Environmental Impact Assessment - for the proposed Elandsfontein Coal Mining Project

Mpumalanga Province, South Africa

Hydropedology Assessment

March 2020

CLIENT

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Report Name	Environmental Impact Assessment -for the Proposed Elandsfontein Coal Mining Project: Hydropedology Assessment
Submitted to	EIMS Environmental Impact Management Services
Report Reviewer	**Andrew Husted** Andrew Husted is Pr Sci Nat registered (400213/11) in the following fields of practice: Ecological Science, Environmental Science and Aquatic Science. Andrew is an Aquatic, Wetland and Biodiversity Specialist with more than 12 years' experience in the environmental consulting field. Andrew has completed numerous wetland training courses, and is an accredited wetland practitioner, recognised by the DWS, and also the Mondi Wetlands programme as a competent wetland consultant.
Report Writer and Fieldwork	**Ivan Baker** Ivan Baker is Cand. Sci Nat registered (119315) in environmental science and geological science. Ivan is a wetland and ecosystem service specialist, a hydropedologist and pedologist that has completed numerous specialist studies ranging from basic assessments to EIAs. Ivan has carried out various international studies following FC standards. Ivan completed training in Tools for Wetland Assessments with a certificate of competence and completed his MSc in environmental science and hydropedology at the North-West University of Potchefstroom.
Report Writer and Review	**Johan van Tol** Johan van Tol is an Associate Professor in Soil Science at the University of the Free State and director of Digital Soil Africa. He is a NRF Y1 rated researcher and author of 35 peer reviewed publications. He presented his research at more than 60 national and international congresses and lead/involved in more than 12 externally funded research projects. He is Pr.Sci.Nat registered and has produced more than 50 scientific consultancy reports mainly on hydropedology.
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. 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.

EXECUTIVE SUMMARY

GNR 326	Appendix 6 (n): Specialist Opinion

The effects of the proposed activities will have insignificant impacts towards lateral sub-surface flows within the vadose zone predominantly due to the dominance of recharge soils and the current disturbances within the mining right area that already have affected the vadose zone significantly.

It is the specialist's opinion that the proposed activities may proceed as have been planned on the condition that a geohydrological assessment be conducted to inform the feasibility of the proposed activities keeping in mind the recharge of associated wetland systems by means of groundwater systems. The geohydrological assessment must advise on mitigatory measures for risks posed to the wetland recharge.

The Elandsfontein Colliery comprises of two Mining Right Areas (MR63 and MR314). The applicant plans to combine these two Mining Right Areas (MRAs) into one single MRA with an associated consolidated Environmental Management Programme (EMPR). In addition, the applicant plans to expand current mining areas and include new open cast and underground mining areas.

The purpose of the specialist study is to provide relevant input into the authorisation process and to provide a report for the proposed activities associated with mining and ancillary activities proposed to take place on site.

The Biodiversity Company was commissioned to conduct a level 3 hydropedological assessment as part of the environmental authorisation process for the relevant mining activities (open cast and underground). The project will also be undertaken to meet the requirements of the National Environmental Management Act 107 of 1998, specifically Appendix 6.

Large portions of the studied area are already impacted upon by current mining activities. These modifications have altered natural flow paths of and complicates hydropedological interpretations in relation to proposed future developments. With this being said, it is worth noting that the recharge soils occupy long sections of the slopes, especially those areas where the proposed pits will be located. Conceptually, the impact of the development on lateral flow paths through the vadose zone will therefore be insignificant. This conceptual understanding was supported by hydrological simulations of one slope which was not yet impacted by development. The simulations indicate that the proposed development will only result in drying of the soils directly below the open cast pits. Approximately 300 m downslope of the pit, differences in soil water contents were not observed. Similarly, there was no difference in the outflow and lateral flux to the stream between the natural and developed state.

With large areas being occupied by recharge soils, the geohydrological study should advise on the impact of the proposed development on the contribution of groundwater to streamflow and wetland water regimes.

DECLARATION

I, Ivan Baker, declare that:

- I act as the independent specialist in this application;
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, regulations and any guidelines that have relevance to the proposed activity;
- I will comply with the Act, regulations and all other applicable legislation;
- I have no, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing any decision to be taken with respect to the application by the competent authority; and the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- All the particulars furnished by me in this form are true and correct; and
- I realise that a false declaration is an offence in terms of Regulation 71 and is punishable in terms of Section 24F of the Act.

Ivan Baker

Soil Specialist

The Biodiversity Company

March 2020

Declaration

I, Johan van Tol declare that:

- I act as the independent specialist in this application;
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, regulations and any guidelines that have relevance to the proposed activity;
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- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing any decision to be taken with respect to the application by the competent authority; and the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- all the particulars furnished by me in this form are true and correct; and
- I realise that a false declaration is an offence in terms of Regulation 71 and is punishable in terms of Section 24F of the Act.

Prof. Johan van Tol

Soil Specialist

Digital Soils Africa

October 2019

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1. Introduction & Background

The Elandsfontein Colliery comprises of two Mining Right Areas (MR63 and MR314). The applicant plans to combine these two Mining Right Areas (MRAs) into one single MRA with an associated consolidated Environmental Management Programme (EMPR). In addition, the applicant plans to expand current mining areas and include new open cast and underground mining areas.

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The Biodiversity Company was commissioned to conduct a level 3 hydropedological assessment as part of the environmental authorisation process for the relevant mining activities (open cast and underground). The project will also be undertaken to meet the requirements of the National Environmental Management Act 107 of 1998, specifically Appendix 6.

A single hydropedological site visit was conducted from the 12th to the 16th of August 2019, This report, after taking into consideration the findings and recommendation provided by the specialist herein, should inform and guide the Environmental Assessment Practitioner (EAP) and regulatory authorities, enabling informed decision making with regards to the proposed activity.

2. Document Structure

The table below provides the NEMA (2014) Requirements for Ecological Assessments, and also the relevant sections in the reports where these requirements are addressed:

GNR 326	Description	Section in the Report
Specialist Report		
Appendix 6 (a)	A specialist report prepared in terms of these Regulations must contain— details of— i. the specialist who prepared the report; and ii. the expertise of that specialist to compile a specialist report including a curriculum vitae;	Page iv.
Appendix 6 (b)	A declaration that the specialist is independent in a form as may be specified by the competent authority;	Appendix A
Appendix 6 (c)	An indication of the scope of, and the purpose for which, the report was prepared;	Section 4
Appendix 6 (cA)	An indication of the quality and age of base data used for the specialist report;	Section 8
Appendix 6 (cB)	A description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change;	Section 9
Appendix 6 (d)	The duration, date and season of the site investigation and the relevance of the season to the outcome of the assessment;	Section 1
Appendix 6 (e)	A description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of equipment and modelling used;	Section 7
Appendix 6 (f)	Details of an assessment of the specific identified sensitivity of the site related to the proposed activity or activities and its associated structures and infrastructure, inclusive of a, site plan identifying site alternatives;	Section 9
Appendix 6 (g)	An identification of any areas to be avoided, including buffers;	Section 11
Appendix 6 (h)	A map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers;	Section 11
Appendix 6 (i)	A description of any assumptions made and any uncertainties or gaps in knowledge;	Section 12
Appendix 6 (j)	A description of the findings and potential implications of such findings on the impact of the proposed activity [including identified alternatives on the environment] or activities;	Section 9
Appendix 6 (k)	Any mitigation measures for inclusion in the EMPr;	Section 10
Appendix 6 (l)	Any conditions for inclusion in the environmental authorisation;	Section 11
Appendix 6 (m)	Any monitoring requirements for inclusion in the EMPr or environmental authorisation;	10
Appendix 6 (n)	A reasoned opinion— i. [as to] whether the proposed activity, activities or portions thereof should be authorised; (iA) regarding the acceptability of the proposed activity or activities; and ii. if the opinion is that the proposed activity, activities or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan;	Section 11
Appendix 6 (o)	A description of any consultation process that was undertaken during the course of preparing the specialist report;	None
Appendix 6 (p)	A summary and copies of any comments received during any consultation process and where applicable all responses thereto; and	None
Appendix 6 (q)	Any other information requested by the competent authority.	None

3. Specialist Details

3.1 Report Writer and Fieldwork

Ivan Baker

Ivan Baker is Cand. Sci Nat registered (119315) in environmental science and geological science. Ivan is a wetland and ecosystem service specialist, a hydropedologist and pedologist that has completed numerous specialist studies ranging from basic assessments to EIAs. Ivan has carried out various international studies following FC standards. Ivan completed training in Tools for Wetland Assessments with a certificate of competence and completed his MSc in environmental science and hydropedology at the North-West University of Potchefstroom.

3.2 Report Writer and Review

Prof. Johan van Tol

Johan van Tol is an Associate Professor in Soil Science at the University of the Free State and director of Digital Soil Africa. He is a NRF Y1 rated researcher and author of 35 peer reviewed publications. He presented his research at more than 60 national and international congresses and lead/involved in more than 12 externally funded research projects. He is Pr.Sci.Nat registered and has produced more than 50 scientific consultancy reports mainly on hydropedology.

3.3 Report Reviewer

Andrew Husted

Andrew Husted is Pr Sci Nat registered (400213/11) in the following fields of practice: Ecological Science, Environmental Science and Aquatic Science. Andrew is an Aquatic, Wetland and Biodiversity Specialist with more than 12 years' experience in the environmental consulting field. Andrew has completed numerous wetland training courses, and is an accredited wetland practitioner, recognised by the DWS, and also the Mondi Wetlands programme as a competent wetland consultant.

4. Terms of Reference

The following tasks were completed in fulfilment of the terms of reference for this assessment:

- Identification of soil profiles and morphology;
- Determining the Saturated Hydraulic Conductivity (*Ks*) of bedrock;
- Undisturbed sampling of all soil horizons for each land type;
- Conceptualising impacts towards hillslope hydrology;
- Using results from laboratory tests on undisturbed samples for the parameterisation of the relevant modelling software;
- Quantifying the loss of interflow towards watercourses; and
- The prescription of mitigation measures and recommendations for identified risks.

5. Project Description

5.1 Project area

The Elandsfontein Colliery is located in the Witbank Coal Field on the farm Elandsfontein 309 JS. The property is approximately 16 km west of the town of Witbank in the Mpumalanga Province, South Africa. The centre point of the site is 25°53'05.01"S and 29°05'36.57"E. The Elandsfontein Colliery comprises 2 distinct mining rights (MR314 and MR63). The applicant plans to consolidate the two mining right areas into a single mining right with associated consolidated EMPR. In addition, the applicant wishes to expand their existing mining operations to include additional mineral resource areas (i.e.: new open cast & underground areas within the consolidated mining right boundary) (GSW, 2019). The dominant land uses surrounding the project area includes watercourses, cultivation, urban sprawls and mining. A locality map of the project area is shown in Figure 5-1.

5.2 Background

Elandsfontein Colliery is an existing mine with opencast and underground sections. Elandsfontein Colliery holds two mining rights, namely MP 314 MR (~593 ha) and MP 63 MR (~237 ha). It produces coal for the local and the export market, at a rate of ~500 000 tons/annum. Coal has been produced historically from the No. 1 Seam (underground bord and pillar operation) and an opencast operation on the No. 4 Seam and on the No. 2 Seam.

The roll over strip mining method is utilised to extract coal from the shallower No.2 coal seam. The existing opencast operations have an approximate extent of 257 ha (some of this area has already been mined and other areas are currently being mined in accordance with the previous approved mine plan) while the applicant wishes to authorise an additional 69.47 ha of opencast mining. Deeper coal will be extracted by underground bord and pillar mining using decline shafts to access the No. 1 coal seam. The historical underground footprint covers an approximate area of 182 ha, while Elandsfontein Colliery wishes to authorise an additional 485 ha of underground mining and 249 ha of opencast mining. Associated infrastructure consists of a discard dump, coal RoM stockpiles, overburden stockpiles, pollution control dams (PCD) and slurry dam.

Elandsfontein Colliery is planning to add additional opencast and underground mining areas within the existing mining right areas to extend the life-of-mine (LoM). As such a MPRDA S102 amendment process is being undertaken by the mine, supported by the integrated EIA/WML and WULA applications. The EIA process will result in a consolidation of the numerous authorisation processes that have been undertaken to date to produce a single overarching EMPr for holistic management of the Colliery going forward. Elandsfontein Colliery will be applying for the relevant approvals to cover their extended LoM which will include future opencast and underground mining operations and associated infrastructure. Various amendments to the existing EA/EMP as well as IWUL will also be applied for to align the specific conditions with the current status of the mine as well as to provide more clarity on certain conditions.

The following rights, authorisations and approvals are currently in place and have been considered in the compilation of the report:

- Mining Right 63 MR renewal, granted to Elandsfontein Colliery (Pty) Ltd, in terms of Section 24 (3) of the MPRDA on 6 August 2019 which covers the following portions of the farm Elandsfontein 309 JS: Portion of the RE of Portion 6, Portion of the RE of Portion 8 and RE of Portion 1.

- Mining Right 314 MR renewal, granted to Elandsfontein Colliery (Pty) Ltd, in terms of Section 24 (3) of the MPRDA on 6 August 2019 which covering the following portions of the farm Elandsfontein 309 JS: RE of Portion 7, Portion of the RE of Portion 8, Portion 44 and Portion 14;
- An amended EMPr dated August 2017;
- Approved IWUL, File No. 16/2/7/B100/C11 granted on 20 October 2015 for various S21 (g), (c) and (i) which covers Portions 1, 7, 8 and 14 of Elandsfontein 309 JS (amended 23 July 2019).

The existing approved surface infrastructure at Elandsfontein Colliery consists of the following:

- Opencast pit;
- Underground mining areas;
- Stockpiles;
- Offices;
- Beneficiation Plant area (crushing and screening);
- Contractors yard;
- Weighbridge;
- Access and haul roads;
- Security point and fencing;
- Pumps and sumps;
- Clean water trenches;
- Dirty water trenches;
- 3 PCD's; and
- Storm water control trenches.

5.3 Description of Activities to Be Undertaken

This section describes the current authorization process activities as provided. The proposed project includes inter alia the following application processes with associated activities:

- New Integrated Environmental Authorisation (Scoping and Environmental Impact Report (S&EIR)) for:
  - New opencast and underground mining areas;
  - New PCDs and stormwater management infrastructure;

  - New residue deposits and/or residue stockpiles (requiring Waste Management Licence); and
  - Various activities including the primary processing of a mineral resource related to the extended LoM.
- Renewal of Integrated Water Use Licence (IWUL) and application for new water uses for:
  - Residue stockpiles/deposits;
  - Dewatering of pits and underground areas;
  - New PCD’s and stormwater management infrastructure; and
  - GN704 exemptions.
- MPRDA Section 102 Amendment:
  - Revised Mine Works Programme;
  - Revised Social and Labour Plan;
  - Revised Regulation 2.2 Plan; and
  - Revised consolidated EMPr.

The proposed mining can be seen in Figure 5-2 whereas the proposed surface infrastructure, stockpiles and the related activities can be seen in Figure 5-3.

