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Wetland flow driver assessment

for

Proposed Koppie Colliery

Compiled for:

ECO Elementum (Pty) Ltd.

Project No.: ECOV-21-3231
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Offices in: Gauteng, Western Cape, KwaZulu-Natal & Mozambique

Geo Pollution Technologies (Pty) Ltd

Report Type:	Wetland flow driver assessment
Site Name:	Proposed Koppie Colliery
Site Location:	Near Bethal in the Mpumalanga Province
Compiled For:	ECO Elementum (Pty) Ltd.
Compiled By:	S. C. Nkosi; M. Sc.; Cand. Sci. Nat (100105/13)
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Reviewed by:	M. Burger; M. Sc.; Pr. Sci. Nat (400296/12)

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The results and conclusions of this report are limited to the Scope of Work agreed between GEM-GPT and the Client for whom this investigation has been conducted. All assumptions made and all information contained within this report and its attachments depend on the accessibility to and reliability of relevant information, including maps, previous reports and word-of-mouth, from the Client and Contractors.

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I hereby declare:

- I have no vested interest (present or prospective) in the project that is the subject of this report as well as its attachments. I have no personal interest with respect to the parties involved in this project.
- I have no bias with regard to this project or towards the various stakeholders involved in this project.
- I have not received, nor have I been offered, any significant form of inappropriate reward for compiling this report.

(electronic signature)	*(electronic signature)*
S. C. Nkosi; M. Sc.; Cand. Sci. Nat (100105/13)	M. Burger; M. Sc.; Pr. Sci. Nat (400296/12)

Customer Satisfaction:

Feedback regarding the technical quality of this report (i.e. methodology used, results discussed and recommendations made), as well as other aspects, such as timeous completion of project and value of services rendered, can be posted onto GPT's website at www.gptglobal.com.

NEMA Regs (2014) - Appendix 6	**Relevant section in report**
Details of the specialist who prepared the report	Page i
The expertise of that person to compile a specialist report including a curriculum vitae	Page i
A declaration that the person is independent in a form as may be specified by the competent authority	Page i
An indication of the scope of, and the purpose for which, the report was prepared	Detailed in report
The date and season of the site investigation and the relevance of the season to the outcome of the assessment	Detailed in report
A description of the methodology adopted in preparing the report or carrying out the specialised process	Detailed in report
The specific identified sensitivity of the site related to the activity and its associated structures and infrastructure	Detailed in report
An identification of any areas to be avoided, including buffers	Detailed in report
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;	Detailed in report
A description of any assumptions made and any uncertainties or gaps in knowledge;	Detailed in report
A description of the findings and potential implications of such findings on the impact of the proposed activity, including identified alternatives, on the environment	Detailed in report
Any mitigation measures for inclusion in the EMPr	Detailed in report
Any conditions for inclusion in the environmental authorisation	Detailed in report
Any monitoring requirements for inclusion in the EMPr or environmental authorisation	Detailed in report
A reasoned opinion as to whether the proposed activity or portions thereof should be authorised and	Detailed in report
If the opinion is that the proposed activity 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	
A description of any consultation process that was undertaken during the course of carrying out the study	N/A
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LIST OF ABBREVIATIONS

Abbreviation	Explanation
ARD	Acid Rock Drainage
BPG	Best Practice Guidelines
CMS	Catchment Management Strategy
CSM	Conceptual Site Model
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
IWRMP	Integrated Water Resources Management Plan
IWRM	Integrated Water Resources Management
km^2	Square kilometre
L/s	Litres per second
mamsl	Metres above mean sea level
Ml/d	Megalitres per day
m	metre
mm	Millimetre
mm/a	Millimetres per annum
mS/m	Millisiemens per metre
m^3	Cubic metre
MAP	Mean Annual Precipitation
MPRDA	Mining and Petroleum Resources Development Act (Act No. 73 of 2002) 1989)
NEMA	National Environmental Management Act (Act No. 107 of 1998)
NWA	National Water Act (Act No. 36 of 1998)
ppm	Parts per million
RDM	Resource Directed Measures
RQO	Resource Quality Objective
RWQO	Resource Water Quality Objective
TDS	Total Dissolved Solids
WMA	Water Management Area
WMP	Water Management Plan

DEFINITIONS

Definition	Explanation
Aquiclude	A geologic formation, group of formations, or part of formation through which virtually no water moves
Aquifer	A geological formation which has structures or textures that hold water or permit appreciable water movement through them. Source: National Water Act (Act No. 36 of 1998).
Borehole	Includes a well, excavation, or any other artificially constructed or improved underground cavity which can be used for the purpose of intercepting, collecting or storing water in or removing water from an aquifer; observing and collecting data and information on water in an aquifer; or recharging an aquifer. Source: National Water Act (Act No. 36 of 1998).
Boundary	An aquifer-system boundary represented by a rock mass (e.g. an intruding dolerite dyke) that is not a source of water, and resulting in the formation of compartments in aquifers.
Cone of Depression	The depression of hydraulic head around a pumping borehole caused by the withdrawal of water.
Confining Layer	A body of material of low hydraulic conductivity that is stratigraphically adjacent to one or more aquifers; it may lie above or below the aquifer.
Dolomite Aquifer	See “Karst” Aquifer
Drawdown	The distance between the static water level and the surface of the cone of depression.
Fractured Aquifer	An aquifer that owes its water-bearing properties to fracturing.
Groundwater	Water found in the subsurface in the saturated zone below the water table.
Groundwater Divide or Groundwater Watershed	The boundary between two groundwater basins which is represented by a high point in the water table or piezometric surface.
Groundwater Flow	The movement of water through openings in sediment and rock; occurs in the zone of saturation in the direction of the hydraulic gradient.
Hydraulic Conductivity	Measure of the ease with which water will pass through the earth's material; defined as the rate of flow through a cross-section of one square metre under a unit hydraulic gradient at right angles to the direction of flow (m/d).
Hydraulic Gradient	The rate of change in the total hydraulic head per unit distance of flow in a given direction.
Infiltration	The downward movement of water from the atmosphere into the ground.
Intergranular Aquifer	A term used in the South African map series referring to aquifers in which groundwater flows in openings and void spaces between grains and weathered rock.
Karst (Karstic)	The type of geomorphological terrain underlain by carbonate rocks where significant solution of the rock has occurred due to flowing groundwater.

