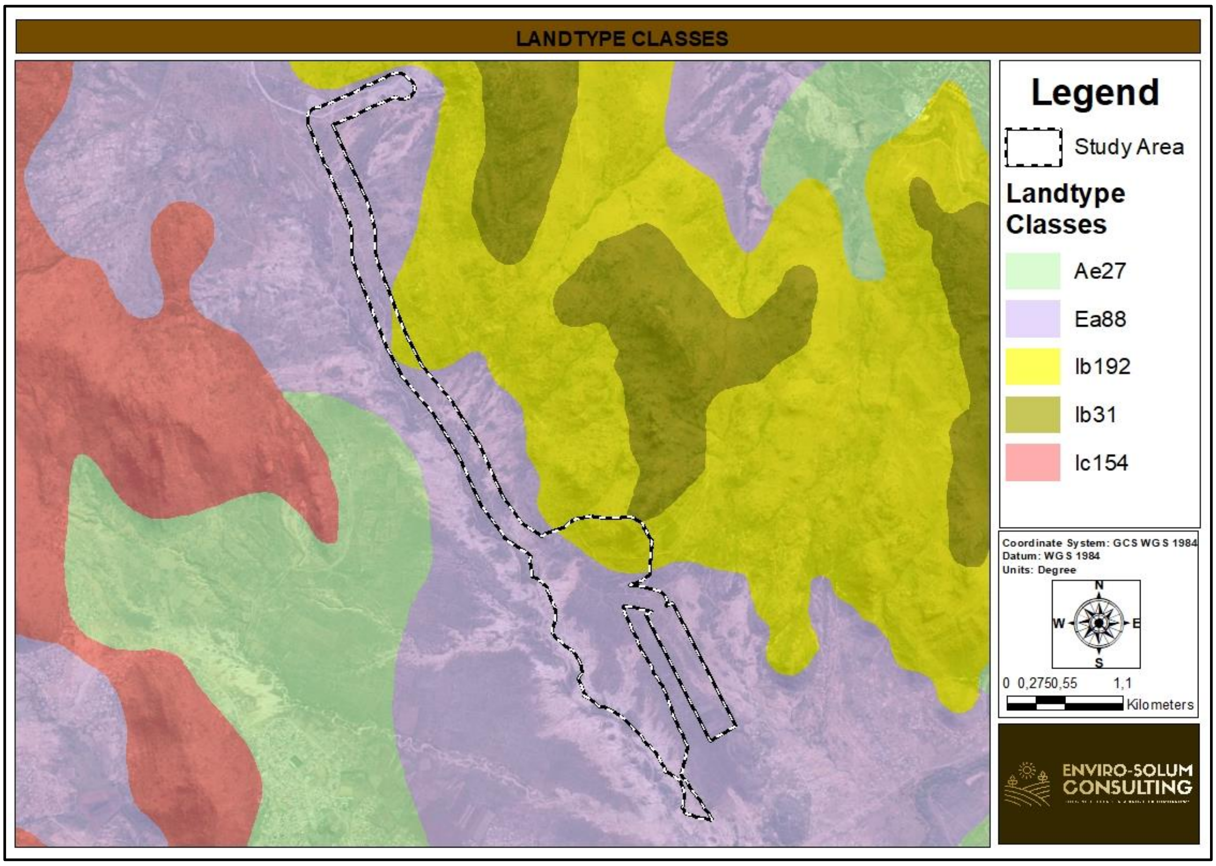

Figure 9: Landtype Classes associated with the study area.

3.3 SOTER DOMINANT SOILS

The SOTER Database indicates that the majority of the study area is characterised by calcic vertisols and, to a lesser extent, dominated by lithic leptosols. Calcic vertisols are characterised by high clay and the presence of lime. The presence of lime indicates water is present in the landscape lost through evaporation and precipitation. The shallow lithic soils indicate that the contribution to the watercourse is likely to be via surface runoff.

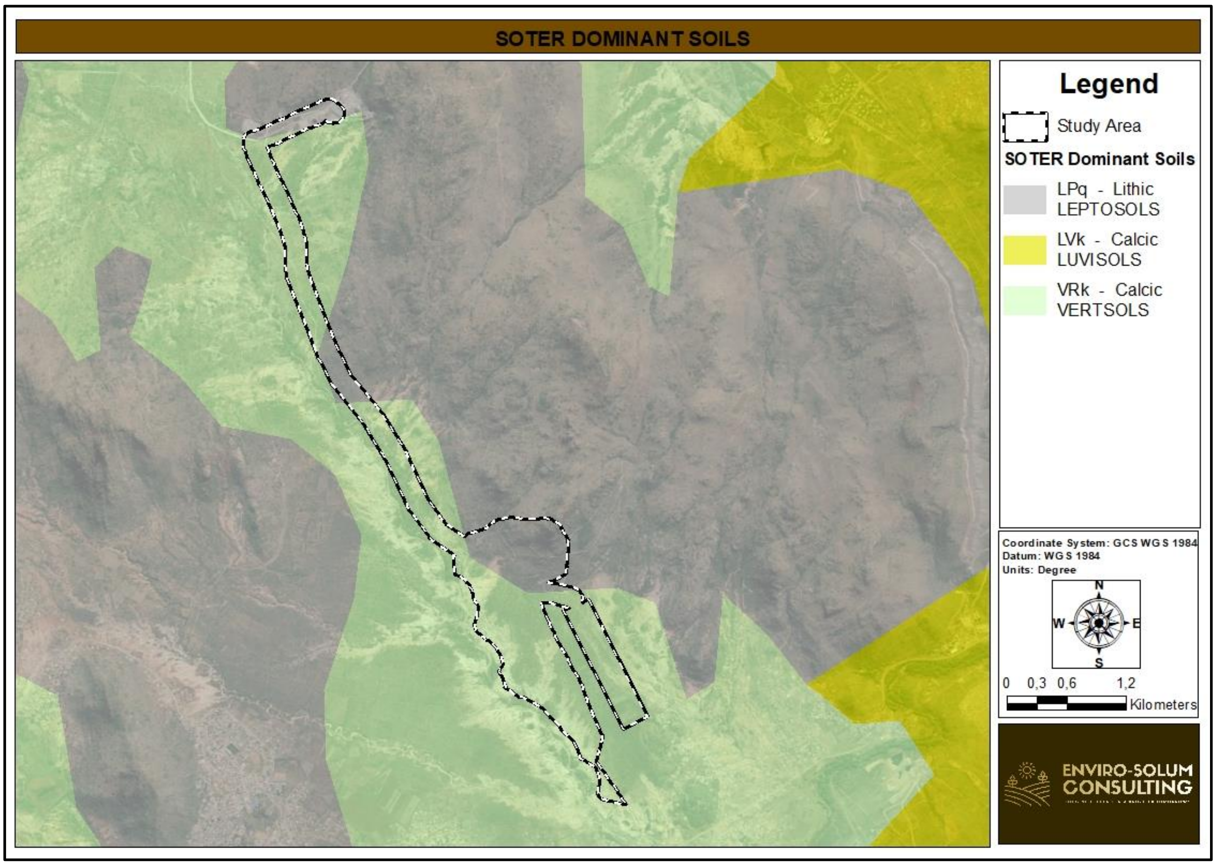

Figure 10: SOTER dominant soils associated with the study area.

6. FIELD VERIFIED RESULTS AND DISCUSSIONS

The study area is primarily characterised by soils of Mispah/Glenrosa, Coega and Rocky Outcrops formation in the crest and in the midslope positions the soils of Bonheim/Abbotspoort and along the valley bottom the soils of Inhoek/Dundee formation were identified. Figures 15 and 16 below depicts the spatial distribution of the soils associated with the study area.