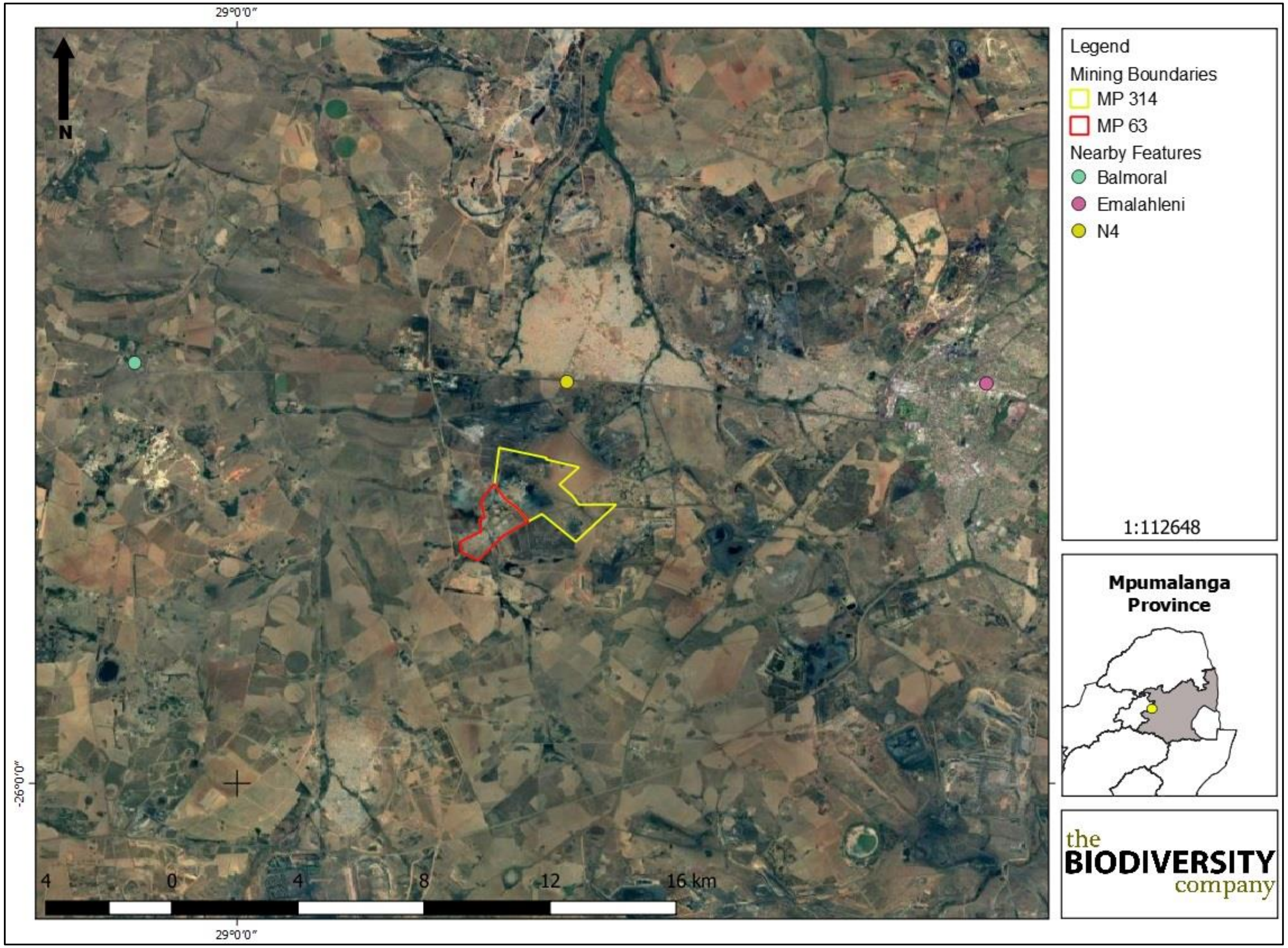

Figure 5-1 Locality map of the project area

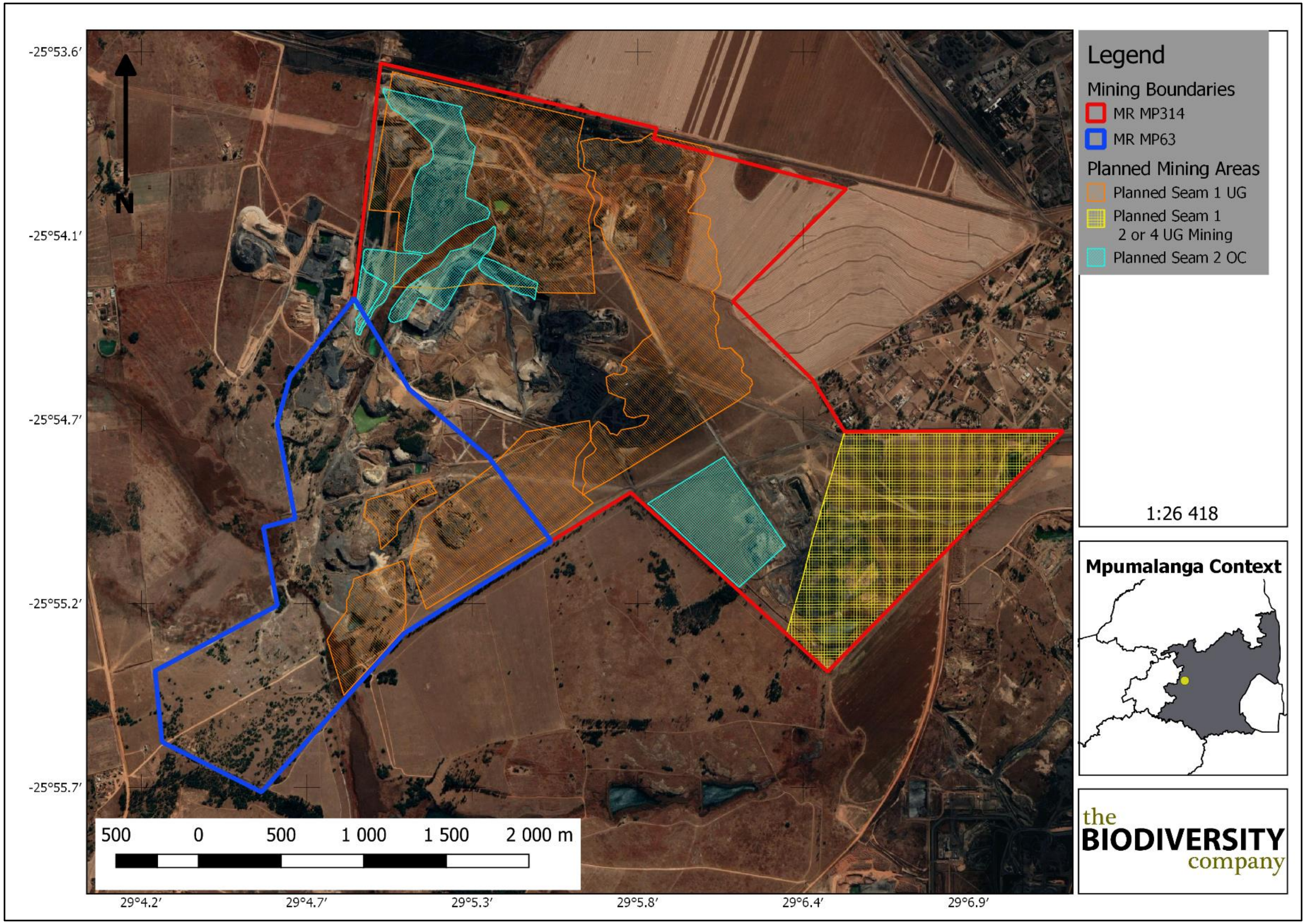

Figure 5-2 Extent of proposed open cast and underground mining areas

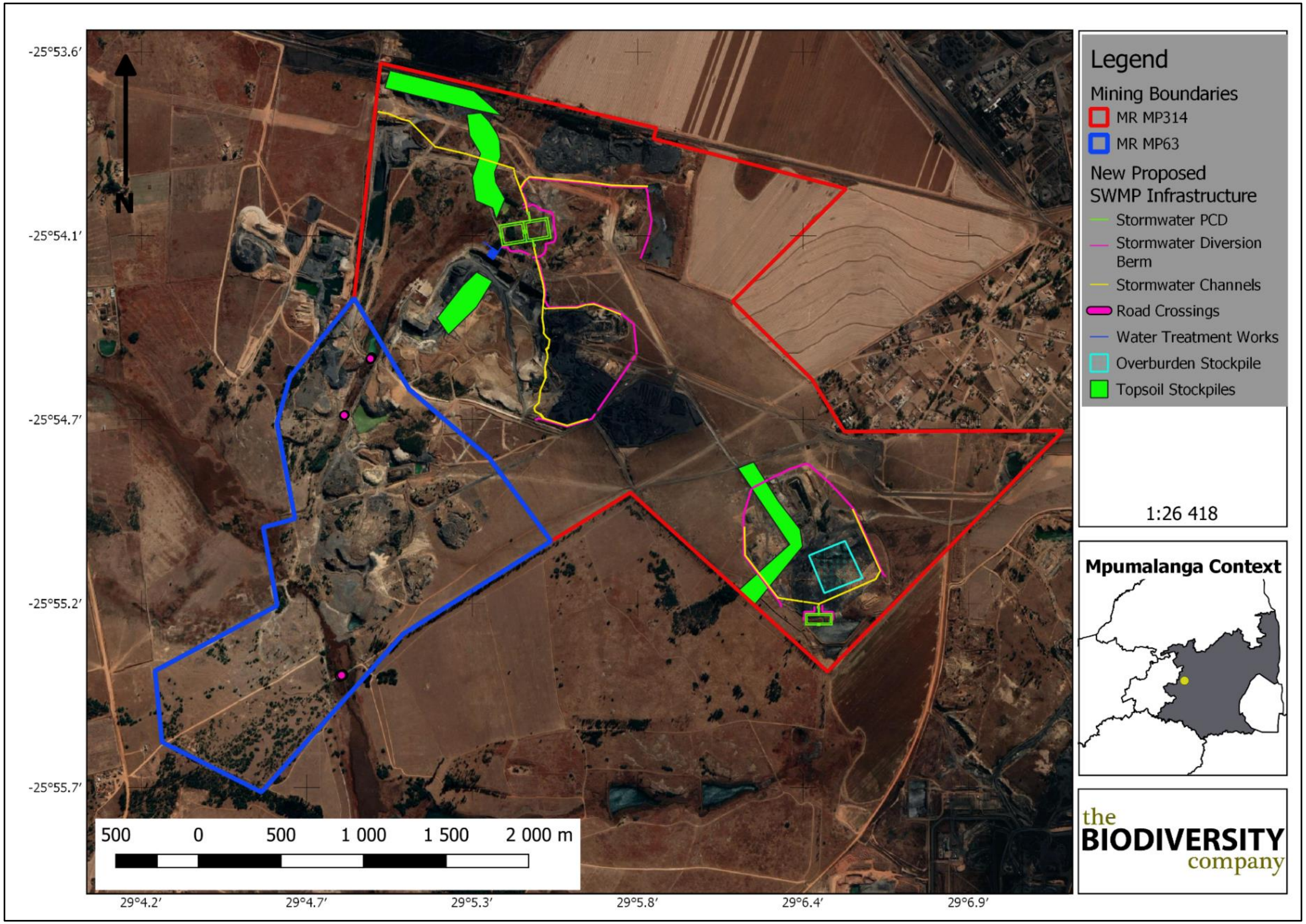

Figure 5-3 Layout map indicating new stormwater management infrastructure

6. Legislative and Policy Framework

6.1 National Water Act (Act No. 36 of 1998)

The Department of Water & Sanitation (DWS) is the custodian of South Africa's water resources and therefore assumes public trusteeship of water resources, which includes watercourses, surface water, estuaries, or aquifers. The National Water Act (NWA) (Act No. 36 of 1998) allows for the protection of water resources, which includes:

- The maintenance of the quality of the water resource to the extent that the water resources may be used in an ecologically sustainable way;
- The prevention of the degradation of the water resource; and
- The rehabilitation of the water resource.

A watercourse means:

- A river or spring;
- A natural channel in which water flows regularly or intermittently;
- A wetland, lake or dam into which, or from which, water flows; and
- Any collection of water which the Minister may, by notice in the Gazette, declare to be a watercourse, and a reference to a watercourse includes, where relevant, its bed and banks.

The NWA recognises that the entire ecosystem, and not just the water itself, and any given water resource constitutes the resource and as such needs to be conserved. No activity may therefore take place within a watercourse unless it is authorised by the DWS.

For the purposes of this project, a wetland area is defined according to the NWA (Act No. 36 of 1998): "Land which is transitional between terrestrial and aquatic systems where the water table is usually at or near the surface, or the land is periodically covered with shallow water, and which land in normal circumstances supports or would support vegetation typically adapted to life in saturated soil".

Wetlands have one or more of the following attributes to meet the NWA wetland definition (DWAF, 2005):

- A high water table that results in the saturation at or near the surface, leading to anaerobic conditions developing in the top 50 cm of the soil;
- Wetland or hydromorphic soils that display characteristics resulting from prolonged saturation, i.e. mottling or grey soils; and
- The presence of, at least occasionally, hydrophilic plants, i.e. hydrophytes (water loving plants).

6.2 National Environmental Management Act (Act No. 107 of 1998)

The National Environmental Management Act (NEMA) (Act 107 of 1998) and the associated Regulations as amended in April 2017, states that prior to any development taking place within a wetland or riparian area, an environmental authorisation process needs to be followed. This could follow either the Basic Assessment Report (BAR) process or the Environmental Impact Assessment (EIA) process depending on the scale of the impact.

7. Methodologies

7.1 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)
- Contour data (5 m); and
- Mucina & Rutherford (2006).

7.2 Field Procedure

The hydropedological assessment was done in August 2019, during which the proposed mining areas illustrated in Figure 7-1 and Figure 7-2 was focussed on. For this particular assessment (March 2020), the proposed mining areas differ in locality but are similar in extent. Therefore, assumptions have been made that previous results in regard to total loss to receptors are similar. Therefore, modelling results for the previous assessment was used for this particular assessment. The conceptual models of Transect 2 and 3 have been adjusted to illustrate the effect of the current proposed mining areas to the hillslope hydrology. The conceptual results from these models emphasise similar impacts towards hillslope hydrology from the previous mining layout to the current mining layout.

The slopes within the project area were assessed during the desktop assessment to identify possible transects that will represent typical terrain and soil distribution patterns. These locations where 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. A total of four transects were identified in which all pits have been excavated up to refusal (see Figure 7-1 and Figure 7-2). Access could not be gained at Observation 8 and 9. Therefore, three pits have been added (“added pit 1, 2 and 3”) to resemble the soil profiles relevant to Observation 8 and 9. These added pits are based on similar land types, topography, slope and vegetation characteristics than Observation 7, 8 and 9 to ensure accuracy.

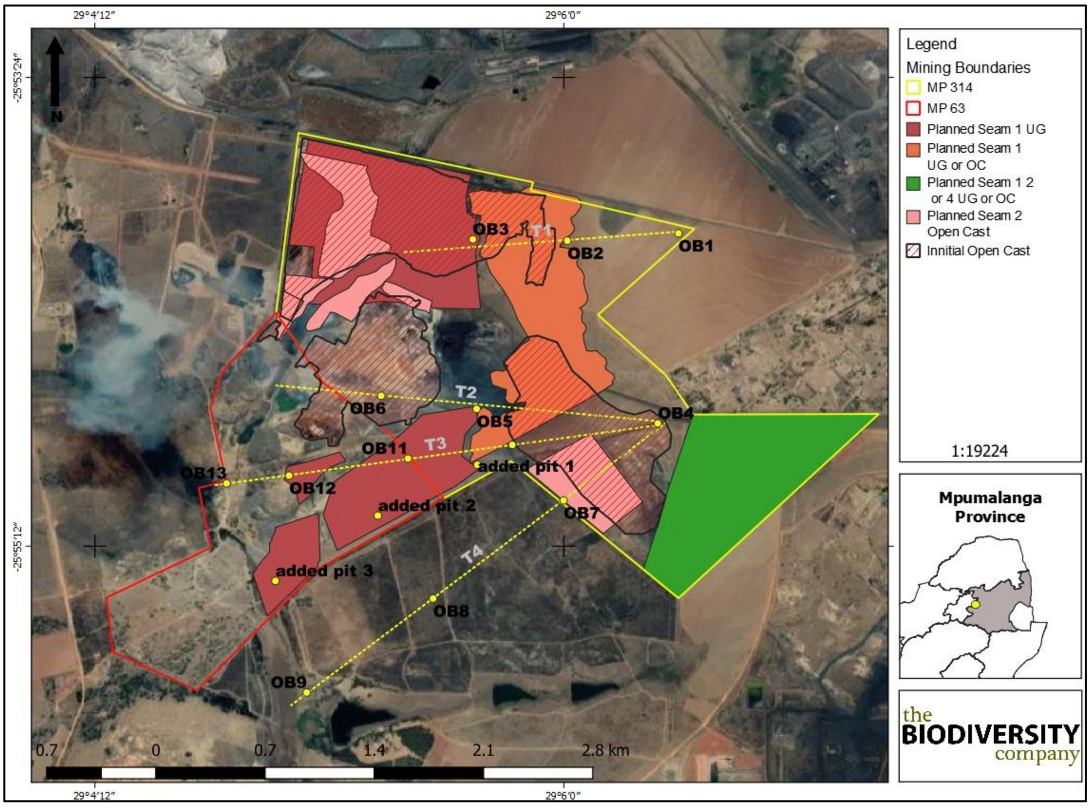

Figure 7-1 Comparison between current and historically proposed mining areas (open cast)

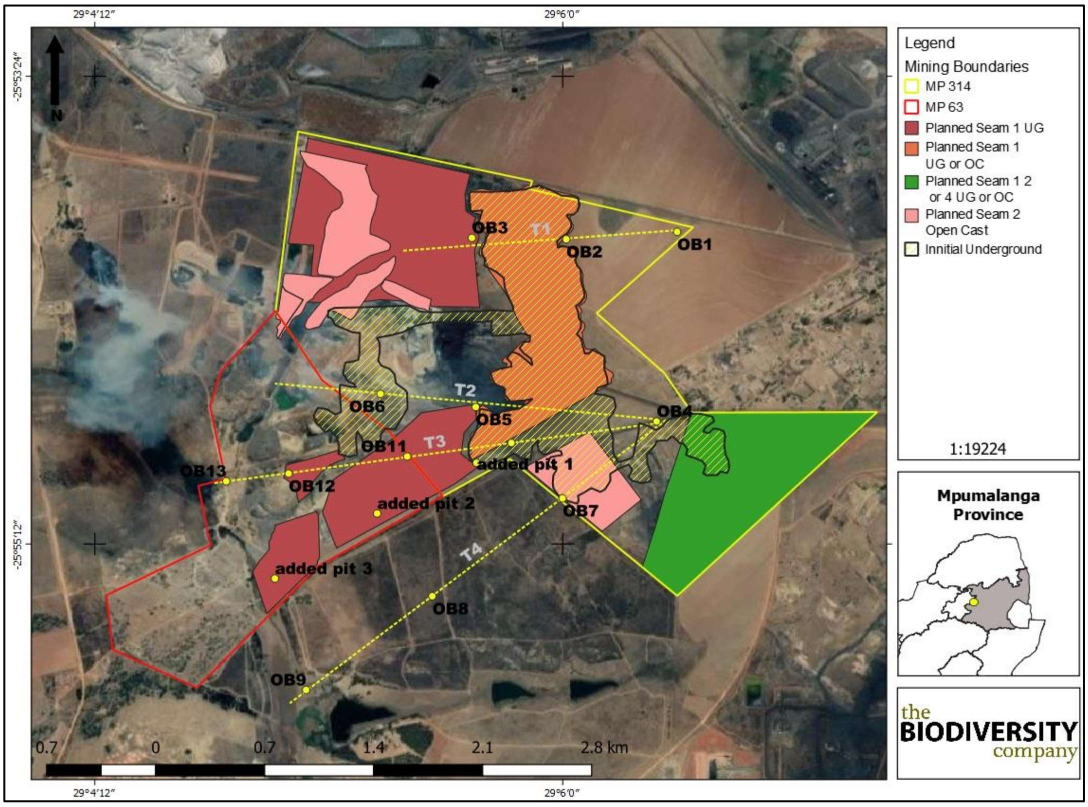

Figure 7-2 Comparison between current and historically proposed mining areas (underground)

7.2.1 Identification of Soil Types and Hydrological Soil Types

Soil types have been identified according to the South African soil classification (Soil Classification Working Group, 1991) 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 7-1.

Table 7-1 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.		

7.2.2 Undisturbed Sampling

Undisturbed samples were collected for each of the diagnostic horizons. These samples were sent to *Van's lab* (Pty) Ltd. in Bloemfontein to determine the particle size distribution, saturated hydraulic conductivity (*Ks*), bulk density, and water retention characteristics. A cylindric Poly Vinyl Chloride (PVC) is gently inserted laterally into a diagnostic soil type to extract an undisturbed sample of the relevant soil type. Wooden lids are then taped to the pipe to ensure that the sample stays intact.

7.2.3 *In-Situ* Testing of Hydraulic Conductivity

In-situ Ks was tested by means of a single ring infiltrometer within the excavated pits. These tests are vital for the sections of the profile undisturbed sampling is not possible due to the physical properties of such a layer, i.e. bedrock.

