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Hydropedology Assessment for the Proposed Co-Disposal Facility & Water Treatment Plant at Kangra Maquasa East Operations

Report

Version - Final 1

17 November 2023

Kangra Coal

GCS Project Number: 22-0161_PED

Client Reference: 111862



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DECLARATION OF INDEPENDENCE

GCS (Pty) Ltd was appointed to conduct this specialist study and to act as the independent hydropedological specialist. GCS objectively performed the work, even if this results in views and findings that are not favourable. GCS has the expertise in conducting the specialist investigation and does not have a conflict of interest in the undertaking of this study. This report presents the findings of the investigations which include the activities set out in the scope of work.

APPENDIX 6 OF THE EIA REGULATION – CHECKLIST AND REFERENCE FOR THIS REPORT

Table 1 - Requirements from Appendix 6 of GN 326 EIA Regulation 2017

Requirements from Appendix 6 of GN 326 EIA Regulation 2017	Chapter
(a) Details of: (i) The specialist who prepare the reports; and (ii) the expertise of that specialist to compile a specialist report including a curriculum vitae	Page ii
(b) Declaration that the specialist is independent in a form as may be specialities by the competent authority	Appendix E.
(c) Indication of the scope of, and purpose for which, the report was prepared	Page ii
(cA) Indication of the quality and age of base data used for the specialist report	Appendix B.
(cB) A description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change	Section 1.
(d) Duration, Date and seasons of the site investigation and the relevance of the season to the outcome of the assessment	Sections 1, 2 and 3.
(e) Description of the methodology adopted in preparing the report or carrying out the specialised process include of equipment and modelling used	Section 4.
(f) Details of an assessment of the specifically identified sensitivity of the site related to the proposed activity or activities and its associate's structures and infrastructure, inclusive of a site plan identifying alternative	Section 1.3.
(g) Identification of any areas to be avoided, including buffers	Section 1.2
(h) Map superimposing the activity and associated structures and infrastructure on environmental sensitivities of the site including areas to be avoided, including buffers	Sections 1, 2, 3 and 4
(i) Description of any assumptions made and uncertainties or gaps in knowledge	Section 5.1
(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	Sections 1, 2 and 3
(k) Mitigation measures for inclusion in the EMPr	Sections 2, 4, and 5.
(l) Conditions for inclusion in the environmental authorisation	Executive summary, Section 5.
(m) Monitoring requirements for inclusion in the EMPr or environmental authorisation	Section 5.
(n) 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, and avoidance, management, and mitigation measures should be included in the EMPr, and where applicable, the closure plan	Refer to Section 5.3
(o) Description of any consultation process that was undertaken during preparing the specialist report	None required.
(p) A summary and copies of any comments received during any consultation process and where applicable all responses thereto	None required.
(q) Any other information requested by the competent authority	None required.

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LIST OF ACRONYMS

Acronym	Description
A	Diagnostic A horizon
A/B	Interflow soil type A/B
A/Bedrock	Interflow soil type A/Bedrock
B (B1, B2, B3 etc.)	Diagnostic B horizon
BA	Basic Assessment
BOD	Biological oxygen demand
COD	Chemical oxygen demand
CSWMP	A conceptual stormwater management plan
CVB	channel valley bottom wetland
CVB	Channelled valley bottom wetland
DEM	Digital Elevation Model
DWS	Department of Water and Sanitation
E	Diagnostic E horizon
G	G Horizon/soil
GCS	GCS Water and Environment (Pty) Ltd.
GN704	General Notice 704
ha	Hectare
HOSASH	Hydrology of South African Soils and Hillslopes
HRU	Hydrological Response Unit
HST	Hydrological Soil Type
IWULA	Integrated Water Use Licence Application
m^3	Cubic Metres
MAE	Mean annual evaporation
MAR	Mean Annual Runoff
MIPI	Midgley and Pitman
NEMA	National Environmental Management Agency
n-Value	Manning's Roughness Coefficients
NWA	National Water Act, 1998 (Act No. 36 of 1998)
O	Orthic Horizon/soil
PCD	Pollution Control Dam
PFD	Process flow diagram
RP	Riparian zone/wetland
S	Seepage wetland
SDF	Standard design flood
SW	Surface Water
TDS	Total dissolved solids
TIN	Triangulated Irregular Network
UCVB	Unchanneled valley bottom wetland
UVB	un-channelled valley bottom
V	Vertic Horizon/soil
WMA	Water Management Area
WR2012	Water Resources of South Africa 2012
WTW	Water Treatment Works
PES	Present Ecological State
EIS	Ecological importance and Sensitivity

1 INTRODUCTION

GCS Water and Environment (Pty) Ltd (GCS) was appointed by Kangra Coal (Pty) Ltd to undertake a hydropedology assessment for the proposed development of a Co-Disposal Facility and Water Treatment Plant (WTP) at Maquasa East operations, near Driefontein, Mpumalanga Province (refer to Figure 1-4). The project falls in quaternary catchment W51B of the Pongola to Mtamvuna Water Management Area (WMA) (DWS, 2016).

1.1 Project background

Kangra Coal is an existing coal mine located in Driefontein, near Piet Retief, in the Mkhondo Local Municipality within the Gert Sibande District Municipality. The Maquasa East (MQE) operations include the historical opencast and underground operations. Kangra is proposing to construct a water treatment plant as well as a co-disposal facility at their Maquasa East operations. The treatment plant will be used to treat water from the existing decant point as well as any surplus water within the mining operations.

1.1.1 Water Treatment Plant:

Decant is currently observed in the form of clear groundwater discharge emanating from the old underground workings at MQE close to the Heyshope Dam. This decant is observed at an elevation range of approx. 1303 to 1306 mamsl and is contained in an unlined contamination dam. This excess decant is currently pumped from the unlined dam back to the MQE PCDs. Based on available data from previous studies undertaken at the mine decant observed emanating from the old workings occurs at a rate ranging from 1 220 to 2 700 m^3/d (average 1 800 m^3/d), depending on the rainfall season.

Kangra intends to upgrade the current contamination dam with a correctly lined dam as approved by the Department of Water and Sanitation to prevent any seepages onto the Heyshope Dam. The decant will be pumped into the proposed wastewater treatment plant that will be situated close to the Maquasa East PCDs. Construction and operation of the discussed infrastructure will trigger listed activities that will require authorisation.

The master layout plan associated with the proposed water treatment plant and brine storage facilities proposed (and existing PCDs) is shown in Figure 1-1.

It should also be noted that Kangra is investigating the possibility of storing brine on the discard dump/co-disposal that will come from the water treatment plant. This is one of the two options, with the other being dedicated brine evaporation ponds. GCS has not yet received confirmation as to which option Kangra are opting for, thus impacts relating to both are considered in this assessment.

Treated water will be discharged into the Heyshope dam at the existing decant rate at pristine water quality (in line with GA limits for treated effluent discharge), and therefore will likely not have a negative impact on water quantity or quality. Compared to the active decant wate quality, the proposed activity is predicted to improve the Heyshope water quality. Proposed discharge will take place at an existing abstraction point west of Driefontein, that is no longer in use.

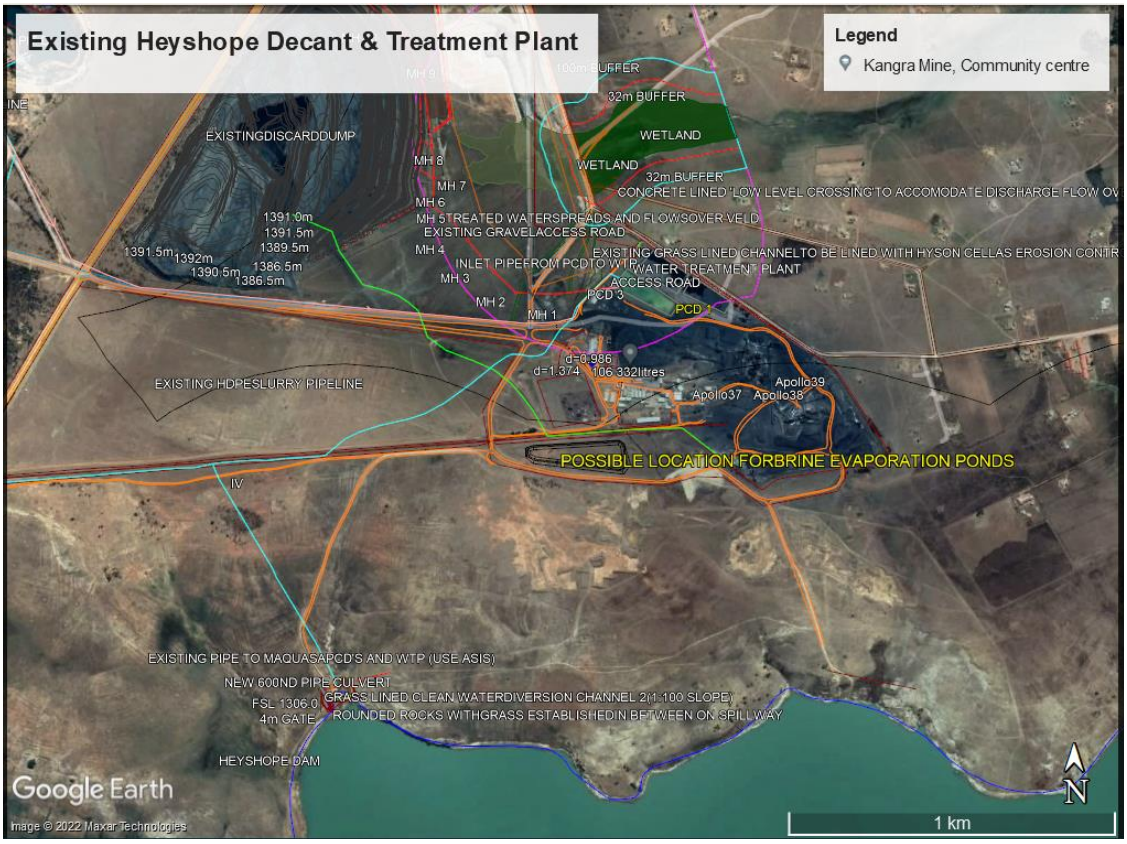


Figure 1-1: Proposed WTP and possible brine evaporation pond

1.1.2 Co-Disposal Facility

The discard dump at MQE has an approved environmental authorisation and a water use license. As a result of changing operational requirements, there is now a need for a co-disposal facility at MQE, this co-disposal facility is not authorised.

- The co-disposal facility will be located within the MQE operation on the remaining (RE) portion of the farm Rooikop 18 HT. The co-disposal facility will accommodate discarded produced from the benefaction plant located at Maquasa East, which currently washes and processes coal from the surrounding Kangra Coal operations and will receive coal from future expansion areas.
- This discard dump was originally designed as a three-compartment side hill-type dump with a footprint of approximately 65ha. The three-compartment layout allows for a modular implementation approach with the benefit of delaying capital expenditure. The implementation of this project will be done in two phases:

- Phase 1 will entail the use of the approved discard dump, and
- Phases 2 and 3 will entail the use of a co-disposal facility that requires authorisations.

In the phases, the plan is to build the full waste dump over 20 years. Phase 1 (7 years capacity), Phase 2 (7 years capacity), and Phase 3 (6 years capacity). GFK are undertaking detailed designs of the dump, as well as stormwater sizing. The facility will be lined with an impermeable barrier. The layout plan for the co-disposal facility is shown in Figure 1-2.

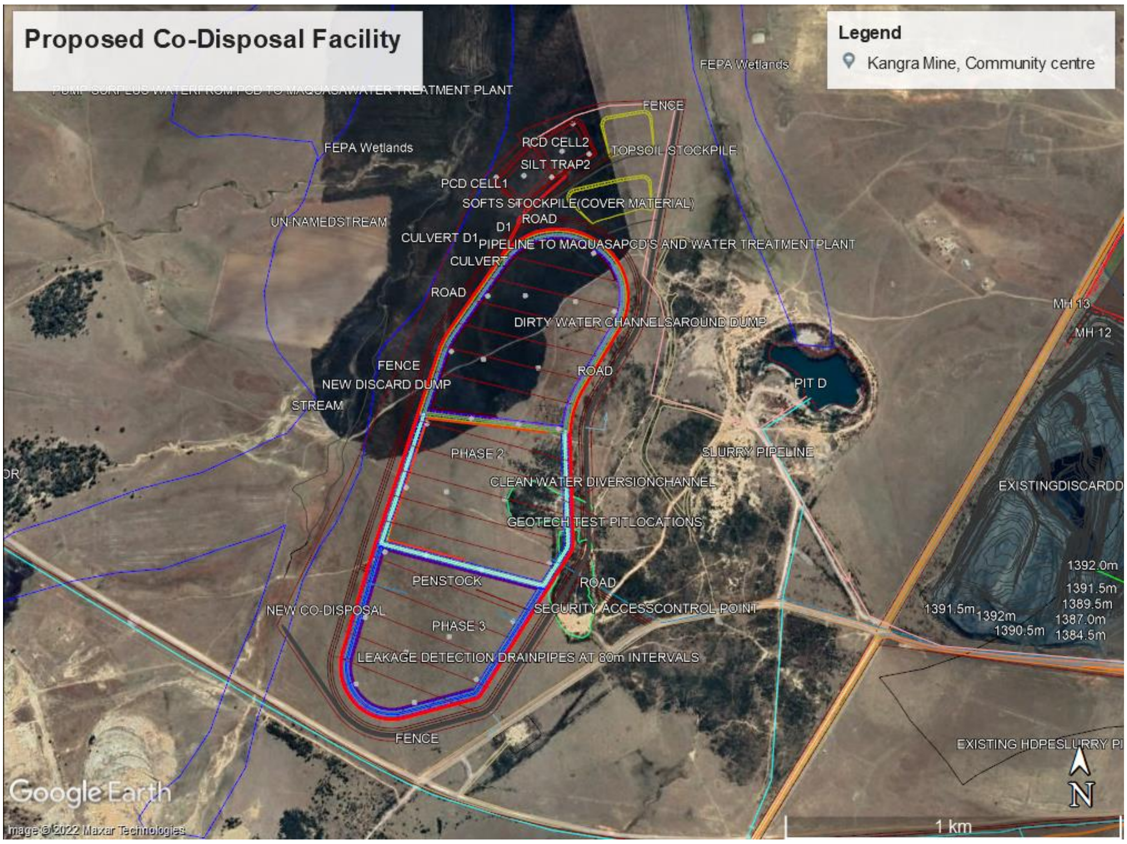


Figure 1-2: **Proposed Co-Disposal Facility (Phase 1 already approved, Phase 2 & 3 will be co-disposal)**

1.2 The focus of this study

This hydropedology assessment focuses on the proposed co-disposal facility and probable impacts on the hydropedological flow drivers if the co-disposal facility is constructed. The proposed WTP and the brine pond are situated in an already impacted area (near and in the beneficiation area). As such, there may have already been an impact on hydropedology since mining started in 1996. Considering scaling, the co-disposal facility has a higher potential to impact hydropedology flow drivers, as opposed to the small WTP and brine pond.

1.3 Study objectives and methodology

Soils develop over time under the influence of chemical, physical, and biological processes (refer to Figure 1-3). Soils are predominantly the result of in-situ weathering of the host rock (i.e. has characteristics associated with the parent geological occurrence/rock). Soil has an interactive relationship with hydrology (i.e. climate, rainfall duration, runoff patterns, groundwater contribution to baseflow, evaporation etc.). It is a product of water-related processes (physical and chemical) and a first-order control of the destination of rainwater. Though hydrological processes change seasonally, soil characteristics and water transfer capabilities remain similar throughout the year. A once-off study was undertaken.

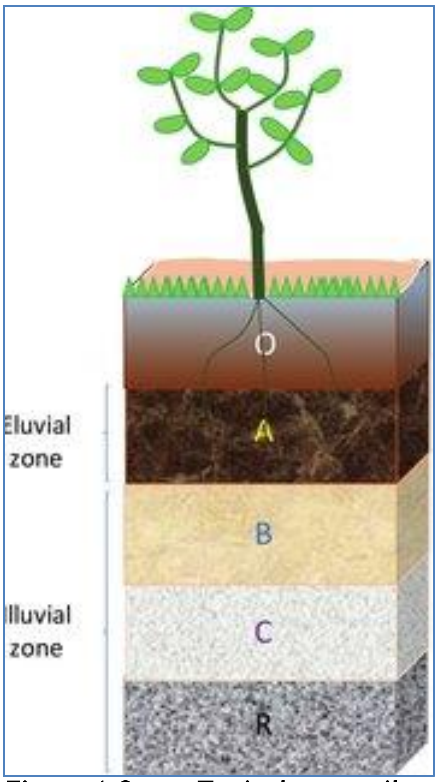


Figure 1-3: Typical soil genesis

The objectives of this hydropedological assessment were to:

1. Evaluate the soils in the study area:
    - Soils were classified per the taxonomic system for South Africa (Department of Agricultural Development, 1991); (SCWG, 2018)
    - Soil permeability was estimated based on available data (i.e. field characterised textures and public soil data) and according to best practice guidelines (FAO, 1980); and (DWS, 2011).
2. Derive hydropedological flow regimes and interaction areas:
    - In the determination of Hydrological Soil
    - Types (HST), soils were divided into classes based on their expected hydrological responses (Van Tol, et al., 2013).
3. Quantification of the hydropedological fluxes using a spreadsheet-based water balance model:
    - A simple spreadsheet-based water balance model was used to illustrate unsaturated zone fluxes/water balances.
4. Conceptualise the water flow dynamics and derive hydropedological flow buffer areas (if required) for wetlands identified in the area.
    - Hydrological processes were perceived from traceable signatures in the soil matrix resulting from the soil's ability to transmit, store and react with water (Le Roux, et al., 2011).

5. Identify potential hydropedological impacts per standard DWS & EIA impact criteria and risk rating (refer to **Appendix B**).

1.4 Legislative considerations

The study scope of works and objectives coincide with DWS guidelines for Hydropedology Studies (Van Tol; Bouwer, J.J, 2021). Based on the proposed activities, the scope of this study, the budget allocated to this study and time frames during this study, a "Step 1 to Step 4" type study could be completed, which entails:

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

1.5 Study relevance to the season in which it was undertaken

This study was undertaken as a once-off study and relies on historical hydrological and climate data for the site; as well as recognized hydrological and water resource databases for South Africa. Data generated during the time of this study is not seasonally bound as average yearly data was applied where required and as scientifically acceptable.

1.6 Scope of Work

The scope of work completed was as follows:

1. **Desktop study:**
    a. All available reports (which were provided by the client) relating to the site were assessed.
    b. Evaluation of soil occurrences in the study area, based on available South African databases.
2. **Field investigation:**
    a. Several auger holes were drilled in the project area, in pre-determined hillslope areas.
    b. The soils identified in the study area were screened per the Soil Classification guidelines for South Africa (Department of Agricultural Development, 1991) and (SCWG, 2018) to derive hydropedological flow regimes.
3. **Hydropedological assessment:**
    a. Meteorological evaluation.
    b. Catchment delineation.

c. Estimation of soil permeability and soil flow processes based on field observation and desktop data.

d. HOSASH (Hydrology of South African Soils and Hillslopes) index.

4. **Water balance and flow modelling:**

   a. A simple spreadsheet-based water balance model was used to illustrate unsaturated zone fluxes/water balances.

   b. The total water loss during a development phase concerning the natural water processes in a sub-catchment was estimated. This was used in conjunction with the water balance flow model to determine the natural stream loss % for a sub-catchment and associated hillslopes.

5. **Risk assessment:**

   a. The risk and impact criteria (refer to **Appendix B**) were applied to the study area, to evaluate hydropedological risks.

   b. Natural flow losses were estimated, using a spreadsheet water balance developed for the site.

6. **Mapping and report:**

   a. Several hydrological hillslope profiles, soil distribution and hydrological soil type maps were produced; and

   b. This report was compiled.

1.7 Gaps and limitations

The following study limitations are recognised:

- The concepts presented are simplifications of the temporal variability of water transfer functions. Realistically, water transfer functions, such as throughflow and groundwater sources, may take a few months up to several years to recharge streams (Le Roux, et al., 2011) However, hydropedology hillslopes have been effectively applied to simulate runoff response mechanisms (Van Tol, et al., 2013).
- Per minimum requirements for hydropedology studies published by DWS (Van Tol, J.J., Bouwer, D. & Le Roux, P.A.L., 2021), this “Level 3” study was undertaken (field investigation, conceptualisation of hillslopes and soil flow suppression). No numerical unsaturated flow modelling was undertaken, but simple analytical spreadsheet water balance/flux modelling.
- It is understood that all gaps and data limitations noted during this investigation will be committed to as future works. This report can therefore be considered a work-in-progress document, which can be updated as the project changes from planning to the closure phase.

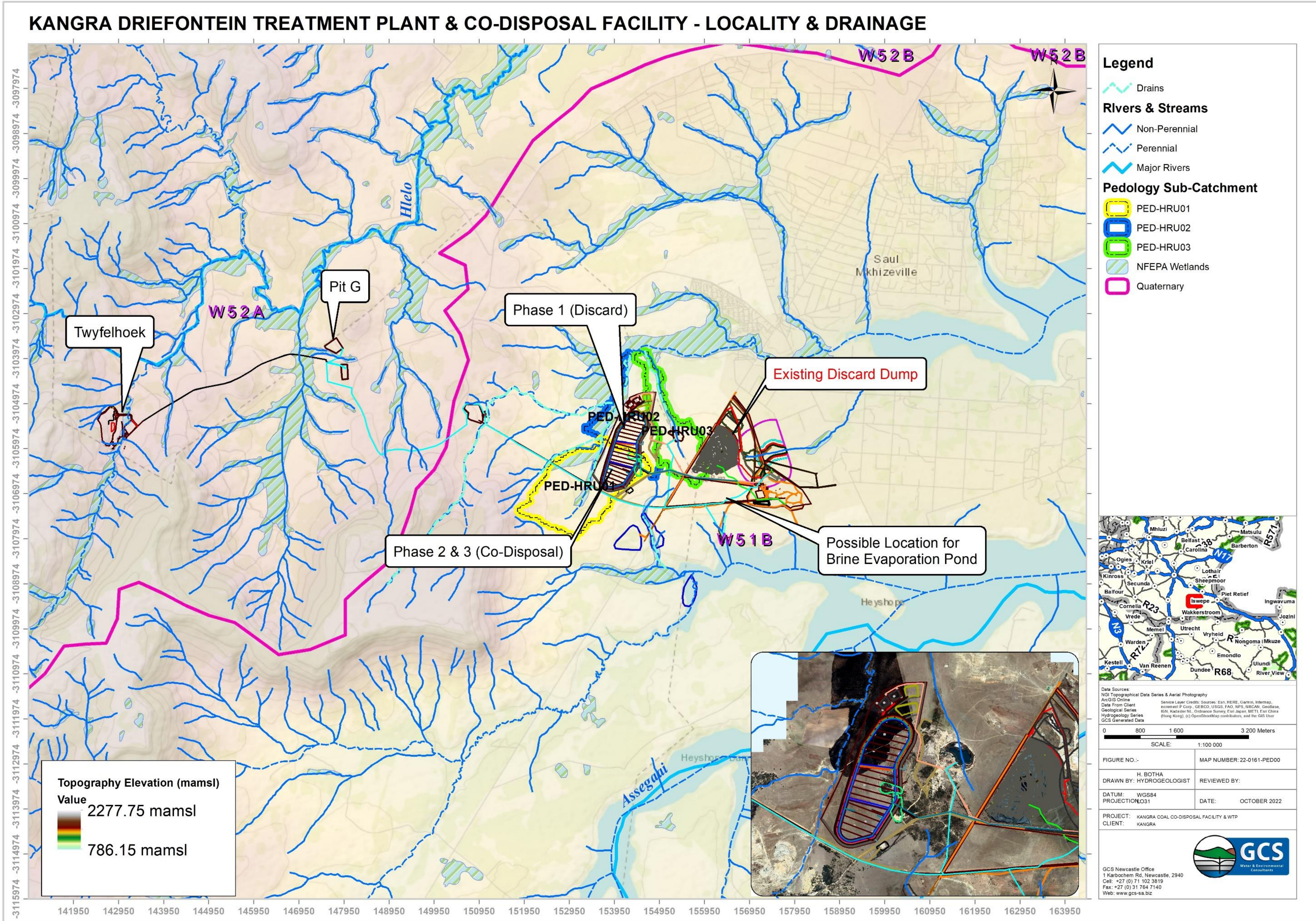


Figure 1-4: **Site locality and drainage**

2 SITE OVERVIEW

As mentioned previously, the project falls in quaternary catchment W51B of the Pongola to Mtamvuna Water Management Area (WMA) (DWS, 2016). Elevations on the site typically range from 1 300 to 1 600 meters above mean sea level (mamsl).

2.1 Sub-catchments/hydrological response units (HRUs)

Three (3) hydrological response unit (HRUs) describes the natural drainage and hydropedology flow boundaries associated with the site (using a 1:1 000 stream count and 30 m DTM fill) – refer to Figure 1-4 and Figure 2-1. The sub-catchment relates well to desktop-delineated drainage lines for the project area, as well as verified streams associated with the project area.