6.1 Soil Forms in the Study Area

6.1.1 Mispah/Glenrosa, Coega and Rocky Outcrops (Responsive Shallow)

The Mispha/Glenrosa and Coega soil forms are shallow and characterised by an orthic horizon underlain by lithic or hard rock material and hard carbonate horizons, respectively. The rocky outcrops are associated with the mountainous areas with miscellaneous soils. Limited storage capacity results in the generation of overland flow after rain events. Shallow-responsive soils lead to a rapid runoff response time during intense rainfall events attributed to their shallow nature, which inhibits infiltration. The impermeability of the underlying rock promotes slow and limited discharge to the stream on the soil/bedrock interface because it competes with ET extraction of soil water. The slope position of the soils is typically the crest and scarp in most instances. It must be noted that these are not wetland soils, however, they are important for the recharge of wetlands during rainfall events. However, subdominant flowpaths through the fractured rock can still occur under the influence of gravity.

Figure 11: The responsive (shallow) hydropedological soil type associated with the study area.

6.1.2 Bonheim/Abbotspoort – (Recharge Deep)

These soils are deep, dark-coloured, clayey and structured with pedocutanic and neocutanic characteristics. Generally, these soils would contribute to groundwater recharge in many landscapes; however, the climatic conditions and the topographical setting under which these soils occur impact the hydropedological regime of these soils. The highly intensive rainfall events of short duration and the clayey nature of these soils promote surface runoff and discourage infiltration, sometimes leading to erosion gullies which ultimately act as preferential flow path drainage lines. In the event of no internal drainage impediments, these soils may allow water percolation downward through the profile to weather rock and lime-rich subsoil horizons.

Figure 12: View of the recharge (deep) hydropedological soil type associated with the study area.

The Witbank soils are disturbed anthrosols which have not undergone intentional transportation. The disturbance is such that the diagnostic horizons are no longer arranged in any discernible order or recognisable horizonation. As in the case of the anthrosols identified on site, they have undergone significant disturbance, and the dominant flow path is still expected to move vertically through the profile; however, in some instances where the surface is hardened, it may contribute more to overland flow.

Figure 13: View of The Witbank soil forms associated with the recharge (deep) hydropedological soil type.

6.1.3 Inhoek/Dundee (Responsive Saturated)

The Inhoek/Dundee soils form is associated with watercourses due to the alluvial deposition especially on low-lying terrain positions. These soils are characterised by little evidence of pedogenic horizonation and consists of unconsolidated fluvial or lacustrine sediments. These soils generally have a significant component of vertical flow (although often slowly permeable) leading to the accumulation of water overtime. Upward flow of water can be expected in these soils due to evapotranspiration and capillary rise.

Figure 14 View of The Dundee soil forms associated with the responsive (saturated) hydropedological soil type.

Table 3: Dominant soil forms identified within the study area and the associated hydropedological soil type.

Soil Form (Soil Classification Working Group, 2018)	Diagnostic Horizons	Hydropedological soil type (van Tol and Le Roux, 2019)
MispahGlenrosa (Gs)	Orthic A/Lithic	Responsive (Shallow)
Coega	Orthic A/Hard Carbonate	
Bonheim/Abbortpoort	Orthic A/Pedocutanic or Neocutanic/Lithic	Recharge (Deep)
Witbank	Disturbed Soil	
Inhoek/Dundee	Alluvial Material	Responsive (Saturated)

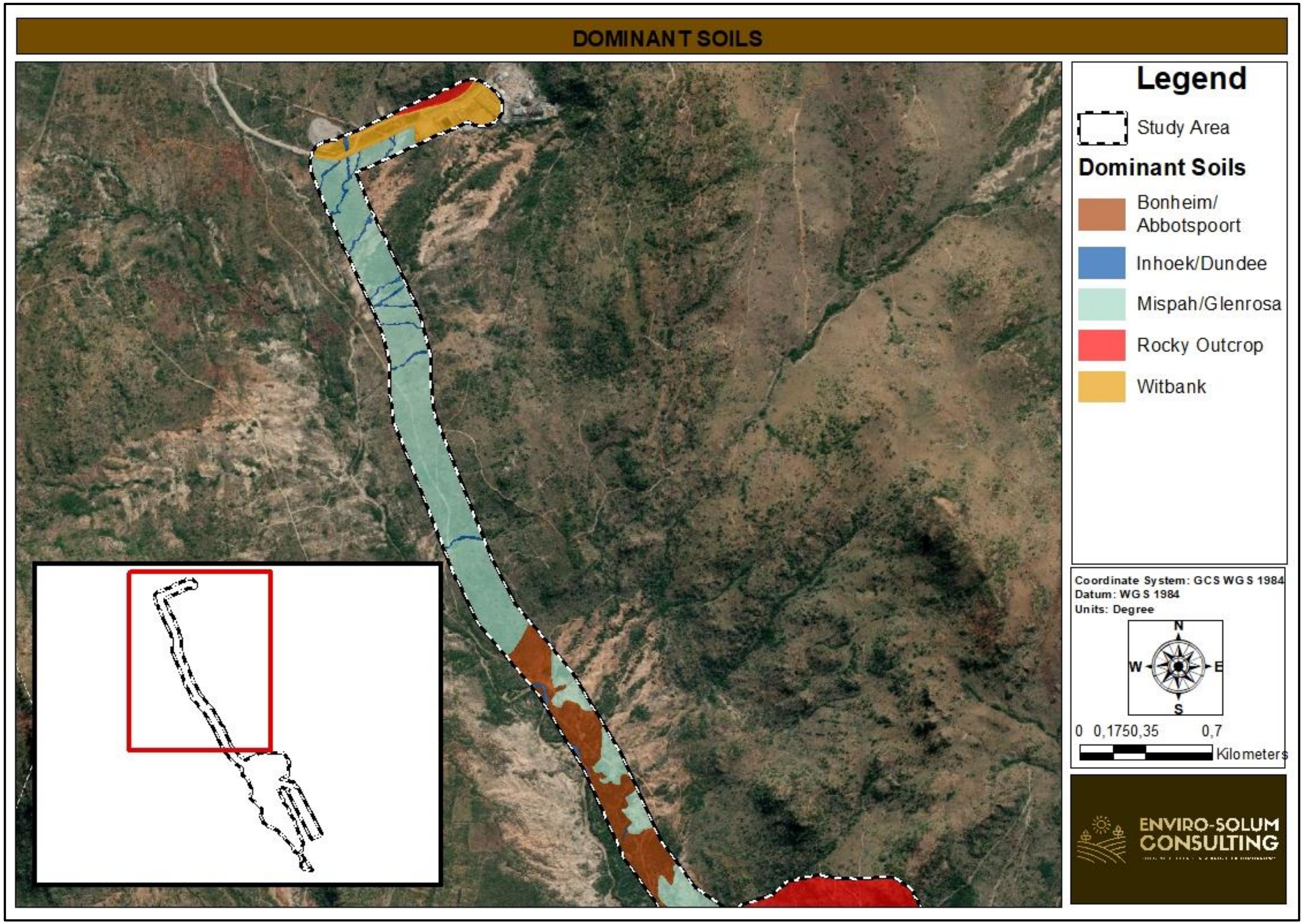

Figure 15: Dominant soils form within the northern portion of the study area.