A single ring infiltrometer consists of a metal sheet driven into a soil profile which is used as a constant head test. Water is poured into the sheet up to a specific mark in the inside of the sheet that resembles the upper part of a line set to measure the drop of water in a one-centimetre interval. The time the water takes to infiltrate a centimetre (from the upper mark to the bottom mark) is taken several times, until the infiltration rate remains close to constant (differing no more than 10% of the previous infiltration time). For soil profiles too deep to excavate up to the refusal layer, *Ks* was tested by means of a 55 mm diameter PVC pipe which were inserted into the auger hole. The conductivity was then calculated using:

$$K = \frac{r^2 \ln\left(\frac{L}{R}\right)}{2LT_0}$$

Where K = hydraulic conductivity; r = radius of pipe; L = length of saturated portion of the perforated area; R = radius of perforated area (the same as r in this experiment and T_0 = basic time lag.

7.3 Modelling

The aim of the modelling exercise was to quantify hydrologic processes and how they will be impacted upon by the proposed development. The conceptual models of hillslope hydrological responses developed from soil morphological properties guided the modelling approach. For assessment of the impact of open cast pit on hydropedological processes the Catchment Model Framework (CMF) model was used (Kraft *et al*., 2011). CMF is essentially a toolbox to configure a wide range of different model structures based on the finite volume approach (Figure 7-3). Water fluxes through the landscape are presented as a network of storages and boundary conditions in CMF. Flux governing equations can be assigned to link the storage units with the next one. These equations can be fairly simple e.g. linear storage or tipping bucket approaches or more complex e.g. solving of Kinematic Wave or Richards equation. The compounds of the model are assembled using the scripting language Python.

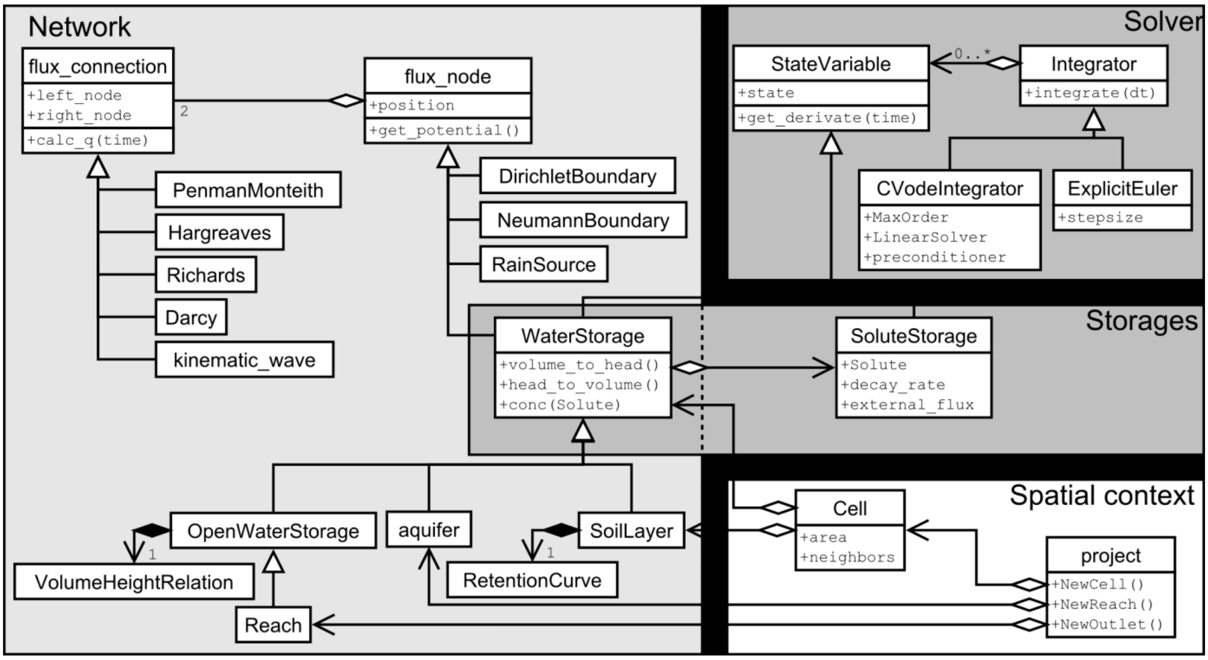

Figure 7-3 Simplified class representation of the Catchment Modelling Framework and its components (Kraft et al., 2011).

In this study, a large portion is already disturbed by development. This resulted in considerable disturbance of natural flow paths associated with the mixing and/or compaction of soil horizons. Hydrological modelling of these areas to mimic natural flowpaths are therefore not possible due to the alteration of these pathways. The modelling therefore only focussed on one transect which is largely undeveloped. The simulated transect lies between T3 and T4 in Figure 7-1.

The soil distribution pattern of the transect were configured in CMF and parameterised using measured data from the field and laboratory analysis. The topography (surface elevations) was obtained from Google Earth and included in the configuration of the transects. The Van Genuchten-Maulem hydraulic model was used for sub-surface flows. Relevant Van Genuchten parameters were derived from measured hydraulic properties in combination with PedoTransfer Functions in Rosetta (Schaap et al., 2001).

The slope was initially saturated by applying 100 mm rain per day for 10 consecutive days to the surface boundary. The slope was then allowed to drain for 20 days under low evaporative demands where after 50 mm rain was applied. The slope was then allowed to dry for another 30 days for 30 mm of rain to be added. Water content and fluxes were evaluated from the onset of rain free drainage (day 11) until drainage ceased following the 30 mm event (roughly day 80). This approach was repeated for natural and ‘developed’ conditions. For the latter, the relative location and coverage of the open cast pit was considered in the model setup (Figure 7-4b). The assumption was that there is a *‘no flow’* boundary below the open cast pit i.e. the area above the lower boundary of the open cast pit does not contribute to the water fluxes downslope. The transect was therefore shortened to exclude the soils in/above the open cast pits. The overall objective of the hydrological simulations was to compare the lateral flows into the stream from the bottom of the slope as well as well as the water content in the valley bottom under the two scenarios.

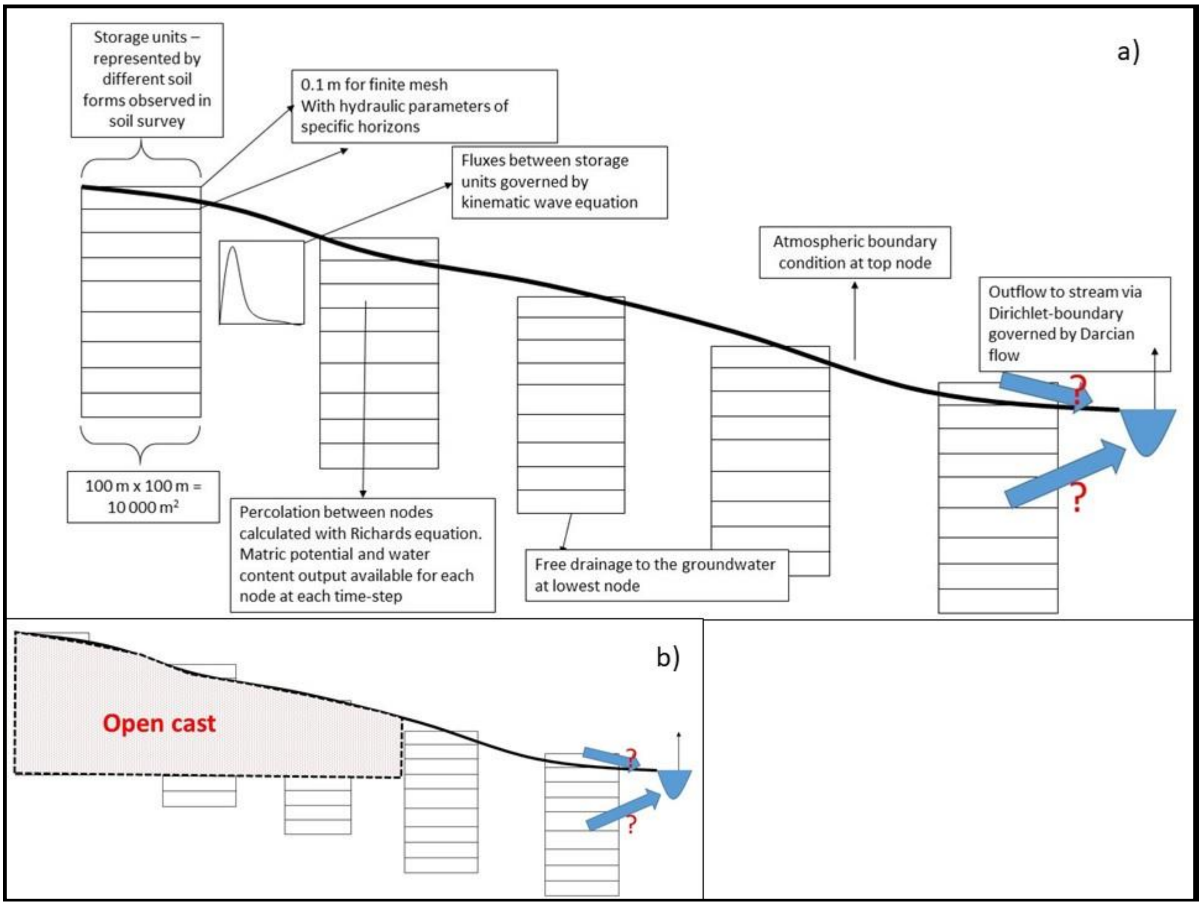

Figure 7-4 Modelling set-up under natural conditions used to quantify the impact of the proposed pit on surface and subsurface flows; a) natural conditions and b) after the proposed development (adapted from Van Tol et al., 2019).

8. Receiving Environment

8.1 Hillslope Hydrology

The hydropedology survey was conducted in August 2019. The survey was conducted to obtain information required to conceptualise the dominant behaviour of representative hillslopes as well as to provide data for the hydropedological modelling. Four transects were traversed to acquire information regarding the hillslope hydrology, the hydropedological type properties as well as physical properties (i.e. permeability, bulk density, wilting point and texture). The hydropedological types classified during the site assessment are illustrated in Figure 8-1 and Figure 8-9.

8.1.1 Transect 1

The hydropedological behaviour of transect 1 is illustrated in a conceptual hydrological response model (see Figure 8-4). The processes involved within this slope is described according to the number assigned to the relevant hydrological response.

8.1.1.1 Hydropedological Type #1

Observation 1 is located on the crest of the slope relevant to Transect 1 and has been classified as a Carolina soil form, which consists of an Orthic topsoil on top of a Yellow Brown Apedal horizon which in turn overlays a Hard Rock layer (see Figure 8-1). This soil form has been identified as a deep recharge hydropedological type, which ensures infiltration through the profile and into the bedrock layer.

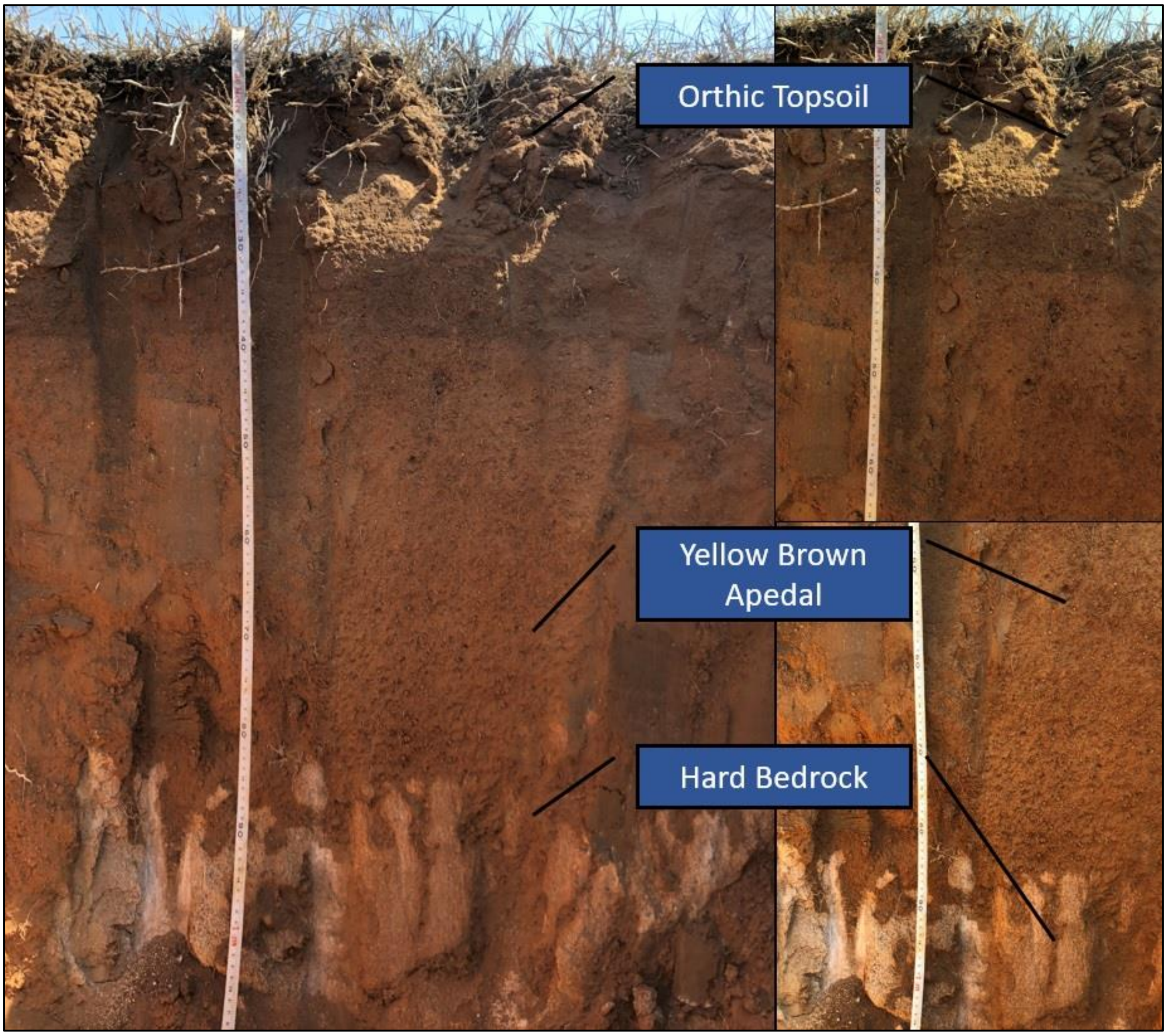

Figure 8-1 Recharge (soil/bedrock) (Carolina) hydropedological type identified

8.1.1.2 Hydropedological Type #2

Observation 2 is located within the mid-slope terrain unit of transect 1. The soil form relevant to observation 2 has been classified as a Bainsvlei soil form, which consists of an Orthic topsoil on top of a Red Apedal horizon which in turn is underlain by unspecified material with signs of wetness (see Figure 8-2). The latter mentioned is characterised by a high concentration plinthite-like soft concretions which is evidence of fluctuating levels of saturation and a degree of interflow within this horizon.

Given the fact that no signs of wetness were identified within the first subsoil (the Red Apedal horizon), this soil form has been identified as an interflow (between soil and bedrock) hydropedological type. It is worth noting that this soil profile is characterised by a depth of 230 cm. This soil form has been identified as a Bloemdal soil form given the presence of an unspecified material with signs of wetness.

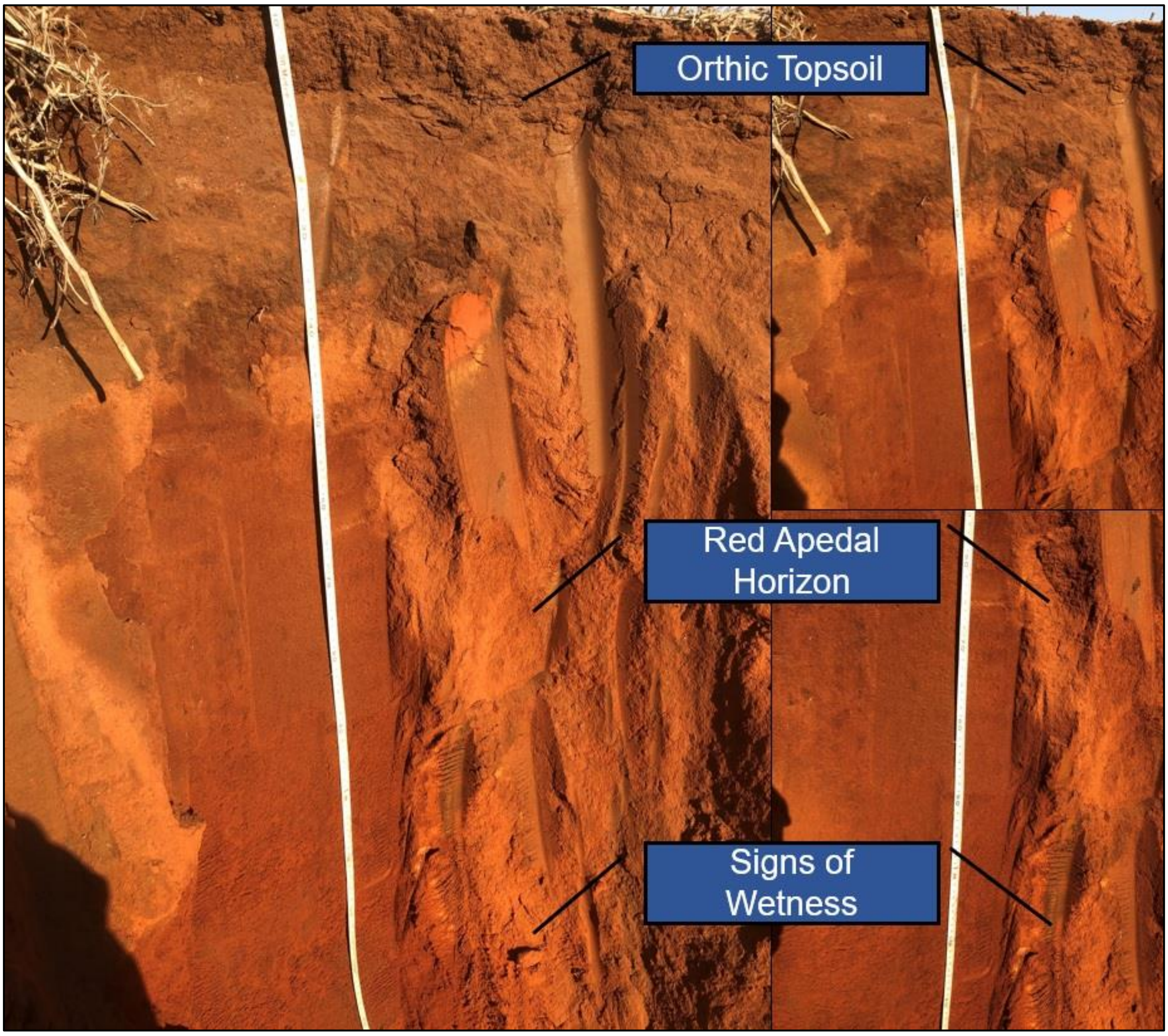

Figure 8-2 Interflow (soil/bedrock) (Bainsvlei) hydropedological type identified in observation 2, transect 1

8.1.1.3 Hydropedological Type #3

The entire portion of the hillslope from Observation 2 downwards is characterised by disturbances from mining activities. The soil form identified within this section is a Transported Technosol (and more specifically a Witbank soil form) due to the presence of artificial material transported and deposited within this area (see Figure 8-3).