Definition	**Explanation**
Karst (Karstic) Aquifer	A body of soluble rock that conducts water principally via enhanced (conduit or tertiary) porosity formed by the dissolution of the rock. The aquifers are commonly structured as a branching network of tributary conduits, which connect together to drain a groundwater basin and discharge to a perennial spring.
Monitoring	The regular or routine collection of groundwater data (e.g. water levels, water quality and water use) to provide a record of the aquifer response over time.
Observation Borehole	A borehole used to measure the response of the groundwater system to an aquifer test.
Phreatic Surface	The surface at which the water level is in contact with the atmosphere: the water table.
Piezometric Surface	An imaginary or hypothetical surface of the piezometric pressure or hydraulic head throughout all or part of a confined or semi-confined aquifer; analogous to the water table of an unconfined aquifer.
Porosity	Porosity is the ratio of the volume of void space to the total volume of the rock or earth material.
Production Borehole	A borehole specifically designed to be pumped as a source of water supply.
Recharge	The addition of water to the saturated zone, either by the downward percolation of precipitation or surface water and/or the lateral migration of groundwater from adjacent aquifers.
Recharge Borehole	A borehole specifically designed so that water can be pumped into an aquifer in order to recharge the ground-water reservoir.
Saturated Zone	The subsurface zone below the water table where interstices are filled with water under pressure greater than that of the atmosphere.
Specific Capacity	The rate of discharge from a borehole per unit of drawdown, usually expressed as m3/d•m.
Specific Yield	The ratio of the volume of water that drains by gravity to that of the total volume of the saturated porous medium.
Storativity	The volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.
Transmissivity	Transmissivity is the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. It is expressed as the product of the average hydraulic conductivity and thickness of the saturated portion of an aquifer.
Unsaturated Zone (Also Termed Vadose Zone)	That part of the geological stratum above the water table where interstices and voids contain a combination of air and water.
Watershed (Also Termed Catchment)	Catchment in relation to watercourse or watercourses or part of a watercourse means the area from which any rainfall will drain into the watercourses or part of a watercourse through surface flow to a common point or points. Source: National Water Act (Act No. 36 of 1998).
Water Table	The upper surface of the saturated zone of an unconfined aquifer at which pore pressure is equal to that of the atmosphere.

1 INTRODUCTION

Geo Pollution Technologies (Pty) Ltd (GPT) was instructed to conduct a wetland flow driver (hydropedological) assessment for the proposed underground mining on the Farm Koppie 228 IS and portions of the Farm Uitgedacht 229 IS. Sibande District Municipality, Mpumalanga Province.

The extent of the area required for mining is 1955.450 ha with the surface infrastructure compromising 80 ha. The planned mining below surface is expected to be:

- 4 Seam – 58.96 to 118.8m below surface;
- 2 Seam – 89.35m to 132.72m below surface;

1.1 Normative references

The following normative references are indispensable to this report as it contains information used in terms of wetland flow drivers:

- Oasis, August 2021 - Watercourse and Biodiversity Proposed Koppie Mining Project, located near Bethal in the Mpumalanga Province, Located Near Middelburg in the Mpumalanga Province - WET-20-013;
- Digital Soils Africa, November 2020 - Koppie Mining Right Application Hydropedology;

1.1.1 Main report findings

Oasis May 2021

The overall results of the aquatic and wetland assessment based on the various methodologies concluded that:

- *Two floodplain wetland systems (HGM 1 and HGM 2) were identified within the 500 m buffer of the Proposed Koppie Mining Project. The floodplain wetland systems were assessed in terms of health and was found to be categorised as largely modified (Category D). The Ecological Services of the wetland has been recorded as intermediate and the sensitivity and importance (EIS) has been recorded as moderate.*
- *From an ecological perspective these wetlands can be regarded as a highly sensitive area as it is a nesting and foraging area for a diversity of avifauna and aquatic life. The grasslands between the wetlands and transformed areas can be regarded as moderately sensitive. The remainder of the study area can be regarded as a low sensitive area as this represents heavily transformed landscape. A recommended buffer of 110 m is implemented for the protection of the wetlands*

Digital Soils Africa November 2021

The overall results of the hydropedological assessment concluded that:

- *The dominant flowpaths in the study area are recharge in the apedal horizons and overland flow on the responsive soils. Evaporation will be high on the responsive soils as water moves slowly through the profile.*
- *The probability of the impacts is all high, but due to the small surface footprint, the extent of the activities is at hillslope scale and therefore the activities have a limited impact in context of the catchment.*

2 GEOGRAPHICAL SETTING

2.1 Site Location, Topography and Drainage

The site layout shown in Figure 1. The Proposed Koppie Colliery is located in the Olifants catchment management area and lies within quaternary catchment B11A. A MAP of ±700 is obtained from rain station 0478546W. The monthly A-Pan evaporation was determined from the SA Atlas Isohyets. The monthly Symons Pan evaporation was determined from South African Weather Station B1E004 which lies approximately 13km north west of the site. The S-Pan evaporation from station B1E004 was used. The site has a typical highveld topography with long gentle slopes. The general drainage direction of water flow is from the south in a northern direction. Most of the survey area has a slope of less than 6°.