Primary drainage from the position of the proposed co-disposal site, and much of the MQE area is towards the northeast, to the perennial Egude River, which makes up the bottom inflow of the Heyshope Dam. Drainage from the southern portions of the MQE area, and Maquassa West (MQW) is towards the south, via several perennial and non-perennial drainage lines, towards the southern inflow of the Heyshope Dam. The Heyshope Dam is therefore the end received of any surface water-related pollution that may take place at the MQE operations.

2.2 Land cover & slope rise

The dominant land types associated with the sub-catchment are shown in Figure 2-1 (DEA, 2019), and is observed to be natural grasslands. The slope % rise for the general area is shown in Figure 2-2. Slope rise % was used to characterise the sub-catchment slope, hydropedology flow fields and general drainage.

2.3 Local geology & soils

According to the 1:250 000 geological series (2730 Vryheid), the local surface geology is characterised by occurrences of dolerite, and sediments associated with the Vryheid Formation, of the Ecca Group, of the Karoo Sequence (DMEA, 1998g) – refer to Figure 2-3.

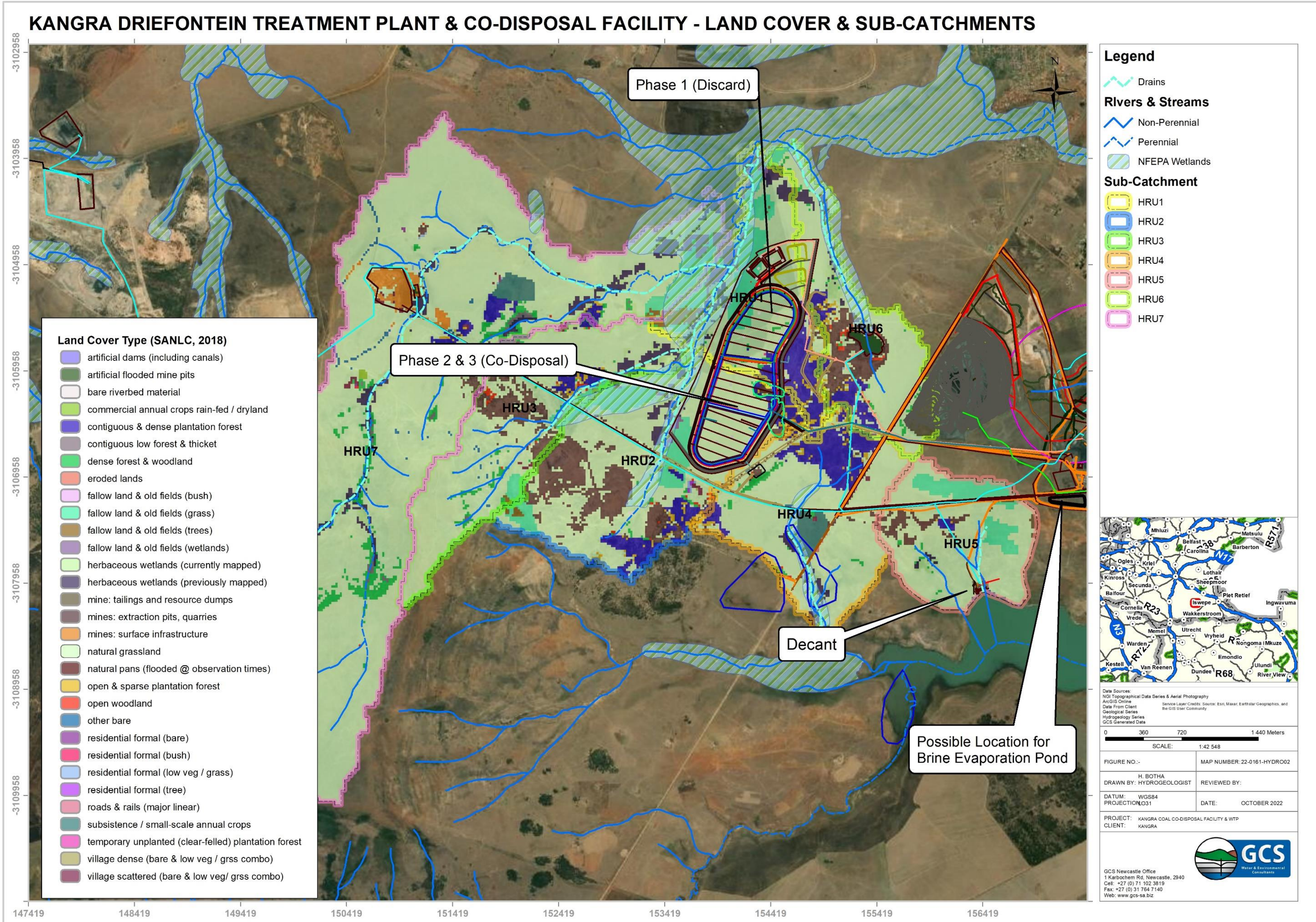


Figure 2-1: Sub-catchments and land cover types

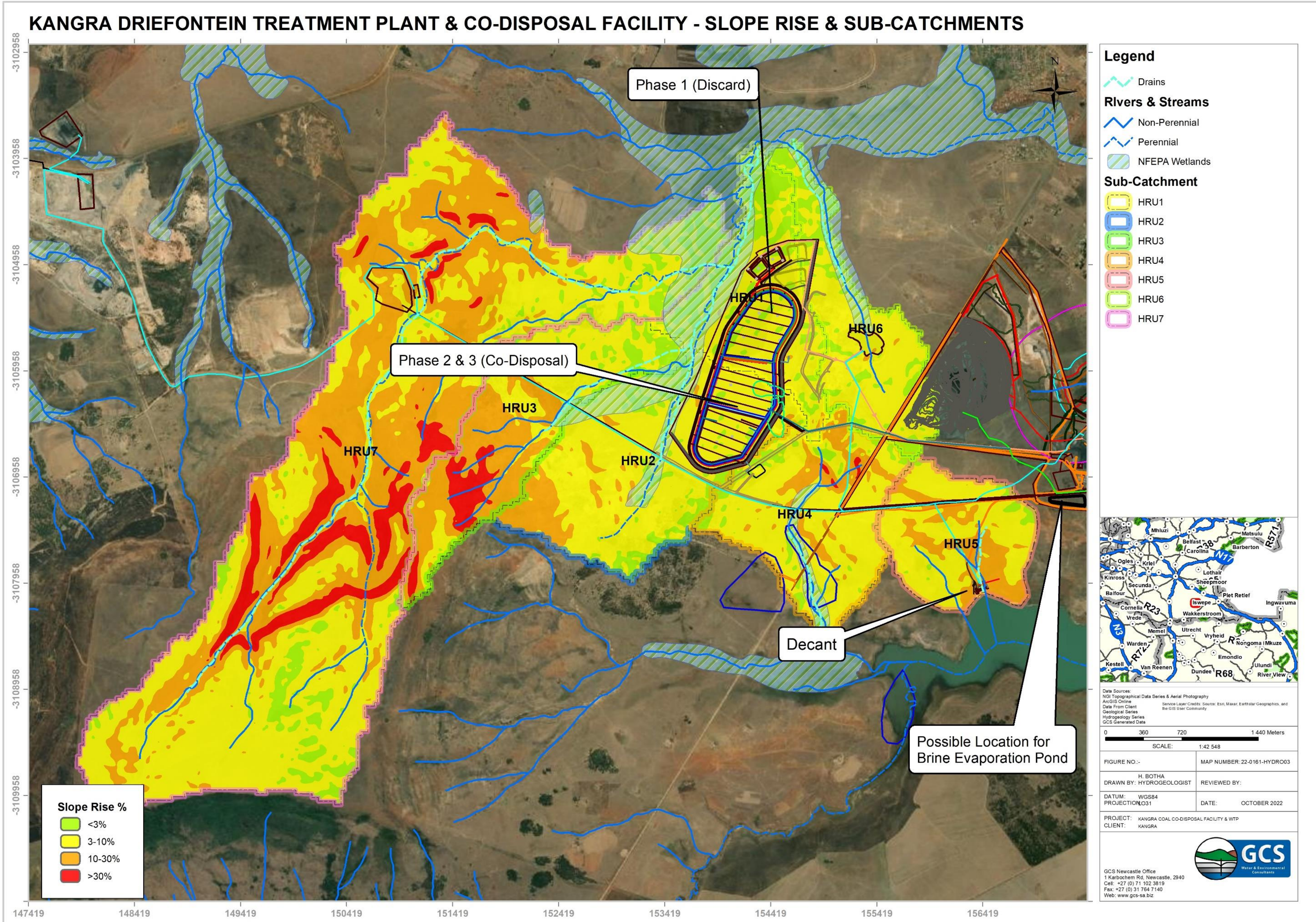


Figure 2-2: Sub-catchments and surface slope rise %

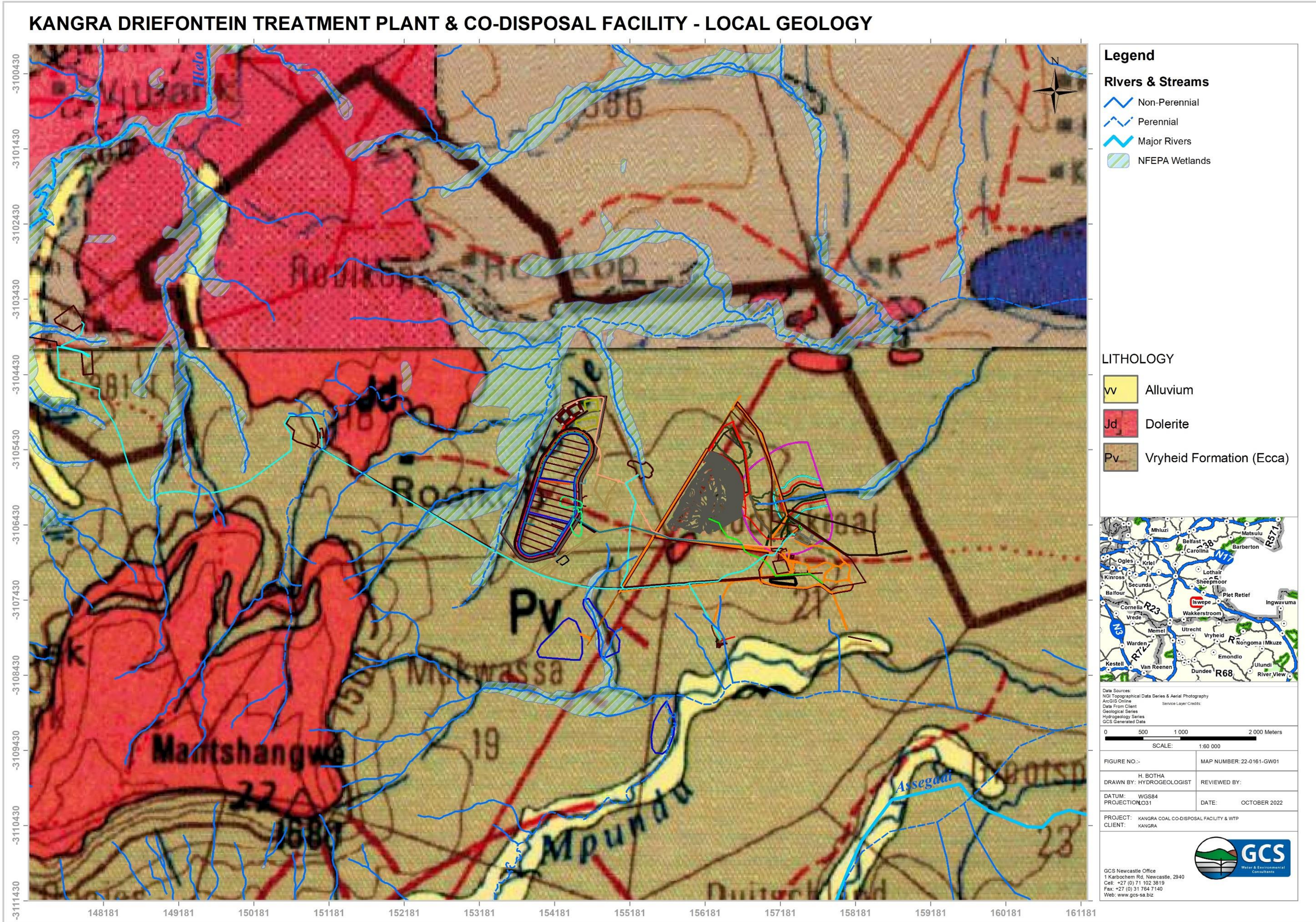


Figure 2-3: Local geology

2.4 Climate

Climate, amongst other factors, influences soil-water processes. The most influential climatic parameter is rainfall. Rainfall intensity, duration, evaporative demand and runoff were considered in this study to indicate rainfall partitioning within the project area.

2.4.1 Temperature

The average yearly temperature (refer to Figure 2-4) for the project area ranges from 25 to 33°C (high) and -4 to -2°C (Low). The study area is situated in a subtropical highland climate or temperate oceanic climate with dry winters (Cwb) area, as per the Köppen Climate Classification (Kottek, et al., 2006). The project area receives summer rainfall.

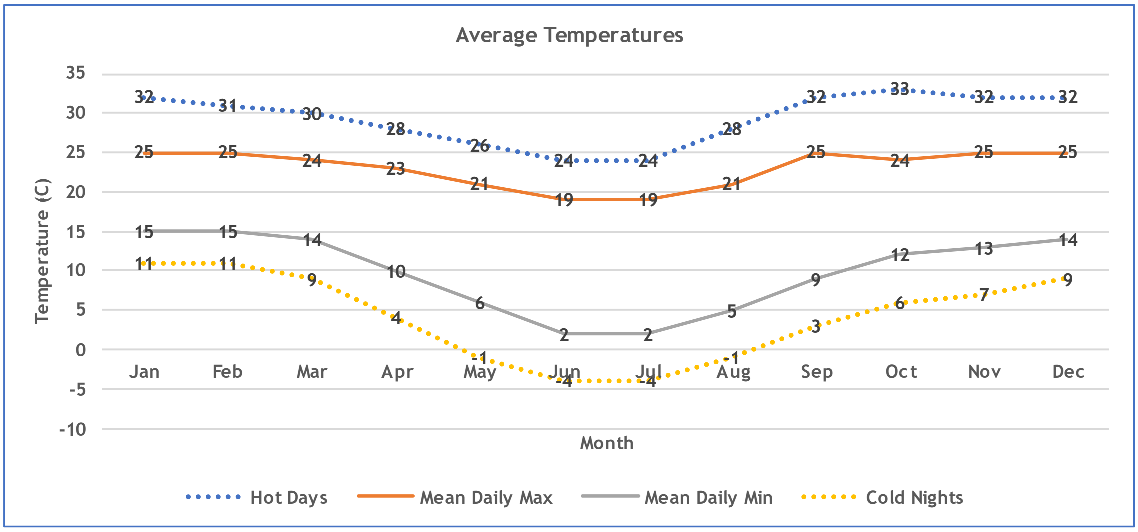


Figure 2-4: Average yearly temperatures (Meteoblue, 2022)

2.4.2 *Wind speed and direction*

Figure 2-5 shows the wind rose for the project area (Vryheid used as reference) and presents the number of hours per year the wind blows from the indicated direction. The wind blows from WW, ENE and E more often, at velocities ranging from 1 km/hr to 28 km/hr; and from other directions but less frequently and at lower velocities (< 19 km/hr).

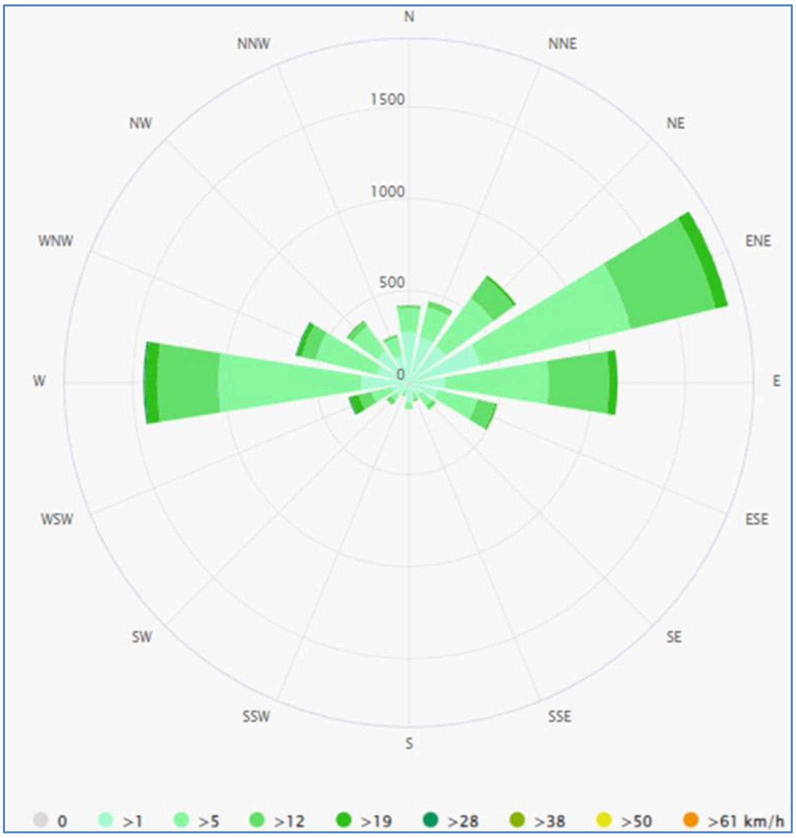


Figure 2-5: Wind rose (Meteoblue, 2022)

2.4.3 *Rainfall and evaporation*

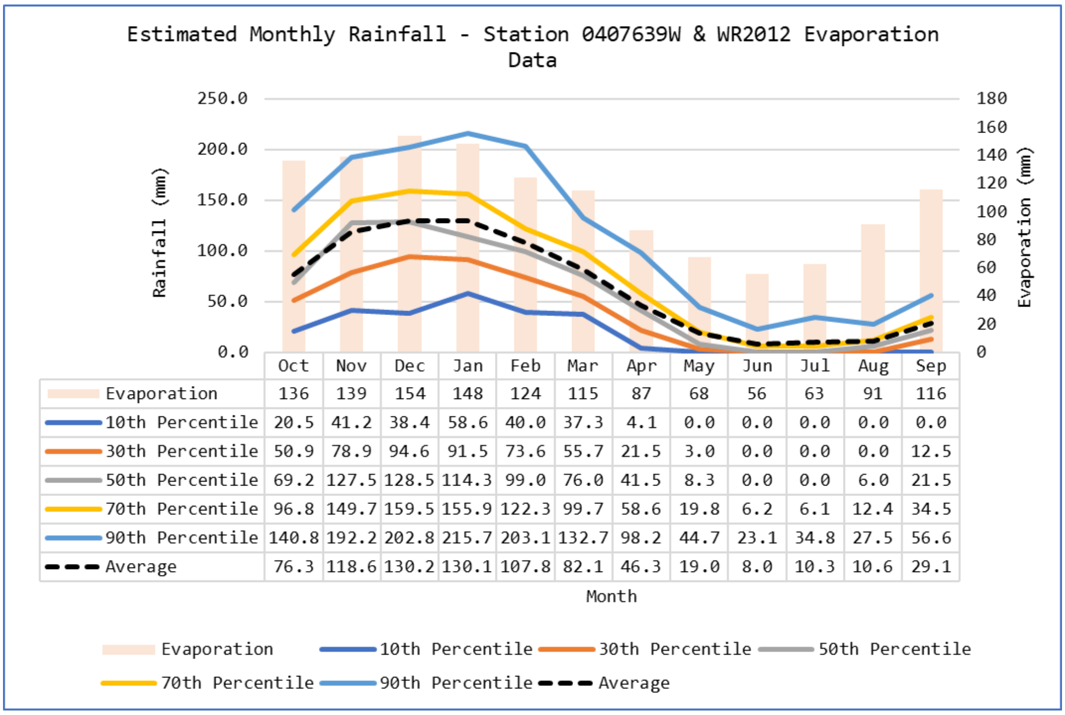
The project area is situated in rainfall zone W5A. The mean annual precipitation (MAP) measured at several rainfall stations that fall close to the site is summarised in Table 2-1, below.

Table 2-1: MAP of nearest rainfall stations

Station Name	ID	MAP (mm/yr)
GROOT RIETVLEI	0407639_W	770
DIRKIESDORP (POL)	0407730_W	681
SPITSKOP	0407397_W	800
BRERETON PARK	0443807_W	900
Average		**787.75**

The monthly rainfall data used to calculate MAP was obtained from rainfall station 0407639W (Grootvlei). The rainfall record is for the period 1929 to 2003 (74 years). Monthly rainfall for the site is likely to be distributed as shown in Figure 2-6, below.

Available rainfall data suggest a MAP ranging from 482 (30th percentile) to 1372 (90th percentile) mm/yr. The average rainfall is in the order of 768 mm/yr. The project area falls within evaporation zone 13A, of which Mean Annual Evaporation (MAE) ranges from 1 200 to 1 300 mm/yr. The MAE far exceeds the MAP for the site, which implies greater evaporative losses when compared to incident rainfall. Monthly evapotranspiration for the site is likely to be distributed as shown in Figure 2-6, below.



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Evaporation	136	139	154	148	124	115	87	68	56	63	91	116
10th Percentile	20.5	41.2	38.4	58.6	40.0	37.3	4.1	0.0	0.0	0.0	0.0	0.0
30th Percentile	50.9	78.9	94.6	91.5	73.6	55.7	21.5	3.0	0.0	0.0	0.0	12.5
50th Percentile	69.2	127.5	128.5	114.3	99.0	76.0	41.5	8.3	0.0	0.0	6.0	21.5
70th Percentile	96.8	149.7	159.5	155.9	122.3	99.7	58.6	19.8	6.2	6.1	12.4	34.5
90th Percentile	140.8	192.2	202.8	215.7	203.1	132.7	98.2	44.7	23.1	34.8	27.5	56.6
Average	76.3	118.6	130.2	130.1	107.8	82.1	46.3	19.0	8.0	10.3	10.6	29.1

Figure 2-6: Average rainfall for Station 0407639W & WR2012 evaporation

2.4.4 Runoff

Runoff from natural (unmodified) catchments for quaternary catchment W51B is simulated in WR2012 (WRC, 2015) as being equivalent to 103.5 mm/yr (or 13% of the MAP). This is approximately 51.369 Mm^3/yr NMAR for the surface area of W51B.

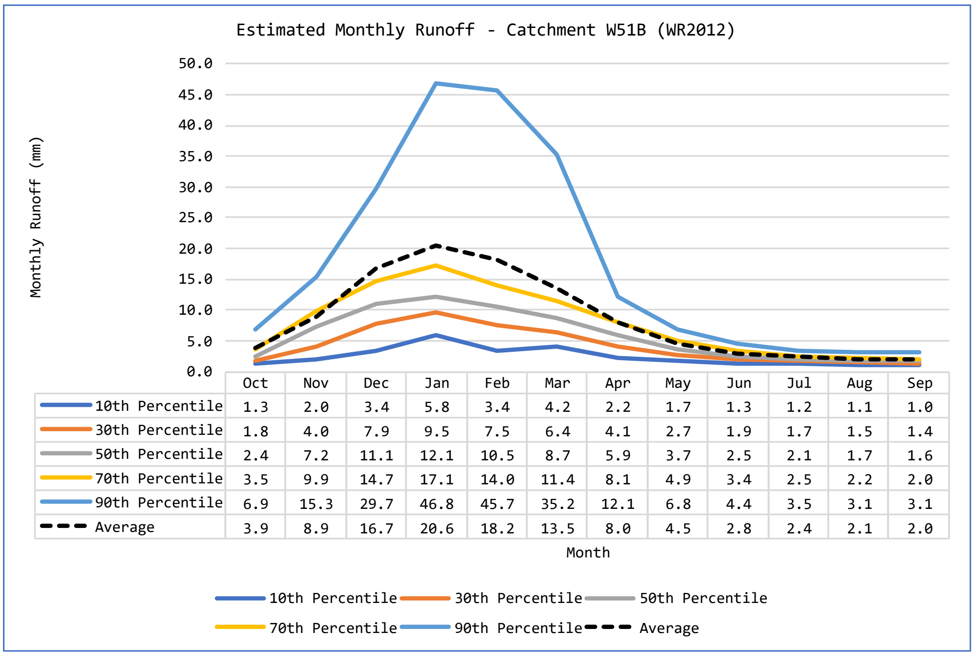


Figure 2-7: Simulated natural (unmodified) runoff for W51B

2.5 Surface water and groundwater users in the study area

According to Water Allocation Registration Management System (WARMS, 2019), there are no WARMS water users within a 5 km radius of the proposed activity. According to SADAC GIP and National Groundwater Activities (NGA) data, there are at least 3 registered boreholes within a 5 km radius of the proposed activities (refer to Figure 1-4 and Table 2-2).