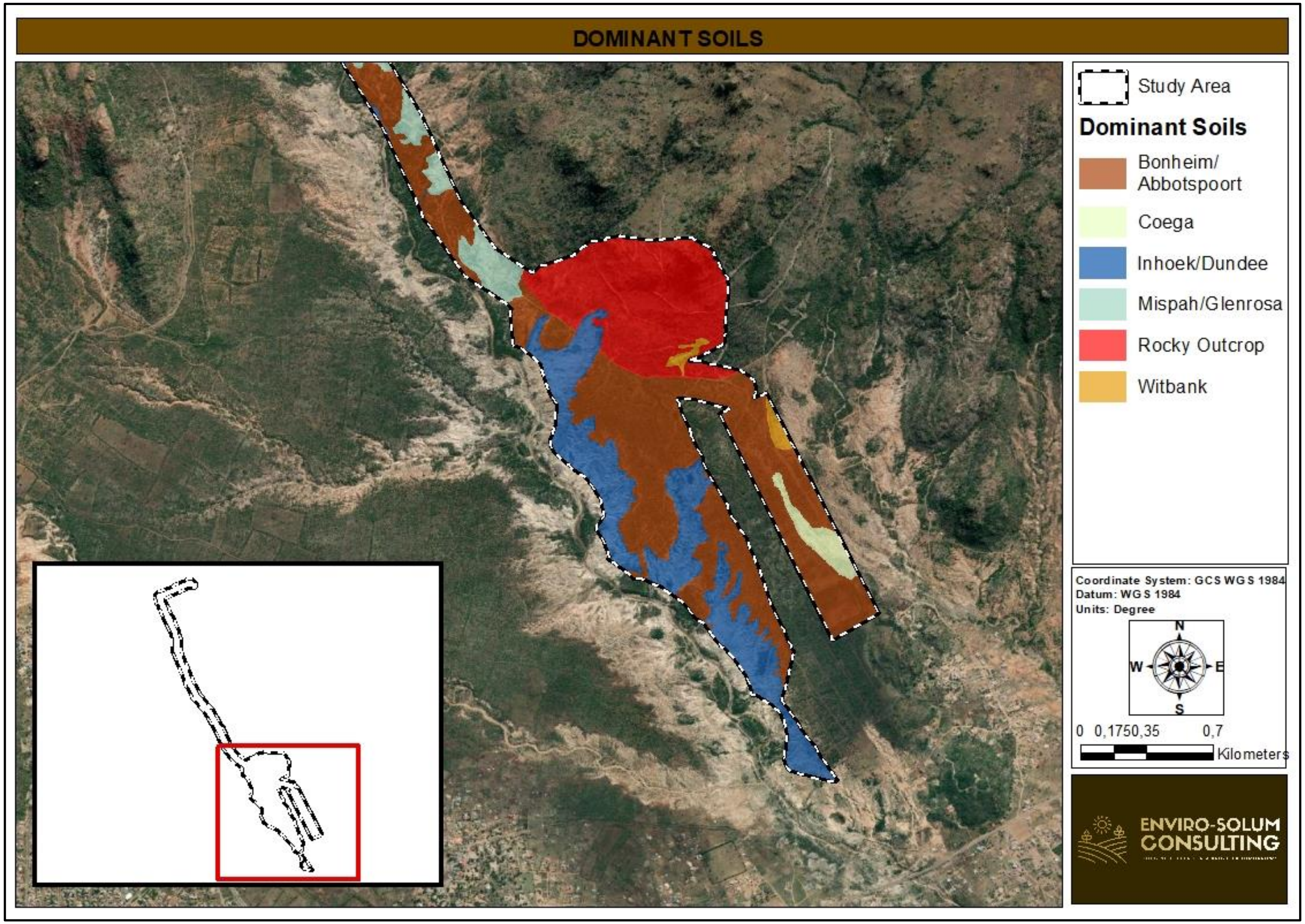

Figure 16: Dominant soils form within the northern portion of the study area.

6.2 Hydropedological Implications for Downstream Watercourse

This section will focus on the impacts that can be anticipated should the proposed development proceed. This is in consideration that the proposed development will likely entail bulk earthworks and excavation for the proposed open cast pit, waste dump as well as access road, thus potentially altering hydropedological flowpaths and modify the dominant hydropedological processes of the landscapes and the state of the nearby freshwater ecosystems. Hydropedological conceptual models will be used to illustrate the dominant flowpaths and the anticipated impacts on the water flowpaths from the proposed development. Figure 17 below depicts the identified transect within the study area and their associated elevation profiles. While Figures 18 and 19 depicts the hydropedological soil types associated with the study area

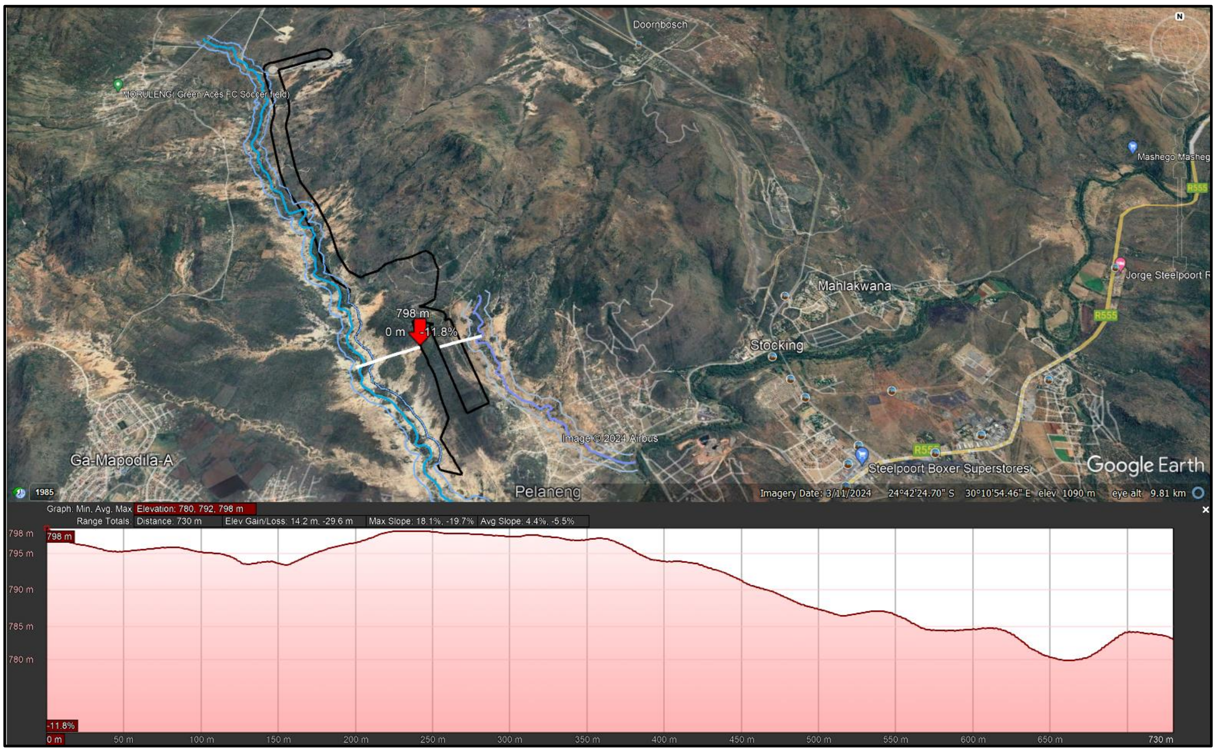

Figure 17: View of the Identified transect within the study area.