The material within this soil profile has no diagnostic properties and are mixed together with other soils, waste rock and is compacted severely. A rock-hard soil profile rendered the soil impossible to sample with no morphology indicating dominant flow paths. The lack of morphological indicators and the compaction of the Witbank soil form has rendered the dominant flow paths overland flow, which also is evident from a high concentration of drains and gullies that have formed from significant surface run-off.

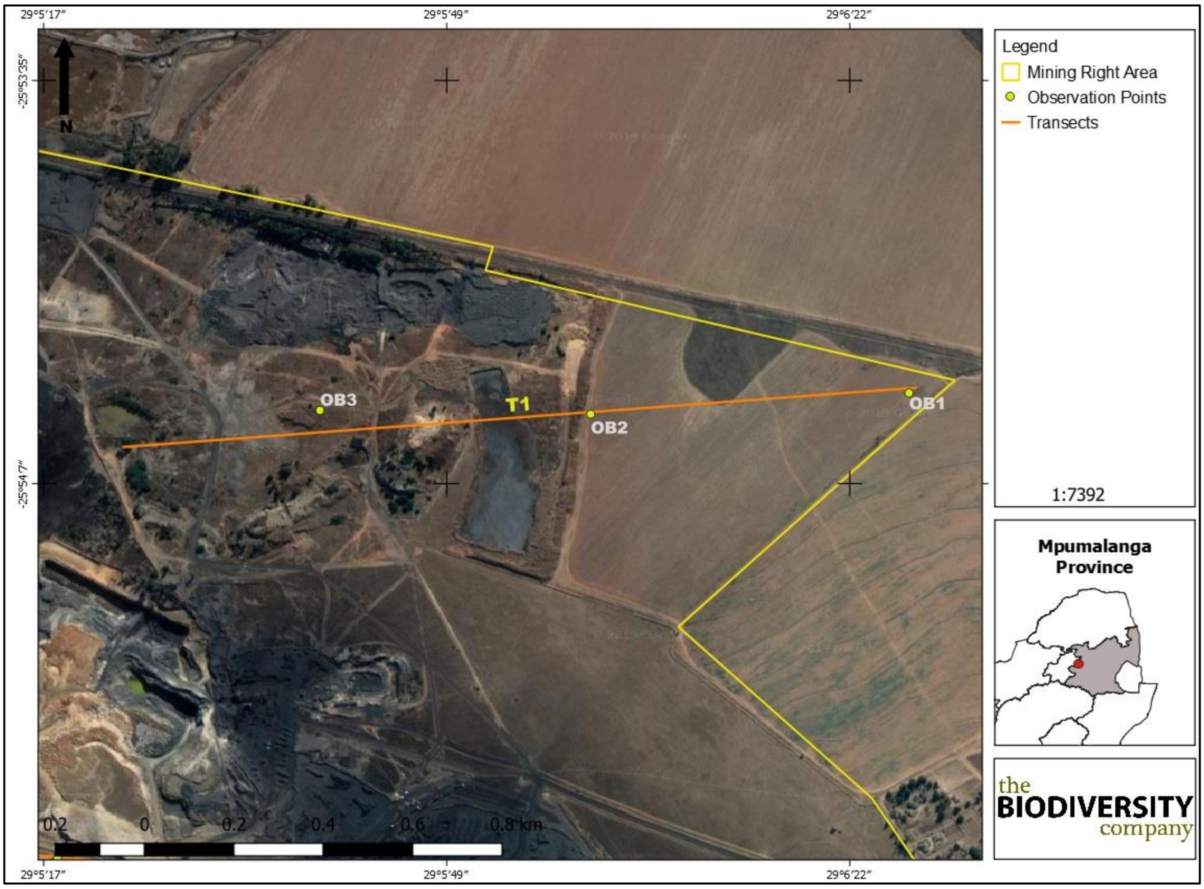

Figure 8-3 Extent of disturbed areas (Witbank soil form)

8.1.1.4 Transition “A”

Deep recharge seeps out into the following hydropedological type, which is an interflow (between soil and bedrock) hydropedological type. An influx of sub-surface flow to the bedrock interface joins up with infiltration of precipitation to ensure a steady interflow between soil and bedrock.

8.1.1.5 Transition “B”

A high degree of modification, inputs of Technosols and severe compaction have resulted in an extremely low Ks, which forces interflow up the Witbank soil form after which overland flow dominates.

8.1.1.6 Transition “C”

Overland flow from the previous hydropedological type (Witbank) is transitioned into the watercourse downslope from Transect 1. The dominance of overland flow is emphasised by the concentrations of drains and gullies. It is the specialist’s opinion that very little water from the hillslope will reach the watercourse, with the dominant influx towards the watercourse being during precipitation events. Additionally, inputs from waste impoundments and mining areas adjacent to the watercourse will provide fortuitous inputs.

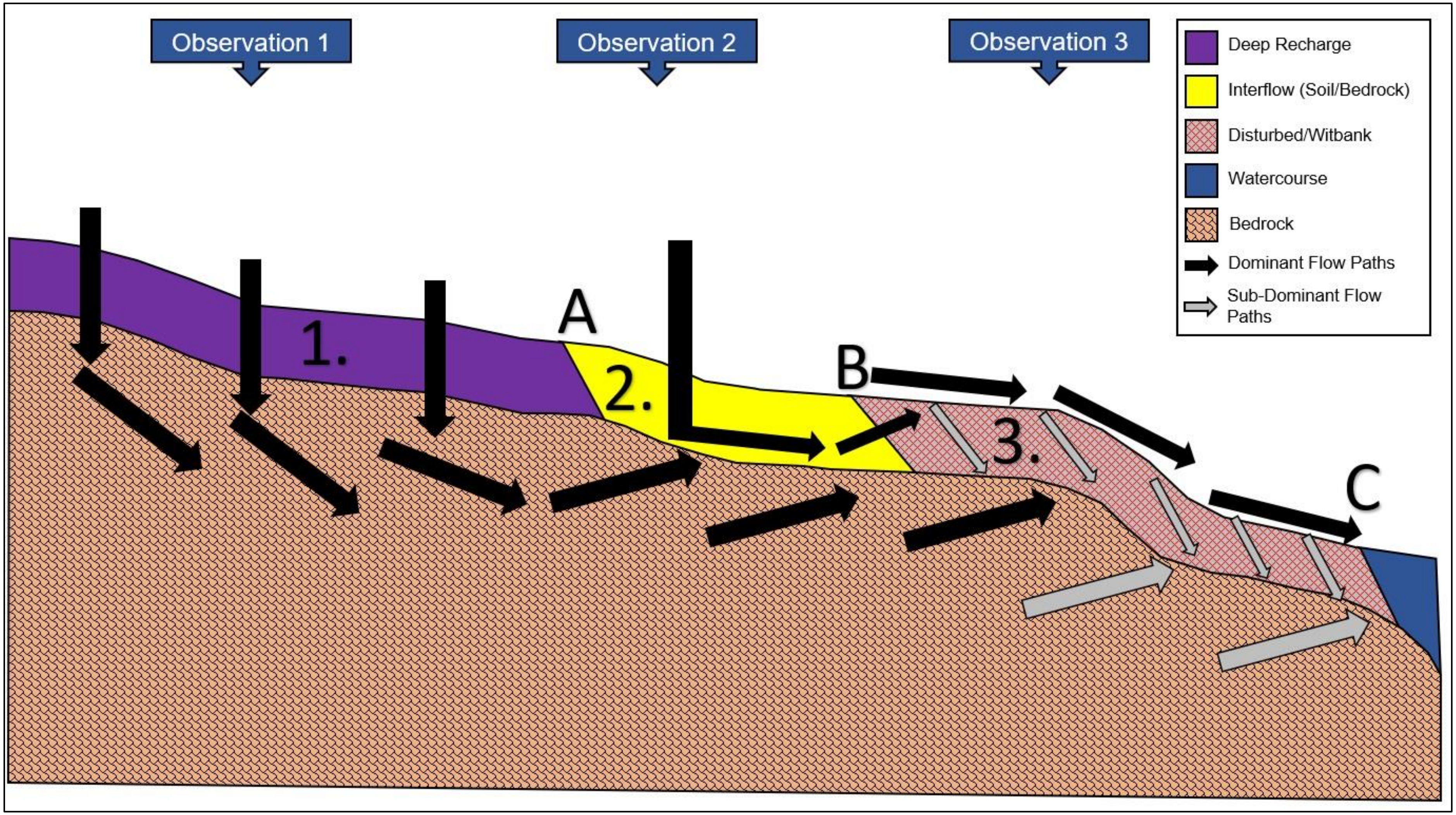

Figure 8-4 Conceptual hydropedological response model of transect 1 (in current state)

8.1.2 Transect 2

The hydropedological behaviour of transect 2 is illustrated in a conceptual hydrological response model (see Figure 8-6). The processes involved within this slope is described according to the number assigned to the relevant hydrological response.

8.1.2.1 Hydropedological Type #1

Observation 4 is located on the crest of the slope relevant to Transect 2. This soil form constitutes a recharge (shallow) hydropedological type given the high *in-situ Ks* and the lack of wetness. The *in-situ Ks* has been calculated at 24 mm/h, which ensures a high recharge volume. It is worth noting that this soil profile is very shallow with a depth of only 30 cm.

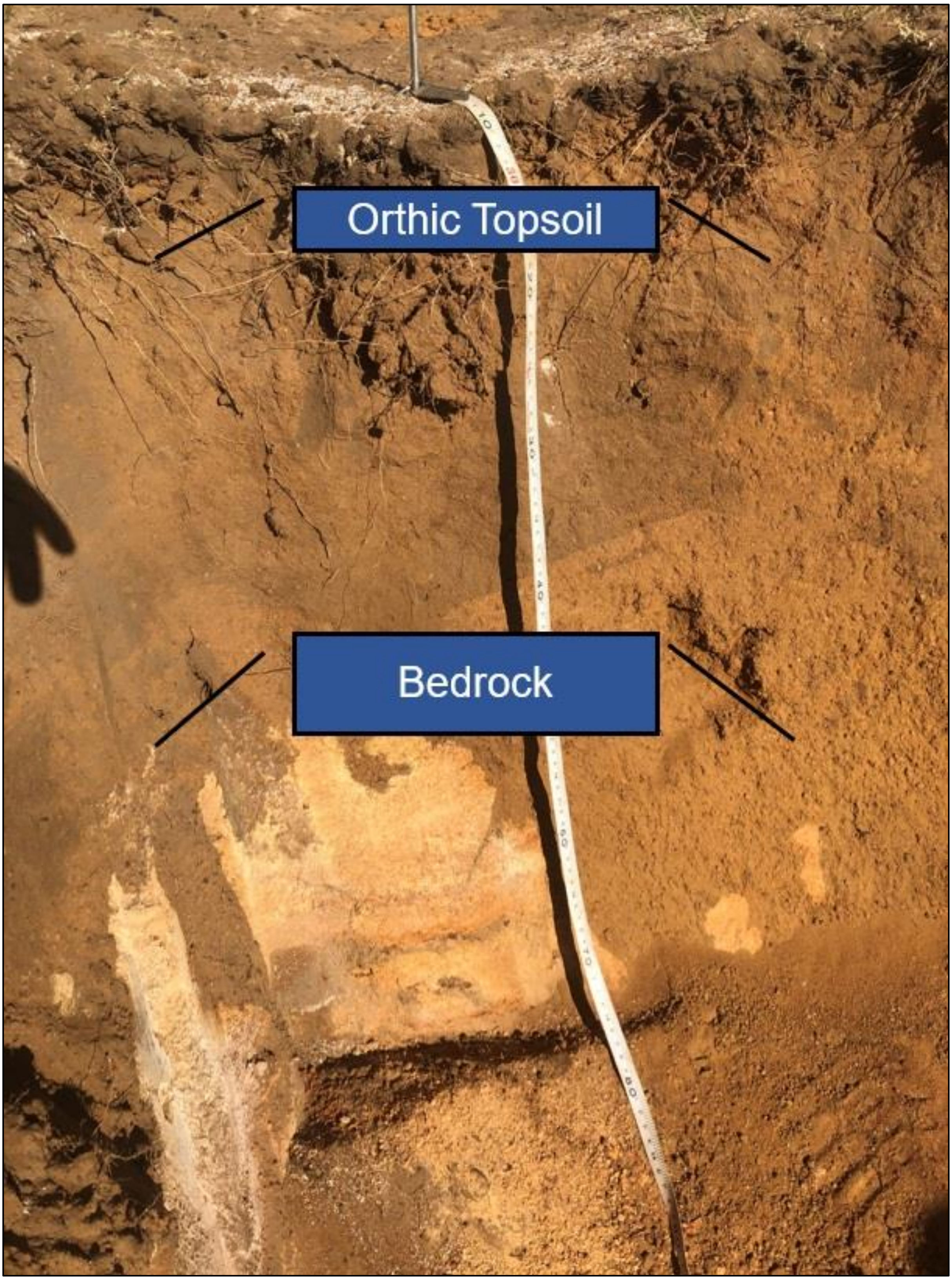

Figure 8-5 Recharge (shallow) (Mispah) hydropedological type identified in observation 4, transect 2

8.1.2.2 Hydropedological Type #2

The second hydropedological type is characterised by current open cast mining activities, which increases compaction, alters soil dynamics and therefore decreases infiltration. Overland flow also is deemed to be insignificant given the gentle slope as well as the dammed topography of the open cast pit, which ultimately ensures that evaporation is the dominant flow path. This feature therefore already has affected the hillslope hydrology, which affects all portions upslope of the open cast pit.

8.1.2.3 Hydropedological Type #3

The third hydropedological type is characterised by a deep Carolina soil form, which has been described in Section 8.1.1 (Transect 1). This soil form constitutes a deep recharge hydropedological type due to the lack of signs of wetness.

8.1.2.4 Hydropedological Type #4

The fourth hydropedological type has been identified as an interflow (soil/bedrock) hydropedological type due to the presence of a Bainsvlei soil form, which has been described in Section 8.1.1 (Transect 1).

8.1.2.5 Hydropedological Type #5

The fourth hydropedological type has been identified as an overland flow hydropedological type due to the presence of a Witbank soil form, which has been described in Section 8.1.1 (Transect 1).

8.1.2.6 Transition “A”

A large fraction of the shallow recharge seeps out into the open cast pit, after which evaporation of moisture takes place. Additionally, a large portion of sub-surface water that would have passed underneath the open cast pit now is subject to evaporation due to a decrease in soil depth.

8.1.2.7 Transition “B”

Very little interflow/overland flow reaches the third hydropedological type due to the disturbances from the open cast pit.

8.1.2.8 Transition “C”

Deep recharge seeps out into the next hydropedological type and is channelled across the bedrock interface together with infiltrated precipitation.

8.1.2.9 Transition “D”

Interflow is forced up the Witbank soil profile, after which overland flow and evaporation becomes dominant.

8.1.2.10 Transition “D”

Interflow is forced up the Witbank soil profile, after which overland flow and evaporation becomes dominant.

8.1.2.11 Transition "E"

Interflow is forced up the Witbank soil profile, after which overland flow and evaporation becomes dominant. Overland flow will enter the watercourse together with a small degree of recharge from the bedrock. It is the specialist's opinion that very little water from the hillslope will reach the watercourse due to disturbances.

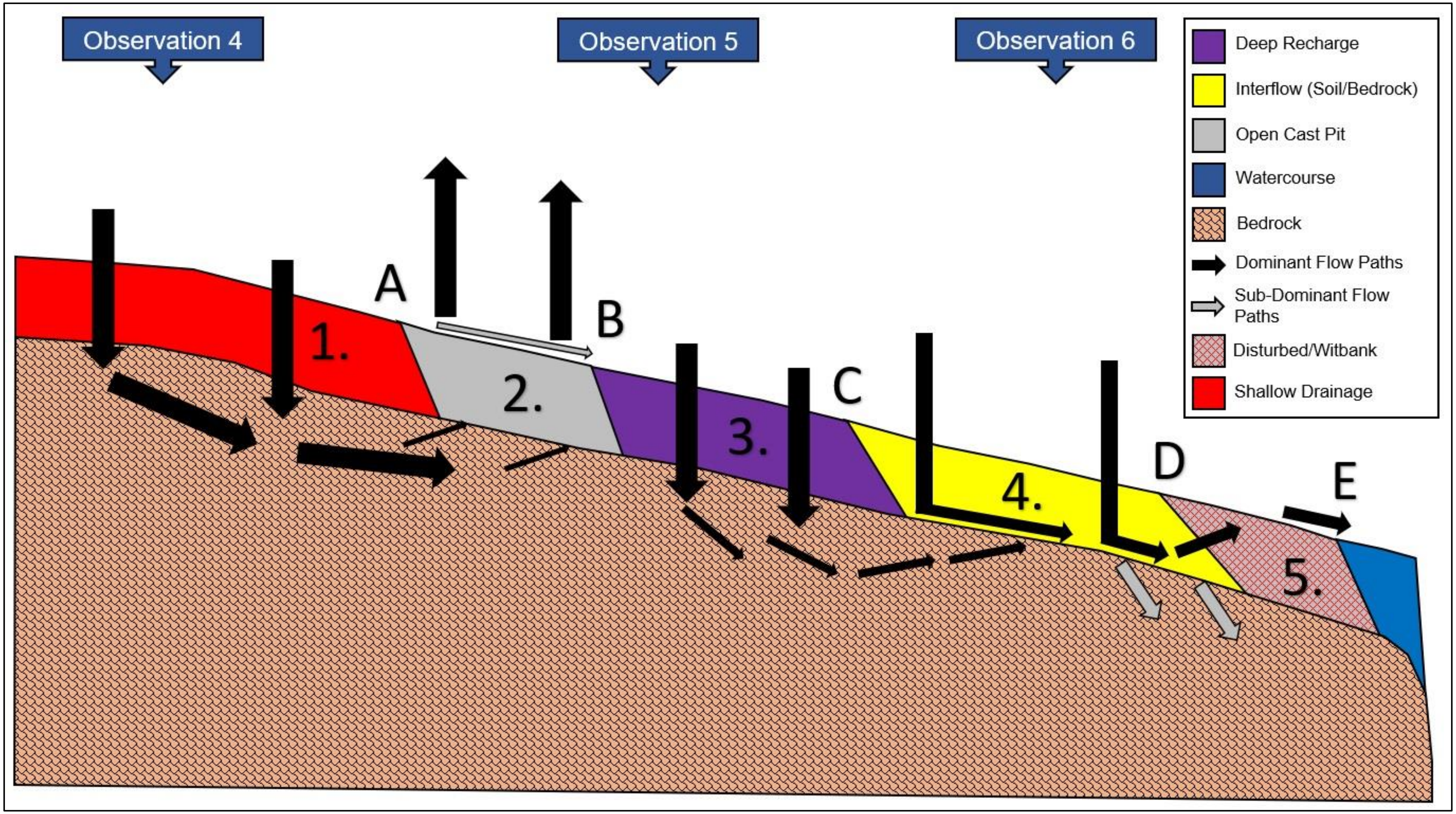

Figure 8-6 Conceptual hydropedological response model of transect 2 (in current state).