Table 2-2: Groundwater users within a 2.5 km radius of the site

ID	Source	Latitude (WGS84) Decimal Degrees	Longitude (WGS84) Decimal Degrees	Elevation (mamsl)	Water Level (mbgl)
736675	SADAC GIP / NGA 2022	-27.06383	30.39031	1322	2.1
736687	SADAC GIP / NGA 2023	-27.02717	30.41504	1351	15
611988	SADAC GIP / NGA 2024	-26.974167	30.400833	1351	No Data

GCS (2022) identified two (2) groundwater boreholes within a 5 km radius of the proposed co-disposal facility (namely FB7 and FB8) that are used for groundwater supply. The boreholes are used by Kangra to supply water to the Community Health Centre.

2.6 Depth to groundwater

According to (Vegter, 1995) and (DWAF, 2006), the groundwater levels within the region are expected to range from 15 to 30 mbgl (meters below ground level). Available monitoring boreholes data for Kangra suggest a water level range from 1.28 to 131 mbgl (nearing the MQW underground workings in the mountains), with an average water level in the order of 12.4 mbgl for the MQE area.

Available water level data for boreholes in the area suggest there is a good correlation between the surface topography and the groundwater table (refer to Figure 2-8, R ~ 90%). The groundwater table is expected to mimic the topography and be shallower closer to perennial streams (i.e. these are prominent groundwater contributions to base-flow areas or areas where groundwater seepage from the resource into the aquifer units may take place).

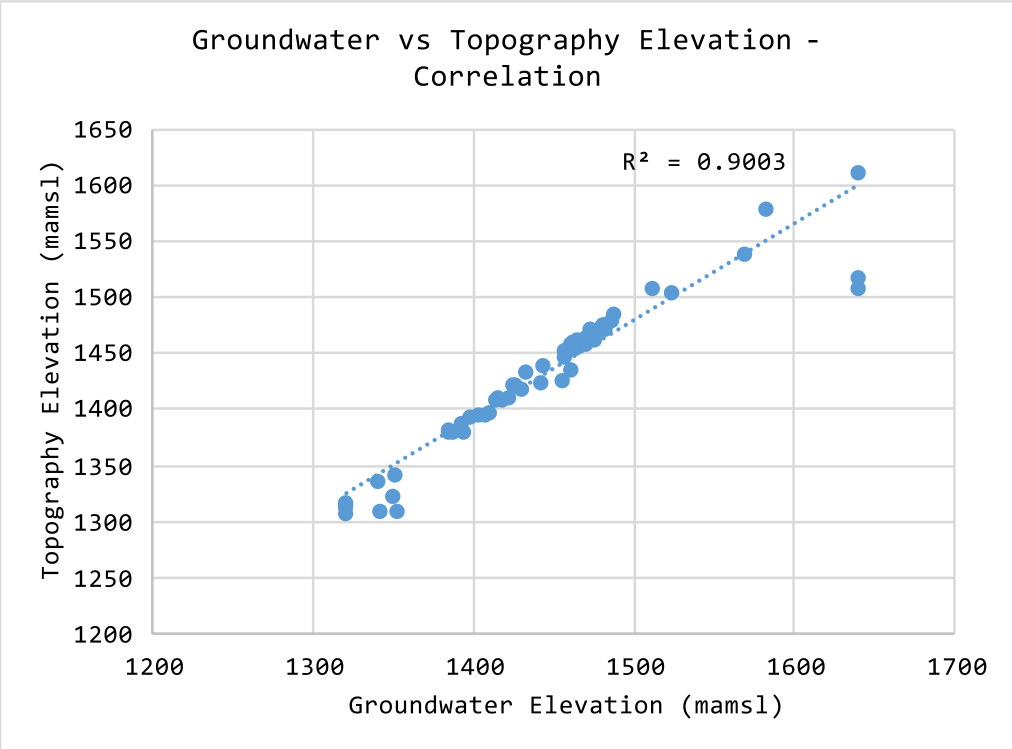


Figure 2-8: Groundwater elevation vs topography elevation - correlation (Kangra Monitoring Holes)

2.7 Wetland areas

Based on available National Wetland Freshwater Ecosystem Priority Areas (NFEPA) (Van Deventer, 2018) the non-perennial and perennial drainage areas situated downstream of the proposed co-disposal facility are classified as channelled valley bottom (CVB) wetland areas of the Mesic Highveld Grassland Bioregion (refer to Figure 1-4).

In terms of wetland geo-hydrology, base flow is considered the most important contributor to wetland health. Base flow (refer to Figure 2-9) is a non-process-related term to signify low amplitude high-frequency flow in a river during dry or fair-weather periods. Base flow is not a measure of the volume of groundwater discharged into a river or wetland, but it is recognised that groundwater contributes to the base-flow component of river or wetland flow.

Available literature (WRC, 2015; DWAF, 2006) suggests groundwater contribution to baseflow ranges from 9.8 mm/yr (PITMAN MODEL) to 43.45 mm/yr (HUGHES MODEL). This relates to approximately 2% to 6% of rainfall.

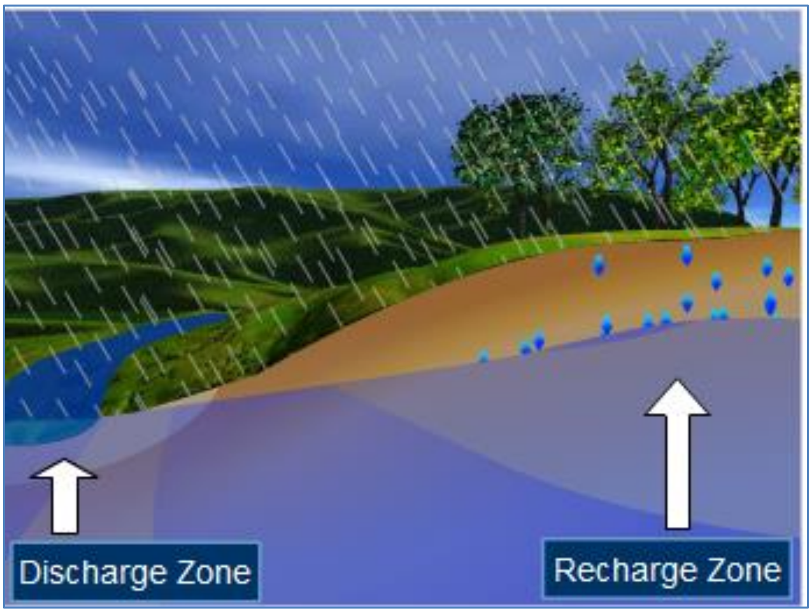


Figure 2-9: Groundwater base-flow concept (DWS, 2011)

2.8 Present ecological state (PES) and environmental sensitivity and ecological importance (EIS) – quaternary scale

Table 2-3 provides a summary of the PES and EIS for the quaternary catchment associated with the project area (WRC, 2015). It is recommended that the resource management objectives (RMO) for wetlands in the project area need to maintain the current PES and EIS post development

Table 2-3: Summary of PES and EIS for the Quaternary Catchment

Quat	PES	EIS
W51B	Class B: Largely Natural	High

2.9 Land morphology and soils

Different soil types are encountered within shoulder, mid-slope and valley positions of the project area (referred to as soil hillslope) and are mainly due to sub-surface geology, products of weathering, degree of saturation, soil texture and slope position (refer to Figure 2-10). The terrain in the project area is slightly sloping to flat (due to undulating hills), with soil depths ranging from 600 mm to 1200 mm generally with clay content ranging from 15 to 60%.

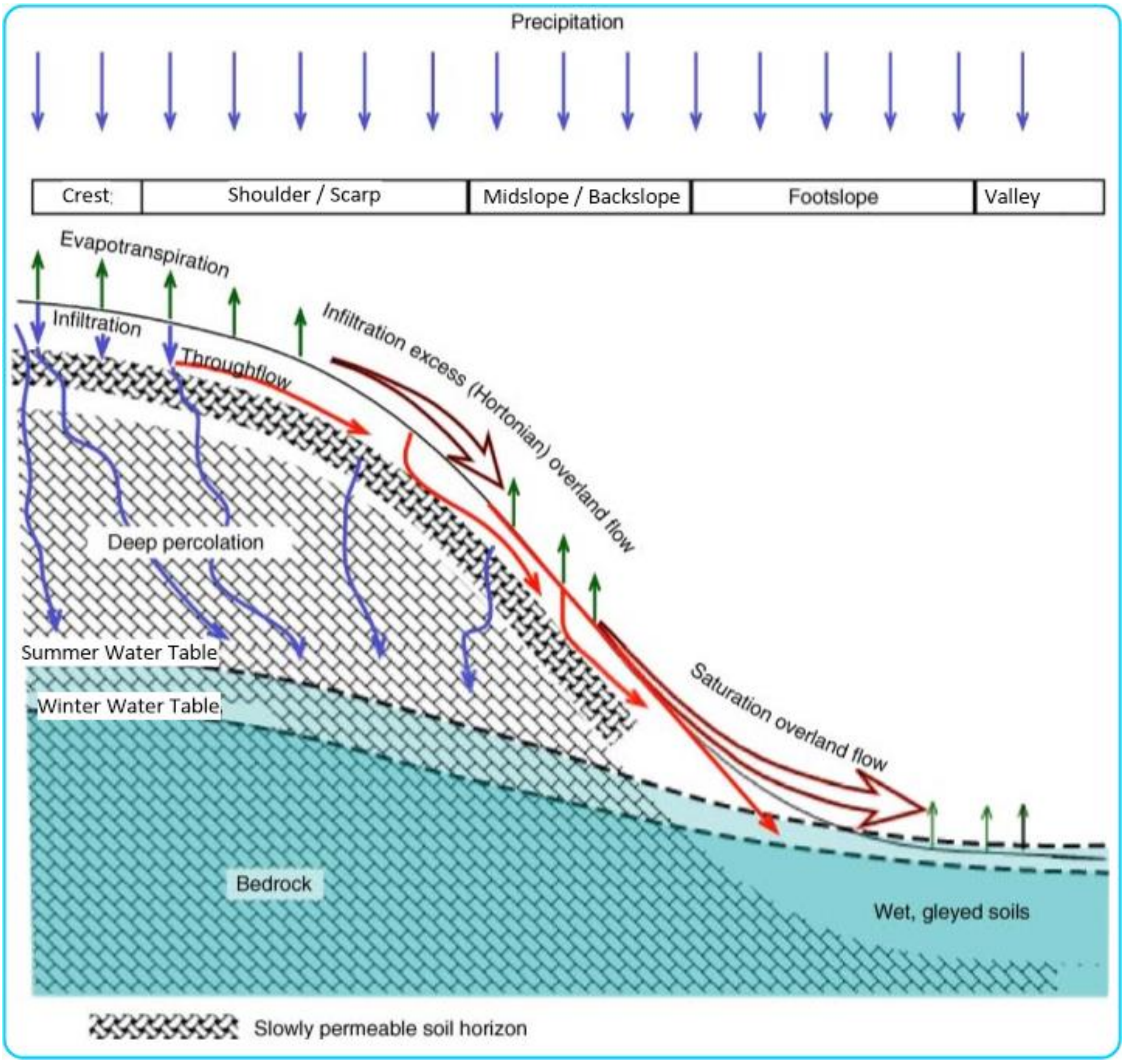


Figure 2-10: Land morphology concept (Almond, 2016)

According to the Land types of South Africa databases (Land Type Survey Staff, 1972 – 2006c), the soils in the area typically conform to land types of the Bb62 group, which entail duplex soils typically red and yellow, dystrophic/mesotrophic, apedal soils with plinthic subsoils (plinthic soils comprise > 10% of land type, red soils comprise < 33% of land type). According to WR2012 soil data for the area, the erodibility of the soils for the area can be considered medium (WRC, 2015). Typical soil types on hillslopes associated with this landform are shown in Figure 2-11 and Figure 2-12 shows the soil land types associated with the greater project area.

Duplex soils are characterised by a distinct difference in saturated and unsaturated hydraulic conductivity between the coarser overlying and higher clay content structured underlying horizons. In this regard, the coarser materials can accommodate more distinct lateral flows of water with its associated redox morphology in the form of bleaching and removal of sesquioxides. The structured subsoil horizon may exhibit a certain degree of redox morphology expression (redox depletions and redox accumulations) that can, in its maximal expression< lead to the classification of a G horizon in the lower parts of the landscape. Wetlands are often identified in areas with E horizons and shallow lateral seepage due to the perching of the water on the structured subsoil.

Distinct water accumulation and lateral flows may also occur beneath the structured horizons in unconsolidated materials or fractured and weathering rock. In these cases, the redox morphology is consistent with the criteria used for wetland identification except for the depth criteria that preclude it from formal wetland identification (Der Waals, 2019).

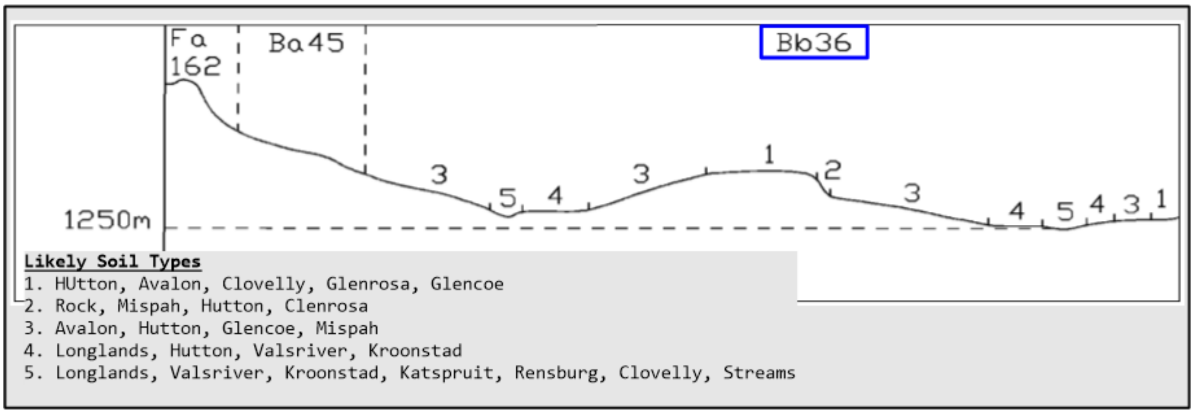


Figure 2-11: Bb62

2.9.1 Site-specific

GCS undertook a soil survey to evaluate the soil types, and to derive the hydropedological soil types. The auger hole positions are indicated in Figure 2-13 and soil profiles are available in **Appendix A.** Four (4) dominant hillslopes define the site and soil hydrological processes (from the position of the proposed co-disposal facility).

From the soil survey undertaken, the following is noted:

- The majority of the co-disposal facility footprint area is characterised by shallow soils classified as the Glencoe soil type. The soil type was observed to have relatively shallow orthic A (topsoil) horizons, followed by a yellow-brown apedal B horizon with evidence of Fe and Mn concretions, clay matter (more than in the A horizon) that gradually transitions into very hard plinthic rock (horizon). The presence of clay matter and weathered plinth will likely cause temporary perched water tables, during prolonged rainfall events/storm events. Stagnant flow along the hard plinthic / soil interface is expected in a lateral direction. The Glencoe soil form was observed in 42% of the test auger holes.
- Towards the southeast side of the site (crest/hilltop) very shallow soils were encountered off the Mispah soil type. Augering in these areas hit refusal at depths <0.1m. The Mispah soil form was encountered in 28% of the test auger holes. It was noted that the area southeast of the proposed co-disposal facility gradually extends into backfilled material used to rehabilitate the old opencast pit associated with the area. The Mispah soil form occurred in areas that appear to be associated with the high wall of the old pit.
- Towards the northeastern side of the site, soils of the Hutton soil type were observed. These soil are signified by deeply weathered soils, having a distinct A horizon, followed by thick yellow-brown apedal B horizons. Deeper in the profile, weathered zone material was observed, with signs of wetness. The soils lacked pedological features which would classify this layer as soft plinthic B. The Hutton soil form was encountered in 14% of the auger test holes.
- Towards the northeast and northwest of the site, near the drainage line areas in depression areas or areas where stagnant water was observed, soils of the Katspruit and Rensburg soil forms were encountered. The presence of a saturated G horizon, with mottling and gleying, suggests long-term saturated conditions. These soil types were inferred to the greater project area, based on their position of the hillslopes. The Katspruit and Rensburg soil forms were encountered in 16% of the auger test holes.
- The estimated soil distribution at the site is presented in Figure 2-13.

2.10 Soil permeability

Several soil samples were taken from both A and B horizons and subjected to particle size distribution (PSD) tests. The laboratory test results are available in **Appendix B** and soil texture classes are summarized in Table 2-4. Based on available soil data for the project area, it is anticipated that the area is characterized by sandy loam to sandy clay loam soil types. As such, the anticipated permeability of the soils is estimated at 1.3 cm/hr to 4.1 x 10^{-3} cm/hr.

Table 2-4: Summary of soil classes identified

Lab ID	Sample ID	Media
189388	A11 0-0.3M	Sandy Loam
189389	A11 1-1.3M	Sandy Clay Loam
189390	A12 0-0.3M	Loamy Sand
189391	A12 1.2-1.5M	Sandy Clay Loam
189392	A14 0.4-0.6M	Sandy Loam
189393	A14 0-0.4M	Sandy Clay Loam
189394	A15 Composite	Sandy Clay Loam
189395	A16 0.3M	Sandy Clay Loam
189396	A16 0-0.2M	Sandy Clay Loam
189397	A17 0.0.3M	Sandy Clay Loam
189398	A17 1.3-1.5M	Sandy Loam
189399	A6 0-0.03M	Sandy Loam
189400	A6 1.3-1.5M	Sandy Loam
189401	A7 0.7-0.9M	Loamy Sand
189402	A7 0-0.2M	Sandy Loam
189403	A8 0-0.3M	Loamy Sand
189404	A8 1.2-1.5M	Sandy Loam

Table 2-5: Soil permeability classes for agriculture and conservation (Food and Agriculture Organization (FAO, 1980)

Soil Texture	**Permeability (cm/hour)**
Sand	5
Sandy Loam	2.5
Loam	1.3
Clay Loam	0.8
Silty Clay	0.25
Clay	0.05

Table 2-6: DWS range of hydraulic conductivities in different soil types (DWS, 2011)

Type	Saturated Hydraulic Conductivity, K_s (cm/s)
Gravel	$3x10^{-2}$ – 3
Coarse Sand	$9x10^{-5}$ – $6x10^{-1}$
Medium Sand	$9x10^{-5}$ – $5x10^{-2}$
Fine Sand	$2x10^{-5}$ - $2x10^{-2}$
Loamy Sand	$4.1x10^{-3}$
Sandy Loam	$1.2x10^{-3}$
Loam	$2.9x10^{-4}$
Silt, Loess	$1x10^{-7}$ – $2x10^{-3}$
Silt Loam	$1.2x10^{-4}$
Till	$1x10^{-10}$ - $2x10^{-4}$
Clay	$1x10^{-9}$ – $4.7x10^{-7}$
Sandy Clay Loam	$3.6x10^{-4}$
Silty Clay Loam	$1.9x10^{-5}$
Clay Loam	$7.2x10^{-5}$
Sandy Clay	$3.3x10^{-5}$
Silty Clay	$5.6x10^{-6}$
Un-weathered marine clay	$8x10^{-11}$ – $2x10^{-7}$

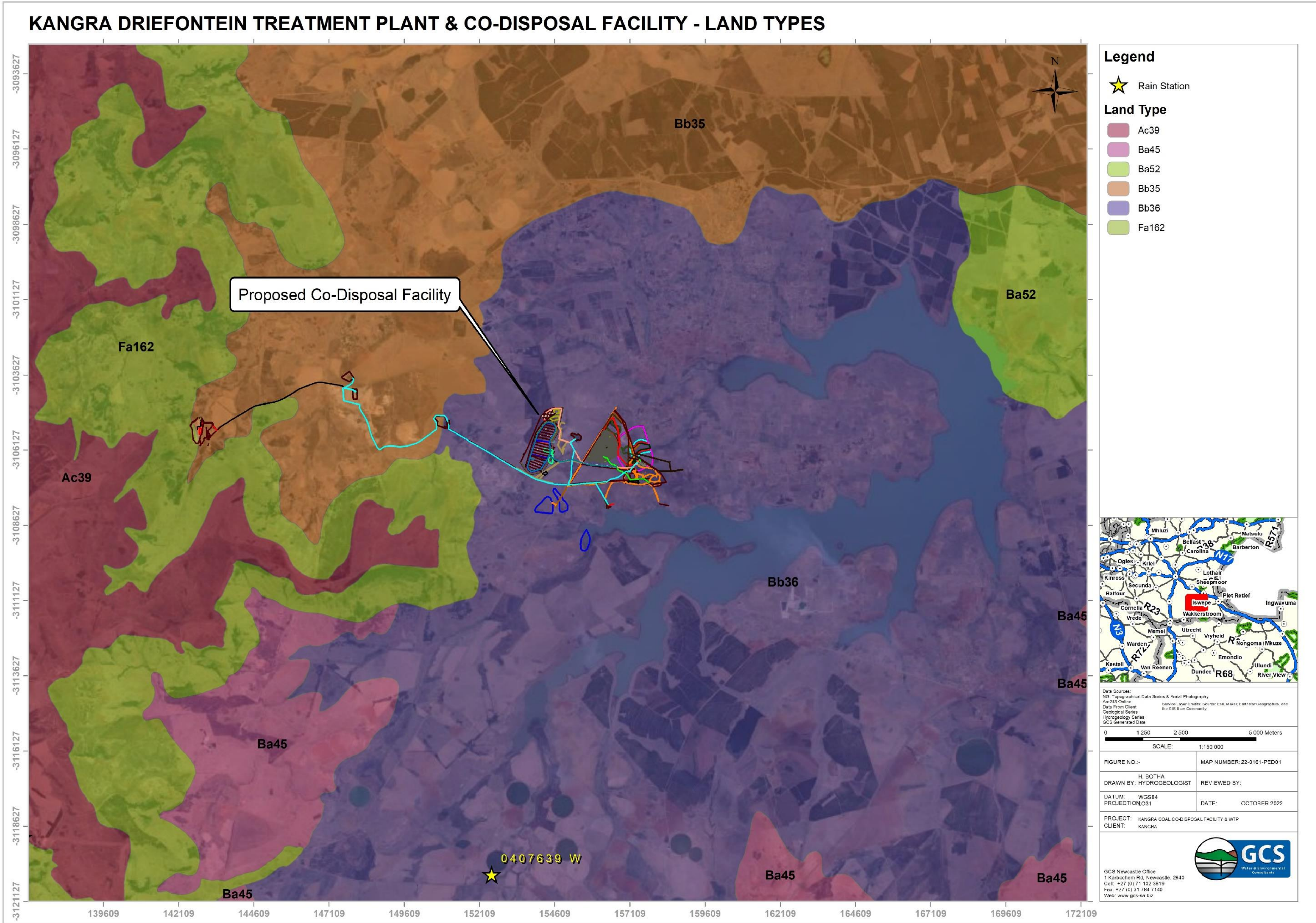


Figure 2-12: Land types associated with the project area

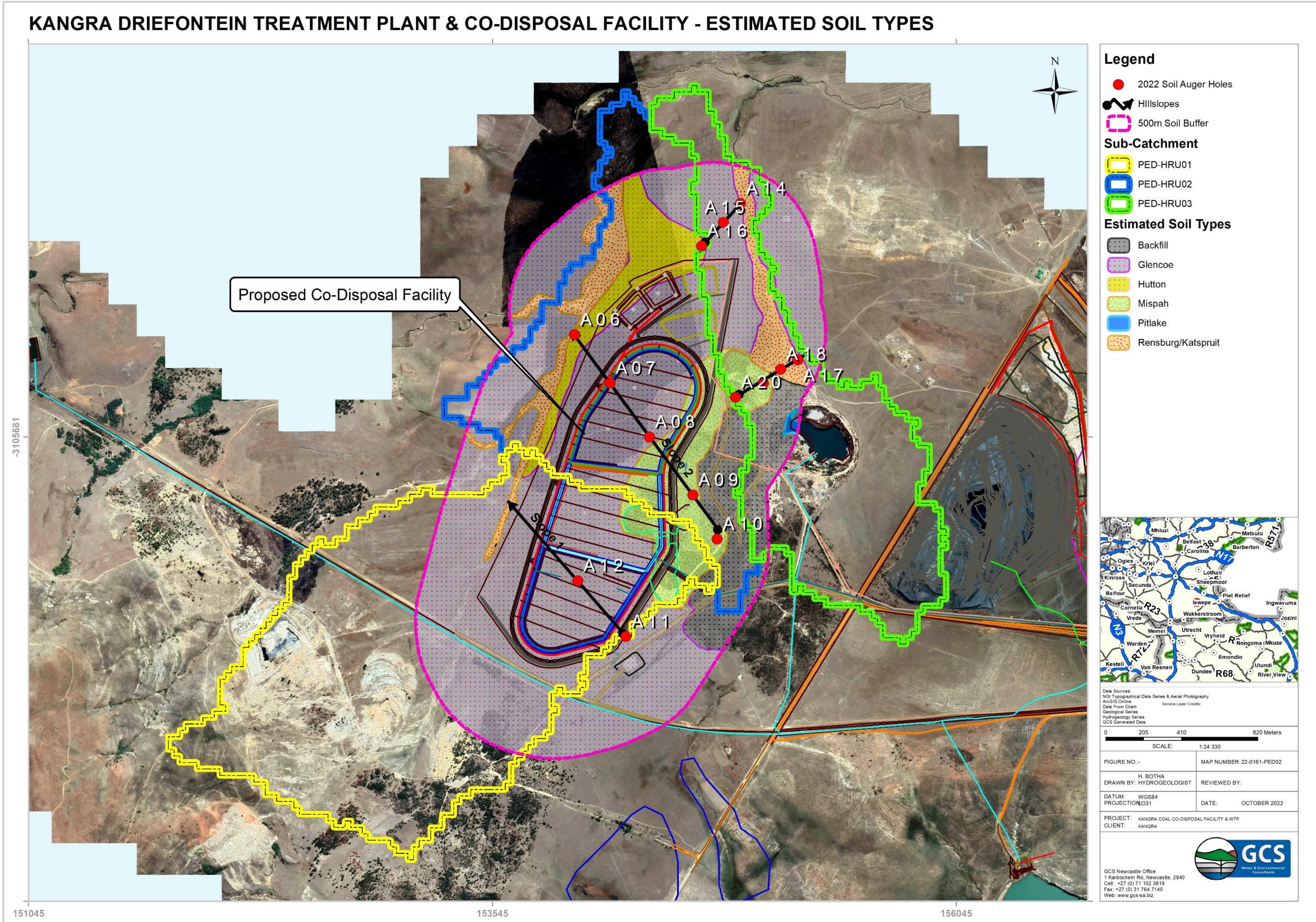


Figure 2-13: Estimated soil distribution for sub-catchments associated with the project

3 HYDROPEDOLOGICAL ASSESSMENT

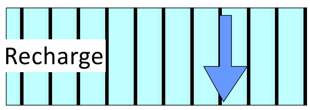
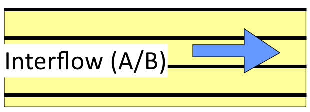
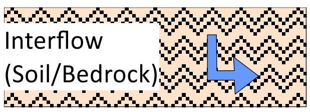
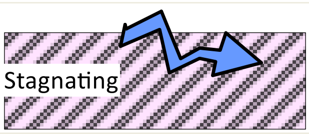
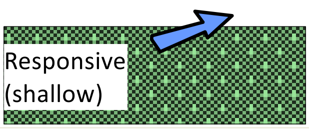
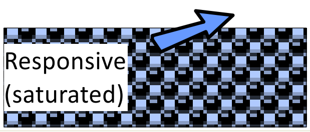
Soil genesis is influenced by physical and chemical water-related processes and soils are, therefore, the first-order control of hydrological processes. The water transfer function of soils varies on several factors including soil properties, topography, and climate.