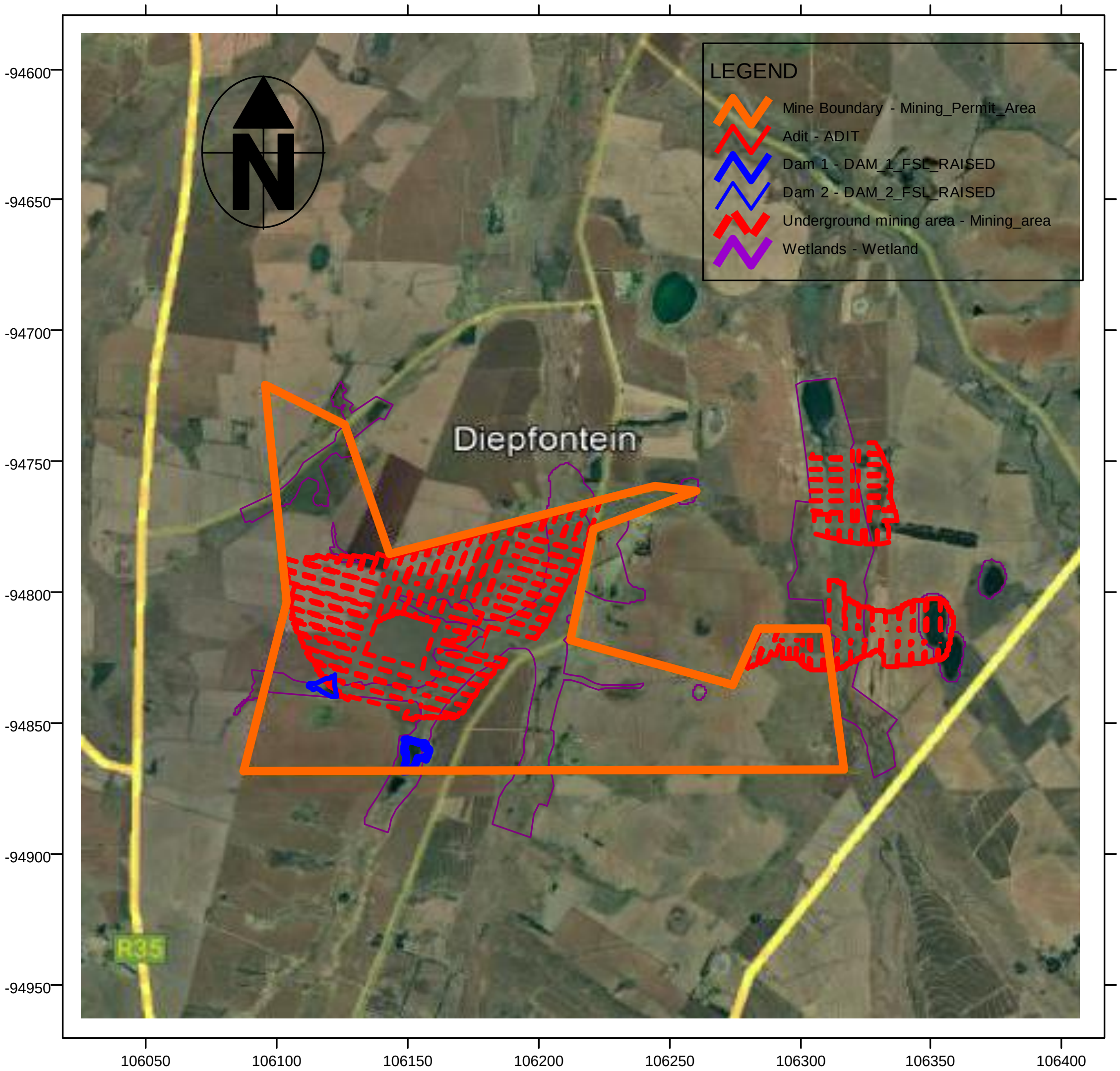

Figure 1: Site Layout

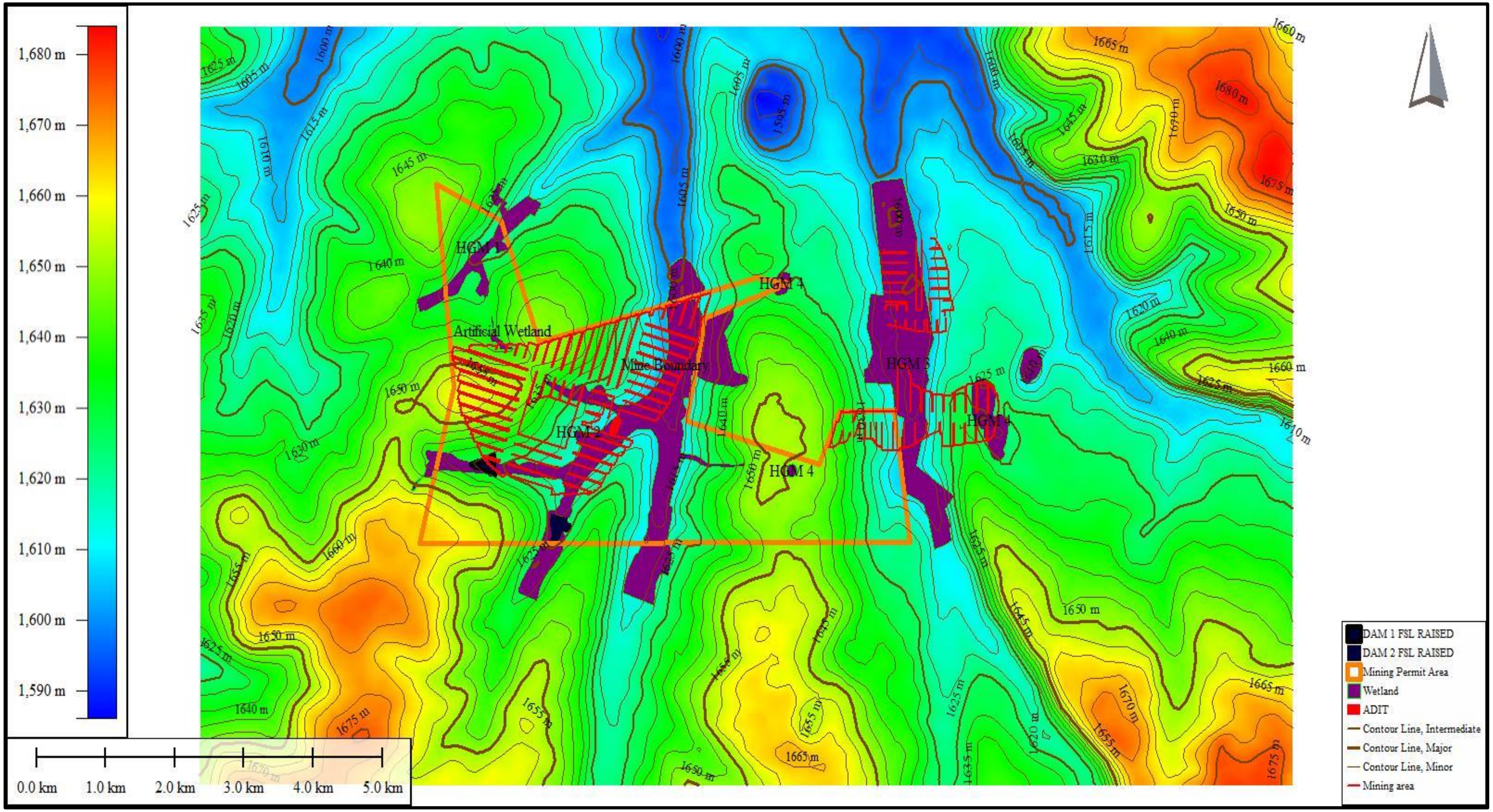

Figure 2: Site drainage and topography

2.2 Climate

The regional climate is characterised by relatively warm wet summers and cold dry winters. Rainfall occurs mostly in the form of thunderstorms during summer months (October to March). This high variability in rainfall during the year, results in excess surface runoff water duration summer rainfall events while there is little to no available water during the winter months. This has the potential for water erosion of exposed surfaces in summer (such as in the case of opencast mining), with wind erosion of dry exposed/disturbed surfaces during winter. The local wind directions show variations throughout the day and over the seasons; however generally the trend is east-west (predominantly southeast-northwest). A MAP of approximately 700 mm is obtained from rain station 0478546W. The monthly A-Pan evaporation was determined from the SA Atlas Isohyets. The monthly Symons Pan evaporation was determined from South African Weather Station B1E004 which lies approximately 13km north west of the site. The S-Pan evaporation from station B1E004 was used

2.3 Surface runoff

Runoff from natural (unmodified) catchments in this area is simulated as being equivalent to 635 millimetres per year over the surface area and is equal to approximately 9 % of the Mean Annual Precipitation (MAP).