8.1.3 Transect 3

The hydropedological behaviour of transect 3 is illustrated in a conceptual hydrological response model (see Figure 8-6). The processes involved within this slope is described according to the number assigned to the relevant hydrological response.

8.1.3.1 Hydropedological Type #1

Observation 4 is located on the crest of the slope relevant to Transect 3 and has already been described in Section 8.1.2 (Transect 2). This soil form has been identified as a Mispah soil form and a shallow recharge hydropedological type.

8.1.3.2 Hydropedological Type #2

Observation 10 is located on the mid-slope of the slope relevant to Transect 3 and has already been described in Section 8.1.2 (Transect 2). This soil form has been identified as a Carolina soil form and a deep recharge hydropedological type.

8.1.3.3 Hydropedological Type #3

Observation 11 is located on the toe of the slope relevant to Transect 3 and has already been described in Section 8.1.2 (Transect 2). This soil form has been identified as a Witbank soil form and an overland flow hydropedological type.

8.1.3.4 Hydropedological Type #4

The fourth hydropedological type has been identified as an interflow (soil/bedrock) hydropedological type due to the presence of a Mispah soil form characterised by signs of wetness on the bedrock interface.

8.1.3.5 Transition "A"

Shallow recharge seeps into the Witbank soil form and either evaporates, or, to a lesser extent is channelled across the bedrock layer. Overland flow will be dominant during precipitation events. A degree of recharge will also feed back directly into the final interflow hydropedological type.

8.1.3.6 Transition "B"

Overland flow, interflow and recharge feeds back into the final hydropedological type to ensure an interflow between bedrock and soil. It is the specialist's opinion that some of the sub-surface flows from the hillslope reaches the watercourse due to the fact that signs of wetness have been identified in a shallow soil profile 50 cm in depth.

8.1.3.7 Transition "B"

Shallow interflow (between soil and bedrock) gradually feeds into the watercourse.

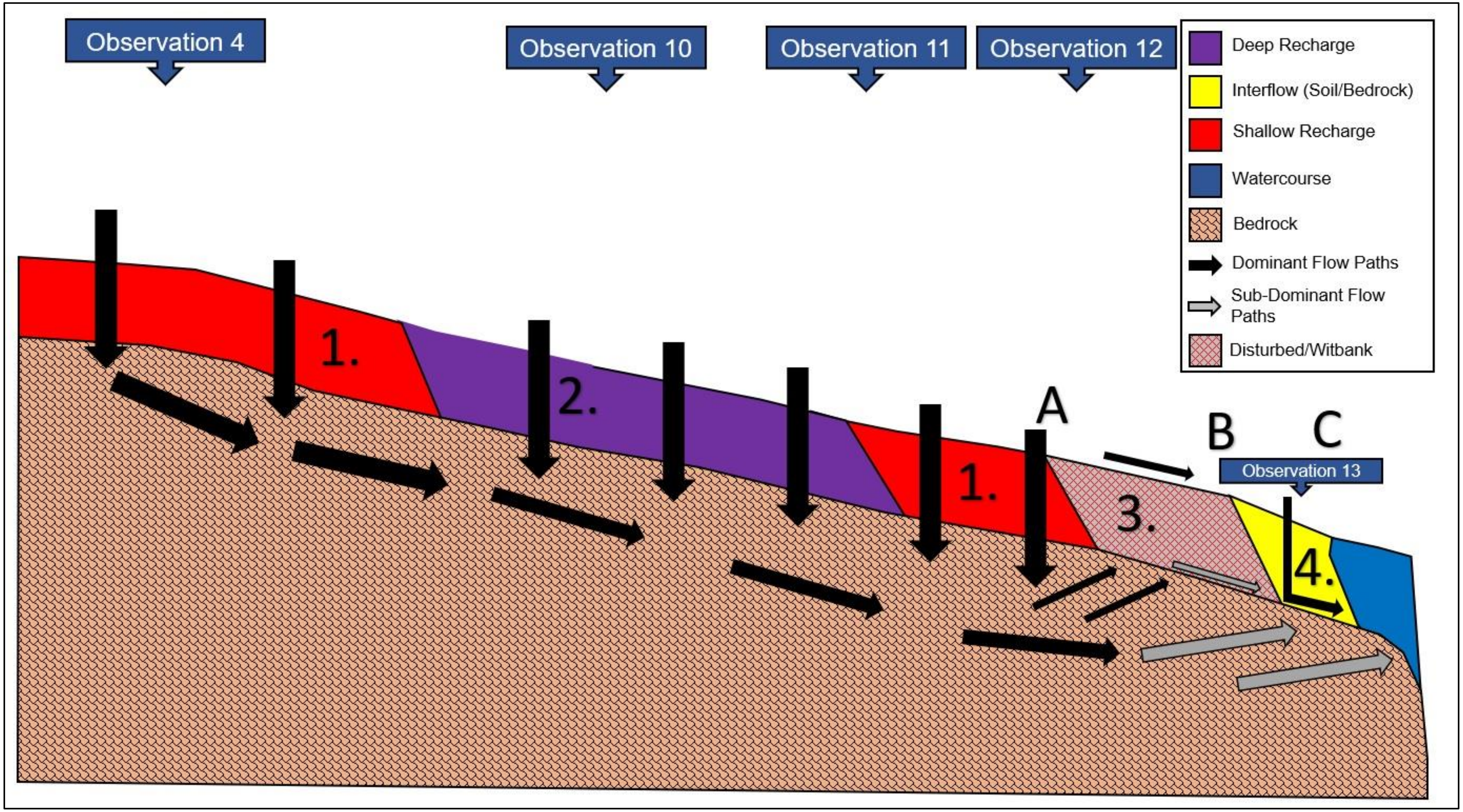

Figure 8-7 Conceptual hydropedological response model of transect 3 (in current state)

8.1.4 Transect 4

The hydropedological behaviour of transect 4 is illustrated in a conceptual hydrological response model (see Figure 8-6). The processes involved within this slope is described according to the number assigned to the relevant hydrological response.

8.1.4.1 Hydropedological Type #1

Observation 4 is located on the crest of the slope relevant to Transect 4 and has already been described in Section 8.1.2 (Transect 2). This soil form has been identified as a Mispah soil form and a shallow recharge hydropedological type.

8.1.4.2 Hydropedological Type #2

Observation 7 is located on the mid-slope of the slope relevant to Transect 4 and has already been described in Section 8.1.1 (Transect 1). This soil form has been identified as a Bainsvlei soil form and an interflow (soil/bedrock) hydropedological type.

8.1.4.3 Hydropedological Type #3

Added pit "3" is located on the toe of the slope relevant to Transect 4 and has already been described in Section 8.1.1 (Transect 1). This soil form has been identified as a Carolina soil form and a deep recharge hydropedological type.

8.1.4.4 Transition "A"

Shallow recharge seeps into interflow (soil/bedrock) hydropedological type to join up with infiltrated precipitation. Sub-surface flows then are channelled over the bedrock interface.

8.1.4.5 Transition "B"

Interflow reaches the next hydropedological type (shallow recharge) and infiltrates to recharge reserves within and below the bedrock layer.

8.1.4.6 Transition "C"

No interaction occurs between shallow and deep recharge zones.

8.1.4.7 Transition "D"

Recharge feeds back into the watercourse directly from the bedrock layer and/or the groundwater aquifer.

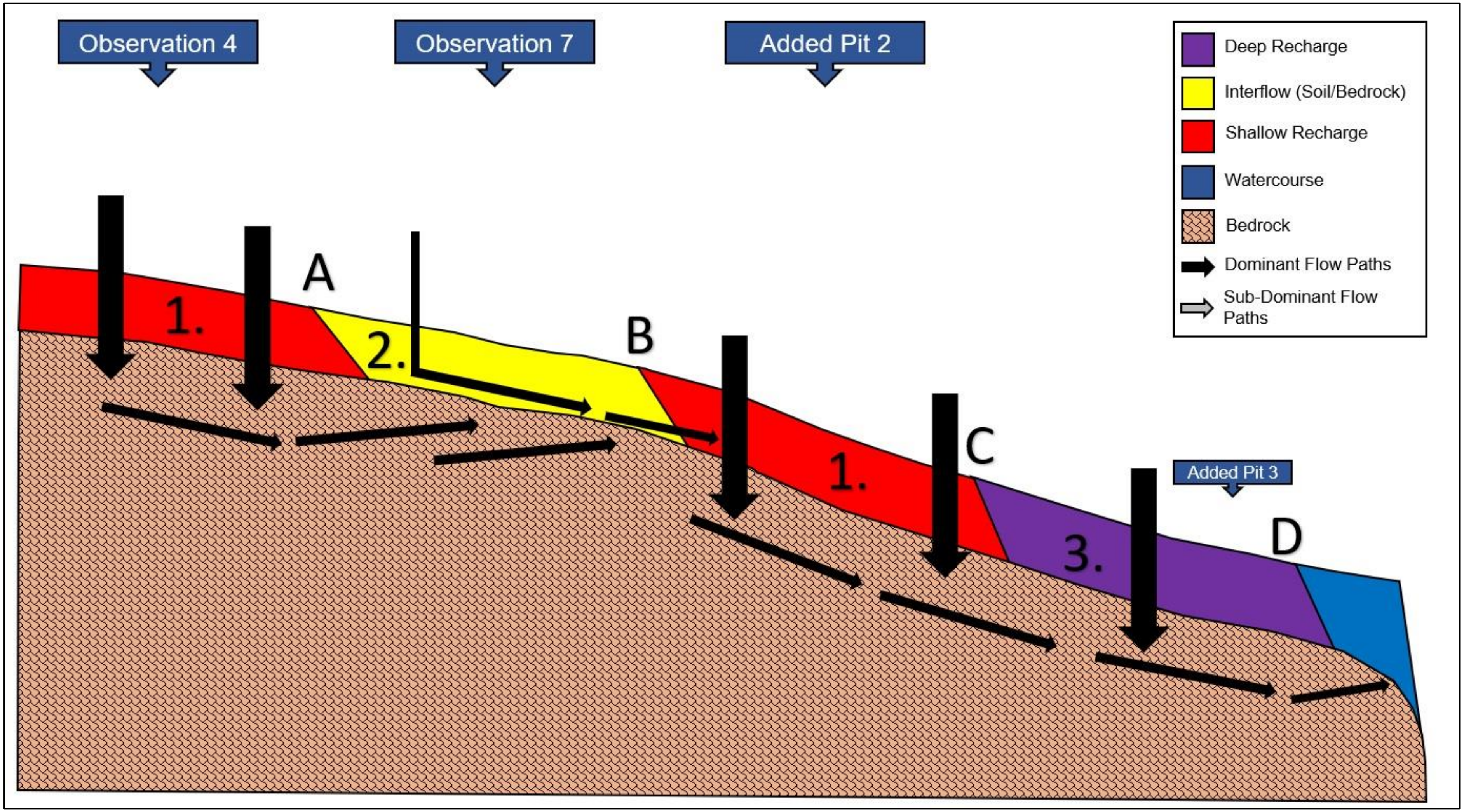

Figure 8-8 Conceptual hydropedological response model of transect 4 (in current state)

8.2 Conceptual Impacts

The following sections describe the conceptual impacts towards the hillslope hydrology by means of the proposed activities. These arguments aren't final and are subject to change with analysis of results from modelling that integrates various parameters derived from laboratory tests.

8.3 Transects

8.3.1 Transect 1

It has been anticipated that disturbances within the lower regions of the slope relevant to transect 1 will result in overland flow being the dominant flow path. Evaporation will be dominant at the transition between the interflow zone and the Witbank soil form with overland flow occurring during rainfall events (see Figure 8-9 and Figure 8-10). The predominant loss from the proposed open cast mining activities will be that of overland flow during rainfall events, which, by means of stormwater systems can be reintroduced via overland flow as is currently the situation. The proposed underground mining will have very little to no effect on the hillslope hydrology of Transect 1, with the odd chance of subsidence and fracturing of rock occurring.

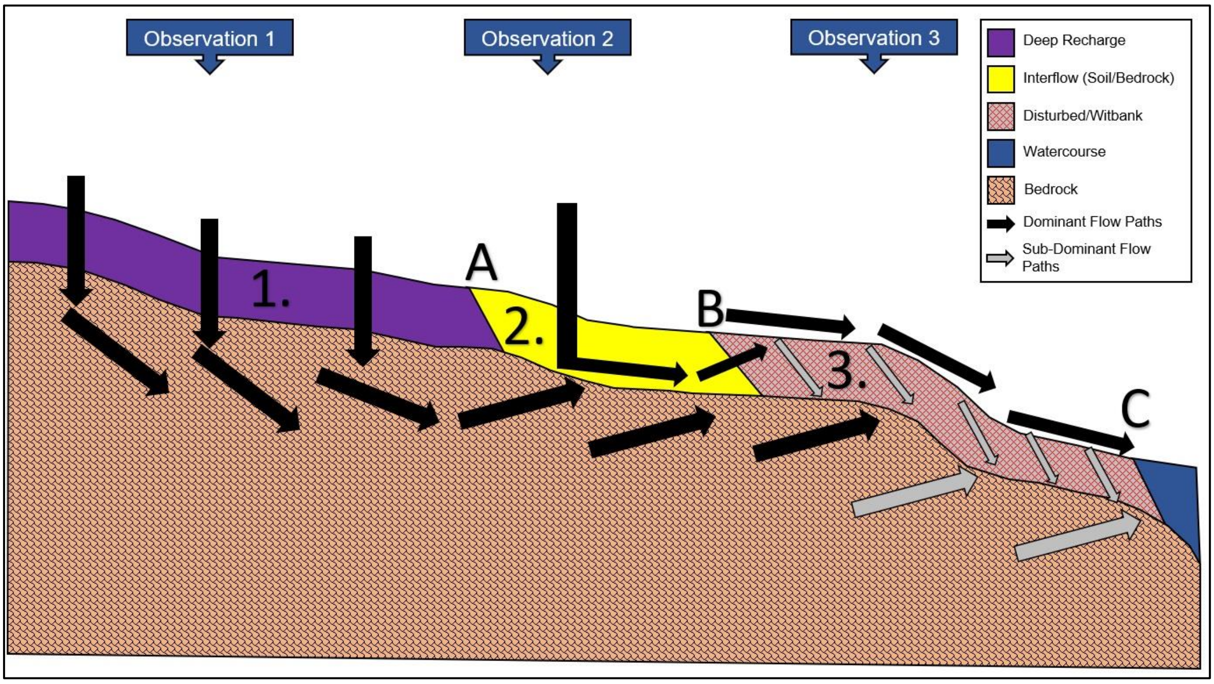

Figure 8-9 Conceptualisation of the hillslope hydrology relevant to Transect 1 (current state)

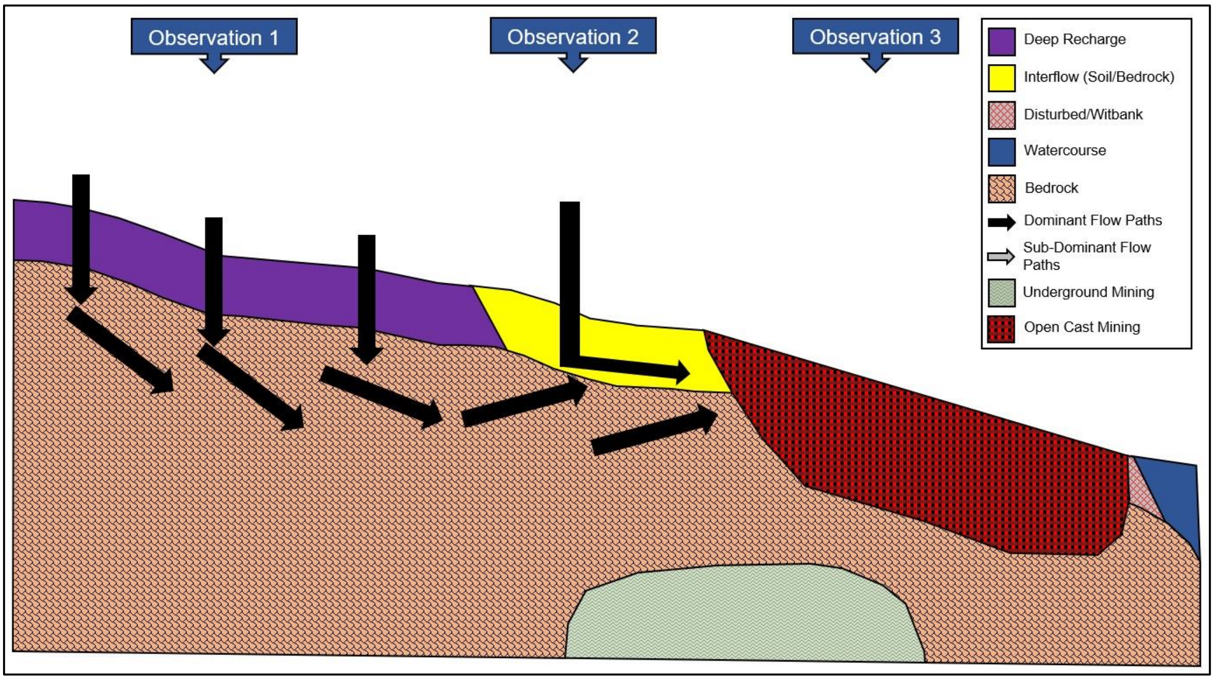

Figure 8-10 Conceptualisation of the hillslope hydrology relevant to Transect 1 (proposed state)

8.3.2 Transect 2

It is the specialist's opinion that the first open cast pit will have very little effect on the hillslope hydrology due to the current presence of an open cast pit that has resulted in the loss of interflow entering the system. Some degree of overland flow during precipitation events will be lost, which can be mitigated with ease (Figure 8-11 and Figure 8-12). Ultimately, even though the second pit at the lower regions of the slope will completely intercept interflow as well as the bulk of the recharge water seeping into the interflow zone, very little change in interflow to the watercourse will be caused by the proposed open cast mining activities.