Characteristic soil properties make it possible to conceptualise hillslope hydrological responses within catchments. The approach followed in this study includes the classification of hillslopes for the site, and the development of a soil map (refer to Section 2.9.1), which were used to determine the HST. Finally, a conceptualization of hydrological processes that occur on the various hillslopes, based on HST was undertaken.

3.1 Hydrological Soil Types (HST)

In the determination of Hydrological Soil Types (HST), soils were divided into classes based on their expected hydrological responses (Van Tol, et al., 2013). Hydrological processes were perceived from traceable signatures in the soil matrix resulting from the soil's ability to transmit, store and react with water (Le Roux, et al., 2011). The HST descriptions and representative symbols are presented in Table 3-1, below.

Table 3-1: Hydrological soil types

Hydrological soil type	Description	Symbol
Recharge	The soils do not have any morphological indication of saturation. Vertical flow through and out of the profile into the underlying bedrock is the dominant flow path. These soils are deep and freely drained and are experiencing the leaching of nutrients to underlying soil horizons.	
Interflow (A/B)	The soils have a textural discontinuity which facilitates the build-up of water in the topsoil, the water that sits on the upper layer then flows laterally into the stream on the A/B horizon interface. The flow path is predominantly downslope in a lateral direction.	
Interflow (Soil/Bedrock) Or Interflow (A/ Bedrock)	Soils overlying relatively impermeable bedrock. Hydromorphic properties signify the temporal build of water on the soil/bedrock interface and slow discharge in a predominantly lateral direction.	
Stagnating	Stagnating soils tend to act like interflow (soil/bedrock) soil types, however, due to the presence of abundant clays lateral discharge is slow. A build-up of water content in the soil, profile leads to temporary perched groundwater after high rainfall events.	
Responsive (Shallow)	The soils are shallow, and they are over a relatively less permeable weathered rock or bedrock. They have limited storage capacity which results in the generation of overland flow after rainfall events.	
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.	

*Adapted from (Van Tol, et al., 2013)

3.2 Hillslopes and hillslope hydrology

Hillslopes and preferential soil flow paths were evaluated based on a 30 m ALOS digital terrain model (DTM) (JAXA, 2022), and can be seen in Figure 3-5. The hillslopes generally feed into responsive soil types or streams/rivers.

3.3 Conceptual hydrological flow processes

The hydrological processes associated with the land types and soil types in the project area are discussed concerning the numbered arrows in Figure 3-1 to Figure 3-4, and the hillslope positions are indicated in Figure 3-6. The following provides a summary of the likely soil flow paths and the HSTs.

3.3.1 Hillslope 1

Crest to midslope/backslope:

On the crest to midslope position of the hillslope, stagnating soils of the Glencoe soil types were encountered.

2. a. Stagnating soils tend to act like interflow (soil/bedrock) soil types, however, due to the presence of abundant clays lateral discharge is slow. Slow discharge in a predominantly lateral direction is expected for water that can make it to the plinthic interface. A build-up of water content in the soil, profile leads to temporary perched groundwater after high rainfall events.

2. b. Deep percolation into the sub-soils/hard rock and subsequent aquifers towards the lower topography areas is expected.

Footslope:

On the footslope position of the hillslope, deep/shallow recharge soils of the Hutton soil types were encountered.

1.a. Shallow and deep vertical recharge to sub-soils are expected, as well as some lateral movement where sub-soils turn to hard rock/plinthic material (as per greater site context).

1. b. Deep percolation into the sub-soils/hard rock and subsequent aquifers towards the lower topography areas is expected. This deep percolation water contributes to surface water streams as groundwater baseflow.

Valley bottom:

On the valley positions of the hillslope, responsive (saturated) soils occur.

4.a. b. In responsive soils, the build-up of water is expected in the B and upper A horizons after rain and overland discharge and minor lateral seepage are expected (due to saturation excess). Secondary vertical seepage to deeper soil zones from the saturated B horizon is expected. At the transition from one soil type to the other (upstream to downstream) overland flow may take place during wet seasons.

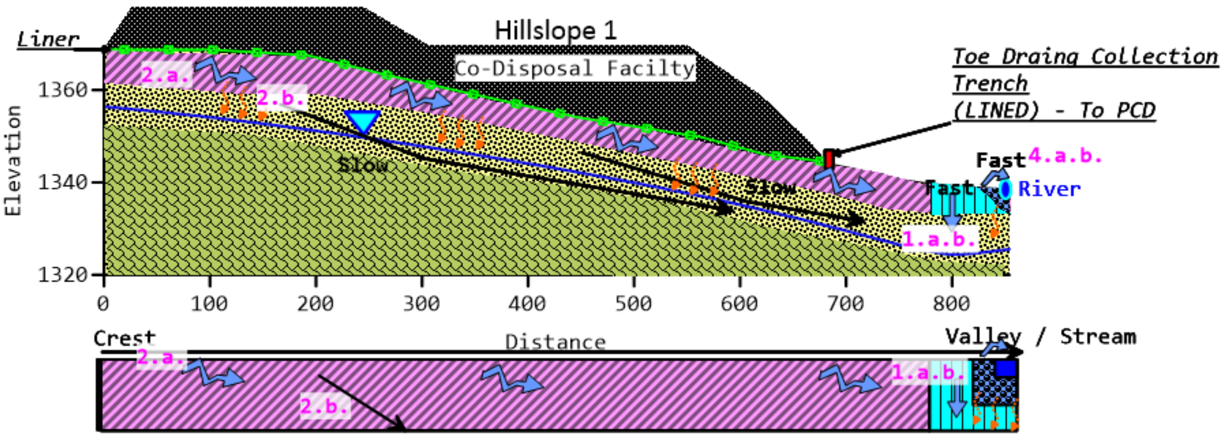


Figure 3-1: Hillslope 1 – conceptual hydropedology flow regimes

3.3.2 Hillslope 2

Crest:

On the crest position of the hillslope, the rehabilitated opencast associated with the area will act as anthropogenic recharge soils.

1.a. Shallow and deep vertical recharge to sub-soils are expected, as well as some lateral movement where sub-soils turn to hard rock/plinthic material (as per greater site context).

1. b. Deep percolation into the sub-soils/hard rock and subsequent aquifers towards the lower topography areas is expected. This deep percolation water contributes to surface water streams as groundwater baseflow.

Shoulder to midslope:

On the shoulder to midslope position of the hillslope, interflow (soil/bedrock) soils of the Mispah type were encountered.

3.a. Shallow hard rock or soft plinthic B horizons will signify a temporal build of water on the soil/bedrock interface and slow discharge in a predominantly lateral direction will occur.

3. b. In areas where bedrock has been subjected to fracturing secondary flow paths towards the groundwater table could exist. Water in the fractured zone will likely seep vertically down into the groundwater table.

Footslope:

On the footslope position of the hillslope, deep/shallow recharge soils of the Hutton soil types were encountered.

1.a. Shallow and deep vertical recharge to sub-soils are expected, as well as some lateral movement where sub-soils turn to hard rock/plinthic material (as per greater site context).

1. b. Deep percolation into the sub-soils/hard rock and subsequent aquifers towards the lower topography areas is expected. This deep percolation water contributes to surface water streams as groundwater baseflow.

Valley bottom:

On the valley positions of the hillslope, responsive (saturated) soils occur.

4.a. b. In responsive soils, the build-up of water is expected in the B and upper A horizons after rain and overland discharge and minor lateral seepage are expected (due to saturation excess). Secondary vertical seepage to deeper soil zones from the saturated B horizon is expected. At the transition from one soil type to the other (upstream to downstream) overland flow may take place during wet seasons.

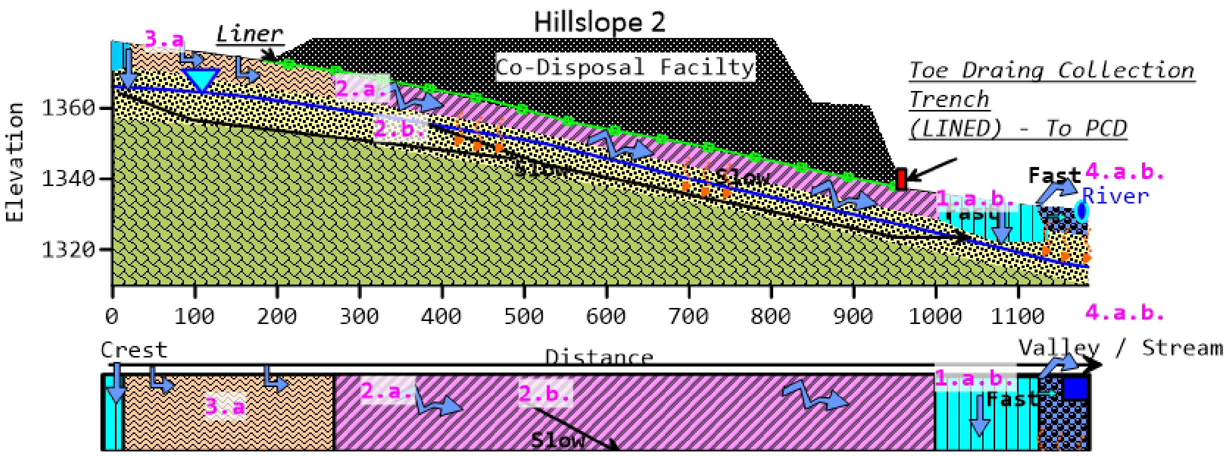


Figure 3-2: Hillslope 2 - conceptual hydropedology flow regimes

3.3.3 Hillslope 3

Crest to midslope

On the crest to midslope position of the hillslope, interflow (soil/bedrock) soils of the Mispah type were encountered.

3.a. Shallow hard rock or soft plinthic B horizons will signify a temporal build of water on the soil/bedrock interface and slow discharge in a predominantly lateral direction will occur.

3. b. In areas where bedrock has been subjected to fracturing secondary flow paths towards the groundwater table could exist. Water in the fractured zone will likely seep vertically down into the groundwater table.

Footslope to the valley bottom

On the valley positions of the hillslope, responsive (saturated) soils occur.

4.a. b. In responsive soils, the build-up of water is expected in the B and upper A horizons after rain and overland discharge and minor lateral seepage are expected (due to saturation excess). Secondary vertical seepage to deeper soil zones from the saturated B horizon is expected. At the transition from one soil type to the other (upstream to downstream) overland flow may take place during wet seasons.

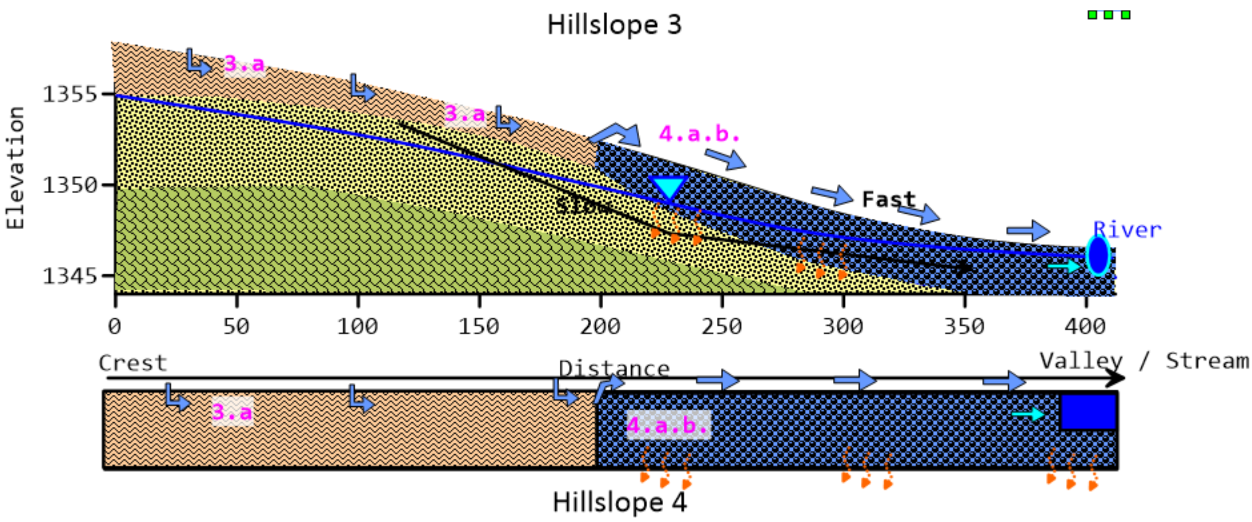


Figure 3-3: Hillslope 3 – conceptual hydropedology flow regimes

3.3.4 Hillslope 4

Crest

On the crest position of the hillslope, deep/shallow recharge soils of the Hutton soil types were encountered.

1.a. Shallow and deep vertical recharge to sub-soils are expected, as well as some lateral movement where sub-soils turn to hard rock/plinthic material (as per greater site context).

1. b. Deep percolation into the sub-soils/hard rock and subsequent aquifers towards the lower topography areas is expected. This deep percolation water contributes to surface water streams as groundwater baseflow.

Scarp to footslope

On the scarp to footslope position of the hillslope, stagnating soils of the Glencoe soil types were encountered.

2. a. Stagnating soils tend to act like interflow (soil/bedrock) soil types, however, due to the presence of abundant clays lateral discharge is slow. Slow discharge in a predominantly lateral direction is expected for water that can make it to the plinthic interface. A build-up of water content in the soil, profile leads to temporary perched groundwater after high rainfall events.

2. b. Deep percolation into the sub-soils/hard rock and subsequent aquifers towards the lower topography areas is expected.

Valley bottom

On the valley positions of the hillslope, responsive (saturated) soils occur.

4.a. b. In responsive soils, the build-up of water is expected in the B and upper A horizons after rain and overland discharge and minor lateral seepage are expected (due to saturation excess). Secondary vertical seepage to deeper soil zones from the saturated B horizon is expected. At the transition from one soil type to the other (upstream to downstream) overland flow may take place during wet seasons.

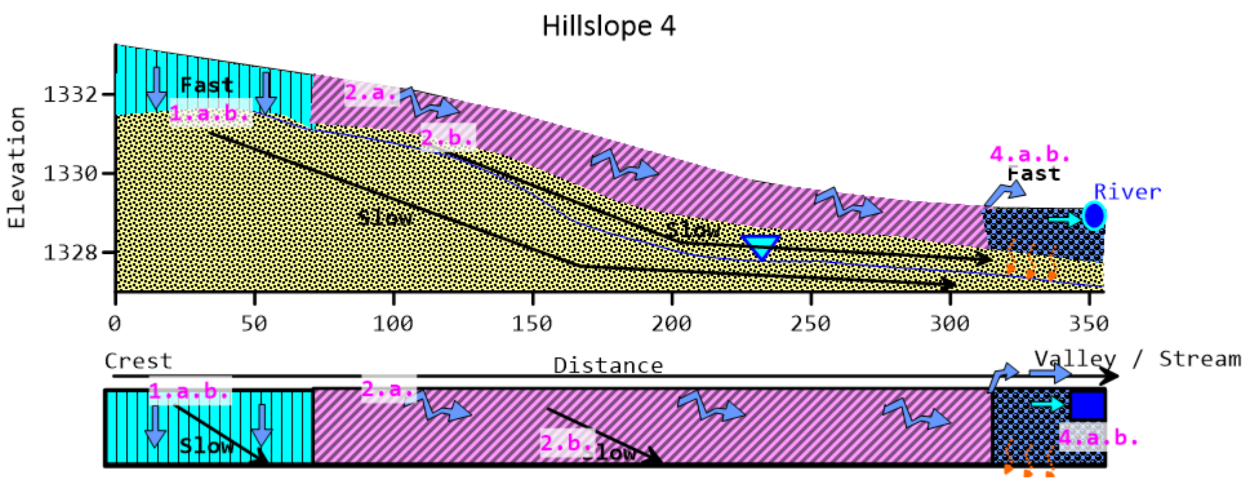


Figure 3-4: Hillslope 4 - conceptual hydropedology flow regimes

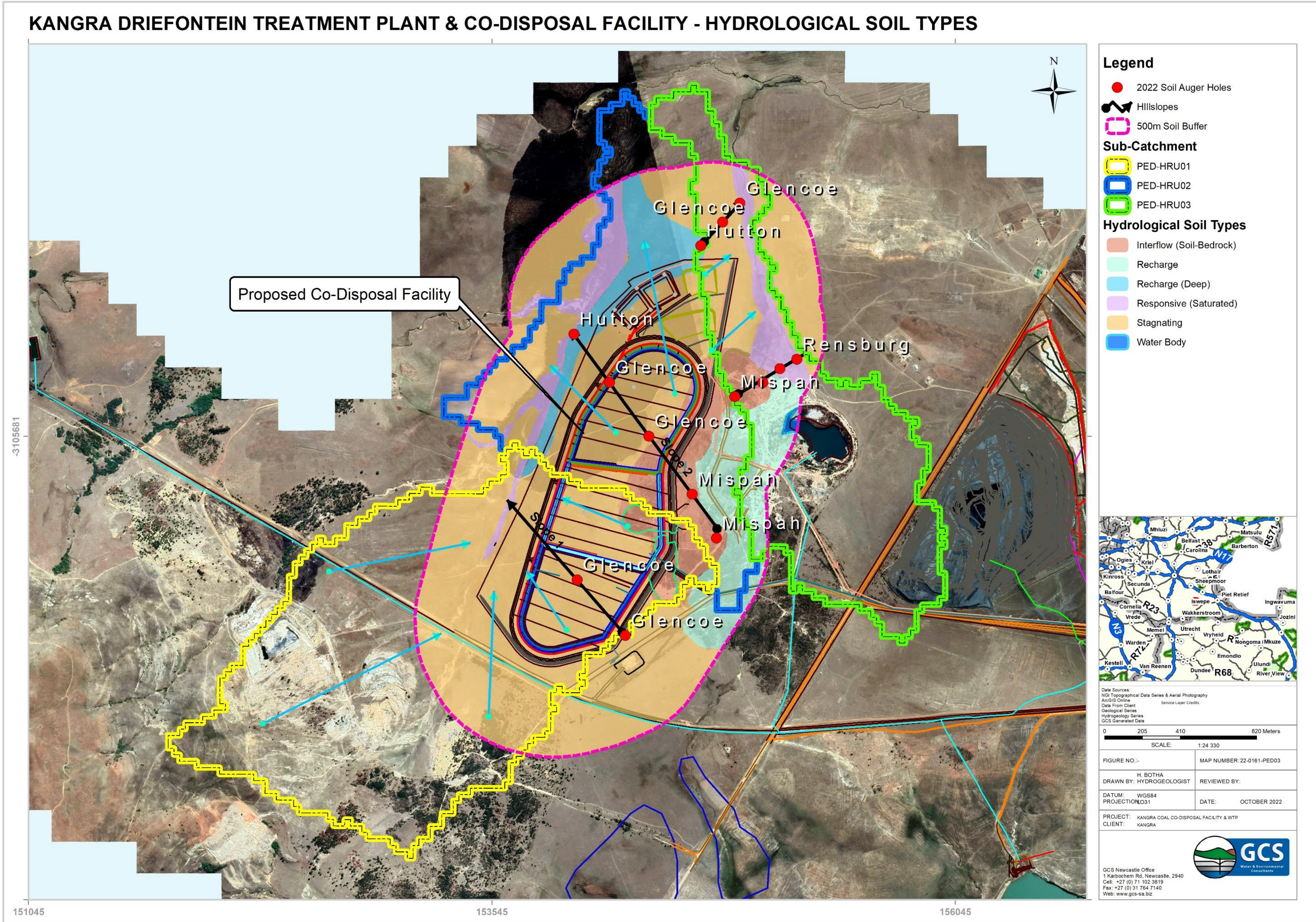


Figure 3-5: Hydrological soil types in the study area and soil flow paths

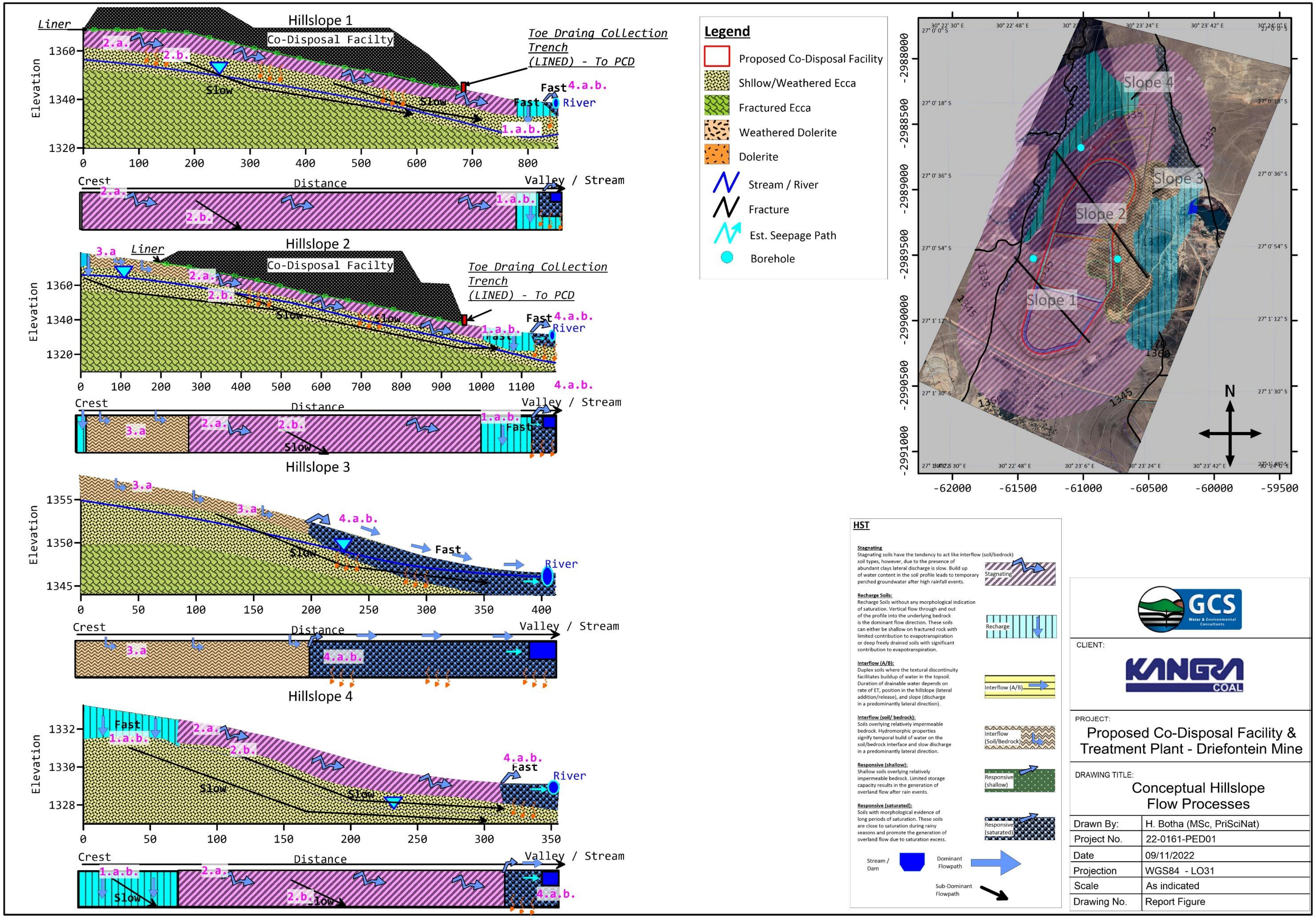


Figure 3-6: **Conceptualisation of hydrological soil flow paths**

4 FLOW DRIVER ASSESSMENT & RISKS

The impact on the hydropedological functions is founded on basic principles of geo-hydrology (Harbaugh, et al., 2000) and hydropedology (Job & le Roux, 2019; Job, et al., 2019; Le Roux, et al., 2011). The general hydropedological flow drivers, and coupled geohydrological processes, for a natural setting are presented in Figure 4-1, below.