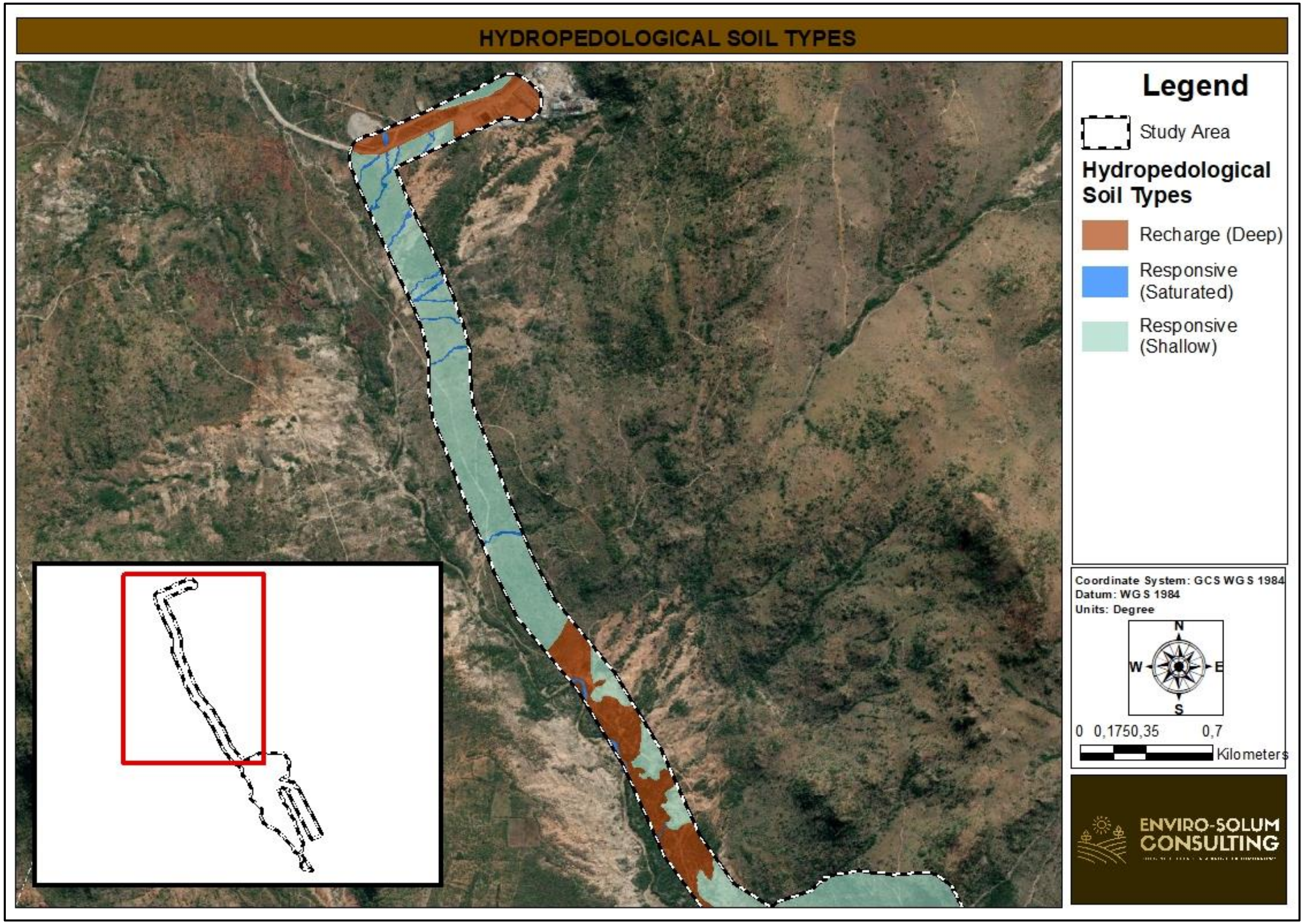

Figure 18: Hydropedological soil types within the northern portion of the study area.

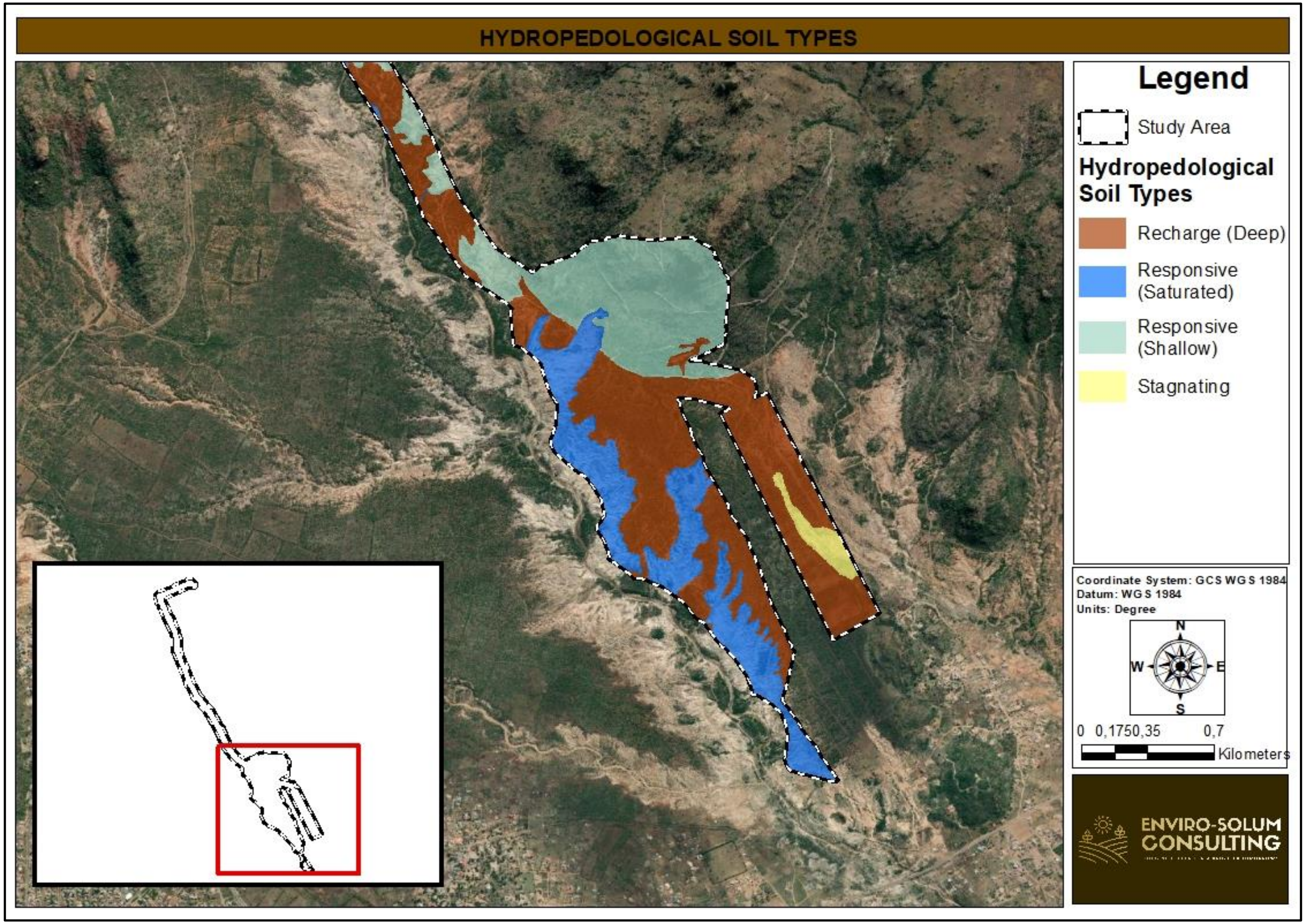

Figure 19: Hydropedological soil types within the sourthern portion of the study area.