The latter mentioned can mainly be described to the current extent of disturbances which renders the hillslope hydrology ineffective. The proposed underground mining will have very little to no effect on the hillslope hydrology of Transect 2, with the odd chance of subsidence and fracturing of rock occurring.

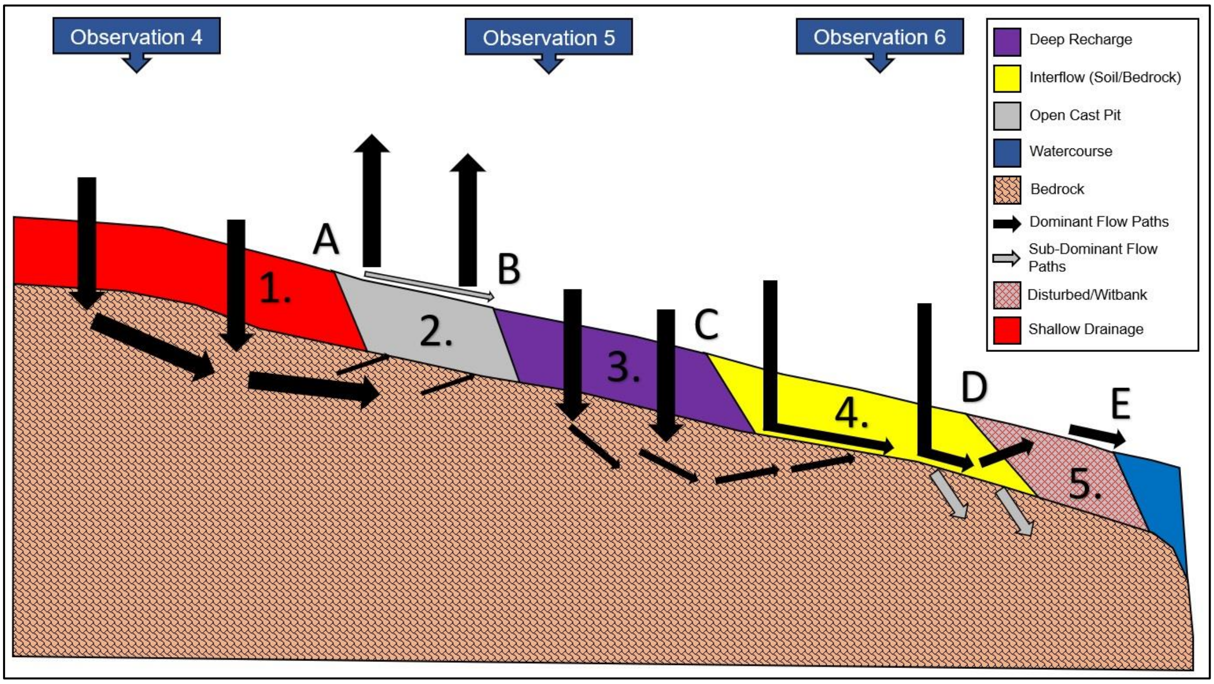

Figure 8-11 Conceptualisation of the hillslope hydrology relevant to Transect 2 (current state)

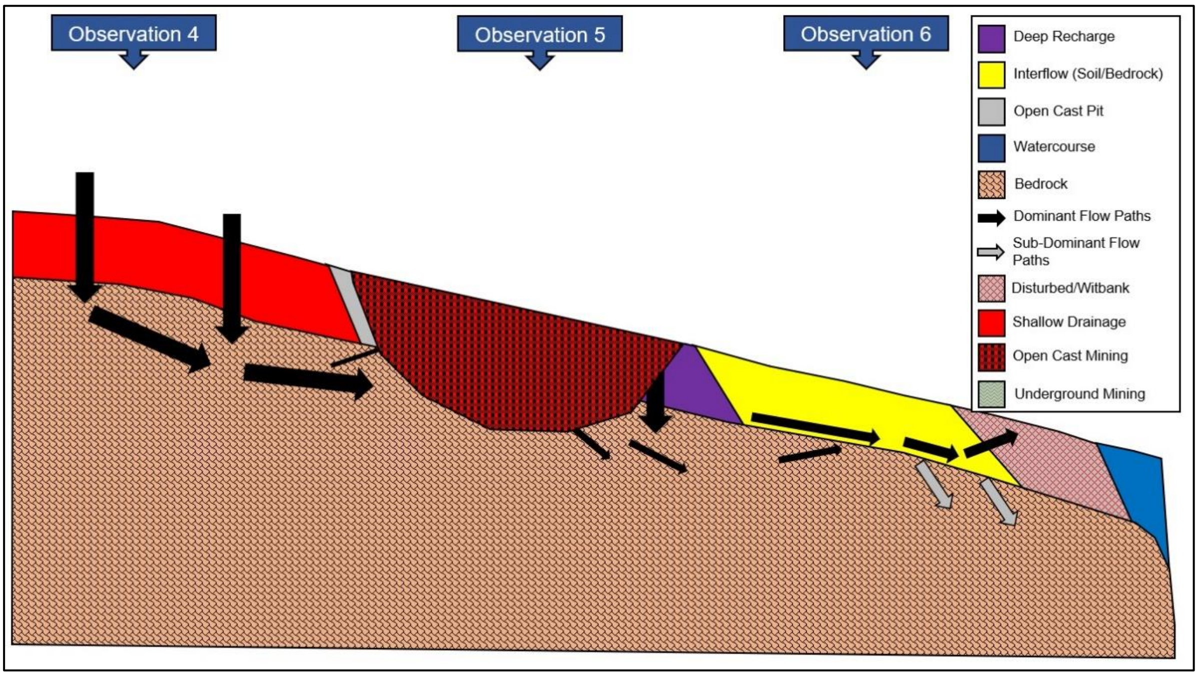

Figure 8-12 Conceptualisation of the hillslope hydrology relevant to Transect 2 (proposed state)

8.3.3 Transect 3

For this transect, recharge (deep and shallow) is dominant throughout the hillslope. It also has been determined, that regardless of the extent of current disturbances, some of the recharge water seeps out at the bottom of the current disturbed area, which results in shallow interflow (see Figure 8-13 and Figure 8-14). This interflow is anticipated to be rather significant to overcome evapotranspiration rates in such a shallow profile (50 cm in depth).

The proposed underground mining will have very little to no effect on the hillslope hydrology of Transect 3, with the odd chance of subsidence and fracturing of rock occurring.

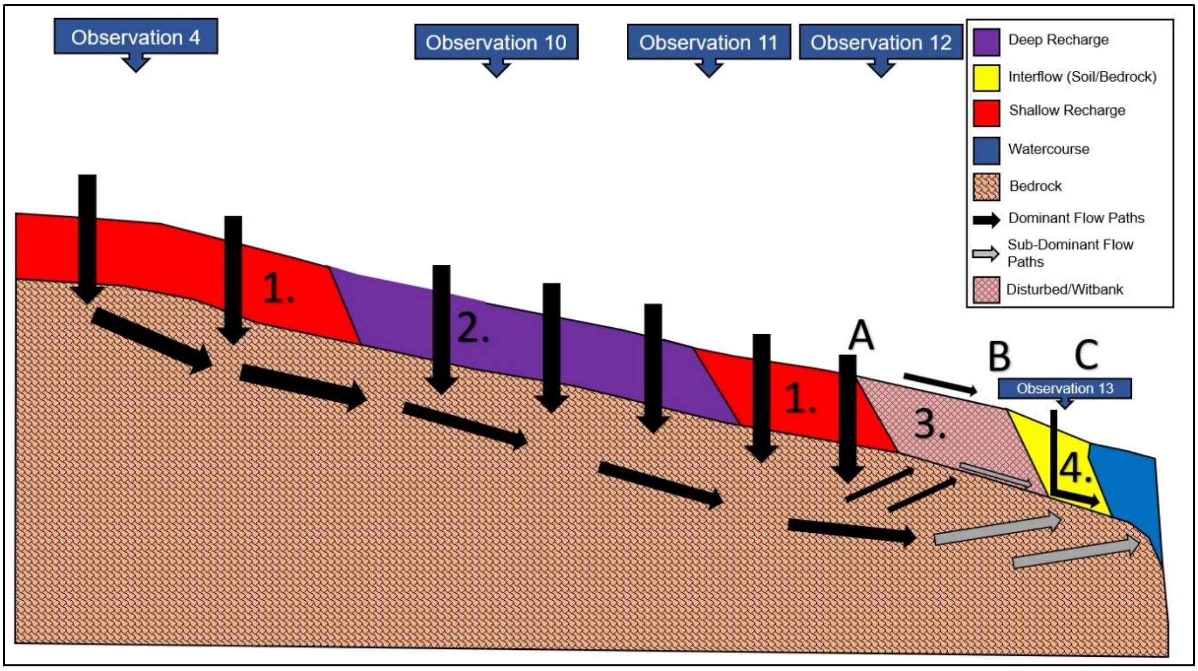

Figure 8-13 Conceptualisation of the hillslope hydrology relevant to Transect 3 (current state)

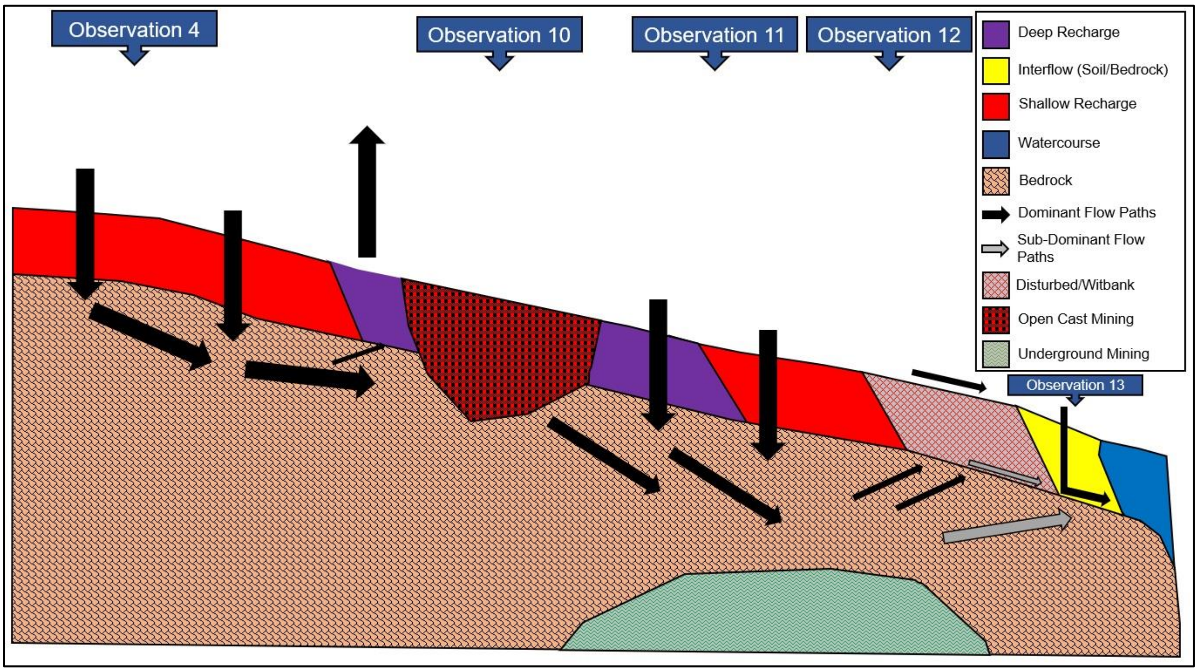

Figure 8-14 Conceptualisation of the hillslope hydrology relevant to Transect 3 (proposed state)

8.3.4 Transect 4

Only approximately 25% of the slope will be affected by the proposed open cast mining activities, and, given the fact that the proposed open cast pit will be at the crest of the hillslope, low to moderate losses are expected. The hillslope is in a natural condition without any disturbed areas (Technosols, mining activities, disturbed areas etc) (see Figure 8-15 and Figure 8-16).

The proposed underground mining will have very little to no effect on the hillslope hydrology of Transect 4, with the odd chance of subsidence and fracturing of rock occurring.

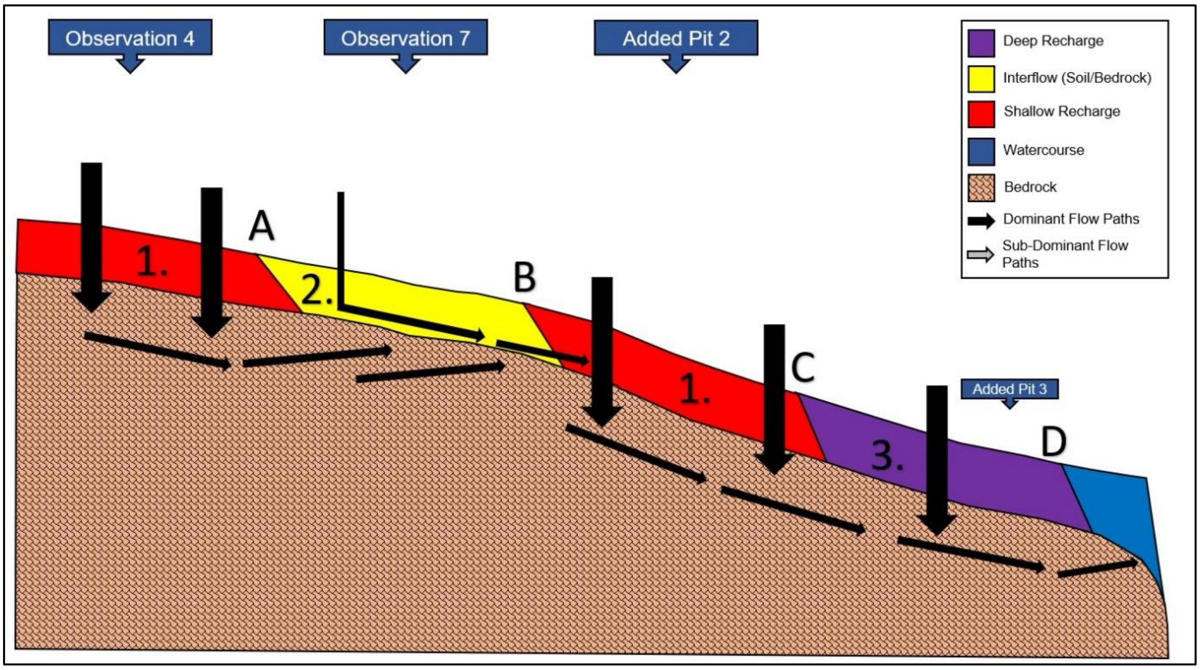

Figure 8-15 Conceptualisation of the hillslope hydrology relevant to Transect 4 (current state)

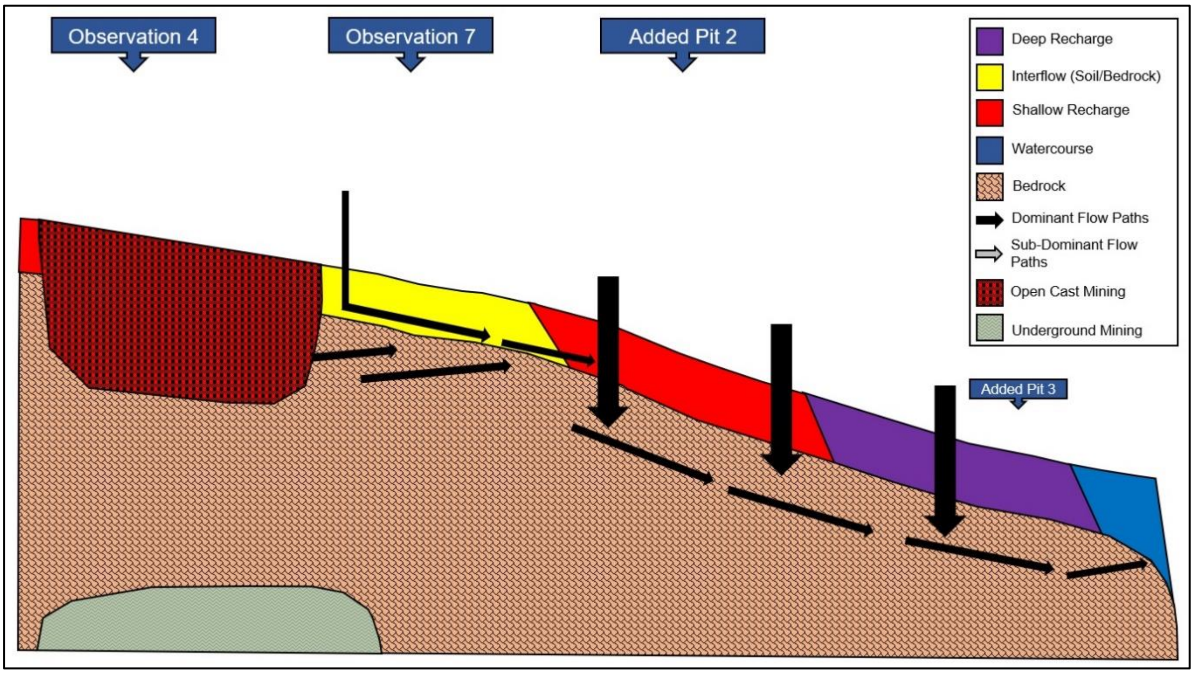

Figure 8-16 Conceptualisation of the hillslope hydrology relevant to Transect 4 (proposed state)

8.4 Laboratory Results

The hydraulic parameters from *in-situ* and laboratory measurements of the dominant horizons are presented in (Table 8-1).

with the van Genuchten parameters estimated in Rosetta presented in Table 8-2.