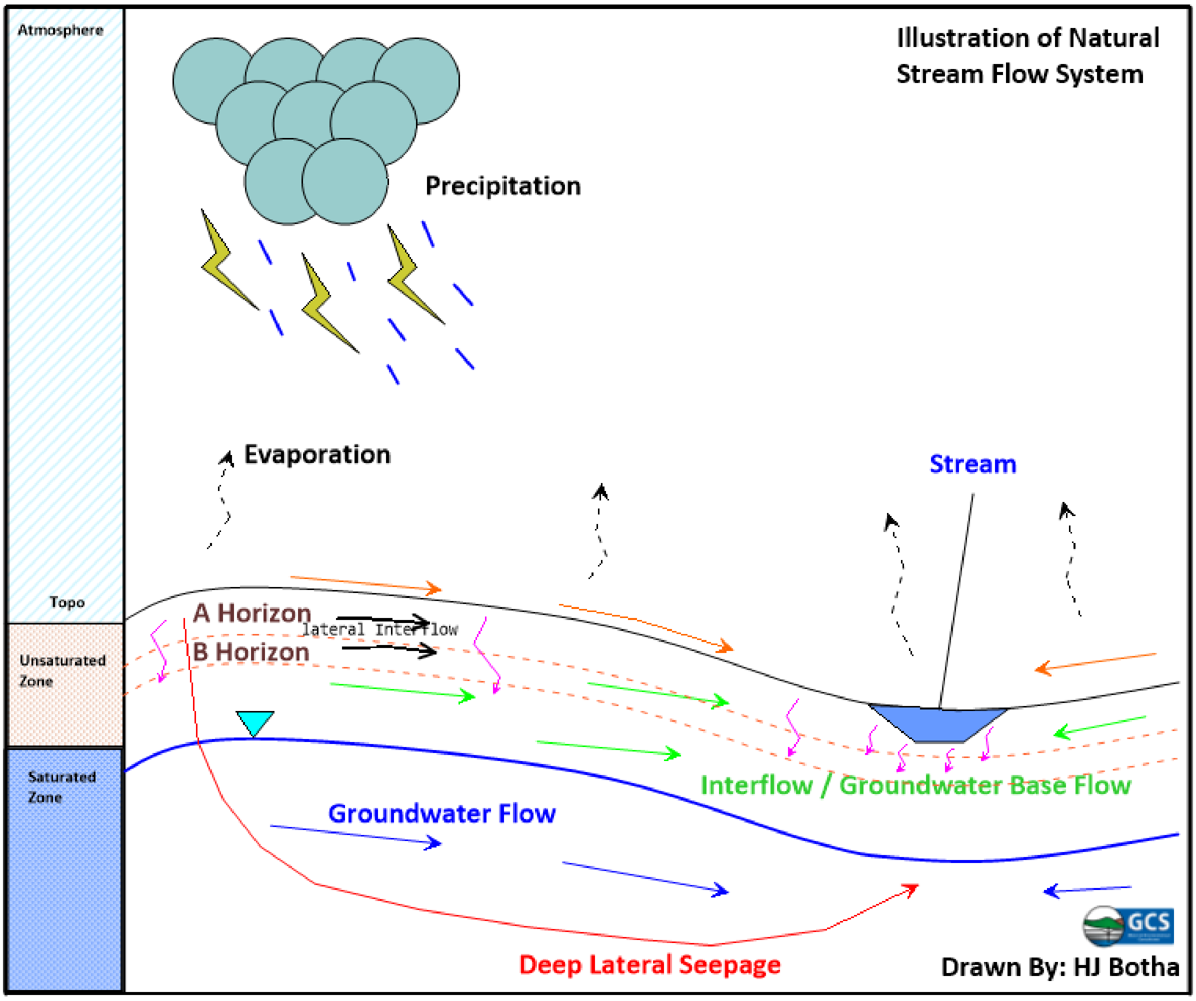


Figure 4-1: Natural flow drivers

It can be seen that the main hydrological processes in a non-mining setting are:

- Atmospheric zone:
    - Precipitation;
    - Runoff; and
    - Evaporation.
- Unsaturated zone:
    - Infiltration;
    - Interflow (soil capillary rise, percolation, vertical soil water flow); and

- Groundwater baseflow (lateral soil water possibly saturated lateral groundwater flow – in areas where shallow groundwater levels occur).

- Saturated zone:
  - Deep lateral seepage; and
  - Groundwater flow (baseflow and aquifer flow).

For the proposed development (built-up areas, that make the land surface impervious) the hydrological process will be altered and is presented in Figure 4-2, below.

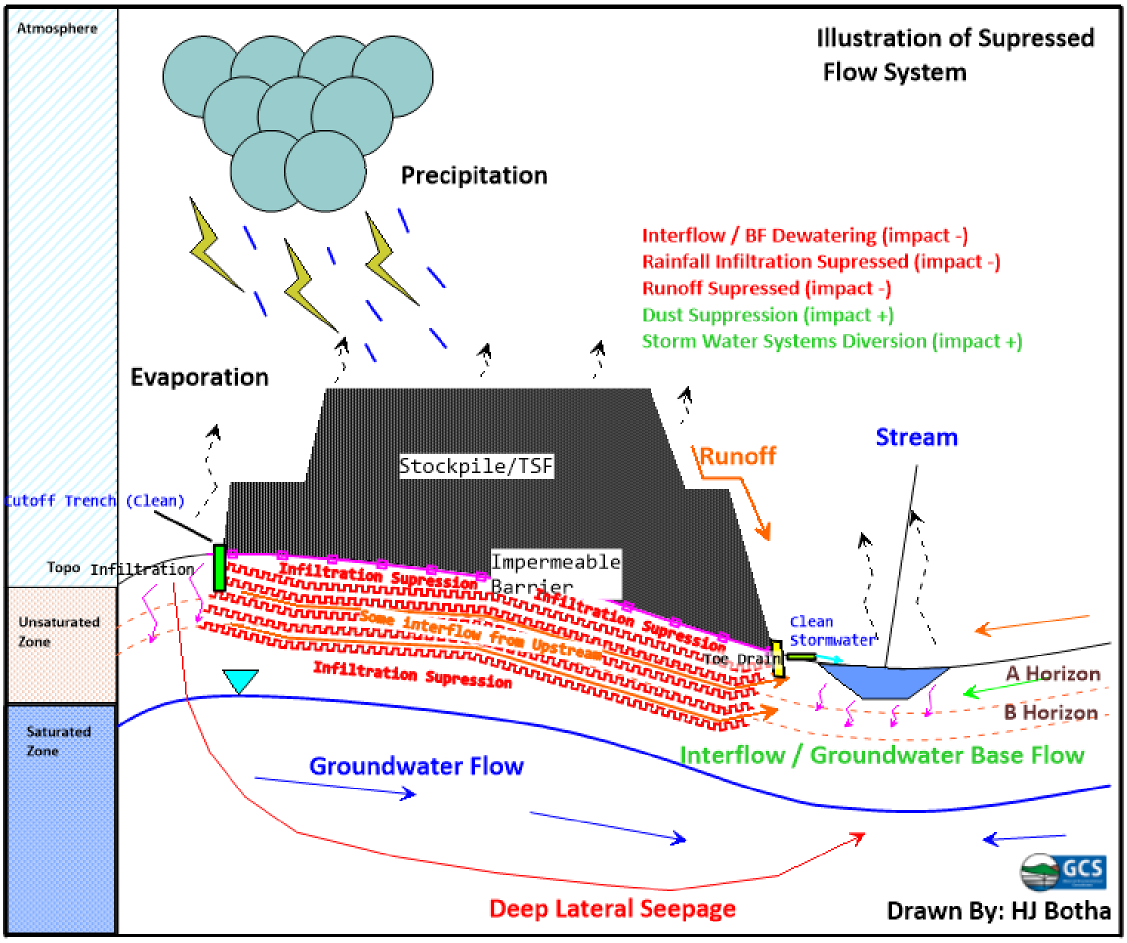


Figure 4-2: Altered flow drivers - built-up area for a lines TSF/Landfill

The following components will highly likely be impacted and will depend on the geomorphology and HSTs of a specific sub-catchment and associated hillslopes, namely:

- Natural runoff towards the valley areas will be disturbed. All runoff from the co-disposal facility will collect in the toe drain systems and report to the PCDs.
- Infiltration over the surface area that is disturbed will be suppressed/removed completely, and no longer be available to add to soil interflow and deep percolation soil functions.
- Interflow (vertical or lateral or both) will be intercepted by the upstream cut-off trench, acting as a clean water diversion system.
- Runoff from the upper reaches of the sub-catchment will be intercepted and removed (if not diverted).

4.1 Flow driver loss calculation/impact estimation

A water balance approach was adopted to estimate the potential impacts on the flow drivers. The equation used was as follows:

$$\text{Flow Loss \%} = \frac{FN\ (\text{m}^3/\text{yr.})}{\text{WT}\ (\text{m}^3/\text{yr.})} \text{ x } 100 \text{ (convert to \%)}$$ Equation 1

Where:

- FN = Sum of Total Negative flow driver impacts in a given sub-catchment.
- WT = Total water in the system.

And:

$$FN = RRI + GBR + AII + NRF$$ Equation 2

- RRI = Est. direct rainfall runoff intercepted by the development (m^3/yr.).
- GBR = Est. reduced groundwater contribution to flow drivers / GW dewatering (m^3/yr.).
- AII = Est. aquifer and soil interflow intercepted by the development/activity (m^3/yr.); and
- NRF = Est. surface runoff intercepted which would naturally flow from upper catchments to the downstream environment (m^3/yr.) – estimated at 80% of the MAP.

Adding positive water releases to the flow driver system (i.e. diverting rainwater to the environment via stormwater systems) may offset the negative. The equation used, was as follows:

$$\text{Net Flow loss impact (\%)} = [\boldsymbol{\Sigma}\textbf{Total Negative} \text{ flow driver impacts } (m^3/yr.) - \textbf{Positive Adjustments } (m^3/yr.)\,] \,/\, \text{Total water in the system } (m^3/yr.) \times 100 \text{ (convert to \%)}$$ Equation 3

<u>Where:</u>

The Sum of Positive Adjustments (m^3/yr.) are:

- Est. positive flow releases previously impacted (m^3/yr.); and
- Est. new positive flow releases not impacted on (m^3/yr.).

4.1.1 Assumptions

The following assumptions were made:

- Constant evaporation is assumed for the sub-catchments – sink in the water balance model.
- No groundwater dewatering takes place.
- Groundwater contribution to baseflow is assumed to be in the order of 43.4 mm/yr. (DWAF, 2006) – Hughes Model.
- Upstream interception along the length of the proposed clean water diversion trench up to a maximum depth of 3m is assumed.
- No artificial recharge, other than in the case of a mitigation measure (i.e. attenuated stormwater releases to wetlands/streams/drainage lines), is accounted for. Artificial recharge from dams is not considered.
- The existing setting and activities proposed are evaluated. The co-disposal facilities and PCDs will be lined, and hence are assessed as being impermeable or no-flow boundaries. This was done to evaluate the likely impacts of PES/EIS.
- The above-mentioned assumptions were made to give a worst-case overview of the likely impacts on the hydropedological flow water balance, as a result of the activities at the site.

4.1.2 Calculations

The calculations for impact on the hydropedological flow drivers, pre- and post-mitigation, are shown in Table 4-1.

Table 4-1: Flow driver calculations

Drivers / Description	Status	Item	HRU1	HRU2	HRU3
		Rainfall	**HRU1**	**HRU2**	**HRU3**
		mm/yr	768.4413333	768.441333	768.441333
		GW Recharge - DEEP	**HRU1**	**HRU2**	**HRU3**
		%	5	5	5
		mm/yr	38.42206667	38.4220667	38.4220667
		BF - SHALLOW	**HRU1**	**HRU2**	**HRU3**
		mm/yr	43.45	43.45	43.45
		Runoff	**HRU1**	**HRU2**	**HRU3**
		Stormwater factor (%)	90%	90%	90%
		Runoff Factor (%)	80%	80%	80%
		Sub-Catch Area	**HRU1**	**HRU2**	**HRU3**
Drivers	**Status**	**km^2**	2.608994	1.548668	1.35857
Natural Water Processes					
	+	**Total Rain Volume (m^3/yr)**	2004858.83	1190060.50	1043981.34
	-	**Runoff (m^3/yr)**	1603887.06	952048.40	835185.07
	+	**Re AQ - Deep / Shallow Percolation (m^3/yr)**	100242.94	59503.03	52199.07
	+	**BF - Shallow Soil Interflow (m^3/yr)**	113360.79	67289.62	59029.87
	-	**Evap (m^3/yr)**	187368.03	111219.45	97567.33
		Balance	***0***	***0***	***0***
Description		**Development**	**HRU1**	**HRU2**	**HRU3**
The area that becomes impermeable or altered.		**Est. Disturbance Area (km^2) - Above Ground / Impermeable**	0.4780	0.3930	0.0400
		Est. Disturbance Area (km^2) - Soil Removal	0.0048	0.0039	0.0004
		Est. Disturbance Area (km^2) - Under Ground	0.0000	0.0000	0.0000
		Est. Intercepted Flow Area (m^2)	3027	2334	1443
		Est. Groundwater Dewatering (l/sec)	0	0	0
		Est. Dewater/Decant Rate	**HRU1**	**HRU2**	**HRU3**
		m^3/day			
Drivers	**Status**				
Impacted Processes	-	**Rainfall Intercepted (m^3/yr)**	367314.96	301997.44	30737.65
	-	**Soil Zone Water Loss (m^3/yr)**	207.69	170.76	17.38
	-	**Deeper Zone Water Loss (under soils) (m^3/yr)**	0.00	0.00	0.00
	-	**Deeper Vadose Zone & Water Table - DEWATER (m^3/yr)**	0.00	0.00	0.00
	-	**Horizontal Interflow Removed (m^3/day)**	9.57	9.08	3.91
	+	**Storm Water (m^3/yr)**	330583.46	241597.96	24590.12
		Potential Negative Impacts	367532.21	302177.28	30758.94
		% Impact on Natural Flow System	18.33%	25.39%	2.95%
		% After Storm Water Convey	1.84%	5.09%	0.59%

4.2 Flow driver Impact categories

Table 4-2 summarises the criteria used for the hydropedological flow driver impact assessment.

The flow driver impact assessment aims to characterise the likely impacts on the hydropedological flow drivers (i.e. what are the likely impacts of the development on the hydropedological flow drives sustaining a wetland or stream after the development has taken place).

Table 4-2: Impact categories for describing the impact on the wetlands and associated hydropedological drivers

Severity	Flow Driver Reduction	Change Class	Description
No Impact	0 - 2.5%	No change	The hydropedological process is predicted to be unmodified and the functionality of the wetland will remain unchanged
Low	2.5 - 5%	No Significant change	A small effect on the hydropedological process is predicted, however, the functionality of the wetland remains unchanged and no change in resource class is expected.
Low to Moderate	5 - 10%	Limited change with a change in the PES category is possible	A slight change in hydropedological processes is predicted and a small change in the wetland may have taken place but is changed to the (present ecological state) PES, EIS (ecological importance and sensitivity) or wetland functionality and eco service provision is limited with no more than one PES class predicted.
Moderate	10 - 15%	A significant change with a change in PES Category definite and possibly a change of more than one category	A moderate change in the hydropedological processes is predicted to occur, the change in PES may exceed one category but no change in EIS takes place. No loss of important eco-services is predicted to occur
High	15 - 22.5%	A very significant change with a change in PES of more than two categories	Modifications have reached a very significant level and the hydropedological processes are predicted to be largely modified with a large change in the PES, and EIS of the wetland feature as well as a significant loss in eco service provision.
Very High	22.5 -60%	Serious to Critical change with a change in PES of more than three categories or a permanent complete loss of wetland resource	Modifications have reached a serious level and the hydropedological processes have been seriously modified with an almost complete loss of wetland integrity, functionality, and service provision.

4.3 Estimated flow losses and risk rating

Based on the sub-catchments delineated and the proposed co-disposal facility and PCD footprints, the overall impacts on the sub-surface natural flow systems were estimated. Table 4-3 summarises the estimated % loss ratings for the sub-catchments – pre- and post-mitigation.

As the areas are mainly undeveloped, natural soil water processes are expected. The predicted impact on the wetlands and watercourses fed by the hydropedological processes ranges from 2.95% (expected no impact) to 25.39% (expected high impact) for the hydropedological sub-catchments.

It is assumed that wetlands that do exist in the area need to maintain the current PES and EIS post-development, as per the resource management objectives (RMO). The calculation suggests that the PES will likely change if the wetland units were only fed by the sub-catchments. However, considering the greater sub-catchment and drainage area, the severity decreases to low and moderate for HRU1 and HRU2.

The table below shows how the severity of a sub-catchment scale can further be improved by incorporating stormwater attenuation back into the environment. No defined hydropedological buffer areas are recommended, however, it is proposed that stormwater attenuation from the development area back to the natural environment be considered. Wetland buffers should be at least 15m to 25 m, or as per the dedicated wetland assessment report for the site (refer to GCS, 2022 – wetland assessment report). Efforts should be made to maintain the current PES and EIS of the wetland units identified during the operational phase of the project, as well as during the closure phase.

Table 4-3: Estimated % Loss rating for micro-catchments (hillslopes)

Sub-Catchment	Est. Flow Driver Impact (No Mitigation)	Severity	Est. Flow Driver Impact (Mitigation)	Severity
Pedology - HRU01	18.33%	High	1.84%	No Impact
Pedology - HRU02	25.39%	Very High	5.09%	Low to Moderate
Pedology - HRU03	2.95%	Low	0.59%	No Impact

4.4 Hydrogeology risk assessment

The anticipated hydrological risk concerning the operational phase of the construction, operational and closure phase of the proposed co-disposal facility and PCDs. The SPR model (DWAF, 2008) was used to evaluate potential pollution sources and primary receptors within the study area.

Risk assessment entails understanding the generation of a hazard, the probability that the hazard will occur, and the consequences if it should occur. The net consequence is established by the following equation:

Consequence = (Duration + Extent + Irreplaceability of resource) x Severity

And the environmental significance of an impact was determined by multiplying consequence by probability. The risk significance rating is summarised in Table 4-4.

Table 4-4: Risk rating scale

Criteria	Rating Scales
Significance	Very high - negative (-49 to -66)
	High - negative (-37 to -48)
	Moderate - negative (-25 to -36)
	Low - negative (-13 to -24)
	Neutral - Very low (0 to -12)
	Low-positive (0 to 12)
	Moderate-positive (13 to 24)
	High-positive (24 to 48)
	Very high - positive (49 to 66)

The potential impacts identified and environmental significance for the construction, operational and closure phases of the project are captured in Table 4-5 to Table 4-7. Based on the available conceptual mine layout plans the following will likely contribute to impacts of hydropedological flow drivers, and soil quality and may compromise surface water quality in the nearby watercourses.

4.4.1 Impacts on the soil interflow processes, soil structure and land capability

There is potential to impact the soil interflow processes, namely:

- Alteration to natural hydropedological flow paths by infilling or cut and fill activities.
- Suppression of rainfall infiltration as a result of the installation of an impermeable barrier and initial deposition of coal wastes onto the impermeable barrier.
- Impacts on the macro-soil structure.
- Impacts on the hydropedological processes supporting the watercourses.

This will result in subsequent impacts on soil structure & land capability and could compromise soil quality. These impacts are expected from the preparation to the closure phase of the project. There is the potential for soil contamination and suppression of natural hydropedological flow drivers in areas associated with the proposed co-disposal facility and PCDs. Potential contaminants from the project are expected to include construction-related consumables, fuels, hydrocarbons, residues and hazardous wastes. A waste classification will be undertaken for the EIA as well as to inform the final design of the secured landfill facility and liner requirements. In the absence of mitigation, however, the intensity of unmitigated impacts would be high, particularly for the suppression of the natural hydropedological flow drivers and that relating to soil quality. In time, reduced soil water quality could be reversed, however, at this stage, the related period is not known. The related unmitigated significance is, therefore, moderate. Important to note is that the use or potential contamination of water resources is regulated through Water Use Licensing requirements of the DWS as the custodian of water resources in South Africa. Where the project plan takes into account the findings of specialist studies, applies the necessary mitigation to avoid, minimize or remedy impacts in line with the mitigation hierarchy and operates under a water use license, the significance of potential impacts can be reduced.

The following activities may contribute to these impacts:

- **Preparation phase:**
  - Site preparation, including placement of contractor laydown areas and storage (i.e. temporary stockpiles, bunded areas etc.) facilities.
  - Disturbing vadose zone during soil excavations/infilling activities.
  - In-situ placement of new soils, altering existing soil-flow processes (i.e. cut-and-fill areas).
  - Linear developments (pipelines, electrical pylons & transmission lines and roads associated with the project) will likely not have a major impact on hydropedology as these structures entail disturbing a very shallow or small surface area. However, soil compaction due to road and pipeline installations, and the movement of heavy vehicles and mining machinery is highly likely to occur.
  - Vegetation loss will likely decrease soil infiltration and increase runoff, which will likely increase erosion.
- **Operational phase:**
  - Surface water interception and reduced rainfall runoff to watercourses and drainage servitudes.
  - Decreased groundwater recharge due to interception of natural soil water occurrences and dewatering.

- **Closure / decommission phase**
  - The activities will generally entail rehabilitation and site clean-ups, whereby the aim would be to restore natural flow processes. Similar impacts to those associated with the commissioning phase are anticipated but will be limited to areas that are further disturbed/rehabilitated.
  - The following is anticipated and assumes that the co-disposal site will be rehabilitated and the area stabilised:
    - New hydropedology flow regimes will form as a result of the rehabilitated co-disposal facility and PCDs, with liners that still prevent infiltration.

4.4.2 Reduced hydropedological flow to surface water (perennial & non-perennial streams and wetlands) as well as impacts on soil and water quality

There is potential to impact the water quality and quantity of watercourses/wetlands sustained by the hydropedological flow, using suppression or alteration of the natural flow as a result of the proposed activities. Moreover, contamination of soils during the project may compromise water quality. The following is anticipated:

- **Preparation phase:**
  - Soil & surface water contamination and sedimentation from the following activities:
    - Leakages from vehicles and mine machines, and seepage from mine materials (i.e. construction material for permanent facilities, cement, paint, etc.).
    - Erosion and sedimentation of watercourses as a result of mine preparation activities, stockpiling and initial mining phase due to unforeseen circumstances (i.e. bad weather); and
    - Alteration of natural drainage lines may lead to ponding or increased runoff patterns (i.e. may cause stagnant water levels or increase erosion).
  - Vegetation loss will likely decrease soil infiltration and increase runoff, which will likely increase erosion.
- **Operational phase:**
  - Surface water interception and reduced rainfall runoff to watercourses and drainage servitudes.
  - Decreased groundwater recharge due to interception of natural soil water occurrences.

  - Soil pollution through nutrient leaching from the co-disposal facility and PCDs (though unlikely as the areas will be lined).
  - Soil quality could be compromised if oil & fuel spills from vehicles occur during the operational phase at the site.

- **Closure / decommission phase:**
  - The activities will generally entail rehabilitation and site clean-ups, whereby the aim would be to restore natural flow processes. Similar impacts to those associated with the commissioning phase are anticipated but will be limited to areas that are further disturbed/rehabilitated.

4.5 Cumulative impacts and impacts on the hydrological cycle

As all activities will take place on the same property, there will be cumulative impacts. The risk tables considered cumulative risk about the site and existing activities at the mine.

Treated water will be discharged into the Heyshope dam at the existing decant rate at pristine water quality (in line with GA limits for treated effluent discharge), and therefore will likely not have a negative impact on water quantity or quality. Compared to the active decant wate quality, the proposed activity is predicted to improve the Heyshope water quality. Proposed discharge will take place at an existing abstraction point west of Driefontein, that is no longer in use.