6.2.1 Pre-Development

Figure 20 below illustrates the current hydropedological regime of soils associated with the study area.

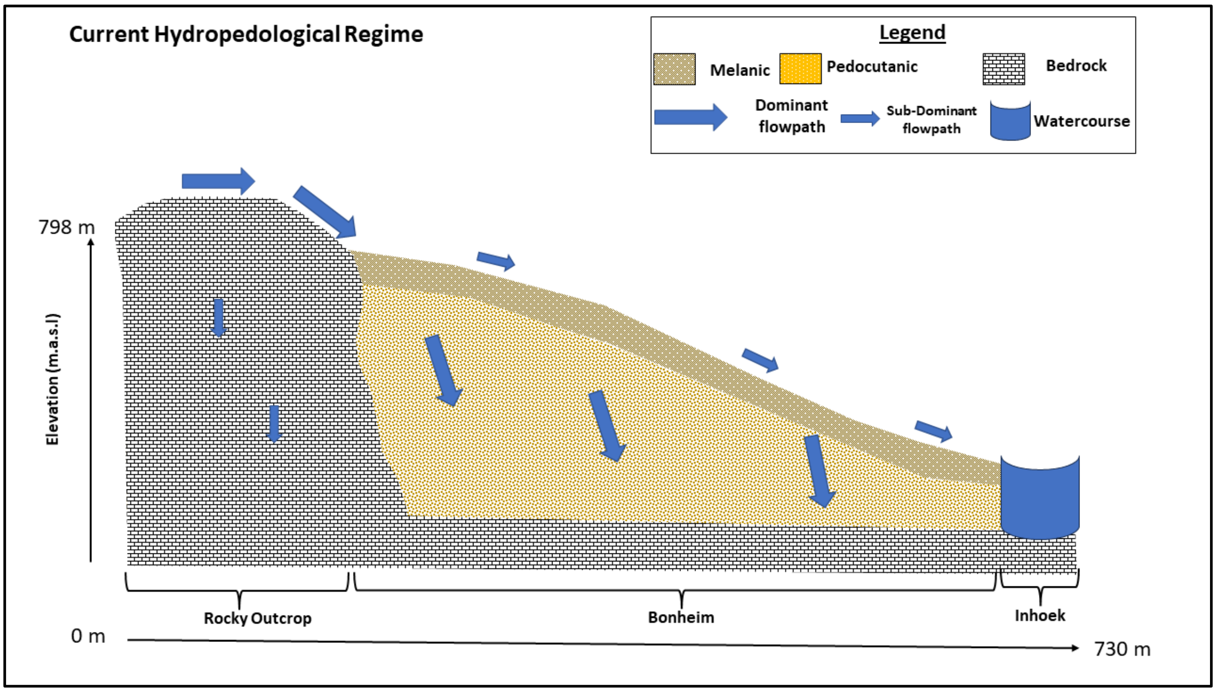

Figure 20: Hillslope hydropedological behaviour for transects identified within the study area.

The crest position is primarily characterised by rocky outcrops, where miscellaneous soils are identified. Water either infiltrates via the preferential flow paths created by the tree roots or flows downslope as overland flow, as these areas can saturate quickly due to limited storage capacity. Towards the mid-slope and lower slope positions along the hillslope soils of Bonheim were identified, and thus, these soils are characterised by a vertical flow of water through and out of the profile. This is supported by the lack of any soil morphological features which typically indicate long-term saturation with water (e.g., mottling and gleying). However, the deeper layers of the B-horizons were characterised by lime precipitates, which may indicate periodic deep preferential flow paths within these soils. This is a result of water, which evaporates under great evaporative demand, and the lime concentrates and precipitates as calcium carbonate ($CaCO_3$), where the water evaporates, and the concentration exceeds the solubility product. Thus, the calcareous character may also indicate limited leaching due to the low rainfall in the area.

This hillslope is classified under Class 3 (Recharge to groundwater) hillslope class due to the nature of the expected water movement based on the hillslope classification devised by van Tol *et al*. (2013). The hillslope classification aims to categorise the contribution of different slopes to streamflow. It is doubtful that this hillslope contributes to the streamflow, apart from the preferential flowpaths in the form of erosion dongas created by high-intensive rainfall. The shallow rocky outcrops soils were observed on the hilltop positions and might generate overland flow. It is, however, hypothesised that the generated overland flow will re-infiltrate the freely drained soils. The absence of signs of saturation indicates either 1) evapotranspiration exceeds precipitation to such an extent that periodic saturation does not occur or 2) recharge of groundwater levels, not connected to the vadose zone in lower lying areas, is dominant (van Tol *et al*.,2013). Figure 21 below illustrates the Perceptual flow models of hillslope class 5 (a) and (b) anticipated hillslope hydrograph.

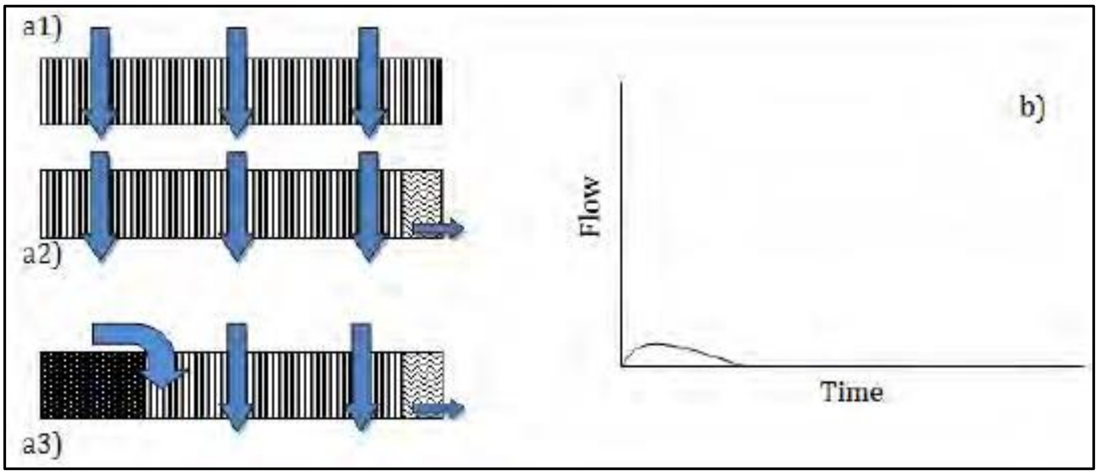

Figure 21: Perceptual flow models of hillslope class 3 and the anticipated hillslope hydrograph.

6.2.2 Post Development Scenario

Figures 22 and 23 below illustrates the post development hydropedological regime and the altered hydrological functioning as a result of the proposed development.