Table 8-1 Selected hydraulic properties for representative horizons

	Obs	Soil form	Horizons	Depth (mm)	Sand (%)	Silt (%)	Clay (%)	Db ($g.cm^{-3}$)	DUL ($mm.mm^{-1}$)	Ks ($mm.h^{-1}$)
Transect 3&4	4	Ms	ot	300	85.7	6.0	10.0	1.44	0.26	156.0
			R	300+						5.1
	7	Bv	ot	400	85.7	6.0	10.0	1.44	0.26	156.0
			re	2300	76.0	10.8	14.2	1.45	0.25	66.5
			sp	2500	45.0	10.8	45.2	1.45	0.25	6.7
	Pit 2	Gc	ot	300	71.8	10.4	17.8	1.52	0.24	87.4
			ye	1200	66.7	13.0	21.8	1.49	0.31	14.9
			hp	1200+						5.1
	Pit 3	Ca	ot	200	71.8	10.4	17.8	1.52	0.24	87.4
			ye	1200	66.7	13.0	21.8	1.49	0.31	14.9
			R	1200+						5.1

Table 8-2 Van Genucthen parameters for representative horizons

	Obs	Soil form	Horizons	Depth (mm)	Θr ($mm.mm^{-1}$)	Θs ($mm.mm^{-1}$)	α	n	λ
Transect 3&4	4	Ms	ot	300	0.05	0.42	0.00147	1.44	0.5
			R	300+	0.04	0.26	0.00427	1.14	0.5
	7	Bv	ot	400	0.05	0.42	0.00147	1.44	0.5
			re	2300	0.05	0.42	0.00184	1.42	0.5
			sp	2500	0.09	0.44	0.00228	1.26	0.5
	Pit 2	Gc	ot	300	0.06	0.40	0.00241	1.37	0.5
			ye	1200	0.06	0.42	0.00128	1.34	0.5
			hp	1200+	0.04	0.26	0.00427	1.14	0.5
	Pit 3	Ca	ot	200	0.06	0.40	0.00241	1.37	0.5
			ye	1200	0.06	0.42	0.00128	1.34	0.5
			R	1200+	0.04	0.26	0.00427	1.14	0.5

8.5 Modelling Results

The proposed open cast pit is located on the crest position, largely covered by shallow recharge soils. Due to the location and the hydropedological type, differences in total outflow and lateral flows between natural and developed scenarios were not expected for this slope. This is clearly illustrated in Figure 8-17 and Figure 8-18, where virtually no differences were simulated.

The only difference between the natural and developed state was observed in the soil water contents (expressed as matric potential), directly below the open cast pit (Figure 8-19). Here the soils under the natural state will be slightly wetter than under the developed state. This is due to lateral flows from upslope which will maintain soil water longer under the natural state compared to the developed state (when the upslope section is removed due to mining). Approximately 300 m below the proposed development, the simulated soil water contents area however identical (Figure 8-20).

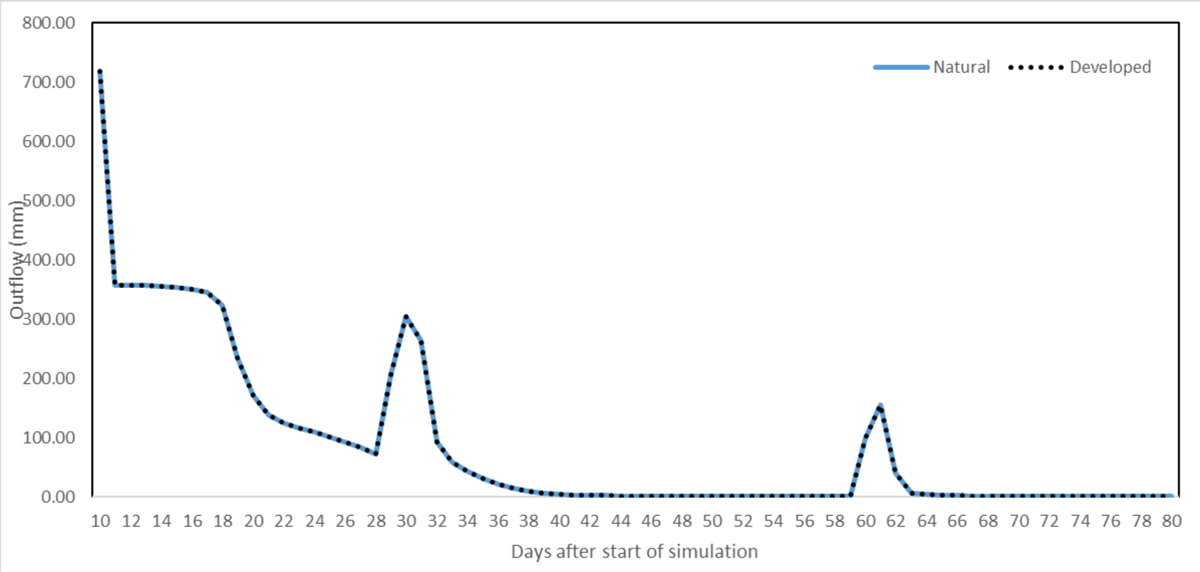

Figure 8-17 Simulated outflow (mm) from the transect under natural and developed conditions.

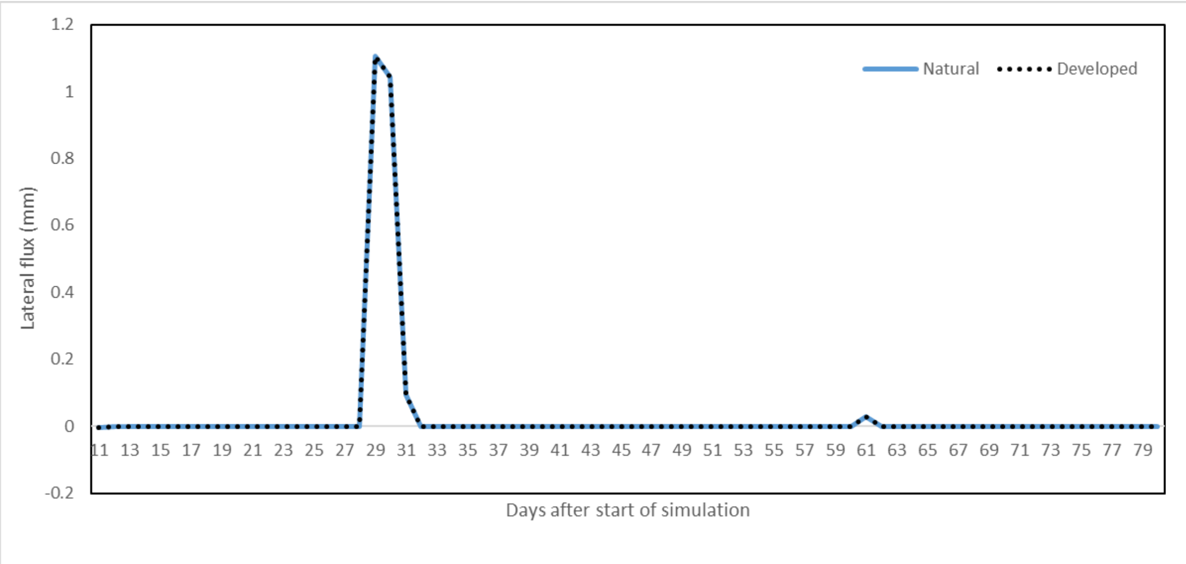

Figure 8-18 Simulated lateral fluxes (mm) from the transect under natural and developed conditions.

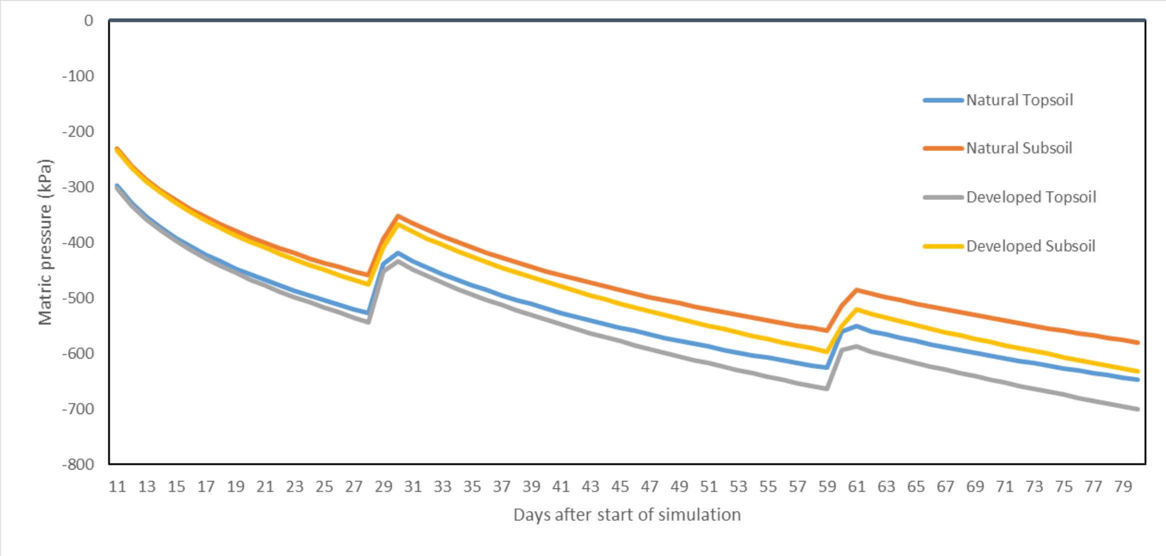

Figure 8-19 Simulated matric potential of top and subsoils under natural and developed conditions, directly below the proposed pit.

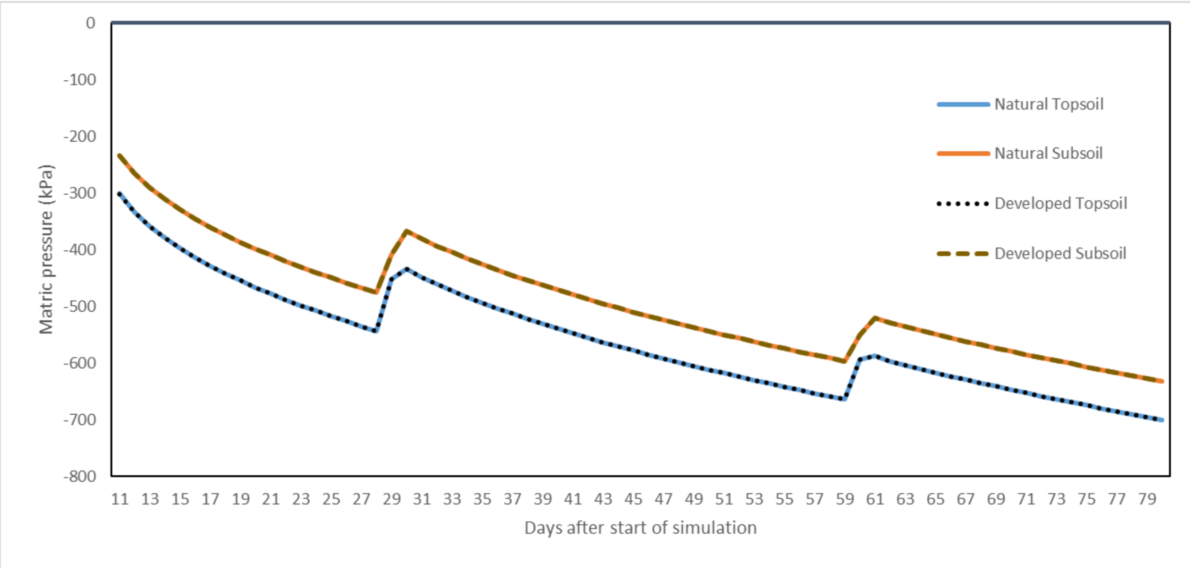

Figure 8-20 Simulated matric potential of top and subsoils under natural and developed conditions, approximately 300 m below the proposed pit.

The hydrological simulations therefore suggest the proposed development will have very little impact on the water regimes of the wetland and on water released to the stream.

9. Impact Assessment

9.1 Impact Assessment Methodology

An impact assessment methodology was provided by EIMS to determine the environmental risk associated with various aspects related to the proposed activities (open cast and underground mining with ancillary infrastructure). This impact assessment takes the following components into consideration;

- The nature of the associated impact (positive or negative);
- The extent of the proposed activities;
- The duration of the proposed activities;
- The magnitude of the effects caused by the proposed activities;
- The reversibility of associated impacts; and
- The probability of relevant aspects affecting sensitive receptors.

Each one of the above-mentioned components are given a rating, which cumulatively provides the specialist with a pre-mitigation environmental risk rating. These components are then scored again taking into consideration mitigating factors. The cumulative impact and irreplaceable loss to sensitive receptors are then scored to ultimately indicate a "Priority Factor" score.

9.2 Planning Phase

The level 3 hydropedological assessment has only been undertaken for the proposed mining areas, which could result in a loss of natural resources due to a disturbed vadose zone. The proposed surface infrastructure is not considered to pose a significant risk to the vadose zone, and has been excluded from the impact assessment. Loss of the vadose zone is likely to result in a loss of wetland systems.

9.2.1 Open Cast Mining

The final significance rating has been determined to be "Low" given the duration of planning activities, the lower magnitude of impacts and the fact that roads already are in existence throughout the project area, which will be utilised during the planning phase.

9.2.1.1 Mitigation Measures

See Section 10 for detailed mitigation measures.

9.2.1.2 Cumulative Impacts

The cumulative impact rating has been scored "Low" given the extent of existing mining activities within the current hillslope as well as the expected degradation of the hillslope hydrology as a result of mining activities.

9.2.1.3 Irreplaceable loss of Resources

The planning phase of the relevant activities are not expected to result in irreplaceable loss of vadose zone processes.

9.2.1.4 Impact on Alternatives Considered

No alternatives have been considered for the impacts related to the proposed mining activities.

9.2.2 Underground Mining

The final significance rating has been determined to be "Low" given the duration of planning activities, the lower magnitude of impacts and the fact that roads already are in existence throughout the project area, which will be utilised during the planning phase.

9.2.2.1 Mitigation Measures

See Section 10 for detailed mitigation measures.

9.2.2.2 Cumulative Impacts

The cumulative impact rating has been scored "Low" given the extent of existing mining activities within the relevant hillslopes as well as the expected degradation of the hillslope hydrology as a result of mining activities.

9.2.2.3 Irreplaceable loss of Resources

The planning phase of the relevant activities are not expected to result in irreplaceable loss of vadose zone processes.

9.2.2.4 Impact on Alternatives Considered

No alternatives have been considered for the impacts related to the proposed mining activities.

9.3 Construction Phase

9.3.1 Open Cast Mining

The final significance rating has been determined to be "Low" given the duration of construction activities, the lower magnitude of impacts and the fact that much of the area already has been transformed and disturbed. Additionally, various roads already are in existence which can be used during the proposed activities.

9.3.1.1 Mitigation Measures

See Section 10 for detailed mitigation measures.

9.3.1.2 Cumulative Impacts

The cumulative impact rating has been scored "Medium" given the extent of existing mining activities within the relevant hillslopes as well as the expected degradation of the hillslope hydrology as a result of mining activities.

9.3.1.3 Irreplaceable loss of Resources

The construction phase of the relevant activities is not likely to result in a loss of natural resources.

9.3.1.4 Impact on Alternatives Considered

No alternatives have been considered for the impacts related to the proposed mining activities.

9.3.2 Underground Mining

The final significance rating has been determined to be "Low" given the duration of construction activities, the lower magnitude of impacts and the fact that much of the area already has been transformed and disturbed. Additionally, various roads already are in existence which can be used during the proposed activities.

9.3.2.1 Mitigation Measures

See Section 10 for detailed mitigation measures.

9.3.2.2 Cumulative Impacts

The cumulative impact rating has been scored "Low" given the extent of existing mining activities within the relevant hillslope as well as the expected degradation of the hillslope as a result of mining activities.

9.3.2.3 Irreplaceable loss of Resources

The construction phase of the relevant activities is not likely to result in a loss of natural resources.

9.3.2.4 Impact on Alternatives Considered

No alternatives have been considered for the impacts related to the proposed mining activities.

9.4 Operational Phase

9.4.1 Open Cast Mining (Process Alternative P3a)

The final significance rating has been determined to be "Medium" given the duration of operational activities, the higher magnitude of impacts and the fact that very little impact towards the receptors are expected as a result of damage to the vadose zone.

9.4.1.1 Mitigation Measures

See Section 10 for detailed mitigation measures.

9.4.1.2 Cumulative Impacts

The cumulative impact rating has been scored "Medium" given the extent of existing mining activities within the relevant hillslopes as well as the expected degradation of the hillslope hydrology as a result of mining activities.

9.4.1.3 Irreplaceable loss of Resources

The operational phase of the relevant activities could result in a loss of natural resources due to a disturbed vadose zone. It is also worth noting that the relevant resources are considered to be of high sensitivity. Loss of the vadose zone is likely to result in a loss of wetland systems.

9.5 Impact on Alternatives Considered

No alternatives have been considered for the impacts related to the proposed mining activities.

9.5.1 Underground Mining Underground Mining (Process Alternative P3b)

The final significance rating has been determined to be "Low" given the duration of operational activities, the higher magnitude of impacts. Mitigation will be required to achieve a "Low" final significance rating.

9.5.1.1 Mitigation Measures

See Section 10 for detailed mitigation measures.

9.5.1.2 Cumulative Impacts

The cumulative impact rating has been scored "Low" given the extent of existing mining activities within the relevant hillslope as well as the expected degradation of the hillslope hydrology as a result of mining activities.

9.5.1.3 Irreplaceable loss of Resources

The operational phase of the relevant activities could result in a loss of natural resources because of a loss of recharge. Loss of recharge is likely to result in the loss of wetland area.

9.5.1.4 Impact on Alternatives Considered

No alternatives have been considered for the impacts related to the proposed mining activities.

9.6 Decommissioning Phase

9.6.1 Open Cast Mining (Process Alternative P3a)

The final significance rating has been determined to be "Low" given the duration of planning activities, the lower magnitude of impacts and the fact that the area is currently altered due to the mining activities. This phase of the project has the potential to provide rehabilitation of the soil characteristics and profile of the area.