Table 4-5: Construction phase hydropedology risks

Component being impacted	Activity Which May Cause the Impact	Activity	Pre- Mitigation Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance	Recommended Mitigation Measures	Post Mitigation Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance	Confidence
Soil interflow processes: • Infilling of wetlands and watercourses inducing alternative flow paths (if infilling occurs). • Alteration to natural hydropedological flow paths. • Impacts on the macro-soil structure. • Impacts on the hydropedological processes supporting the watercourses. Soil structure & land capability: • Exposure of soils, leading to increased runoff from cleared areas and erosion of the watercourses, thus increasing the potential for sedimentation of the watercourses. • Vegetation loss. • Soil compaction; and Soil erosion. Soil quality: • Natural nutrient content decreases due to soil exposure. • Loss of natural bio-organisms essential to soil processes.	Site preparation, including placement of contractor laydown areas and storage (i.e. temporary stockpiles, bunded areas etc.) facilities.	Earthworks	Short-term (2)	Site (2)	Yes (1)	Moderate (-2)	Slightly detrimental (-7 to -12) (-10)	Definite (2)	Low - negative (-13 to -24) (-20)	• Only excavate areas applicable to the project area. • Backfill the material in the same order it was excavated to reduce contamination of deeper soils with shallow oxidised soils. • Cover excavated soils with a temporary liner to prevent contamination. • Keep the site clean of all general and domestic wastes. All development footprint areas are to remain as small as possible and vegetation clearing is to be limited to what is essential. • Retain as much indigenous vegetation as possible. • Exposed soils are to be protected using a suitable covering or revegetating. • Existing roads should be used as far as practical to gain access to the site, and crossing watercourses in areas where no existing crossing is apparent should be unnecessary, but if it is essential crossings should be made at right angles. • Have emergency fuel & oil spill kits on site. • Soil quality monitoring & visual assessments - monthly basis. If obvious pollution is noted (visually) then it is advised that soil screening be undertaken.	Short-term (2)	Site (2)	Yes (1)	Low (-1)	Negligible (-6 to 0) (-5)	Definite (2)	Neutral - Very low (0 to -12) (-10)	Medium
	Disturbing vadose zone during soil excavations/infilling activities.	Earthworks	Short-term (2)	Site (2)	Yes (1)	High (-3)	Moderately detrimental (-13 to -18) (-15)	Definite (2)	Moderate - negative (-25 to -36) (-30)		Short-term (2)	Site (2)	Yes (1)	Moderate (-2)	Slightly detrimental (-7 to -12) (-10))	Definite (2)	Low - negative (-13 to -24) (-20)	Medium
	Vegetation clearing & soil stockpiling.	Earthworks	Short-term (2)	Site (2)	Yes (1)	High (-3)	Moderately detrimental (-13 to -18) (-15)	Definite (2)	Moderate - negative (-25 to -36) (-30)		Short-term (2)	Site (2)	Yes (1)	Moderate (-2)	Slightly detrimental (-7 to -12) (-10))	Definite (2)	Low - negative (-13 to -24) (-20)	Medium
Soil quality	Seepage/leakages/overland flow from the co-disposal facility and PCDs may cause soil degradation. Moreover, oil & fuel spills from vehicles parked at the site may compromise soil quality. Prolonged pollution may migrate to the nearby watercourse and/or percolate into the groundwater table.	Earthworks	Short-term (2)	Site (2)	Yes (1)	High (-3)	Moderately detrimental (-13 to -18) (-15)	Definite (2)	Moderate - negative (-25 to -36) (-30)	• Routine visual inspections of infrastructure and parking areas for signs of soil contamination. • Have emergency fuel & oil spill kits on site.	Short-term (2)	Site (2)	Yes (1)	Negligible (0)	Negligible (0 to -6) (-0)	Probable (1)	Negligible (0 to -12) (0)	Medium

Component being impacted	Activity Which May Cause the Impact	Activity	Pre- Mitigation							Recommended Mitigation Measures	Post Mitigation							Confidence
			Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance		Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance	
Perched Water Table Dewatering	Temporary dewatering of perched groundwater (only expected during intense storm events and shortly thereafter).	Earthworks	Short-term (2)	Site (2)	Yes (1)	High (-3)	Moderately detrimental (-13 to -18) (-15)	Definite (2)	Moderate - negative (-25 to -36) (-30)	• Water quality monitoring and routine visual assessment for contamination. • Discharge dewatered / rainwater collected into the nearby stream. May require authorisation. If water is contaminated, discharge to the closest greywater system (depending on the extent of contamination)	Short-term (2)	Site (2)	Yes (1)	Negligible (0)	Negligible (0 to -6) (-0)	Probable (1)	Negligible (0 to -12) (0)	Medium

Table 4-6: Operational phase hydropedological risks

Component being impacted	Activity Which May Cause the Impact	Activity	Pre- Mitigation							Recommended Mitigation Measures	Post Mitigation							Confidence
			Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance		Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance	
Soil interflow processes: • Alteration to natural hydropedological flow paths. • Impacts on the macro-soil structure. • Impacts on the hydropedological processes supporting the watercourses.	Disturbing the inner-soil architecture of the original soil profile will disturb natural flow processes (i.e. a result of infilling or cut-and-fill activities). Excavated soil will be placed in other areas (i.e. on top of other soils) and will have an impact on the flow dynamics of the soil it is dumped on top of. This may reduce rainfall infiltration and induce runoff. Impermeable areas will decrease rainfall infiltration into soils, and hence reduce interflow (A/B and A/bedrock) or lateral flow to downstream wetland areas.	Site activities	long Term (4)	Site (2)	Yes (1)	Moderate (-2)	Moderately detrimental (-13 to -18) (-14)	Definite (2)	Moderate - negative (-25 to -36) (-30)	• Revegetate areas (with vegetation growing at the site) where heavy machinery movement takes place to prevent erosion. • Ensure that clean stormwater is attenuated back to the natural environment, directly downstream of the development. The release of stormwater will offset the rainfall infiltration reduction impacts on soil interflow and may benefit downstream watercourses and wetland units.	Long-term (4)	Site (2)	Yes (1)	Moderate (2)	Moderately beneficial (13 to 18 (14)	Definite (2)	High-positive (24 to 48) (28)	Medium
Soil quality	Seepage/leakages/overland flow from the co-disposal facility may impact soil quality.	Site activities	Long-term (4)	Site (2)	Yes (1)	Negligible (0)	Slightly detrimental (-7 to -12) (-7)	Definite (2)	Low (12 to -25) (-14)	• Have emergency fuel & oil spill kits on site. • Ensure PCDs are operated at levels that prevent overflow during 1-2 to 1:100-year flood events.	Long-term (4)	Site (2)	Yes (1)	Negligible (0)	Negligible (0 to -6) (0)	Probable (1)	Negligible (0 to -12) (0)	Medium

Table 4-7: Closure phase hydropedology risks

Component being impacted	Activity Which May Cause the Impact	Activity	Pre- Mitigation Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance	Recommended Mitigation Measures	Post Mitigation Duration (D)	Extent (E)	Potential for impact on irreplaceable resources (I)	Severity (S)	Consequence (C)	Probability (P)	Significance	Confidence
Soil interflow processes: • Infilling of wetlands and watercourses inducing alternative flow paths (if infilling occurs). • Alteration to natural hydropedological flow paths. • Impacts on the macro-soil structure. • Impacts on the hydropedological processes supporting the watercourses. Soil structure & land capability: • Exposure of soils, leading to increased runoff from cleared areas and erosion of the watercourses, thus increasing the potential for sedimentation of the watercourses. • Vegetation loss. • Soil compaction; and Soil erosion. Soil quality: • Natural nutrient content decreases due to soil exposure. • Loss of natural bio-organisms essential to soil processes.	Decommissioning of non-essential infrastructure to rehabilitate and close the co-disposal facilities, and rehabilitate the PCD areas.	Rehabilitation	Long-term (4)	Site (2)	Yes (1)	Moderate (2)	Moderately beneficial (13 to 18 (14)	Definite (2)	High-positive (24 to 48) (28)	No mitigation is required. Rehabilitation will likely improve the impact of the development on the hydropedology assessment. General risks associated with the construction phase (refer to Table 4-4) will likely exist during earthworks and rehabilitation activities. Refer to mitigation measures for these activities in Table 4-4.								
	Re-Disturbing vadose zone during soil excavations/infilling activities.	Rehabilitation	Long-term (4)	Site (2)	Yes (1)	Moderate (2)	Moderately beneficial (13 to 18 (14)	Definite (2)	High-positive (24 to 48) (28)									
	Re-vegetation and rehabilitation.	Rehabilitation	Long-term (4)	Site (2)	Yes (1)	Moderate (2)	Moderately beneficial (13 to 18 (14)	Definite (2)	High-positive (24 to 48) (28)									
Soil interflow processes: • Alteration to natural hydropedological flow paths. • Impacts on the macro-soil structure. • Impacts on the hydropedological processes supporting the watercourses.	The presence of the co-disposal facility will have long-term implications in terms of altering the natural hydropedological flow drivers of the subsoils, on which the facility is situated This applies to the proposed PCDs as well.	Site activities	long Term (4)	Site (2)	Yes (1)	Moderate (-2)	Moderately detrimental (-13 to -18) (-14)	Definite (2)	Moderate - negative (-25 to -36) (-30)	• Revegetate areas (with vegetation growing at the site) where heavy machinery movement takes place to prevent erosion. • Ensure that clean stormwater is attenuated back to the natural environment, directly downstream of the development. The release of stormwater will offset the rainfall infiltration reduction impacts on soil interflow and may benefit downstream watercourses and wetland units.	Long-term (4)	Site (2)	Yes (1)	Moderate (2)	Moderately beneficial (13 to 18 (14)	Definite (2)	High-positive (24 to 48) (28)	Medium

5 CONCLUSIONS

Soil data were evaluated for the project area to produce a soil distribution map. The soil map was used to categorize the hydrological soil types (HST), into the following categories:

- Recharge.
- Responsive (shallow).
- Responsive (saturated).
- Stagnating.
- Interflow (A/B); and
- Interflow (soil/bedrock).

Three (3) sub-catchments and four (4) prominent hillslopes were defined for the proposed development area. Generally, recharge soils were observed on the crest and footslope positions of two (2) of the hillslopes, with the remainder of the hillslopes (and the majority of the site) being dominated by stagnating hydrological soil types. It was noted that the area southeast of the proposed co-disposal facility gradually extends into backfilled material used to rehabilitate the old opencast pit associated with the area. These soils were classified as interflow (soil/bedrock) type and occurred in areas that appear to be associated with the high wall of the old rehabilitated pit. The valley positions associated with the site, nearing perennial and non-perennial drainage lines, are dominated by responses (saturated) soil types. In responsive soils, the build-up of water is expected in the B and upper A horizons after rain and overland discharge and minor lateral seepage are expected (due to saturation excess). Secondary vertical seepage to deeper soil zones from the saturated B horizon is expected. At the transition from one soil type to the other (upstream to downstream) overland flow may take place during wet seasons.

As the areas are mainly undeveloped, natural soil water processes are expected. The predicted impact on the wetlands and watercourses fed by the hydropedological processes ranges from 2.95% (expected no impact) to 25.39% (expected high impact) for the hydropedological sub-catchments.

It is assumed that wetlands that do exist in the area need to maintain the current PES and EIS post-development, as per the resource management objectives (RMO). The calculation suggests that the PES will likely change if the wetland units were only fed by the sub-catchments. However, considering the greater sub-catchment and drainage area, the severity decreases to low and moderate for HRU1 and HRU2. The severity of a flow driver suppression on a sub-catchment scale can further be improved by incorporating stormwater attenuation back into the environment.

5.1 Avoidance areas

No defined hydropedological buffer areas are recommended; however, it is proposed that stormwater attenuation from the development area back to the natural environment be considered. Wetland buffers should be at least 15 m to 25 m, or as per the dedicated wetland assessment report for the site (refer to GCS, 2022 – wetland assessment report). Efforts should be made to maintain the current PES and EIS of the wetland units identified during the operational phase of the project, as well as during the closure phase.

5.2 Mitigation measures for inclusion in the EMPr

The following mitigation measures can be considered as part of the EMPr:

- Ensure clean stormwater is conveyed to the natural environment. An attenuation pond can be used to ensure steady seepage of accumulated stormwater into the soils upstream of wetland areas.
- Ensure fuel spill cleaning kits are on standby to mitigate any fuel/oil leakages which could compromise soil quality.
- Ensure that all mine infrastructure footprints are as small as possible, to prevent suppression of hydropedological flow drivers.
- It is recommended that wetland buffers delineated by a wetland specialist be incorporated into the final designs of the co-disposal facility. These buffer areas should also be sufficient to further promote natural hydropedological functions.
- It is recommended that mitigation measures, as described in Section 4.4 be implemented during the construction and operational phase of this project.

5.3 Reasoned opinion on whether the activity should be authorized

This assessment cannot find any grounds or identify high hydropedological risks that do not proceed with the development. This is grounded on the assumption that the proposed mitigation measures and EMPr recommendations are implemented during the construction, operational and closure phases of the development.

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APPENDIX A: SOIL PROFILE DATA & FIELD OBSERVATIONS

Auger hole logging data sheet			
Hole ID:	A6	**Latitude**	-27.008447
Project:	Maquasa	**longitude**	30.383301
Project No:	22-0161	**Elevation (m amsl)**	1320.84192
Province	Mpumalanga	**Depth (m)**	1.5
Logged by	Shuaib and Martin	**Water level (mbgl)**	NA

From (m)	To (m)	Soil form; Moisture; Colour; Consistency; Structure; Origin: Grain size
0	0.2	Orthic A; dry; brown; silty sand; fine
0.3	1	fine
1.1	1.5	Unspecified with wetness
Comment		Hole dug using hand auger (HA).
Soil form		**Hutton**

Auger hole logging data sheet			
Hole ID:	A7	**Latitude**	-27.01055
Project:	Maquasa	**longitude**	30.385021
Project No:	22-0161	**Elevation (m amsl)**	1338.33801
Province	Mpumalanga	**Depth (m)**	0.9
Logged by	Shuaib and Martin	**Water level (mbgl)**	NA

From (m)	To (m)	Soil form; Moisture; Colour; Consistency; Structure; Origin: Grain size
0	0.2	Orthic A; dry; fine; sandy-silt
0.3	0.6	Yellow-brown Apedal B; moist; fine; silt
0.7	0.9	Red Apedal B; Moist; fine; silt
Comment		Hole dug using hand auger (HA).
Soil form		**Glencoe**

Auger hole logging data sheet			
Hole ID:	A8	**Latitude**	-27.012878
Project:	Maquasa	**longitude**	30.38694
Project No:	22-0161	**Elevation (m amsl)**	1349.69287
Province	Mpumalanga	**Depth (m)**	1.5
Logged by	Shuaib and Martin	**Water level (mbgl)**	NA

From (m)	To (m)	Soil form; Moisture; Colour; Consistency; Structure; Origin: Grain size
0	0.3	Orthic A; dry; brown;
0.4	0.8	Yellow Apedal B; slightly moist; fine; silt
0.9	1.5	Red Apedal B; moist; fine; silt
Comment		Hole dug using hand auger (HA).
Soil form		**Glencoe**

Auger hole logging data sheet			
Hole ID:	A9	**Latitude**	-27.015398
Project:	Maquasa	**longitude**	30.389029
Project No:	22-0161	**Elevation (m amsl)**	1347.56812
Province	Mpumalanga	**Depth (m)**	0.2
Logged by	Shuaib and Martin	**Water level (mbgl)**	NA

From (m)	To (m)	Soil form; Moisture; Colour; Consistency; Structure; Origin: Grain size
0	0.2	Orthic A; dry; brown; fine; silt
0.3		Hard Rock.
Comment		Hole dug using hand auger (HA).
Soil form		**Mispha**

Auger hole logging data sheet

Hole ID:	A10	Latitude	-27.017306
Project:	Maquasa	longitude	30.390213
Project No:	22-0161	Elevation (m amsl)	1346.0944
Province	Mpumalanga	Depth (m)	0.3
Logged by	Shuaib and Martin	Water level (mbgl)	NA

From (m)	To (m)	Soil form; Moisture; Colour; Consistency; Structure; Origin: Grain size
0	0.2	dry; yellow-brown; silt; fine
0.3	0.3	dry; blackish-red; silt; fine
0.4		Hard Rock
Comment		Hole dug using hand auger (HA).
Soil form		**Mispah**

Auger hole logging data sheet

Hole ID:	A11	Latitude	-27.021531
Project:	Maquasa	longitude	30.385789
Project No:	22-0161	Elevation (m amsl)	1379.580078
Province	Mpumalanga	Depth (m)	1.3
Logged by	Shuaib and Martin	Water level (mbgl)	NA

From (m)	To (m)	Soil form; Moisture; Colour; Consistency; Structure; Origin: Grain size
0	0.2	Orthic A; dry; brown; fine; silt
0.3	0.6	dry; brown; fine; silt with parent rock inclusions
0.7	1.3	dry; yellow-brown with red mottles; sandy-silt
1.4		Hard Plinthic B
Comment		Hole dug using hand auger (HA).
Soil form		**Glencoe**

Auger hole logging data sheet

Hole ID:	A12	Latitude	-27.02332
Project:	Maquasa	longitude	30.383438
Project No:	22-0161	Elevation (m amsl)	1366
Province	Mpumalanga	Depth (m)	1.5
Logged by	Shuaib and Martin	Water level (mbgl)	NA

From (m)	To (m)	Soil form; Moisture; Colour; Consistency; Structure; Origin: Grain size
0	0.3	Orthic A; dry; brown; fine; silt
0.4	0.5	yellow-brown Apedal B; dry; yellow-brown; fine; silt
0.6	1.5	Red Apedal B; moist; yellow-red; fine; silt
Comment		Hole dug using hand auger (HA).
Soil form		**Glencoe**

Auger hole logging data sheet

Hole ID:	A16	Latitude	-27.004614
Project:	Maquasa	longitude	30.389459
Project No:	22-0161	Elevation (m amsl)	1328
Province	Mpumalanga	Depth (m)	0.4
Logged by	Shuaib and Martin	Water level (mbgl)	NA

From (m)	To (m)	Soil form; Moisture; Colour; Consistency; Structure; Origin: Grain size
0.0	0.2	Orthic A; dry; grey-brown to brown; transported hillwash; very fine to fine silty SAND, with scattered gravels.
0.3	0.4	Yellow-brown Apeadal B; dry; yellow-brown with reddish inclusions; Reworked Residuum; very-fine to fine siltly SAND ,with scattered ferricrete nodules.
0.5		Hard Plinthic B
Comment		Hole dug using hand auger (HA).
Soil form		**Glencoe**

Auger hole logging data sheet			
Hole ID:	A15	Latitude	-27.003583
Project:	Maquasa	longitude	30.390513
Project No:	22-0161	Elevation (m amsl)	1325
Province	Mpumalanga	Depth (m)	0.6
Logged by	Shuaib and Martin	Water level (mbgl)	NA

From (m)	To (m)	Soil form; Moisture; Colour; Consistency; Structure; Origin: Grain size
0	0.45	Orthic A; dry; grey-brown to brown; transported hillwash; very fine to fine silty SAND, with scattered gravels.
0.45	0.6	Yellow-brown Apeadal B; dry; yellow-brown with reddish inclusions; Reworked Residuum; very-fine to fine siltly SAND ,with scattered ferricrete nodules.
0.7		Hard Plinthic B
Comment		Hole dug using hand auger (HA).
Soil form		Glencoe

Auger hole logging data sheet			
Hole ID:	A14	Latitude	-27.002759
Project:	Maquasa	longitude	30.391342
Project No:	22-0161	Elevation (m amsl)	1327
Province	Mpumalanga	Depth (m)	0.7
Logged by	Shuaib and Martin	Water level (mbgl)	NA

From (m)	To (m)	Soil form; Moisture; Colour; Consistency; Structure; Origin: Grain size
0	0.4	Orthic A; dry; grey-brown to brown; transported hillwash; very fine to fine silty SAND, with scattered gravels.
0.5	0.7	Yellow-brown Apeadal B; dry; yellow-brown with reddish inclusions; Reworked Residuum; very-fine to fine siltly SAND ,with scattered ferricrete nodules.
0.8		Unspecified
Comment		Hole dug using hand auger (HA).
Soil form		Hutton

Auger hole logging data sheet			
Hole ID:	A17	Latitude	-27.009542
Project:	Maquasa	longitude	30.394108
Project No:	22-0161	Elevation (m amsl)	1339
Province	Mpumalanga	Depth (m)	1.5
Logged by	Shuaib and Martin	Water level (mbgl)	1

From (m)	To (m)	Soil form; Moisture; Colour; Consistency; Structure; Origin: Grain siz
0	1	Dry - semi-dry becoming moist to very moist; dark gry to black speck orange; sandy silty clay; Alluvium (VERTIC)
1.1	1.5	Wet; dark-grey to black; clay; very fine; alluvium (G-Hor)
Comment		Hole dug using hand auger (HA). Soil very sticky from 1.2m
Soil form		Rensburg

Auger hole logging data sheet			
Hole ID:	A18	Latitude	-27.009948
Project:	Maquasa	longitude	30.39329
Project No:	22-0161	Elevation (m amsl)	1343
Province	Mpumalanga	Depth (m)	1.5
Logged by	Shuaib and Martin	Water level (mbgl)	0.7

From (m)	To (m)	Soil form; Moisture; Colour; Consistency; Structure; Origin: Grain siz
0	0.2	Orthic A; Semi-moist; light-brown to brown; silty clay; fine to very fine.
0.3	1.2	moist-wet, black, clay, very fine, alluvium
1.3	1.3	wet, grey, sandy-clay, fine to very-fine; alluvium
1.4	1.5	wet, reddish-brown, silty sand, fine, alluvium
Comment		Hole dug using hand auger (HA).
Soil form		Katspruit

Auger hole logging data sheet			
Hole ID:	A19	**Latitude**	-27.010557
Project:	Maquasa	**longitude**	30.392456
Project No:	22-0161	**Elevation (m amsl)**	1415
Province	Mpumalanga	**Depth (m)**	0.05
Logged by	Shuaib and Martin	**Water level (mbgl)**	NA

From (m)	To (m)	Soil form; Moisture; Colour; Consistency; Structure; Origin: Grain siz
0	0.1	Topsoil
Comment		Hole dug using hand auger (HA).
Soil form		Mispha

Auger hole logging data sheet			
Hole ID:	A20	**Latitude**	-27.011149
Project:	Maquasa	**longitude**	30.391093
Project No:	22-0161	**Elevation (m amsl)**	1353
Province	Mpumalanga	**Depth (m)**	0
Logged by	Shuaib and Martin	**Water level (mbgl)**	NA

From (m)	To (m)	Soil form; Moisture; Colour; Consistency; Structure; Origin: Grain siz
0	0.1	Topsoil
Comment		Hole dug using hand auger (HA).
Soil form		Mispha

APPENDIX B: SOIL PARTICLE DISTRIBUTION LAB CERTIFICATES

Particle size distribution

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Measurement Details

Sample Name Average of '189399 A6 0-0.03M - Screened'
SDS 421
SOP File Name Default + 60us LV.msop

Measurement Details

Measurement Date Time 2022/10/21 11:45:27
Analysis Date Time 2022/10/21 11:45:27
Original Record Number 261

Analysis

Particle Name Default 1.0
Dispersant Name Water
Particle Absorption Index 1.000
Weighted Residual 0.18 %
Analysis Model General Purpose

Analysis

Particle Refractive Index 1.520
Dispersant Refractive Index 1.330
Laser Obscuration 6.61 %
Scattering Model Mie
Analysis Sensitivity Normal

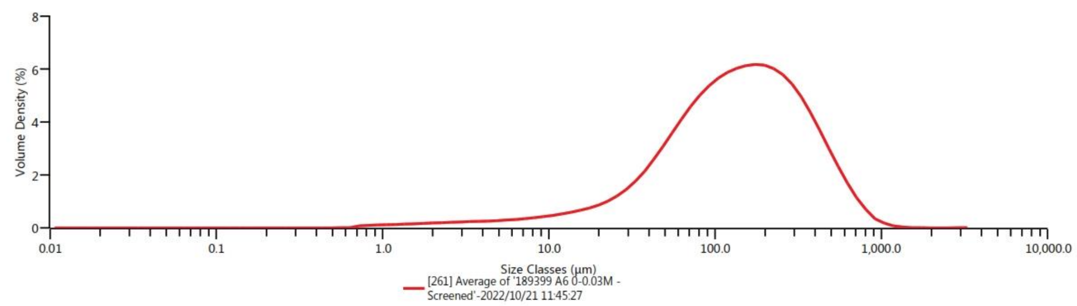
Result

Concentration 0.0333 %
Uniformity 0.865
Specific Surface Area 142.2 m^2/kg
D [3,2] 40.2 µm
D [4,3] 188 µm