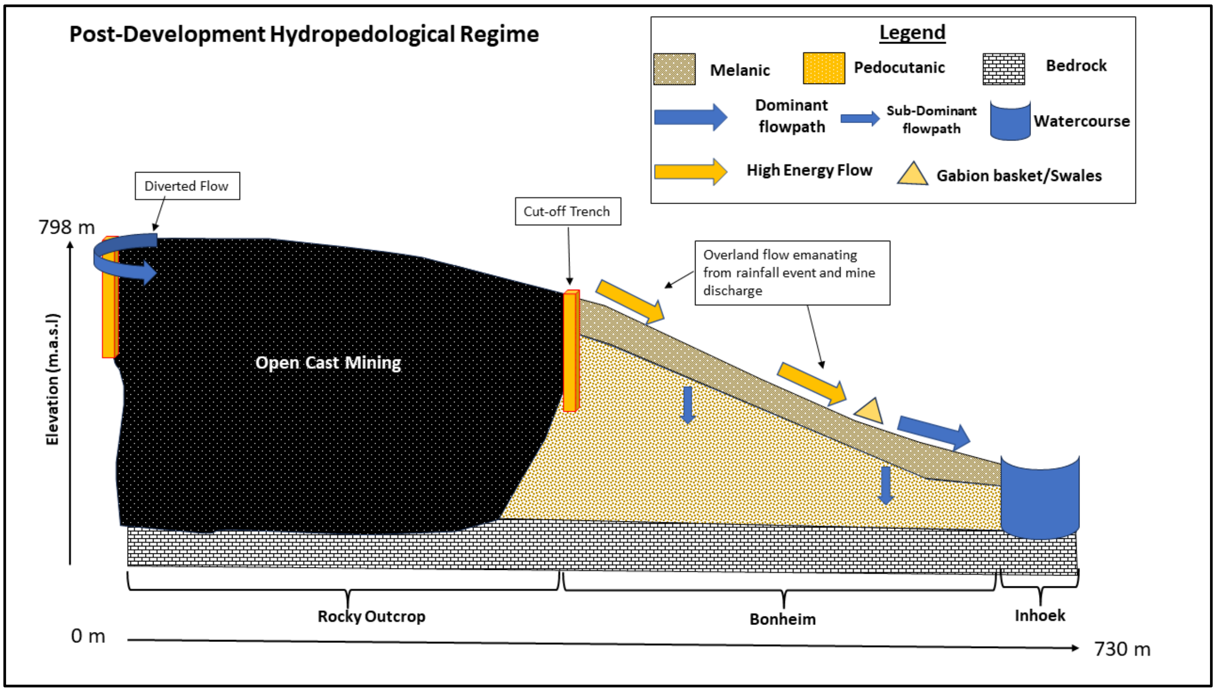

Figure 22: Hillslope hydropedological behaviour after the open cast pit development has taken place.

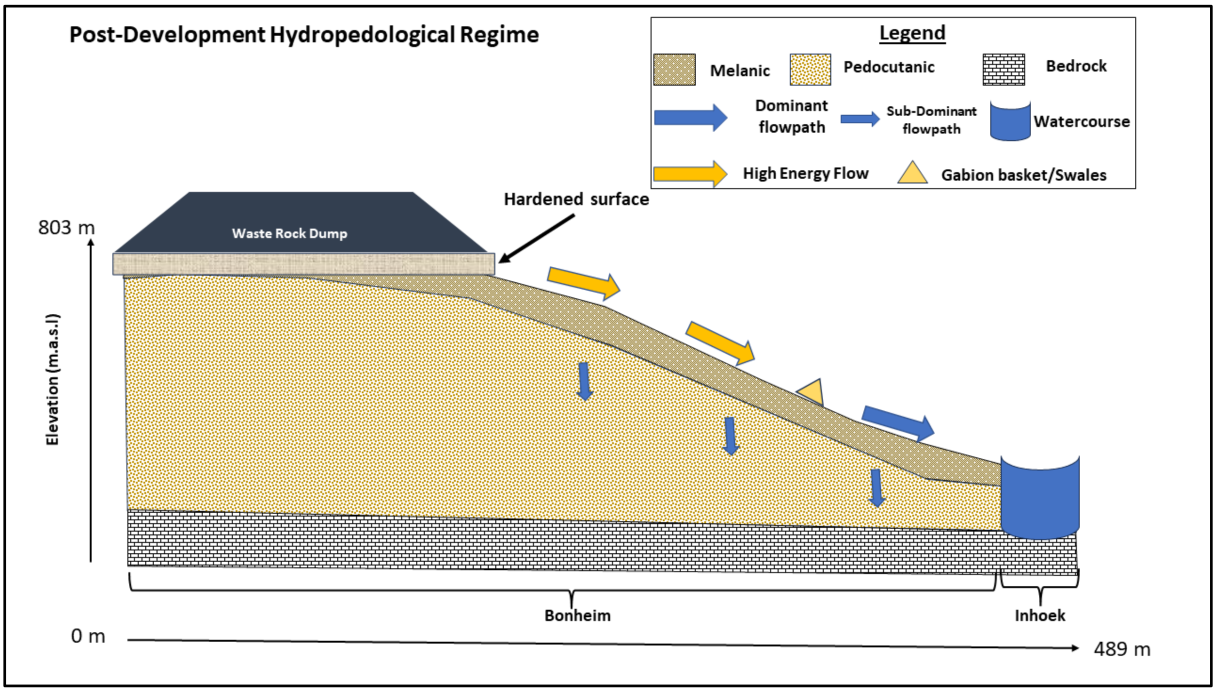

Figure 23: Hillslope hydropedological behaviour after the waste rock dump development has taken place.

The potential impacts from the proposed development will likely pertain to the impacts experienced once the land is excavated for the development of the open cast pits, waste rock dump and the associated access road. The proposed development is largely located on the responsive shallow soils and the recharge deep soils, and these soils are not anticipated to contribute greatly to the nearby watercourse during the rainfall event but are more likely to contribute to the groundwater and thus the impact on the associated watercourses is deemed limited. However, overland flow reporting to the adjacent watercourses may be significant as more preferential flow paths along the erosion dongas may increase as a result of more energised flow of water to the downstream watercourse is anticipated. Appropriate mitigation measures, such as diverting clean water back into the nearby watercourses, are deemed necessary to ensure functionality during all phases of development.

6.3 Quantification of Hydropedological Fluxes

A modelling exercise using the SWAT+(v 2.3.0) model was undertaken in an effort to quantify the losses with specific mention of the lateral flow, which can be anticipated because of the proposed development. The quantification of losses was undertaken at three different scales: the basin scale, landscape unit scale and hydrological response unit scale, and these are discussed below.

6.3.1 Basin Scale

At the basin scale, the proposed open cast footprint area, waste rock dumps and the associated access road are small relative to the basin extent used for the hydrological simulation, and thus, the model predicts a limited impact.

The quantified hydropedological fluxes at the basin scale indicate an increase in the streamflow and surface runoff components by 7.97% and 8.28%, respectively, while they account for less than 2% of the water balance. Nevertheless, these increases are unlikely to follow the same pattern and timing in the landscape, which can impact instream functionality, but this risk is considered low due to the limited contribution to the water balance (WB).

The model simulations indicate an 11.28% and 11.66% decrease in the water balance's lateral flow and percolation components, respectively; however, the contribution to the water balance is less than 1% at this scale. Notably, the model indicates that the contribution of lateral flows before and after development to the occurring wetland features is significantly low, less than 0,07 mm in both pre-and post-development scenarios. This can be attributed to the lack of interflow soils within the larger catchment area and the associated low rainfall.

The most significant loss of water at this scale is through evapotranspiration, which accounts for 98.63% of the water balance as modelled. The model also indicates that rainfall in the basin is largely consumed by evapotranspiration processes and little water from the defined basin is likely exported to the greater catchment. The data thus indicates that rainfall in the area is important in driving the wetland response in the landscape at this scale. The profile water decreases by 14.62% at this scale, the hydropedological processes are anticipated to be unmodified, and the wetland functionality is expected to remain unchanged at this scale.

Table 4: Summary of the water balance pre- and post-development at Basin scale.