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Table 1: Soil description

Area	Number of Auger Holes	Depth of Refusal (m)	Soil Description	Hydropdedological Description	
Crests of the hillslopes	Soil report	Soil report	Nkonkoni, Hutton and Clovelly soils	Recharge soils	In these soils, vertical flow into, through and out of the profile into the underlying bedrock is the dominant flow direction.
Edge of wetland	Soil report	Soil report	Plinthic horizon that develops on the midslope below an apedal horizon	Interflow soils	Subsurface lateral flow (SLF) is the dominant flow direction in interflow soils.
On edge of wetland	Soil report	Soil report	Both on the hillslope and in the wetlands	Responsive soils	These soils respond quickly to rain events and are responsible for overland flow generation during typical rain events.

3 WETLAND FLOW DRIVER IMPACT

The mining area could impact on the flow drivers of the wetland systems through the following:

- Ingress into mine workings that are on surface or close to surface through outcrop openings and shafts (adits, vertical and incline shafts), either through stormwater runoff or through river bed loss where these features intersect watercourses.
- Ingress through boreholes that have not been properly sealed.
- After removal of the orebody, the weight of the overlying strata starts to weaken the support provided during the mining operation, resulting in strata movement which causes cracks to form in the overlying strata. Water bodies overlying the mined area then start to drain into the mine workings.
- Groundwater aquifers above the mining horizon tend to drain into mine workings through cracks that are formed due to subsidence caused as a result of mining.
- Direct rainfall

The previous hydropedology study (DSA, November 2020) indicated different hydropedological soil types comprising of the following:

- **Recharge**- The Nkonkoni, Hutton and Clovelly soils are present on the crests of the hillslopes of the study area. The lack of gleying in the Lithic below the red and yellow-brown apedal horizons indicates that the water is not impeded sufficiently for reduction. The water will exfiltrate the soil into the weathered rock, either recharge the underground aquifer or move along bedding planes to the lower lying wetlands as return flow.
- **Interflow**- is present in the soft plinthic horizon that develops on the midslope below an apedal horizon. Therefore, water will infiltrate the A and B horizons as in the recharge soils, but the soft plinthic horizon will impede vertical flow. Water will then be diverted laterally either above of the soft plinthic horizon in the apedal horizon as fast flow or in the soft plinthic as slow flow.
- **Overland flow**- will be present in the responsive soils, both on the hillslope and in the wetlands. The smectitic clay present swells when saturated, causing a dramatic decrease in infiltration. The low infiltration then causes the overland flow. The gley horizon under the vertic horizons in the Rensburg soil could be cause by return flow from the recharge soils.

3.1 Wetland catchment flow reduction

The SANBI Biodiversity Series 22, (2013) Classification System for Wetlands and other Aquatic Ecosystems in South Africa. User Manual: Inland Systems was consulted in determining the estimated flow losses to the specific wetland catchment systems due to mining.

- Three areas were identified in the wetland delineation (Oasis, 2021), namely, Artificial wetland, HGM 1 and HGM 2. All the wetlands occur with the Rensburg soil form which is classified as a responsive soil. Therefore, overland flow will be a dominant source for the wetlands. The signs of wetness in the subsoil are an indication of poor drainage, therefore, water that accumulates on these soils will most likely not drain vertically but pond due to the slopes of less than 6%.

3.2 Conceptual Model/Understanding

It was observed that most seeps/wetlands originate on the side of hills and can be described by the following conceptual model displayed in Figure 3 and Figure 4. Porous sandstone overlies impervious dolerite/shale/clay creating these perched aquifers. Rainfall infiltrates the porous sandstones until it reaches the impervious layer, this perched aquifer is then drained by gravity until the aquifer daylights which is then the origin of the spring/wetland.

Due to depth of underground mining of more than 50 m impacts on the unsaturated zone is not expected unless subsidence occurs. It is noted that that various exploration holes are situated across the proposed underground mining area which could create preferred pathways from the unsaturated and saturated zone to the dewatered underground. It should be noted that although these exploration holes (if not properly sealed) could create conduits the dewatering impact is expected to be less pronounced in the unsaturated zone than the saturated zone.

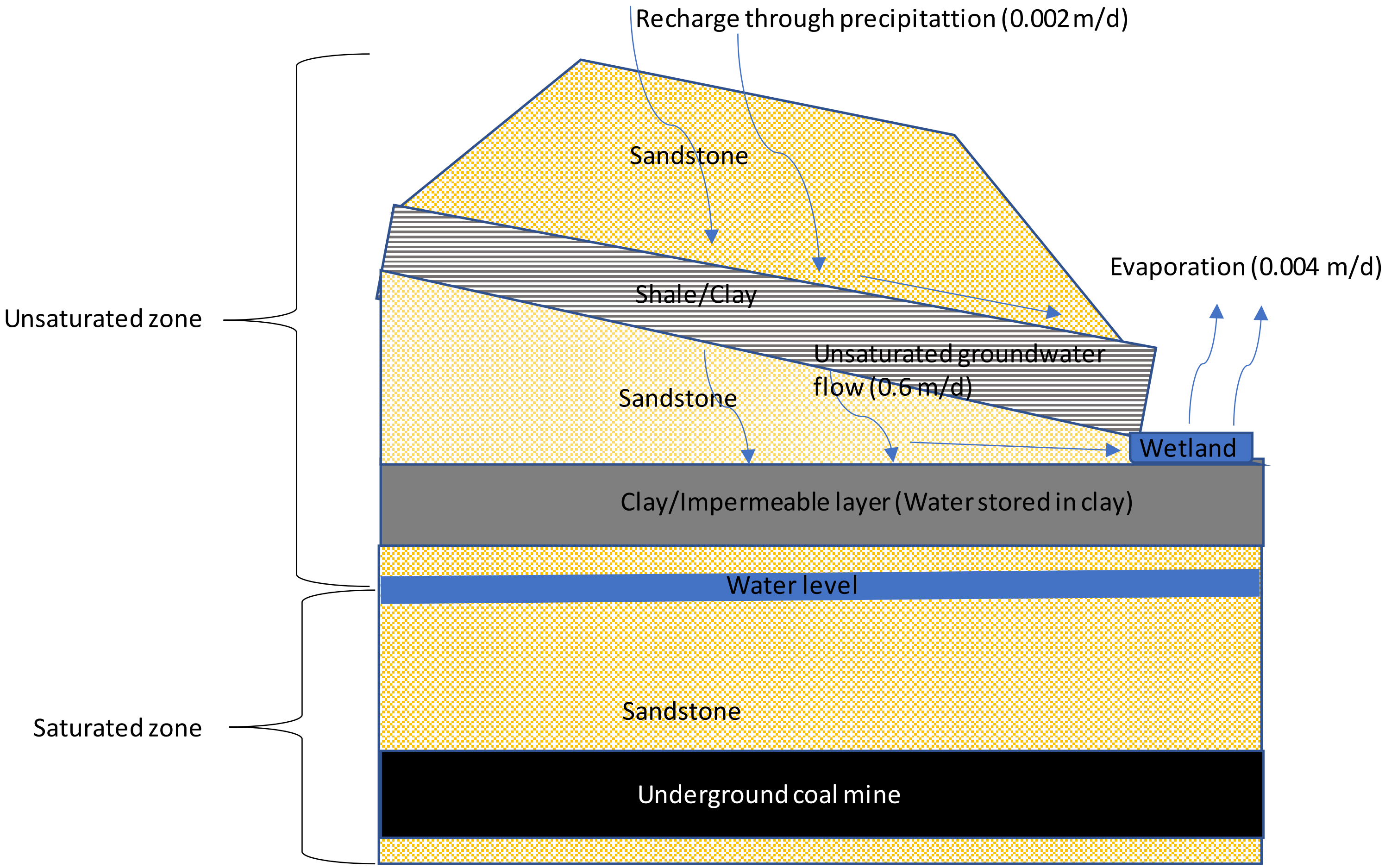
Flow of water in the soil is driven by a hydraulic potential gradient, that it takes place in the direction of decreasing hydraulic potential, and that its rate is proportional to the potential gradient. These principles apply in unsaturated, as well as the saturated zone However, the nature of the moving force and the effective geometry of the conducting pores can be very different. Apart from the gravitational force, which is completely independent of soil water content, the primary moving force in a saturated soil is the gradient of a positive pressure potential. On the other hand, water in an unsaturated soil is subject to a sub-atmospheric pressure, or matric suction that is equivalent to a negative pressure potential. The gradient of this potential likewise constitutes a moving force.