Result

Span 2.772
Result Units Volume
Dv (10) 31.1 µm
Dv (50) 138 µm
Dv (90) 415 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.128	0.00	1.28	0.43	12.7	4.59	111	41.45	1110	99.92
0.0114	0.00	0.146	0.00	1.45	0.54	14.5	5.09	127	46.61	1260	99.98
0.0129	0.00	0.166	0.00	1.65	0.67	16.4	5.62	144	51.57	1430	100.00
0.0147	0.00	0.188	0.00	1.88	0.81	18.7	6.26	163	56.54	1630	100.00
0.0189	0.00	0.214	0.00	2.13	0.96	21.2	6.96	186	61.86	1850	100.00
0.0215	0.00	0.243	0.00	2.50	1.17	24.1	7.80	211	66.93	2100	100.00
0.0278	0.00	0.276	0.00	2.75	1.29	27.4	8.80	240	72.00	2390	100.00
0.0315	0.00	0.314	0.00	3.12	1.48	31.1	9.99	272	76.74	2710	100.00
0.0358	0.00	0.357	0.00	3.55	1.67	35.3	11.44	310	81.39	3080	100.00
0.0407	0.00	0.405	0.00	4.03	1.87	40.1	13.22	352	85.49	3500	100.00
0.0463	0.00	0.460	0.00	4.58	2.08	44.0	14.78	400	89.13		
0.0526	0.00	0.523	0.00	5.21	2.31	45.0	15.16	454	92.18		
0.0597	0.00	0.594	0.00	5.92	2.56	51.8	17.94	516	94.68		
0.0679	0.00	0.675	0.00	6.72	2.82	58.9	20.96	586	96.59		
0.0771	0.00	0.767	0.07	7.64	3.10	66.9	24.38	666	97.99		
0.0876	0.00	0.872	0.14	8.68	3.42	76.0	28.21	756	98.93		
0.0995	0.00	1.00	0.24	10.0	3.81	86.4	32.41	859	99.51		
0.113	0.00	1.13	0.33	11.2	4.16	98.1	36.88	976	99.78		

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Particle size distribution

Malvern Instruments

Measurement Details	
Sample Name	Average of '189400 A6 1.3-1.5M - Screened'
SDS	422
SOP File Name	Default + 60us LV.msop

Measurement Details	
Measurement Date Time	2022/10/21 11:53:16
Analysis Date Time	2022/10/21 11:53:16
Original Record Number	265

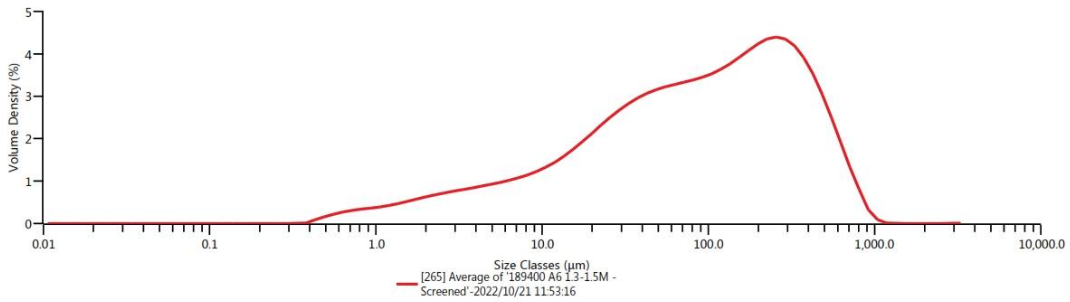
Analysis	
Particle Name	Default 1.0
Dispersant Name	Water
Particle Absorption Index	1.000
Weighted Residual	0.20 %
Analysis Model	General Purpose

Analysis	
Particle Refractive Index	1.520
Dispersant Refractive Index	1.330
Laser Obscuration	13.04 %
Scattering Model	Mie
Analysis Sensitivity	Normal

Result	
Concentration	0.0223 %
Uniformity	1.418
Specific Surface Area	421.6 m^2/kg
D [3,2]	13.6 µm
D [4,3]	161 µm

Result	
Span	4.573
Result Units	Volume
Dv (10)	6.47 µm
Dv (50)	90.8 µm
Dv (90)	422 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.128	0.00	1.28	2.14	12.7	15.40	111	54.59	1110	100.00
0.0114	0.00	0.146	0.00	1.45	2.52	14.5	16.78	127	57.78	1260	100.00
0.0129	0.00	0.166	0.00	1.65	2.95	16.4	18.18	144	60.87	1430	100.00
0.0147	0.00	0.188	0.00	1.88	3.44	18.7	19.84	163	64.04	1630	100.00
0.0189	0.00	0.214	0.00	2.13	3.95	21.2	21.58	186	67.55	1850	100.00
0.0215	0.00	0.243	0.00	2.50	4.67	24.1	23.52	211	71.04	2100	100.00
0.0278	0.00	0.276	0.00	2.75	5.11	27.4	25.62	240	74.70	2390	100.00
0.0315	0.00	0.314	0.00	3.12	5.74	31.1	27.83	272	78.30	2710	100.00
0.0358	0.00	0.357	0.00	3.55	6.41	35.3	30.17	310	82.02	3080	100.00
0.0407	0.00	0.405	0.00	4.03	7.11	40.1	32.64	352	85.51	3500	100.00
0.0463	0.00	0.460	0.08	4.58	7.84	44.0	34.50	400	88.78		
0.0526	0.00	0.523	0.21	5.21	8.61	45.0	34.95	454	91.70		
0.0597	0.00	0.594	0.39	5.92	9.41	51.8	37.84	516	94.25		
0.0679	0.00	0.675	0.62	6.72	10.25	58.9	40.54	586	96.32		
0.0771	0.00	0.767	0.87	7.64	11.15	66.9	43.27	666	97.91		
0.0876	0.00	0.872	1.16	8.68	12.10	76.0	46.05	756	99.01		
0.0995	0.00	1.00	1.48	10.0	13.24	86.4	48.88	859	99.68		
0.113	0.00	1.13	1.79	11.2	14.22	98.1	51.74	976	99.94		

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Particle size distribution

Malvern Instruments

Measurement Details	
Sample Name	Average of '189402 A7 0-0.2M - Screened'
SDS	423
SOP File Name	Default + 60us LV.msop

Measurement Details	
Measurement Date Time	2022/10/21 11:59:50
Analysis Date Time	2022/10/21 11:59:50
Original Record Number	269

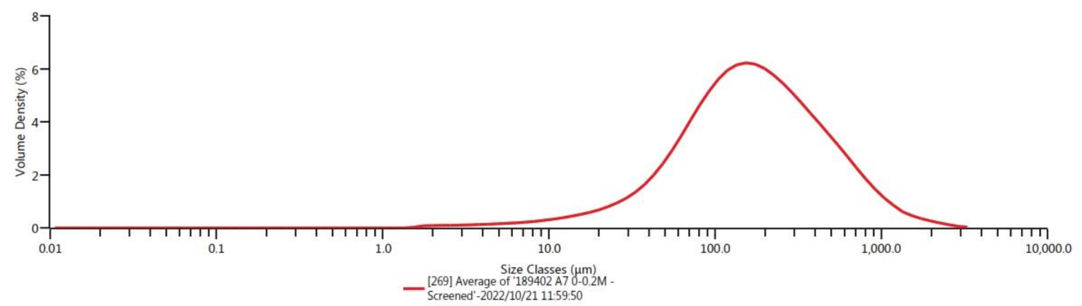
Analysis	
Particle Name	Default 1.0
Dispersant Name	Water
Particle Absorption Index	1.000
Weighted Residual	0.22 %
Analysis Model	General Purpose

Analysis	
Particle Refractive Index	1.520
Dispersant Refractive Index	1.330
Laser Obscuration	5.45 %
Scattering Model	Mie
Analysis Sensitivity	Normal

Result	
Concentration	0.0511 %
Uniformity	1.079
Specific Surface Area	78.31 m^2/kg
D [3,2]	73.0 μm
D [4,3]	264 μm

Result	
Span	3.333
Result Units	Volume
Dv (10)	43.3 μm
Dv (50)	165 μm
Dv (90)	593 μm

Frequency (compatible)



Result

Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under
0.0100	0.00	0.128	0.00	1.28	0.00	12.7	2.33	111	34.15	1110	97.58
0.0114	0.00	0.146	0.00	1.45	0.00	14.5	2.70	127	39.38	1260	98.29
0.0129	0.00	0.166	0.00	1.65	0.02	16.4	3.10	144	44.44	1430	98.79
0.0147	0.00	0.188	0.00	1.88	0.09	18.7	3.60	163	49.49	1630	99.17
0.0189	0.00	0.214	0.00	2.13	0.16	21.2	4.16	186	54.82	1850	99.46
0.0215	0.00	0.243	0.00	2.50	0.25	24.1	4.82	211	59.78	2100	99.68
0.0278	0.00	0.276	0.00	2.75	0.31	27.4	5.60	240	64.64	2390	99.83
0.0315	0.00	0.314	0.00	3.12	0.40	31.1	6.52	272	69.10	2710	99.93
0.0358	0.00	0.357	0.00	3.55	0.50	35.3	7.63	310	73.46	3080	99.98
0.0407	0.00	0.405	0.00	4.03	0.60	40.1	8.99	352	77.38	3500	100.00
0.0463	0.00	0.460	0.00	4.58	0.72	44.0	10.20	400	80.99		
0.0526	0.00	0.523	0.00	5.21	0.85	45.0	10.49	454	84.24		
0.0597	0.00	0.594	0.00	5.92	0.99	51.8	12.68	516	87.19		
0.0679	0.00	0.675	0.00	6.72	1.14	58.9	15.14	586	89.78		
0.0771	0.00	0.767	0.00	7.64	1.32	66.9	18.04	666	92.02		
0.0876	0.00	0.872	0.00	8.68	1.53	76.0	21.43	756	93.89		
0.0995	0.00	1.00	0.00	10.0	1.79	86.4	25.32	859	95.43		
0.113	0.00	1.13	0.00	11.2	2.02	98.1	29.61	976	96.64		

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Particle size distribution

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Measurement Details

Sample Name Average of '189401 A7 0.7-0.9M - Screened'
SDS 424
SOP File Name Default + 60us LV.msop

Measurement Date Time 2022/10/21 12:06:33
Analysis Date Time 2022/10/21 12:06:33
Original Record Number 273

Analysis

Particle Name Default 1.0
Dispersant Name Water
Particle Absorption Index 1.000
Weighted Residual 0.15 %
Analysis Model General Purpose

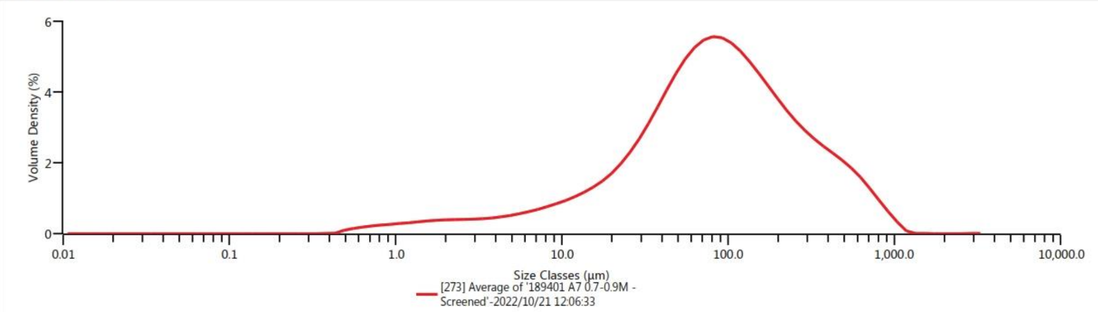
Particle Refractive Index 1.520
Dispersant Refractive Index 1.330
Laser Obscuration 10.52 %
Scattering Model Mie
Analysis Sensitivity Normal

Result

Concentration 0.0253 %
Uniformity 1.289
Specific Surface Area 297.1 m^2/kg
D [3,2] 19.2 µm
D [4,3] 149 µm

Span 4.326
Result Units Volume
Dv (10) 13.2 µm
Dv (50) 84.8 µm
Dv (90) 380 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.128	0.00	1.28	1.44	12.7	9.69	111	59.61	1110	99.95
0.0114	0.00	0.146	0.00	1.45	1.71	14.5	10.70	127	64.15	1260	100.00
0.0129	0.00	0.166	0.00	1.65	2.01	16.4	11.75	144	68.13	1430	100.00
0.0147	0.00	0.188	0.00	1.88	2.33	18.7	13.02	163	71.80	1630	100.00
0.0189	0.00	0.214	0.00	2.13	2.65	21.2	14.41	186	75.39	1850	100.00
0.0215	0.00	0.243	0.00	2.50	3.06	24.1	16.05	211	78.54	2100	100.00
0.0278	0.00	0.276	0.00	2.75	3.31	27.4	17.97	240	81.47	2390	100.00
0.0315	0.00	0.314	0.00	3.12	3.65	31.1	20.18	272	84.06	2710	100.00
0.0358	0.00	0.357	0.00	3.55	4.00	35.3	22.75	310	86.54	3080	100.00
0.0407	0.00	0.405	0.00	4.03	4.37	40.1	25.72	352	88.76	3500	100.00
0.0463	0.00	0.460	0.00	4.58	4.76	44.0	28.18	400	90.81		
0.0526	0.00	0.523	0.08	5.21	5.19	45.0	28.78	454	92.69		
0.0597	0.00	0.594	0.20	5.92	5.65	51.8	32.90	516	94.43		
0.0679	0.00	0.675	0.35	6.72	6.16	58.9	37.05	586	95.97		
0.0771	0.00	0.767	0.53	7.64	6.73	66.9	41.43	666	97.30		
0.0876	0.00	0.872	0.73	8.68	7.36	76.0	45.99	756	98.36		
0.0995	0.00	1.00	0.97	10.0	8.15	86.4	50.66	859	99.16		
0.113	0.00	1.13	1.19	11.2	8.84	98.1	55.26	976	99.68		

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Particle size distribution

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Measurement Details

Sample Name Average of '189403 A8 0-0.3M - Screened'
SDS 425
SOP File Name Default + 60us LV.msop

Measurement Details

Measurement Date Time 2022/10/21 12:13:06
Analysis Date Time 2022/10/21 12:13:06
Original Record Number 277

Analysis

Particle Name Default 1.0
Dispersant Name Water
Particle Absorption Index 1.000
Weighted Residual 0.26 %
Analysis Model General Purpose

Analysis

Particle Refractive Index 1.520
Dispersant Refractive Index 1.330
Laser Obscuration 6.50 %
Scattering Model Mie
Analysis Sensitivity Normal

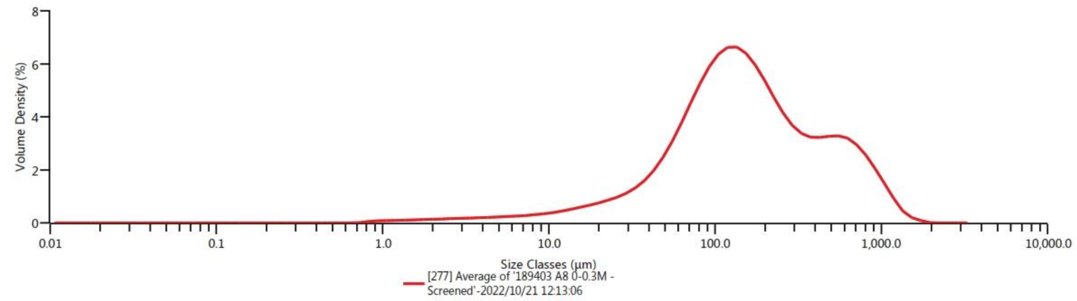
Result

Concentration 0.0413 %
Uniformity 1.166
Specific Surface Area 113.4 m^2/kg
D [3,2] 50.4 μm
D [4,3] 247 μm

Result

Span 4.077
Result Units Volume
Dv (10) 38.1 μm
Dv (50) 146 μm
Dv (90) 633 μm

Frequency (compatible)



Result

Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under
0.0100	0.00	0.128	0.00	1.28	0.26	12.7	3.59	111	38.17	1110	98.63
0.0114	0.00	0.146	0.00	1.45	0.35	14.5	4.03	127	44.01	1260	99.41
0.0129	0.00	0.166	0.00	1.65	0.44	16.4	4.50	144	49.47	1430	99.78
0.0147	0.00	0.188	0.00	1.88	0.55	18.7	5.07	163	54.67	1630	99.93
0.0189	0.00	0.214	0.00	2.13	0.66	21.2	5.69	186	59.82	1850	100.00
0.0215	0.00	0.243	0.00	2.50	0.82	24.1	6.40	211	64.25	2100	100.00
0.0278	0.00	0.276	0.00	2.75	0.92	27.4	7.20	240	68.24	2390	100.00
0.0315	0.00	0.314	0.00	3.12	1.06	31.1	8.12	272	71.64	2710	100.00
0.0358	0.00	0.357	0.00	3.55	1.21	35.3	9.21	310	74.78	3080	100.00
0.0407	0.00	0.405	0.00	4.03	1.37	40.1	10.53	352	77.57	3500	100.00
0.0463	0.00	0.460	0.00	4.58	1.54	44.0	11.73	400	80.26		
0.0526	0.00	0.523	0.00	5.21	1.73	45.0	12.02	454	82.92		
0.0597	0.00	0.594	0.00	5.92	1.92	51.8	14.24	516	85.65		
0.0679	0.00	0.675	0.00	6.72	2.13	58.9	16.82	586	88.39		
0.0771	0.00	0.767	0.00	7.64	2.37	66.9	19.96	666	91.07		
0.0876	0.00	0.872	0.04	8.68	2.62	76.0	23.73	756	93.53		
0.0995	0.00	1.00	0.11	10.0	2.94	86.4	28.13	859	95.67		
0.113	0.00	1.13	0.18	11.2	3.23	98.1	33.02	976	97.38		

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Particle size distribution

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Measurement Details

Sample Name Average of '189404 A8 1.2-1.5M - Screened'
SDS 426
SOP File Name Default + 60us LV.msop

Measurement Details

Measurement Date Time 2022/10/21 13:34:41
Analysis Date Time 2022/10/21 13:34:41
Original Record Number 281

Analysis

Particle Name Default 1.0
Dispersant Name Water
Particle Absorption Index 1.000
Weighted Residual 0.18 %
Analysis Model General Purpose

Analysis

Particle Refractive Index 1.520
Dispersant Refractive Index 1.330
Laser Obscuration 8.19 %
Scattering Model Mie
Analysis Sensitivity Normal

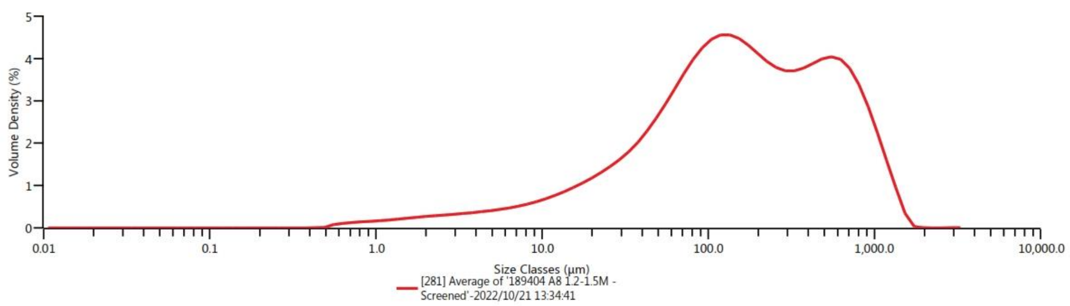
Result

Concentration 0.0298 %
Uniformity 1.372
Specific Surface Area 194.9 m^2/kg
D [3,2] 29.3 µm
D [4,3] 281 µm

Result

Span 4.608
Result Units Volume
Dv (10) 20.4 µm
Dv (50) 156 µm
Dv (90) 741 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.128	0.00	1.28	0.80	12.7	6.92	111	39.84	1110	97.60
0.0114	0.00	0.146	0.00	1.45	0.96	14.5	7.66	127	43.85	1260	98.94
0.0129	0.00	0.166	0.00	1.65	1.15	16.4	8.42	144	47.60	1430	99.73
0.0147	0.00	0.188	0.00	1.88	1.36	18.7	9.33	163	51.22	1630	100.00
0.0189	0.00	0.214	0.00	2.13	1.58	21.2	10.29	186	54.94	1850	100.00
0.0215	0.00	0.243	0.00	2.50	1.88	24.1	11.39	211	58.33	2100	100.00
0.0278	0.00	0.276	0.00	2.75	2.07	27.4	12.60	240	61.64	2390	100.00
0.0315	0.00	0.314	0.00	3.12	2.34	31.1	13.93	272	64.73	2710	100.00
0.0358	0.00	0.357	0.00	3.55	2.62	35.3	15.41	310	67.90	3080	100.00
0.0407	0.00	0.405	0.00	4.03	2.91	40.1	17.09	352	70.97	3500	100.00
0.0463	0.00	0.460	0.00	4.58	3.23	44.0	18.47	400	74.12		
0.0526	0.00	0.523	0.00	5.21	3.57	45.0	18.80	454	77.33		
0.0597	0.00	0.594	0.07	5.92	3.93	51.8	21.15	516	80.67		
0.0679	0.00	0.675	0.16	6.72	4.32	58.9	23.60	586	84.03		
0.0771	0.00	0.767	0.26	7.64	4.75	66.9	26.33	666	87.37		
0.0876	0.00	0.872	0.38	8.68	5.21	76.0	29.37	756	90.50		
0.0995	0.00	1.00	0.52	10.0	5.79	86.4	32.70	859	93.34		
0.113	0.00	1.13	0.65	11.2	6.29	98.1	36.24	976	95.73		

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Particle size distribution

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Measurement Details

Sample Name	Average of '189388 A11 0-0.3M - Screened'
SDS	427
SOP File Name	Default + 60us LV.msop

Measurement Details

Measurement Date Time	2022/10/21 13:41:16
Analysis Date Time	2022/10/21 13:41:16
Original Record Number	285

Analysis

Particle Name	Default 1.0
Dispersant Name	Water
Particle Absorption Index	1.000
Weighted Residual	0.25 %
Analysis Model	General Purpose

Analysis

Particle Refractive Index	1.520
Dispersant Refractive Index	1.330
Laser Obscuration	5.94 %
Scattering Model	Mie
Analysis Sensitivity	Normal

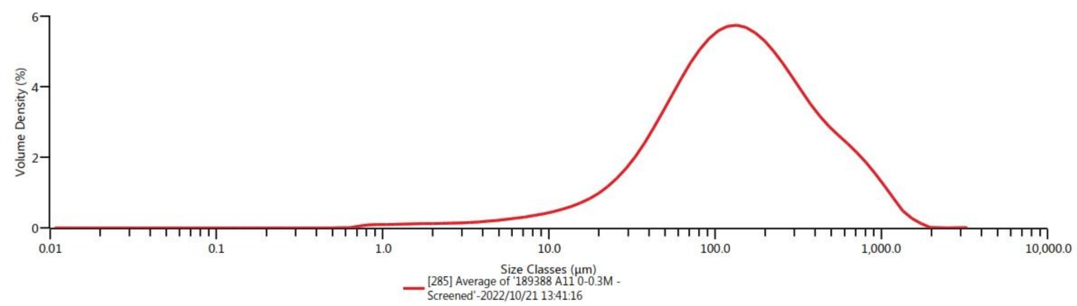
Result

Concentration	0.0342 %
Uniformity	1.164
Specific Surface Area	124.9 m^2/kg
D [3,2]	45.7 µm
D [4,3]	225 µm

Result

Span	3.845
Result Units	Volume
Dv (10)	31.4 µm
Dv (50)	136 µm
Dv (90)	553 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.128	0.00	1.28	0.35	12.7	3.74	111	42.47	1110	98.59
0.0114	0.00	0.146	0.00	1.45	0.44	14.5	4.26	127	47.50	1260	99.29
0.0129	0.00	0.166	0.00	1.65	0.53	16.4	4.82	144	52.21	1430	99.68
0.0147	0.00	0.188	0.00	1.88	0.63	18.7	5.52	163	56.81	1630	99.90
0.0189	0.00	0.214	0.00	2.13	0.73	21.2	6.32	186	61.59	1850	100.00
0.0215	0.00	0.243	0.00	2.50	0.86	24.1	7.30	211	65.96	2100	100.00
0.0278	0.00	0.276	0.00	2.75	0.94	27.4	8.47	240	70.17	2390	100.00
0.0315	0.00	0.314	0.00	3.12	1.05	31.1	9.86	272	73.98	2710	100.00
0.0358	0.00	0.357	0.00	3.55	1.18	35.3	11.53	310	77.64	3080	100.00
0.0407	0.00	0.405	0.00	4.03	1.31	40.1	13.53	352	80.86	3500	100.00
0.0463	0.00	0.460	0.00	4.58	1.47	44.0	15.24	400	83.78		
0.0526	0.00	0.523	0.00	5.21	1.64	45.0	15.66	454	86.40		
0.0597	0.00	0.594	0.00	5.92	1.84	51.8	18.65	516	88.80		
0.0679	0.00	0.675	0.00	6.72	2.06	58.9	21.81	586	90.98		
0.0771	0.00	0.767	0.04	7.64	2.32	66.9	25.35	666	92.98		
0.0876	0.00	0.872	0.11	8.68	2.61	76.0	29.25	756	94.75		
0.0995	0.00	1.00	0.19	10.0	2.98	86.4	33.49	859	96.31		
0.113	0.00	1.13	0.27	11.2	3.31	98.1	37.95	976	97.59		