	Before	% of WB	After	% of WB	Change
Rainfall	356,526		357,729		
Streamflow	4,228	1,186	4,565	1,276	7,973
Surface runoff	4,160	1,167	4,505	1,259	8,283
Lateral flow	0,068	0,019	0,060	0,017	-11,287
Percolation	0,381	0,107	0,337	0,094	-11,666
ET	351,541	98,602	352,827	98,630	0,366
ecanopy	0,045	1,059	0,034	0,747	-23,839
Transpiration	0,204	0,057	0,153	0,043	-25,175
Evaporation	351,292	98,532	352,640	98,578	0,384
ET0	1655,597		1655,597		
Profile available water	6,309		5,387		-14,615
Topsoil available water	2,024		1,961		-3,099

6.3.2 Land Scape Unit Scale (LSU)

The LSU scale, equivalent to the hillslope scale, depicted an increase in streamflow and surface runoff by 13.2% and 13.44% while accounting for less than 2% of the water balance. This can be attributed to the removal of vegetation in preparation for construction and excavation activities, hardening of surfaces, and steeper slopes, which favour surface runoff generation. Due to the increase in surface water catchment yield, the separation of clean and dirty water and appropriate stormwater management are required to fulfil the GN704.

The lateral flow and percolation components will decrease by 10.54% and 11.36%, respectively, while accounting for less than 1% of the water balance. This can be attributed to the discontinuity of subsurface flow processes (albeit in smaller quantities) in the vicinity of the footprint areas and the hardening of surface conditions, which reduces the infiltration rate. This impact at this scale is thus still considered minimal.

The most significant loss of water at this scale is through evapotranspiration, which accounts for 98.12% of the water balance as modelled. The model also indicates that evapotranspiration processes consume rainfall in the hillslope, and little water from the impacted landscape units is exported to the greater catchment. The data thus indicates that rainfall in the area is important in driving the watercourse response in the landscape at this scale in the form of surface runoff. The profile water at scale decreases by 16.49%, and the hydropedological processes are anticipated to be slightly modified; the instream functionality impacted, as well as the present ecological state (PES), may be impacted at this scale, and this will have to be confirmed by the freshwater assessment.

Table 5: Summary of the water balance pre- and post-development at LSU scale.

	Before	% of WB	After	% of WB	Change
Rainfall	345,750		346,398		
Streamflow	5,495	1,589	6,220	1,796	13,202
Surface runoff	5,439	1,573	6,170	1,781	13,446
Lateral flow	0,056	0,016	0,050	0,014	-10,538
Percolation	0,296	0,086	0,263	0,076	-11,375
ET	339,591	98,219	339,915	98,129	0,095
ecanopy	0,036	0,647	0,027	0,442	-22,704
Transpiration	0,163	0,047	0,124	0,036	-23,725
Evaporation	339,393	98,161	339,764	98,085	0,109
ET0	1655,597		1655,597		
Profile available water	5,885		4,915		-16,485
Topsoil available water	1,777		1,720		-3,238

6.3.3 Hydrological Response Unit (HRU) Scale

At the finer scale the major outflow of the water balance remains evapotranspiration which accounts for 98.05% of the water balance. The site clearing activities, excavation of open cast pits, waste rock dump and establishment of the access road will result in a decrease in the evapotranspiration component.

The streamflow and surface runoff components depict an increase of 17.52% and 18.10% respectively in the post mining scenario as a result of overland flow from impervious surfaces emanating from the proposed development. These increases are however unlikely to have the same pattern and timing in the landscape which can impact on instream functionality, and some localise impacts are likely to occur as discussed below.

The model predicts a decrease in the lateral flow component by 35.19%, accounting for less than 1% of the water balance. It should be noted that localised impact on some watercourses in close proximity to infrastructure and open cast pits will occur, and the severity of impact will mostly likely vary across the various systems in the mining landscape. The larger systems will experience the least impact, while the smaller watercourses, such as drainage lines downgradient of mining operations, will be impacted most significantly. Therefore, a stormwater and erosion management plan should be developed and implemented to minimise the potential impact on the watercourses during all phases of development. The PES/EIS and functionality of the watercourses will potentially remain unimpacted during all phases of development, provided that mitigation measures are implemented, such as the management of surface water and ensuring that the clean water is diverted and discharged back into the adjacent watercourses.

Table 6: Summary of the water balance pre- and post-development at HRU scale.

	Before	% of WB	After	% of WB	Change
Rainfall	345,647		339,619		
Streamflow	5,467	1,582	6,425	1,892	17,523
Surface runoff	5,408	1,565	6,387	1,881	18,098
Lateral flow	0,059	0,017	0,038	0,011	-35,185
Percolation	0,292	0,085	0,203	0,060	-30,687
ET	339,517	98,227	332,991	98,048	-1,922
ecanopy	0,125	2,292	0,079	1,233	-36,812
Transpiration	0,576	0,167	0,366	0,108	-36,492
Evaporation	338,816	98,024	332,546	97,917	-1,850
ET0	1663,413		1663,413		
Profile available water	5,869		4,673		-20,371
Topsoil available water	1,763		1,584		-10,188

6.4 Functional Buffer Zone (Areas not suitable for Development)

A functional buffer zone can be defined as a strip of land with a use, function or zoning specifically designed to protect one area of land against impacts from another. As a result, the bigger the buffer, the greater the results thereof. This is to allow a large enough area to allow for subsurface flow of water to provide a steady but slow recharge to the groundwater or the downslope watercourse. Due to the absence of subsurface lateral flows or interflow soils which are considered to be soils of high hydropedological importance, the risk of impact on the receiving environment from impact on hydropedological processes is anticipated to be low. The mining footprint is suitably positioned in the shallow responsive soils, which only contribute to surface overland flow during rainfall events, and recharge deep soils, which are unlikely to be linked to the streamflow. The post-mining scenario will likely alter the catchment yield and surface runoff in the greater landscape. The buffer determination for the protection of important hydropedological soils is deemed irrelevant. However, the development should be cognisant of the edge effects as well as the loss of catchment yield and the surface runoff component reporting to and recharging the watercourse system. A 50 meter edge effect buffer can be considered at this stage. This will ensure that, as far as possible the functionality of the system as well as its Present Ecological State does not deteriorate to an unacceptable future state due to loss of recharge.

7. CUMULATIVE IMPACTS

The cumulative impacts include the anticipated direct and indirect impacts of the proposed development. As such, water flowing through the catchment is increased when human intervention impacts on the drainage systems, often at higher levels than before human impact. This can have severe impacts on the natural systems if not mitigated properly, as these changes in water runoff volumes through the impervious surfaces and runoff timing considerations lead to increased wetness and spikes in water volumes in drainage features as predicted by the modelling. The study area is largely dominated by responsive (shallow) soils, and recharged deep soils are highly prone to erosion, thus indicating a further increase in runoff volumes in the post-development scenario. Henceforth, adequate stormwater mitigation measures should be adhered to at all phases of development to manage the stormwater and channelised water effectively to prevent large pulses in stormwater. A further increase in impervious surfaces may lead to changes in the hydrological flow regimes associated with the study area and may result in accelerated erosion and sedimentation of the lower-lying areas if not properly attenuated and managed through proper landscaping to maintain functionality for downstream users. Therefore the proposed development does not pose a development constraint from a hydropedological perspective. This can be considered in conjunction with a freshwater assessment. Their findings can also be used to determine the current state of the associated watercourses and the ecoservices they provide.