9.6.1.1 Mitigation Measures

See Section 10 for detailed mitigation measures.

9.6.1.2 Cumulative Impacts

The cumulative impact rating has been scored "Medium" given the extent of existing mining activities within the relevant hillslopes as well as the expected degradation of the hillslope hydrology as a result of mining activities.

9.6.1.3 Irreplaceable loss of Resources

The decommissioning phase of the relevant activities is not likely to result in a further loss of natural resources.

9.6.1.4 Impact on Alternatives Considered

No alternatives have been considered for the impacts related to the proposed mining activities.

9.6.2 Underground Mining Underground Mining

The final significance rating has been determined to be "Low" given the duration of planning activities, the lower magnitude of impacts and the fact that roads already are in existence throughout the project area, which will be utilised during the planning phase.

9.6.2.1 Mitigation Measures

See Section 10 for detailed mitigation measures.

9.6.2.2 Cumulative Impacts

The cumulative impact rating has been scored "Medium" given the extent of existing mining activities within relevant hillslopes as well as the expected degradation of the hillslope hydrology as a result of mining activities.

9.6.2.3 Irreplaceable loss of Resources

The decommissioning phase of the relevant activities is not likely to result in a further loss of natural resources.

9.6.2.4 Impact on Alternatives Considered

No alternatives have been considered for the impacts related to the proposed mining activities.

9.7 Rehabilitation Phase

9.7.1 Open Cast Mining

The final significance rating has been determined to be "Low" given the fact that rehabilitation will take place which includes very little degradation to the environment.

9.7.1.1 Mitigation Measures

See Section 10 for detailed mitigation measures.

9.7.1.2 Cumulative Impacts

The cumulative impact rating has been scored "Low" given the extent of existing mining activities the relevant hillslopes as well as the expected degradation of the hillslope hydrology as a result of mining activities.

9.7.1.3 Irreplaceable loss of Resources

The rehabilitation phase of the relevant activities is not expected to result in a loss of natural resources.

9.7.1.4 Impact on Alternatives Considered

No alternatives have been considered for the impacts related to the proposed mining activities.

9.7.2 Underground Mining Underground Mining

The final significance rating has been determined to be "Low" given the fact that rehabilitation will take place which includes very little degradation to the environment.

9.7.2.1 Mitigation Measures

See Section 10 for detailed mitigation measures.

9.7.2.2 Cumulative Impacts

The cumulative impact rating has been scored "Low" given the extent of existing mining activities within the relevant hillslopes as well as the expected degradation of the hillslope hydrology as a result of mining activities.

9.7.2.3 Irreplaceable loss of Resources

The rehabilitation phase of the relevant activities is not expected to result in a loss of natural resources.

9.7.2.4 Impact on Alternatives Considered

No alternatives have been considered for the impacts related to the proposed mining activities.

10. Specialist Management Plan

Table 10-1 presents the recommended mitigation measures and the respective timeframes, targets and performance indicators. The mitigations within this section has been taken into consideration during the impact assessment in cases where the post-mitigation environmental risk is lower than that of the pre-mitigation environmental risk. It is advisable that these measures be re-considered and amended if required on selection of a preferred alternative, if applicable.

Table 10-1 Mitigation measures including requirements for timeframes, roles and responsibilities

Mitigation Measures	Phase	Timeframe	Responsible Party for Implementation	Monitoring Party (Frequency)	Target	Performance Indicators (Monitoring Tool)
• Underground workings must adhere to a safety factor that will avoid subsidence; • Any loss/alteration of flow dynamics must be quantified, and mitigation options to re-introduce water in a safe and environmentally friendly way must be assessed; • Monitoring of adjacent watercourses must be undertaken to assess the impact of AMD to these systems; • Existing roads must be used as much as possible; • Proper stripping and stockpiling techniques must be followed (see the Pedology assessment (TBC, 2020) for more detail); • Concurrent rehabilitation must be carried out rather than full rehabilitation after decommissioning only; • Cut-off trenches must be incorporated into the open cast mining areas' design to decrease contamination of watercourses via AMD. • Construct diversion berms and drains around working areas; • Incorporate green /soft engineering storm water measures. Avoid unnecessary vegetation clearing and avoid preferential surface flow paths; • Storage of potential contaminants in bunded areas; • Cut-off trenches must be used as much as possible to capture interflow and divert it back to attenuation ponds. The hydropedologists involved must be consulted regarding the	Operation & Closure	Permanent	Applicant / Contractor	Monthly surface and groundwater quantity and quality	Avoid or minimise the loss of water input, and impaired water quality	Water quality guidelines (DWS,1996)

reintroduction of attenuated water back into wetlands as general outflow will not respect current hydropedological flow paths and will therefore not be permitted; • All released water must be within DWAF (1996) water quality standards for aquatic ecosystems, and discharge must be managed to avoid scouring and erosion of the receiving systems; • Contain wastewater in a PCD. Contaminated water must not be discharged into the watercourses; • Clean and dirty water must be separated. This water should be looked at for treatment and then re-introduced to mitigate losses to the catchment water hydrodynamics; and • Cut of berms must be installed upslope from the proposed open cast pits. Water intercepted by this trench must be pumped into a PCD and released back into the watercourse affected by means of groundwater recharge. This can be done by reintroducing treated water into aquifers by means of French drains. The geohydrological assessment must inform this reintroduction methodology.						
• All surface infrastructure must be removed from the site; • Compacted areas must be ripped (perpendicularly) to a depth of 300 mm; • A seed mix must be applied to rehabilitated and bare areas; • Any gullies or dongas must also be backfilled; • The area must be shaped to a natural topography;	Closure/Rehabilitation	Ongoing	Applicant	Biomonitoring (bi-annual) Wetland monitoring (bi-annual) Water quality monitoring, frequency to be advised by hydrology specialist	Maintain drinking water quality standards	Water quality guidelines (DWS,1996)

11. Conclusion

11.1 Baseline Results

This report presents findings from a hydropedological survey of four transects to assess the potential impact of mining on vadose zone processes. The soil morphological interpretations were supplemented by measurements of hydraulic properties and simulations of key hydrological processes through the hillslopes.

Various soil forms have been identified on site, which have been grouped into deep recharge, shallow recharge and interflow (between soil and bedrock) hydropedological types. Current and historic mining activities cover the majority of the area which already has resulted in modifications to the vadose zone.

11.2 Impact Assessment

Large portions of the studied area are already impacted upon by current mining activities. These modifications have altered natural flow paths and complicates hydropedological interpretations in relation to proposed future developments. With this being said, it is worth noting that the recharge soils occupy long sections of the slopes, especially those areas where the proposed pits will be located. Conceptually, the impact of the development on lateral flow paths through the vadose zone will therefore be insignificant. This conceptual understanding was supported by hydrological simulations of one slope which was not yet impacted by development. The simulations indicate that the proposed development will only result in drying of the soils directly below the open cast pits. Approximately 300 m downslope of the pit, differences in soil water contents were not observed. Similarly, there was no difference in the outflow and lateral flux to the stream between the natural and developed state.

11.3 Specialist Recommendation

It is the specialist's opinion that the proposed activities may proceed. However, with large areas being occupied by recharge soils, the geohydrological study should advise on the impact of the proposed mining alternatives on the contribution of groundwater to streamflow and wetland water regimes.

12. Assumptions, Uncertainties and Gaps in Knowledge

The following aspects were considered as limitations:

- No site visit was conducted for this particular assessment. The hydropedological assessment undertaken in 2019 (TBC, 2019) was used to supplement this particular report. Therefore, no additional modelling has been done to incorporate the latest mine layout. It is however the specialist's opinion that the effects of the latest layouts for all four transects assessed will be similar to the effects of the layout assessed in 2019 due to the similarities in extent as well as the negligible effect that the proposed mining had on the vadose zone in the previous assessment.
- Only the slopes affected by the proposed mining areas have been assessed;
- No surface impacts (i.e. haul roads, infrastructure, shafts, evaporation ponds etc) have been included into this report;
- Access could not be gained at observation 8 and 9;
- It has been assumed that the mining areas provided to the consultant are correct;
- 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;
- Geohydrological modelling was not part of the hydropedological assessments; and
- The planned Seam 1, 2 or 4 (underground or open cast) area has not been assessed due to the fact that this portion was not part of the initial hydropedological assessment which was used to supplement this particular assessment. It is recommended that a full hydropedological assessment be undertaken for this portion in the event that the open cast alternative be chosen, and that a geohydrological assessment be undertaken in the event that this portion be mined via underground activities.

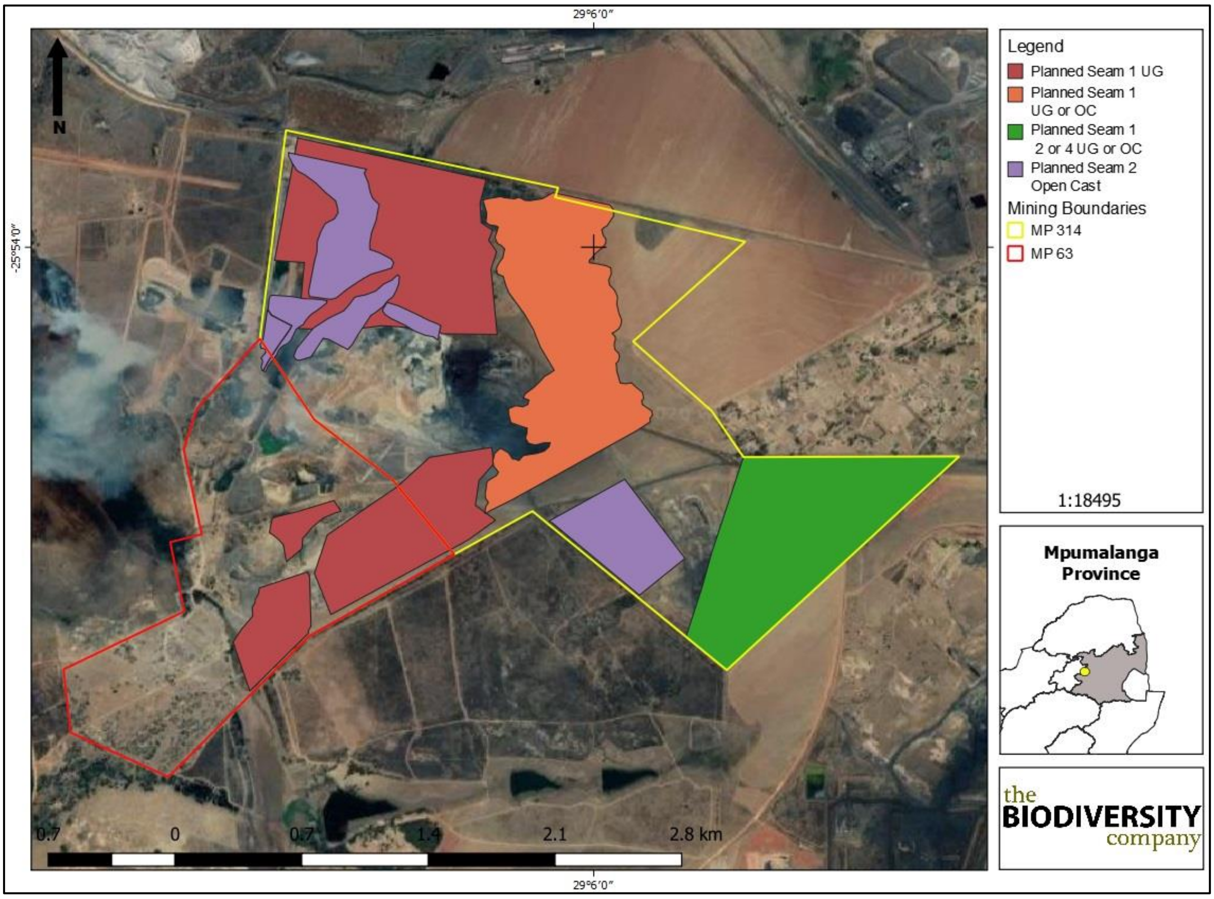

Figure 12-1 Illustration of proposed mining areas

13. References

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Appendix A- Specialist CV

Masters in Environmental Science and Hydropedology

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Identity Number: 9401105251087

Date of birth: 10 January 1994

Profile Summary

Working experience throughout Southern Africa

Working experience in West-Africa

Specialist experience with mining, construction and agriculture.

Specialist expertise include hydropedology, pedology, land contamination, agricultural potential, land rehabilitation, rehabilitation management and wetlands resources.

Experience hydropedological modelling (HYDRUS model)

Areas of Interest

Mining, Oil & Gas, Renewable Energy & Bulk Services Infrastructure Development, Farming, Land contamination, Sustainability and Conservation.

Key Experience

- Environmental Impact Assessments (EIA)
- Environmental Management Programmes (EMP)
- Wetland delineations and ecological assessments
- Rehabilitation Plans and Monitoring
- Soil-and rock classification
- Level 1, 2 and 3 hydropedology assessments
- Agriculture potential assessments
- Land contamination assessments
- Modulation of surface- and subsurface flows (HYDRUS model)

Countries worked in

South Africa	Mozambique
Swaziland	Zimbabwe
Guinea	

Nationality

South African

Languages

English – Proficient

Afrikaans – Proficient

Qualifications

- MSc (North-West University of Potchefstroom) – Hydropedology
- BSc Honours (North-West University of Potchefstroom) – Environmental geology-Pedology and rehabilitation
- BSc Environmental sciences
- Pr Sci Nat candidateship

SELECTED PROJECT EXPERIENCE

Project Name: Environmental impact assessment for the construction of Road DR08606 leading to Mlamli Hospital, Sterkspruit

Personal position / role on project: Wetland ecologist

Location: Sterkspruit, Eastern Cape Province, South Africa

Main project features: To conduct a wetland assessment, as a component of the environmental authorisation process and Water Use Licence Application (WULA) for the construction of Road DR08606 leading to Mlamli Hospital

Project Name: Biodiversity Baseline & Impact Assessment Report for the proposed Nondvo Dam Project

Personal position / role on project: Wetland ecologist

Location: Mbabane, Swaziland

Main project features: To conduct various assessments according to IFC standards in regard to delineation of wetlands and assessing ecosystem services.

Project Name: Agricultural Potential Assessment - Proposed Kalabasfontein Coal Mining Project Extension

Personal position / role on project: Project Manager and Soil Specialist.

Location: Bethal, Mpumalanga, South Africa

Main project features: To conduct a soil assessment to identify any sensitive resources that might be affected by the proposed mining activities and associated infrastructure as part of an environmental impact assessment.

Project Name: Soil assessment for the closure of the St Helena Shaft, Harmony

Personal position / role on project: Soil specialist

Location: Welkom, Free State, South Africa

Main project features: To conduct a thorough soil and fertility assessment to recommend relevant mitigation and rehabilitation measures to finalise closure at the relevant mine

Project Name: Wetland Functionality Assessment for the Environmental, Health and Socio-Economic Baseline Studies for Block 2 at Siguiri Gold Mine

Personal position / role on project: Wetland ecologist

Location: Siguiri, Guinea, West-Africa

Main project features: To conduct various assessments according to IUCN standards in regard to delineation of wetlands and assessing ecosystem services.

Project Name: Level 3 Hydropedological Assessment for the Sara Buffels Mining Project

Personal position / role on project: Hydropedologist

Location: Ermelo, Mpumalanga, South-Africa

Main project features: To conduct various assessments to determine the hillslope hydrology and to acquire information relevant to the vadose zone's hydraulic properties to quantify sub-surface flows by means of modelling.

Project Name: Level 3 Hydropedological Assessment for the Buffalo Coal Mining Project

Personal position / role on project: Hydropedologist

Location: Dundee, KwaZulu-Natal, South-Africa

Main project features: To conduct various assessments to determine the hillslope hydrology and to acquire information relevant to the vadose zone's hydraulic properties to quantify sub-surface flows by means of modelling

Project Name: Biodiversity Baseline & Impact Assessment for the proposed Tetereane 15MW Solar PV Plant

Personal position / role on project: Ecosystem Services Specialist

Location: Cuamba, Mozambique, Southern-Africa

Main project features: To conduct various assessments according to IUCN standards in regard to ecosystem services

Project Name: Land contamination assessment for the proposed Fleurhof Development

Personal position / role on project: Soil Specialist

Location: Fleurhof, South Africa

Main project features: To conduct assessments relevant to the determination of land contamination, including recommendations, mitigations and risk assessments.

OVERVIEW

An overview of the specialist technical expertise include the following:

- Ecological wetland assessment studies, including the integrity (health) and functioning of the wetland systems.
- Wetland offset strategy designs.
- Wetland rehabilitation plans.
- Monitoring plans for wetland systems.
- Soil classification and agricultural assessments.
- Stripping and stockpiling guidelines.
- Soil rehabilitation plans.
- Soil and stockpile monitoring plans.
- Hydropedological assessments.

TRAINING

Some of the more pertinent training undergone includes the following:

- Tools for a Wetland Assessment (Certificate of Competence) – Rhodes University 2018; and
- Workshop on digital soil mapping.

EMPLOYMENT EXPERIENCE

Internship at SRK consulting (January 2017-August 2017)

- **Field assistant** for SRK consulting during 2017 included the sampling of surface and groundwater as well as on site tests, the accumulation of various different data sets from field loggers, presenting and arranging the relevant data and ultimately using it for my own personal post-graduate studies.

Internship at The Biodiversity Company (August 2017-December 2017)

Employed as an intern (wetland and soil scientist) during the last few months of 2017. During this period, I was part of a variety of soil- and wetland projects, both as report writer and/or field assistant.

CURRENT EMPLOYMENT: The Biodiversity Company (January 2018 – Present)

- **Scientific report writing** to ensure that the relevant standards and requirements have been attained, namely local country legislation, as well as WB, EP and IFC requirements.

ACADEMIC QUALIFICATIONS

North-West University of Potchefstroom: MAGISTER SCIENTIAE (MSc) - Hydropedology:

Title: *Characterisation of vadose zone processes in a tailings facility*

North-West University of Potchefstroom (2016): BACCALAUREUS SCIENTIAE HONORIBUS (Hons) – Environmental Geology- Pedology and rehabilitation

North-West University of Potchefstroom (2015): BACCALAUREUS SCIENTIAE IN NATURAL AND ENVIRONMENTAL SCIENCES. Majors: Geology and Geography