One of the most important differences between unsaturated and saturated flow pertains to the hydraulic conductivity. When a soil is saturated, all its pores are water-filled and conducting. The water phase is then continuous and the conductivity is maximal. When the soil desaturates, some pores become air-filled so that the conductive portion of the soil's volume diminishes. Furthermore, as suction develops, the first pores to empty are the largest ones, which are the most potentially conductive. At the same time, those large pores must be circumvented, so that with progressive desaturation, tortuosity increases, as does effective length of the flow path and hence the hydraulic resistance. In coarse-textured soils, water may be confined mainly to the capillary wedges at the contact points of the particles, thus forming separate and discontinuous pockets of water. In aggregated soils, too, the large interaggregate spaces that confer high conductivity at saturation become, when emptied, barriers to liquid flow from one aggregate to another. As high suctions occur, there may also be a change in the viscosity of the mainly adsorbed water, tending to further reduce the conductivity. (Viscosity is temperature-dependent as well.)

The 2D interflow conceptual model is shown in Figure 3. In the figure, the most important features to the perched aquifer are indicated. This includes a highly permeable regolith (soil or softs) layer, underlain by bedrock with much lower permeability. This contrast in permeability results in a higher volume flow in the regolith which cannot be absorbed by the bedrock, and is must perch on the bedrock and flow downstream on this interface under the force of gravity. The higher recharge to the upper aquifer is illustrated as 0.0005 m/d, with the recharge to the deep fractured aquifer estimated at 0.0001 m/d, this difference must either be removed by evapotranspiration or move downstream as a perched water table.

The impact of the proposed underground is also illustrated in this figure. Where the flow upstream would normally be directed to the wetland, an underground can intercept a portion of that flow due do subsidence creating cracks creating preferential flowpaths, leaving the wetland with a decrease in flow and possible degradation.

It is the aim of this model to estimate which wetlands might be impacted and to provide an estimate of the resultant flow decrease. As the model is a simplification of the complexity of nature, the model can only this provide approximations. However, these approximations should be adequate to separate those wetlands in potential danger from the apparent unaffected ones, as well as a flow estimate that can be compared in magnitude and importance to surface water in and out flows.


Recharge through precipitattion (0.002 m/d)
Sandstone
Shale/Clay
Evaporation (0.004 m/d)
Unsaturated zone
Unsaturated groundwater flow (0.6 m/d)
Sandstone
Wetland
Clay/Impermeable layer (Water stored in clay)
Water level
Saturated zone
Sandstone
Underground coal mine