8. CONCLUSION AND MITIGATION MEASURES

The study area is primarily characterised by soils of Mispah/Glenrosa, Coega and Rocky Outcrops formation in the crest and in the midslope positions the soils of Bonheim/Abbotspoort and along the valley bottom the soils of Inhoek/Dundee formation were identified. The crest position is primarily characterised by rocky outcrops, where miscellaneous soils are identified. Water either infiltrates via the preferential flow paths created by the tree roots or flows downslope as overland flow, as these areas can saturate quickly due to limited storage capacity. Towards the mid-slope and lower slope positions along the hillslope soils of Bonheim were identified, and thus, these soils are characterised by a vertical flow of water through and out of the profile. This is supported by the lack of any soil morphological features which typically indicate long-term saturation with water (e.g., mottling and gleying). However, the deeper layers of the B-horizons were characterised by lime precipitates, which may indicate periodic deep preferential flow paths within these soils. This is a result of water, which evaporates under great evaporative demand, and the lime concentrates and precipitates as calcium carbonate ($CaCO_3$), where the water evaporates, and the concentration exceeds the solubility product. Thus, the calcareous character may also indicate limited leaching due to the low rainfall in the area.

The potential impacts from the proposed development will likely pertain to the impacts experienced once the land is excavated for the development of the open cast pits, waste rock dump and the associated access road. The proposed development is largely located on the responsive shallow soils and the recharge deep soils, and these soils are not anticipated to contribute greatly to the nearby watercourse during the rainfall event but are more likely to contribute to the groundwater and thus the impact on the associated watercourses is deemed limited. However, overland flow reporting to the adjacent watercourses may be significant as more preferential flow paths along the erosion dongas may increase as a result of more energised flow of water to the downstream watercourse is anticipated. Appropriate mitigation measures, such as diverting clean water back into the nearby watercourses, are deemed necessary to ensure functionality during all phases of development.

8.1 MITIGATION MEASURES

The following recommendations must be implemented with a suitably qualified engineer, horticulturist (as a landscape planner) and in conjunction with other relevant specialists should the proposed project proceed:

- In terms of both the NWA (National Water Act) and NEMA (National Environmental Management Act) landowners have a duty to protect water resources, watercourses and wetlands. If not adequately managed can lead to criminal prosecution or disciplinary action from relevant authorities;

- Ensure that water of different quality (i.e. clean and dirty water) is kept separate and managed separately, as far as possible. This will ensure that the contact between water of different quality and the potential for unnecessary water quality deterioration is minimised;
- Water from clean water structures should be discharged back into the watercourse in an attenuated manner;
- Structures to trap silt and other sediments should be implemented at strategic locations to prevent further ingress of sediments into the watercourse;
- Ensure proper stormwater management designs are in place; stormwater management should allow for artificial recharge;
- An integrated stormwater management plan has to be drawn up by suitably qualified personnel that takes into account the stormwater generated upslope from the site as well as the stormwater generated on the specific site;
- Infiltration systems should be designed to collect stormwater from adjacent impervious areas and provide a pathway for water to infiltrate into the soil and subsurface areas, providing a natural recharge to groundwater systems (if necessary);
- Connectivity between the source (wetland/stormwater structures) and the stream channels should be prioritised.

From a hydropedological point of view, most of the study area is deemed developable, provided that the above mitigatory measures are implemented.

10. REFERENCES

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APPENDIX A: INDEMNITY

- This report is based on survey and assessment techniques which are limited by time and budgetary constraints relevant to the type and level of investigation undertaken.
- This report is based on a desktop investigation using available information and data related to the site to be affected, *in situ* fieldwork, surveys, and assessments, and the specialist's best scientific and professional knowledge.
- The Precautionary Principle has been applied throughout this investigation.
- The findings, results, observations, conclusions, and recommendations given in this report are based on the specialist's best scientific and professional knowledge as well as information available at the time of the study.
- Additional information may become known or available later in the process for which no allowance could have been made at the time of this report.
- The specialist reserves the right to modify this report, recommendations, and conclusions at any stage should additional information become available.
- Information and recommendations in this report cannot be applied to any other area without proper investigation.
- This report, in its entirety or any portion thereof, may not be altered in any manner or form or for any purpose without the specific and written consent of the specialist as specified above.
- Acceptance of this report, in any physical or digital form, serves to confirm acknowledgment of these terms and liabilities.

Tshiamo Setsipane

03 July 2024

APPENDIX B: DECLARATION OF INDEPENDENCE

- I, Tshiamo Setsipane, in my capacity as a specialist consultant, hereby declare that I:
- Act/acted as an independent specialist to Segope Water and Environmental Services for this project.
- Do not have any personal, business, or financial interest in the project except for financial remuneration for specialist investigations completed in a professional capacity as specified by the Environmental Impact Assessment Regulations, 2014, as amended.
- Will not be affected by the outcome of the environmental process, of which this report forms part.
- Do not have any influence over the decisions made by the governing authorities.
- Do not object to or endorse the proposed developments but aim to present facts and my best scientific and professional opinion about the impacts of the development.
- Undertake to disclose to the relevant authorities any information that has or may have the potential to influence its decision or the objectivity of any report, plan, or document required in terms of the Environmental Impact Assessment Regulations, 2014, as amended.

Tshiamo Setsipane

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(*Pr. Nat. Sci* 114882)

03 July 2024

APPENDIX C: CURRICULUM VITAE OF SPECIALISTS

CURRICULUM VITAE OF TSHIAMO SETSIPANE

PROFESSIONAL EXPERIENCE

Soil Science Consultant

- Conducting Soil, Land Use and Land Capability Assessments:
  - Assess existing information for rainfall data and current land uses.
  - Conduct a desktop assessment within the focus area using the digital satellite imagery and other suitable digital aids.
  - A soil classification survey and agricultural potential will be conducted within the proposed development area.
  - A soil classification survey and agricultural potential will be conducted within the proposed development area.
  - Provide recommended mitigation measures to implement to manage the anticipated impacts and to comply with the applicable legislations.
  - Compile a report on the findings of the assessment and presented in an electronic format.
- Conducting Hydropedological Impact Surveys:
  - Identify dominant hillslopes (from crest to stream) of the project area using terrain analysis.
  - Conduct a transect soil survey on each of the identified hillslope.
  - Hydrological behaviour of the identified hillslope described according to the identified hydropedological groups;
  - Graphical representation of the dominant and sub-dominant flowpaths at hillslope scale prior to development and post development.
  - The impact of the proposed development on the hydropedological behaviour described in a report format.
  - Quantification of hydropedological fluxes using the Soil and Water Analysis Tool (SWAT+) to determine the losses to the wetland systems though the proposed project
- Conducting Land Contamination Assessments and Soil Monitoring Assessments:
  - Assessments of historic and current storage of hazardous waste and materials on soils.
  - Topsoil stockpile quality assessment for future usage.
  - Monitoring programme to determine the dust suppression impact on soil chemical parameters.

EDUCATION

- M.Sc. (Agric): Soil Science **01/2016– 03/2019**
  - Dissertation: Characterisation of hydropedological processes and properties of a sandstone and a tillite hillslope, Kwa-Zulu Natal, South Africa.
  - Graduated *Cum-Laude*.
- B.Sc. (Agric) Honours: Soil Science **01/2014 – 11/2014**
  - Majored in soil fertility, soil physics, soil geography and soil chemistry.
  - Research Project: Soil as an indicator of soil water regime.
- B.Sc. (Agric): Soil Science and Agrometeorology **2010 – 11/2013**
  - Majored in soil science and agrometeorology.
  - Minored in agronomy and plant pathology.

PROFESSIONAL MEMBERSHIP AND AFFILIATION

- Professional Natural Scientist with South African Council for Natural Scientific Professions (SACNASP) Registered, 11/2015 – Current
- Member of the Soil Science Society of South Africa (SSSSA)
- Member, South African Soil Surveyors Organization (SASSO)
- Member of the South African Wetland Society (SAWS)