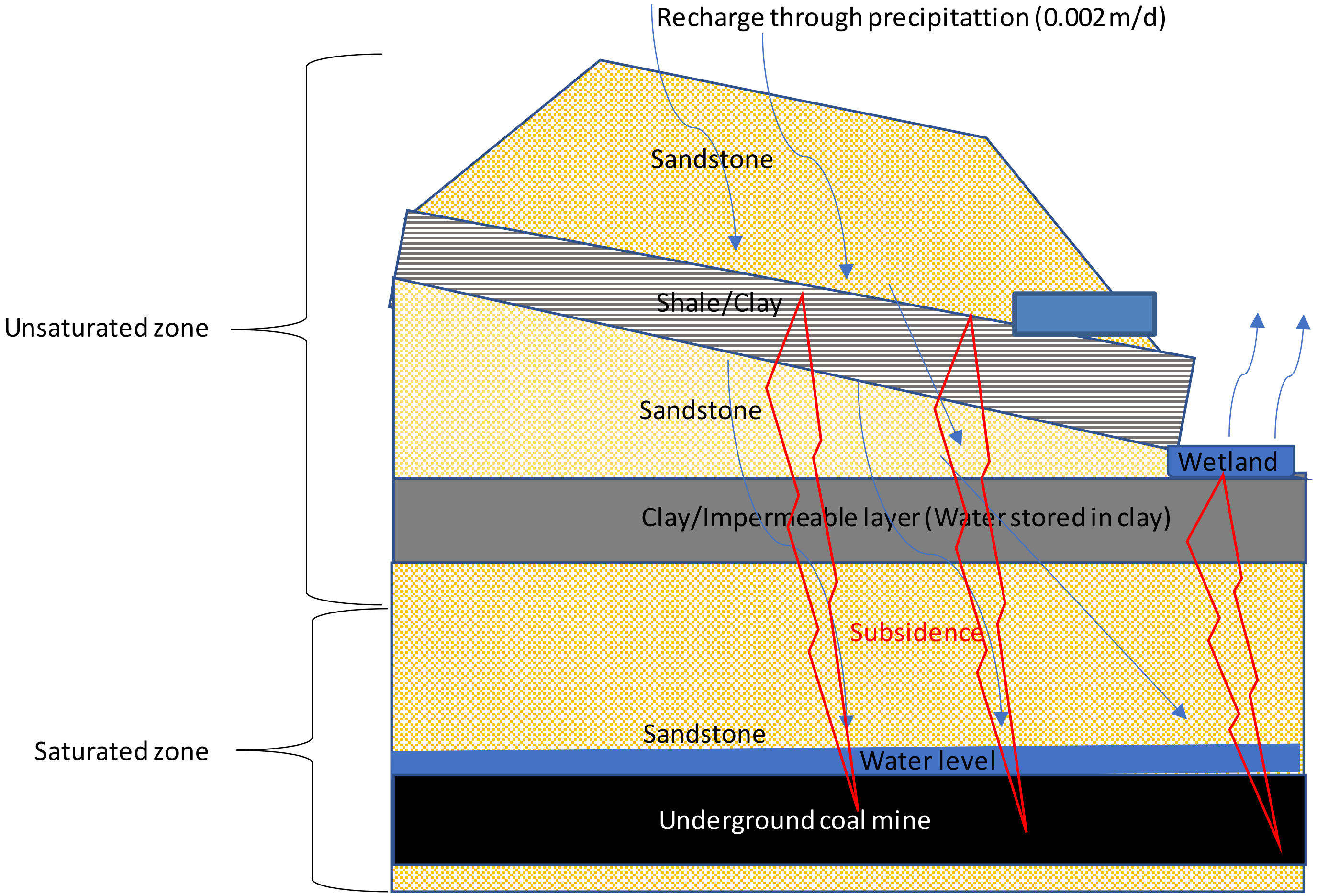


Figure 3: 2D Conceptual Model (With and without subsidence)

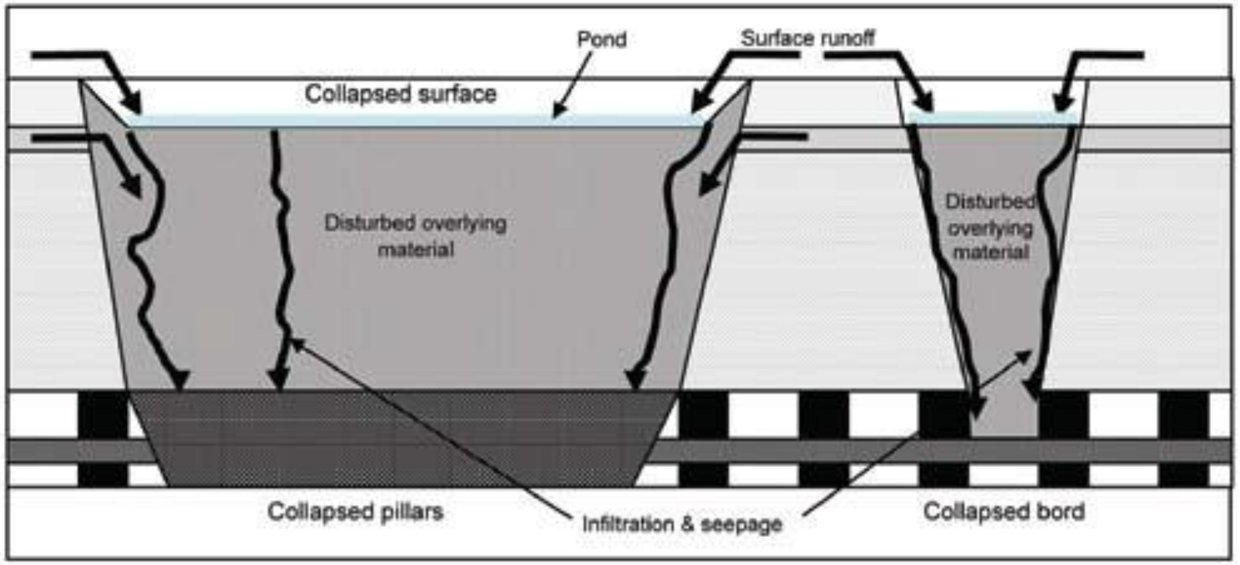


Figure 4: Water ingress during underground mining

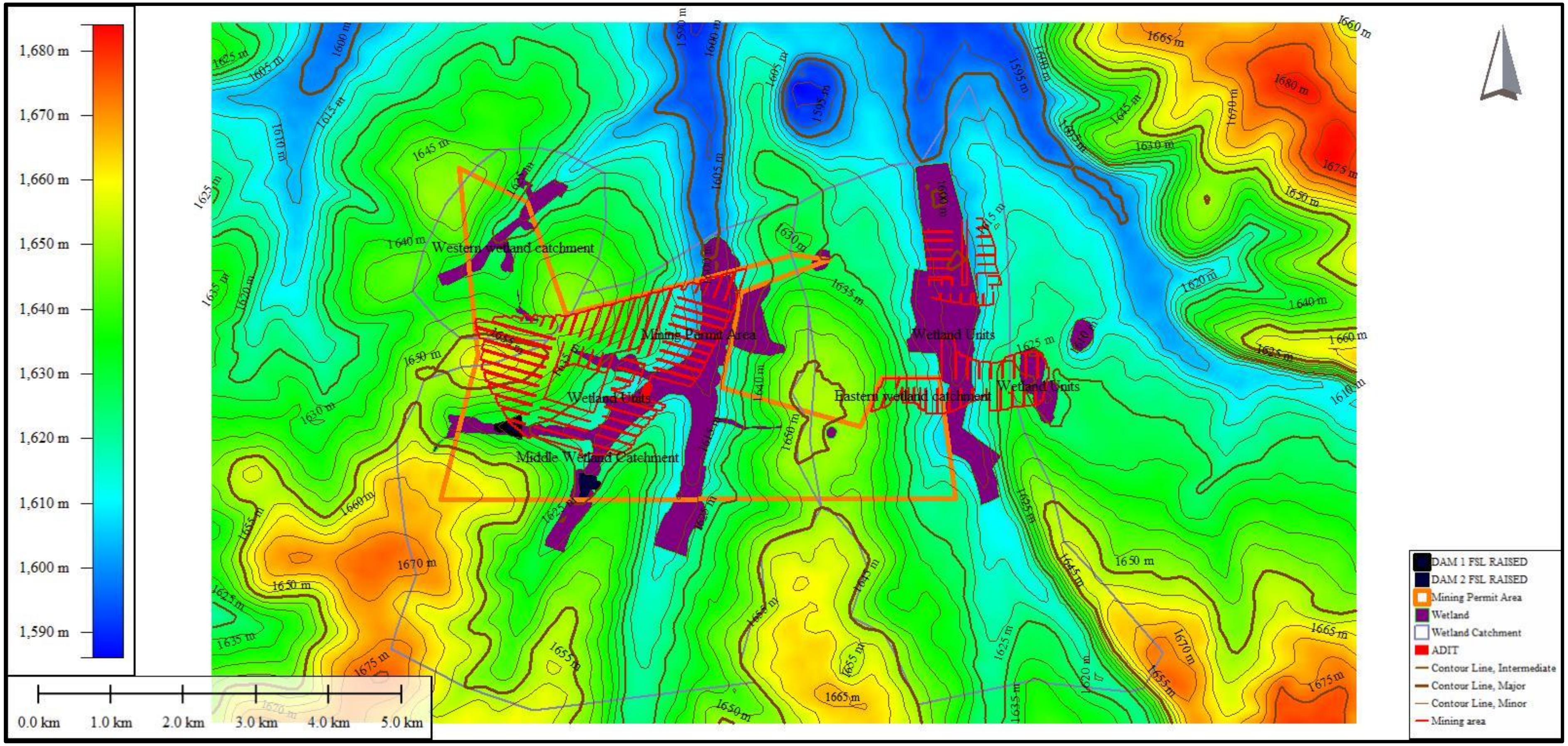


Figure 5: Wetland catchments

3.3 Assumptions

Wetlands are dependent on rainfall infiltrating the upslope soil, being partitioned by the subsoil and fractured rock, before flowing down slope to return to the soil surface and wetland, sometimes via a river system. A wetland may thus be considered a signature of the hydrological dynamics of its surrounding catchment. Wetlands are dependent on rainfall infiltrating the upslope soil, being partitioned by the subsoil and fractured rock, before flowing down slope to return to the soil surface and wetland, sometimes via a river system. A wetland may thus be considered a signature of the hydrological dynamics of its surrounding catchment.

The wetland's catchment determines the relative extent of different hydrological response types in the catchment and within specific hillslopes contained within the catchment. The impact on flow drivers of the wetland catchment is detailed below and is based on the following assumptions (*status quo*). A water balance[1] on the wetland catchment is represented by:

- Rainfall 100% of flow input
- Evapotranspiration is 50 – 70% of rainfall (outflow)
- Runoff is 10% (outflow)[2]
- Groundwater recharge is 5%[3] (outflow)
- 20 -30 % of the water being left in or stored the unsaturated zone or interflow zone feeding the wetland

It is not possible to measure any rates of water transfer exactly, and thus it is inevitable that quantification of the groundwater balance will not be precise. Although uncertainty is often perceived as a negative issue (often associated in people's minds with user error), it is a fact of life, especially when dealing with natural systems, and should be presented explicitly.

Based on the below estimates future efforts can during mining can be focused on the better measurement of the most uncertain mechanisms. One approach to the estimation of uncertainty is to quantify the rate of flow in each water transfer mechanism using various different methods.

The impact assessment is only valid for the Koppie mining area.

[1] Dynamics of MODIS evapotranspiration in South Africa, Nebo Jovanovic1*, Qiaozhen Mu2, Richard DH Bugan1 and Maosheng Zhao3, 1CSIR, Natural Resources and Environment. ISSN 0378-4738 = Water SA Vol. 41 No. 1 January 2015

[2] Midgley, D.C., Pitman, W.V. & Middleton, B.J. (1994) Surface Water Resources of South Africa 1990. Water Research Commission Report No 298/5.1/94, Pretoria, South Africa.

[3] An investigation into recharge in South African underground collieries by P.D. Vermeulen* and B.H. Usher. The Journal of The Southern African Institute of Mining and Metallurgy- Volume 106 -

3.4 Flow driver quantification

Table 2: Wetland flow driver impact only adit/shaft

Wetland system	Pre- Development catchment area	Impact on catchment area	Loss on catchment area	Loss
	m2	m2	m2	%
Western wetland system (HGM1)	6390000.0	0.0	6390000.0	0.0
Central wetland system (HGM 2)	23896000.0	4731.0	23891269.0	0.0
Eastern wetland system (HGM 3)	25141000.0	3038.0	25137962.0	0.0
Pans (HGM 4)	711000.0	0.0	711000.0	0.0

Table 3: Wetland flow driver impact adits and 30 to 50% subsidence

Wetland system	Pre development total flows	Post development total flow	Total loss of flow	Loss
	m3/a	m3/a	m3/a	%
Western wetland system (HGM1)	1789200.0	1744470.0	44730.0	2.5
Central wetland system (HGM 2)	6690880.0	5232045.0	1458835.0	21.8
Eastern wetland system (HGM 3)	7039480.0	6188840.0	850640.0	12.1
Pans (HGM 4)	199080.0	199080.0	0.0	0.0

4 IMPACT ASSESSMENT

The wetlands on site reflect the behaviour of water, predominantly rainfall, and its behaviour following interception and infiltration into the soils. Thus, activities that affect the movement of water as well as its quality in the catchment areas supporting wetlands, translate into changes in the wetlands to which they are invariably linked. Expected impacts include:

- Change in hydrology.
- Change in water quality, and
- Loss of wetlands and the biodiversity supported by these wetlands.

Impacts that lead to a change in hydrology include all impacts that influence the quantity (e.g., increased or decreased run-off) and velocity (e.g., concentration of flows) of flows leaving the site.

Increased flows and increased velocity of flows could result in increased erosion within the receiving environment, while decreased flows could result in a decreased wetland functionality.

Impacts that lead to deteriorating water quality, together with the impacts that change the hydrology, are expected to be the most significant impacts on site. From a wetland perspective, mitigation measures and management plans should focus on these impacts and it will need to be clearly shown in the EIA and EMP how these impacts will be ameliorated to prevent significant deterioration of the quality and quantity of water discharged to downstream areas. The impact assessment is discussed in the heading below.

The impact quantification was done using the procedures for the assessment and minimum criteria for reporting aquatic biodiversity in terms of sections 24(5)(a) and (h) and 44 of the National Environmental Management Act, 1998. In terms of groundwater the proposed development impact on the functioning of the aquatic feature in terms of:

- Baseflow.
- Quantity of water including change in the hydrological regime or hydroperiod of the aquatic ecosystem.
- Quality of water.
- The location of areas not suitable for development, which are to be avoided during construction and operation, where relevant.
- Additional environmental impacts expected from the proposed development
- The degree to which impacts, and risks can be mitigated.
- The degree to which the impacts and risks can be reversed.
- The degree to which the impacts and risks can cause loss of irreplaceable resources.
- A suitable construction and operational buffer for the aquatic ecosystem, using the accepted methodologies.

4.1 Environmental Impact Assessment (EIA) Regulations, 2017

The Environmental Impact Assessment (EIA) 2014 Regulations [as amended] promulgated in terms of Sections 24 (5), 24M and 44 of the National Environmental Management Act, 1998 (Act No. 107 of

1998) [as amended] (NEMA), requires that all identified potential impacts associated with the proposed project be assessed.

Table 4: Significance Rating of Impact(s)

Activity	Impact	Aspect	Phases	Risk Rating	Type Watercourse	Risk Rating
				No Mitigation		With Mitigation
			Phases	RR	Type Watercourse	RR
Proposed underground mining						
Adit	Flow driver impact	Flow cut-off	C	M	Perennial	L
Adit	Flow driver impact	Flow cut-off	O	M	Perennial	L
Underground mining	Water quality impact	Destruction of wetland	C	M	Perennial	L
Underground mining	Flow driver impact	Flow cut-off	O	H	Perennial	L

Table 5: Risk rating description

Low	0 - 19
Low to Medium **<30 low**	20 - 39
Medium **>30 <60**	40 - 59
Medium to High **>60**	60 - 79

5 MITIGATION MEASURES

The following mitigation measures are proposed:

- The shaft should either be (1) moved outside the wetland (at least 32 m) or (2) engineered that water ingress is not allowed during the development or operational phase or (3) the area where the shaft is placed within the wetland be ofsetted by a wetland offset specialist.
- Mining should only be employed where the overlying strata are competent and at least 20m thick. Pillars should be designed with at least a factor of safety (FOS) greater than 2.5 with sufficient strength to support the overlying strata. The FOS is the ratio of the strength of the pillar to the load imposed on it. The FOS is arrived at by carrying out compressive strength tests on core and taking into account the specific gravity of the overlying strata. Good pillar design will support the overlying strata and not result in collapses which impact on the surface land use and water aquifers.
- After mining the shafts/openings should be sealed on closure to prevent/retard water flow and haulages and shafts that should be reinforced on closure to ensure long-term sustainability as major water conduits, The area around the shaft should be free draining of surface water. ***It is imperative that this detailed plan be developed and submitted to regulators for approval at least 5 years before mine closure and definitely before any underground water pump systems are removed and before sections of the mine are allowed to start flooding***.
- The water flow and quality in the wetland system should be measured on a quarterly basis for the following variables:
    - Flow (m^3/day)
    - pH (pH units)
    - TDS (mg/l)
    - SO4 (mg/l)
    - Full metals by ICP-OES (mg/l)
- Expected mine contaminated water should be captured in the underground and either reused in the mine water balance or treated and released to the wetland system;
- Removal and storage of hydrophytes,
- Stockpiling of the stripped topsoil,
- Diversion of clean water into wetland around the mining permit and into the wetland catchments
- Collect the water arising within any dirty area, including water seeping from mining operations, outcrops or any other activity into a dirty water system; and
- Design, construct, maintain and operate any dirty water system at the mine or activity so that it is not likely to spill into any clean water system more than once in 50 years

6 Conclusions

The following conclusions could be drawn from the assessment:

- The floodplain wetland systems (HGM 1 and HGM 2) were identified within the 500 m buffer of the Proposed Koppie Mining Project. The floodplain wetland systems were assessed in terms of health and was found to be categorised as largely modified (Category D). The Ecological Services of the wetland has been recorded as intermediate and the sensitivity and importance (EIS) has been recorded as moderate.
- The soils follow a typical plinthic catena of the highveld that consisted of recharge soils on the crest, soil bedrock interflow on the midslope, more responsive soils on the toe slope and high clay content responsive soils in the valley bottom. The dominant flowpaths in the study area are recharge in the apedal horizons and overland flow on the responsive soils. Evaporation will be high on the responsive soils as water moves slowly through the profile.
- Porous sandstone overlies impervious dolerite/shale/clay creating these perched aquifers. Rainfall infiltrates the porous sandstones until it reaches the impervious layer, this perched aquifer is then drained by gravity until the aquifer daylights which is then the origin of the spring/wetland.
- Due to depth of underground mining of more than 50 m impacts on the unsaturated zone is not expected unless subsidence occurs. It is noted that that various exploration holes are situated across the proposed underground mining area which could create preferred pathways from the unsaturated and saturated zone to the dewatered underground. It should be noted that although these exploration holes (if not properly sealed) could create conduits the dewatering impact is expected to be less pronounced in the unsaturated zone than the saturated zone.
- Flow of water in the soil is driven by a hydraulic potential gradient, that it takes place in the direction of decreasing hydraulic potential, and that its rate is proportional to the potential gradient. These principles apply in unsaturated, as well as the saturated zone However, the nature of the moving force and the effective geometry of the conducting pores can be very different. Apart from the gravitational force, which is completely independent of soil water content, the primary moving force in a saturated soil is the gradient of a positive pressure potential. On the other hand, water in an unsaturated soil is subject to a sub-atmospheric pressure, or matric suction that is equivalent to a negative pressure potential. The gradient of this potential likewise constitutes a moving force.
- Modelling shows that impacts if left unmitigated are potential high with specific emphasis on the adit within the wetland and potential subsidence of underground mining.

7 Recommendations/Mitigation measures

The following recommendations are put forward:

- The shaft should either be (1) moved outside the wetland (at least 32 m) or (2) engineered that water ingress is not allowed during the development or operational phase or (3) the area where the shaft is placed within the wetland be ofsetted by a wetland offset specialist.
- Mining should only be employed where the overlying strata are competent and at least 20m thick. Pillars should be designed with at least a factor of safety (FOS) greater than 2.5 with sufficient strength to support the overlying strata. The FOS is the ratio of the strength of the pillar to the load imposed on it. The FOS is arrived at by carrying out compressive strength tests on core and taking into account the specific gravity of the overlying strata. Good pillar design will support

the overlying strata and not result in collapses which impact on the surface land use and water aquifers.

- After mining the shafts/openings should be sealed on closure to prevent/retard water flow and haulages and shafts that should be reinforced on closure to ensure long-term sustainability as major water conduits, The area around the shaft should be free draining of surface water. ***It is imperative that this detailed plan be developed and submitted to regulators for approval at least 5 years before mine closure and definitely before any underground water pump systems are removed and before sections of the mine are allowed to start flooding***.
- The water flow and quality in the wetland(s) system should be measured on a quarterly basis for the following variables:
    - Flow (m^3/day)
    - pH (pH units)
    - TDS (mg/l)
    - SO4 (mg/l)
    - Full metals by ICP-OES (mg/l)
- Expected mine contaminated water should be captured in the underground and either reused in the mine water balance or treated and released to the wetland system;
- Removal and storage of hydrophytes,
- Stockpiling of the stripped topsoil,
- Diversion of clean water into wetland around the mining permit and into the wetland catchments
- Collect the water arising within any dirty area, including water seeping from mining operations, outcrops or any other activity into a dirty water system; and
- Design, construct, maintain and operate any dirty water system at the mine or activity so that it is not likely to spill into any clean water system more than once in 50 years.