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Particle size distribution

Malvern Instruments

Measurement Details	
Sample Name	Average of '189389 A11 1-1.3M - Screened'
SDS	428
SOP File Name	Default + 60us LV.msop

Measurement Details	
Measurement Date Time	2022/10/21 13:47:34
Analysis Date Time	2022/10/21 13:47:34
Original Record Number	289

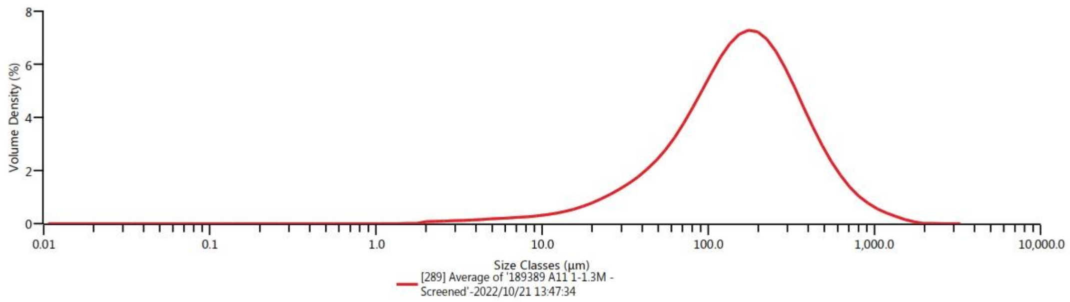
Analysis	
Particle Name	Default 1.0
Dispersant Name	Water
Particle Absorption Index	1.000
Weighted Residual	0.21 %
Analysis Model	General Purpose

Analysis	
Particle Refractive Index	1.520
Dispersant Refractive Index	1.330
Laser Obscuration	6.08 %
Scattering Model	Mie
Analysis Sensitivity	Normal

Result	
Concentration	0.0572 %
Uniformity	0.821
Specific Surface Area	78.51 m^2/kg
D [3,2]	72.8 µm
D [4,3]	215 µm

Result	
Span	2.553
Result Units	Volume
Dv (10)	40.8 µm
Dv (50)	160 µm
Dv (90)	449 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.128	0.00	1.28	0.00	12.7	2.34	111	34.07	1110	99.27
0.0114	0.00	0.146	0.00	1.45	0.00	14.5	2.72	127	39.59	1260	99.60
0.0129	0.00	0.166	0.00	1.65	0.00	16.4	3.15	144	45.16	1430	99.82
0.0147	0.00	0.188	0.00	1.88	0.00	18.7	3.70	163	50.94	1630	99.94
0.0189	0.00	0.214	0.00	2.13	0.06	21.2	4.33	186	57.23	1850	100.00
0.0215	0.00	0.243	0.00	2.50	0.15	24.1	5.10	211	63.20	2100	100.00
0.0278	0.00	0.276	0.00	2.75	0.21	27.4	6.02	240	69.05	2390	100.00
0.0315	0.00	0.314	0.00	3.12	0.30	31.1	7.08	272	74.36	2710	100.00
0.0358	0.00	0.357	0.00	3.55	0.40	35.3	8.32	310	79.37	3080	100.00
0.0407	0.00	0.405	0.00	4.03	0.51	40.1	9.78	352	83.63	3500	100.00
0.0463	0.00	0.460	0.00	4.58	0.64	44.0	11.02	400	87.28		
0.0526	0.00	0.523	0.00	5.21	0.78	45.0	11.32	454	90.28		
0.0597	0.00	0.594	0.00	5.92	0.94	51.8	13.47	516	92.74		
0.0679	0.00	0.675	0.00	6.72	1.11	58.9	15.79	586	94.68		
0.0771	0.00	0.767	0.00	7.64	1.30	66.9	18.49	666	96.19		
0.0876	0.00	0.872	0.00	8.68	1.52	76.0	21.64	756	97.32		
0.0995	0.00	1.00	0.00	10.0	1.79	86.4	25.31	859	98.18		
0.113	0.00	1.13	0.00	11.2	2.03	98.1	29.49	976	98.81		

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Particle size distribution

Malvern Instruments

Measurement Details

Sample Name Average of '189390 A12 0-0.3M - Screened'
SDS 429
SOP File Name Default + 60us LV.msop

Measurement Details

Measurement Date Time 2022/10/21 13:53:51
Analysis Date Time 2022/10/21 13:53:51
Original Record Number 293

Analysis

Particle Name Default 1.0
Dispersant Name Water
Particle Absorption Index 1.000
Weighted Residual 0.16 %
Analysis Model General Purpose

Analysis

Particle Refractive Index 1.520
Dispersant Refractive Index 1.330
Laser Obscuration 6.83 %
Scattering Model Mie
Analysis Sensitivity Normal

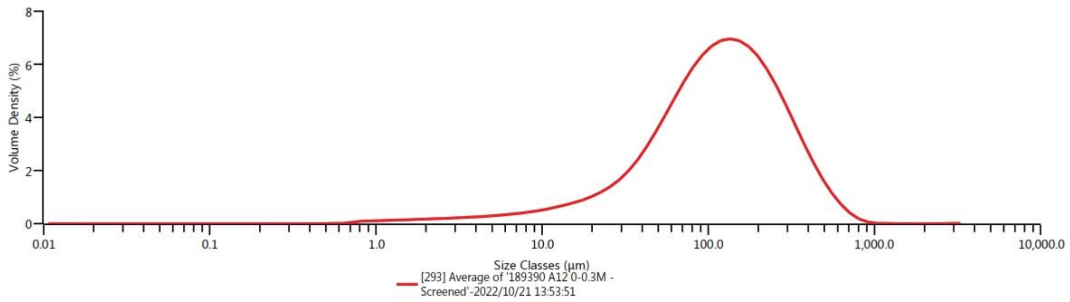
Result

Concentration 0.0335 %
Uniformity 0.781
Specific Surface Area 146.6 m^2/kg
D [3,2] 39.0 µm
D [4,3] 152 µm

Result

Span 2.523
Result Units Volume
Dv (10) 28.1 µm
Dv (50) 117 µm
Dv (90) 324 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.128	0.00	1.28	0.39	12.7	4.78	111	47.51	1110	100.00
0.0114	0.00	0.146	0.00	1.45	0.50	14.5	5.38	127	53.58	1260	100.00
0.0129	0.00	0.166	0.00	1.65	0.62	16.4	6.00	144	59.30	1430	100.00
0.0147	0.00	0.188	0.00	1.88	0.75	18.7	6.76	163	64.89	1630	100.00
0.0189	0.00	0.214	0.00	2.13	0.89	21.2	7.59	186	70.65	1850	100.00
0.0215	0.00	0.243	0.00	2.50	1.09	24.1	8.58	211	75.87	2100	100.00
0.0278	0.00	0.276	0.00	2.75	1.21	27.4	9.74	240	80.77	2390	100.00
0.0315	0.00	0.314	0.00	3.12	1.38	31.1	11.10	272	85.04	2710	100.00
0.0358	0.00	0.357	0.00	3.55	1.57	35.3	12.74	310	88.90	3080	100.00
0.0407	0.00	0.405	0.00	4.03	1.77	40.1	14.74	352	92.04	3500	100.00
0.0463	0.00	0.460	0.00	4.58	1.99	44.0	16.50	400	94.57		
0.0526	0.00	0.523	0.00	5.21	2.23	45.0	16.93	454	96.50		
0.0597	0.00	0.594	0.00	5.92	2.49	51.8	20.07	516	97.92		
0.0679	0.00	0.675	0.00	6.72	2.77	58.9	23.51	586	98.89		
0.0771	0.00	0.767	0.04	7.64	3.09	66.9	27.45	666	99.49		
0.0876	0.00	0.872	0.12	8.68	3.44	76.0	31.90	756	99.82		
0.0995	0.00	1.00	0.21	10.0	3.89	86.4	36.84	859	99.96		
0.113	0.00	1.13	0.29	11.2	4.28	98.1	42.11	976	100.00		

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Particle size distribution

Malvern Instruments

Measurement Details	
Sample Name	Average of '189391 A12 1.2-1.5M - Screened'
SDS	430
SOP File Name	Default + 60us LV.msop

Measurement Details	
Measurement Date Time	2022/10/21 14:00:16
Analysis Date Time	2022/10/21 14:00:16
Original Record Number	297

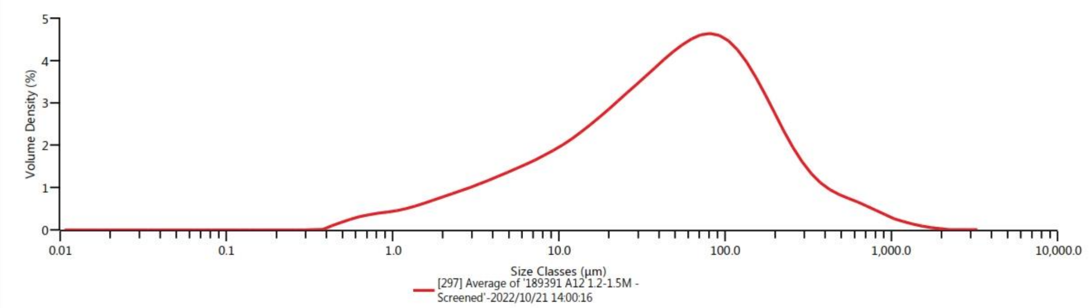
Analysis	
Particle Name	Default 1.0
Dispersant Name	Water
Particle Absorption Index	1.000
Weighted Residual	0.16 %
Analysis Model	General Purpose

Analysis	
Particle Refractive Index	1.520
Dispersant Refractive Index	1.330
Laser Obscuration	10.80 %
Scattering Model	Mie
Analysis Sensitivity	Normal

Result	
Concentration	0.0145 %
Uniformity	1.635
Specific Surface Area	529.7 m^2/kg
D [3,2]	10.8 µm
D [4,3]	100 µm

Result	
Span	4.544
Result Units	Volume
Dv (10)	4.63 µm
Dv (50)	49.7 µm
Dv (90)	231 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.128	0.00	1.28	2.47	12.7	21.37	111	73.69	1110	99.59
0.0114	0.00	0.146	0.00	1.45	2.92	14.5	23.37	127	77.44	1260	99.75
0.0129	0.00	0.166	0.00	1.65	3.45	16.4	25.36	144	80.69	1430	99.86
0.0147	0.00	0.188	0.00	1.88	4.04	18.7	27.64	163	83.60	1630	99.94
0.0189	0.00	0.214	0.00	2.13	4.67	21.2	29.98	186	86.36	1850	99.97
0.0215	0.00	0.243	0.00	2.50	5.58	24.1	32.52	211	88.64	2100	100.00
0.0278	0.00	0.276	0.00	2.75	6.15	27.4	35.23	240	90.61	2390	100.00
0.0315	0.00	0.314	0.00	3.12	6.98	31.1	38.07	272	92.20	2710	100.00
0.0358	0.00	0.357	0.00	3.55	7.89	35.3	41.06	310	93.56	3080	100.00
0.0407	0.00	0.405	0.00	4.03	8.86	40.1	44.25	352	94.66	3500	100.00
0.0463	0.00	0.460	0.08	4.58	9.91	44.0	46.68	400	95.58		
0.0526	0.00	0.523	0.23	5.21	11.05	45.0	47.27	454	96.36		
0.0597	0.00	0.594	0.44	5.92	12.26	51.8	51.12	516	97.06		
0.0679	0.00	0.675	0.70	6.72	13.54	58.9	54.79	586	97.68		
0.0771	0.00	0.767	1.00	7.64	14.92	66.9	58.54	666	98.23		
0.0876	0.00	0.872	1.32	8.68	16.38	76.0	62.38	756	98.69		
0.0995	0.00	1.00	1.70	10.0	18.13	86.4	66.27	859	99.08		
0.113	0.00	1.13	2.06	11.2	19.61	98.1	70.08	976	99.38		

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Particle size distribution

Malvern Instruments

Measurement Details	
Sample Name	Average of '189393 A14 0-0.4M - Screened'
SDS	431
SOP File Name	Default + 60us LV.msop

Measurement Details	
Measurement Date Time	2022/10/21 14:07:10
Analysis Date Time	2022/10/21 14:07:10
Original Record Number	301

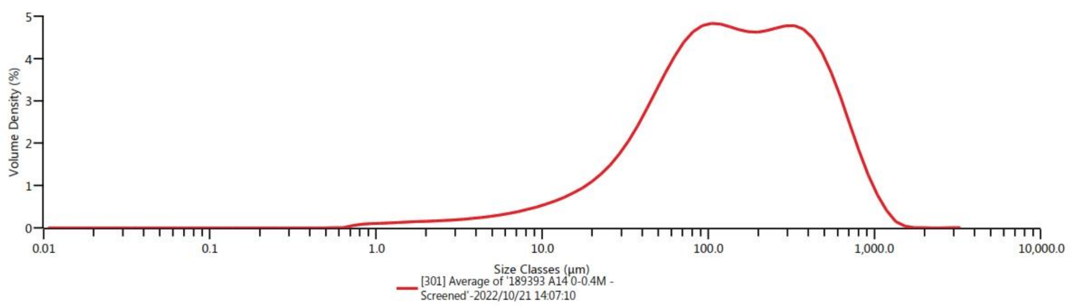
Analysis	
Particle Name	Default 1.0
Dispersant Name	Water
Particle Absorption Index	1.000
Weighted Residual	0.19 %
Analysis Model	General Purpose

Analysis	
Particle Refractive Index	1.520
Dispersant Refractive Index	1.330
Laser Obscuration	10.46 %
Scattering Model	Mie
Analysis Sensitivity	Normal

Result	
Concentration	0.0556 %
Uniformity	1.119
Specific Surface Area	137.7 m^2/kg
D [3,2]	41.5 µm
D [4,3]	226 µm

Result	
Span	3.617
Result Units	Volume
Dv (10)	27.6 µm
Dv (50)	143 µm
Dv (90)	546 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.128	0.00	1.28	0.38	12.7	4.66	111	42.02	1110	99.52
0.0114	0.00	0.146	0.00	1.45	0.48	14.5	5.28	127	46.25	1260	99.86
0.0129	0.00	0.166	0.00	1.65	0.59	16.4	5.94	144	50.15	1430	99.97
0.0147	0.00	0.188	0.00	1.88	0.72	18.7	6.74	163	53.93	1630	100.00
0.0189	0.00	0.214	0.00	2.13	0.84	21.2	7.63	186	57.92	1850	100.00
0.0215	0.00	0.243	0.00	2.50	1.02	24.1	8.69	211	61.73	2100	100.00
0.0278	0.00	0.276	0.00	2.75	1.12	27.4	9.93	240	65.64	2390	100.00
0.0315	0.00	0.314	0.00	3.12	1.28	31.1	11.37	272	69.50	2710	100.00
0.0358	0.00	0.357	0.00	3.55	1.44	35.3	13.07	310	73.58	3080	100.00
0.0407	0.00	0.405	0.00	4.03	1.63	40.1	15.08	352	77.55	3500	100.00
0.0463	0.00	0.460	0.00	4.58	1.83	44.0	16.79	400	81.47		
0.0526	0.00	0.523	0.00	5.21	2.06	45.0	17.20	454	85.18		
0.0597	0.00	0.594	0.00	5.92	2.31	51.8	20.14	516	88.65		
0.0679	0.00	0.675	0.00	6.72	2.59	58.9	23.22	586	91.70		
0.0771	0.00	0.767	0.04	7.64	2.91	66.9	26.60	666	94.28		
0.0876	0.00	0.872	0.11	8.68	3.27	76.0	30.26	756	96.32		
0.0995	0.00	1.00	0.20	10.0	3.73	86.4	34.14	859	97.84		
0.113	0.00	1.13	0.29	11.2	4.14	98.1	38.11	976	98.88		

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Particle size distribution

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Measurement Details

Sample Name	Average of '189392 A14 0.4-0.6M - Screened'
SDS	432
SOP File Name	Default + 60us LV.msop
Measurement Date Time	2022/10/21 14:15:24
Analysis Date Time	2022/10/21 14:15:24
Original Record Number	305

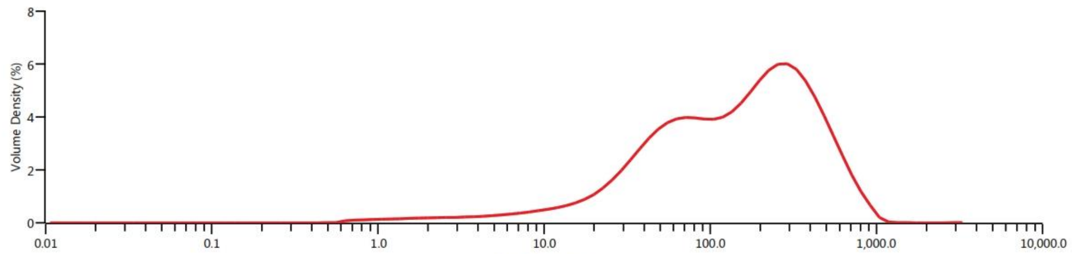
Analysis

Particle Name	Default 1.0
Dispersant Name	Water
Particle Absorption Index	1.000
Weighted Residual	0.29 %
Analysis Model	General Purpose
Particle Refractive Index	1.520
Dispersant Refractive Index	1.330
Laser Obscuration	9.20 %
Scattering Model	Mie
Analysis Sensitivity	Normal

Result

Concentration	0.0426 %
Uniformity	0.935
Specific Surface Area	156.1 m^2/kg
D [3,2]	36.6 µm
D [4,3]	210 µm
Span	2.937
Result Units	Volume
Dv (10)	27.3 µm
Dv (50)	154 µm
Dv (90)	479 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.128	0.00	1.28	0.57	12.7	4.85	111	41.12	1110	99.98
0.0114	0.00	0.146	0.00	1.45	0.69	14.5	5.40	127	44.63	1260	100.00
0.0129	0.00	0.166	0.00	1.65	0.83	16.4	6.00	144	48.06	1430	100.00
0.0147	0.00	0.188	0.00	1.88	0.98	18.7	6.75	163	51.72	1630	100.00
0.0189	0.00	0.214	0.00	2.13	1.13	21.2	7.62	186	55.97	1850	100.00
0.0215	0.00	0.243	0.00	2.50	1.33	24.1	8.71	211	60.41	2100	100.00
0.0278	0.00	0.276	0.00	2.75	1.46	27.4	10.06	240	65.27	2390	100.00
0.0315	0.00	0.314	0.00	3.12	1.62	31.1	11.69	272	70.19	2710	100.00
0.0358	0.00	0.357	0.00	3.55	1.80	35.3	13.66	310	75.34	3080	100.00
0.0407	0.00	0.405	0.00	4.03	1.99	40.1	15.99	352	80.16	3500	100.00
0.0463	0.00	0.460	0.00	4.58	2.19	44.0	17.93	400	84.65		
0.0526	0.00	0.523	0.00	5.21	2.42	45.0	18.40	454	88.59		
0.0597	0.00	0.594	0.00	5.92	2.67	51.8	21.62	516	91.97		
0.0679	0.00	0.675	0.07	6.72	2.94	58.9	24.81	586	94.70		
0.0771	0.00	0.767	0.15	7.64	3.25	66.9	28.08	666	96.81		
0.0876	0.00	0.872	0.24	8.68	3.59	76.0	31.40	756	98.31		
0.0995	0.00	1.00	0.35	10.0	4.01	86.4	34.72	859	99.29		
0.113	0.00	1.13	0.45	11.2	4.38	98.1	37.97	976	99.84		

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Particle size distribution

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Measurement Details	
Sample Name	Average of '189394 A15 Composite - Screened'
SDS	433
SOP File Name	Default + 60us LV.msop

Measurement Details	
Measurement Date Time	2022/10/21 14:21:35
Analysis Date Time	2022/10/21 14:21:35
Original Record Number	309

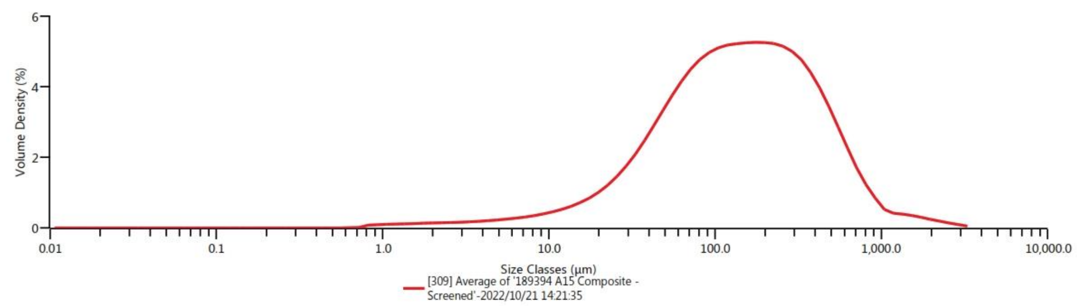
Analysis	
Particle Name	Default 1.0
Dispersant Name	Water
Particle Absorption Index	1.000
Weighted Residual	0.20 %
Analysis Model	General Purpose

Analysis	
Particle Refractive Index	1.520
Dispersant Refractive Index	1.330
Laser Obscuration	7.27 %
Scattering Model	Mie
Analysis Sensitivity	Normal

Result	
Concentration	0.0422 %
Uniformity	1.150
Specific Surface Area	124.7 m^2/kg
D [3,2]	45.8 µm
D [4,3]	230 µm

Result	
Span	3.365
Result Units	Volume
Dv (10)	30.7 µm
Dv (50)	142 µm
Dv (90)	507 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.128	0.00	1.28	0.31	12.7	3.84	111	41.75	1110	98.21
0.0114	0.00	0.146	0.00	1.45	0.40	14.5	4.37	127	46.31	1260	98.55
0.0129	0.00	0.166	0.00	1.65	0.50	16.4	4.94	144	50.59	1430	98.88
0.0147	0.00	0.188	0.00	1.88	0.61	18.7	5.66	163	54.84	1630	99.17
0.0189	0.00	0.214	0.00	2.13	0.72	21.2	6.48	186	59.37	1850	99.42
0.0215	0.00	0.243	0.00	2.50	0.87	24.1	7.49	211	63.70	2100	99.62
0.0278	0.00	0.276	0.00	2.75	0.97	27.4	8.71	240	68.10	2390	99.77
0.0315	0.00	0.314	0.00	3.12	1.10	31.1	10.15	272	72.31	2710	99.89
0.0358	0.00	0.357	0.00	3.55	1.24	35.3	11.88	310	76.59	3080	99.96
0.0407	0.00	0.405	0.00	4.03	1.39	40.1	13.94	352	80.55	3500	100.00
0.0463	0.00	0.460	0.00	4.58	1.56	44.0	15.69	400	84.24		
0.0526	0.00	0.523	0.00	5.21	1.75	45.0	16.11	454	87.52		
0.0597	0.00	0.594	0.00	5.92	1.95	51.8	19.14	516	90.40		
0.0679	0.00	0.675	0.00	6.72	2.18	58.9	22.29	586	92.77		
0.0771	0.00	0.767	0.00	7.64	2.43	66.9	25.75	666	94.66		
0.0876	0.00	0.872	0.07	8.68	2.72	76.0	29.50	756	96.07		
0.0995	0.00	1.00	0.15	10.0	3.09	86.4	33.51	859	97.09		
0.113	0.00	1.13	0.23	11.2	3.42	98.1	37.63	976	97.79		

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Particle size distribution

Malvern Instruments

Measurement Details	
Sample Name	Average of '189396 A16 0-0.2M - Screened'
SDS	434
SOP File Name	Default + 60us LV.msop

Measurement Details	
Measurement Date Time	2022/10/21 14:27:53
Analysis Date Time	2022/10/21 14:27:53
Original Record Number	313

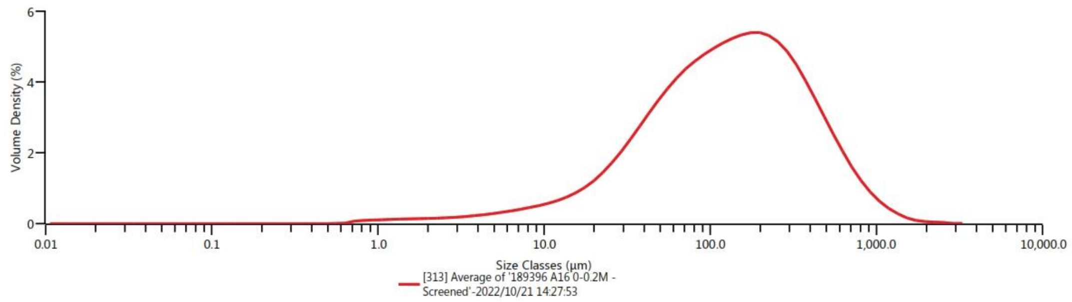
Analysis	
Particle Name	Default 1.0
Dispersant Name	Water
Particle Absorption Index	1.000
Weighted Residual	0.15 %
Analysis Model	General Purpose

Analysis	
Particle Refractive Index	1.520
Dispersant Refractive Index	1.330
Laser Obscuration	7.93 %
Scattering Model	Mie
Analysis Sensitivity	Normal

Result	
Concentration	0.0398 %
Uniformity	1.089
Specific Surface Area	143.8 m^2/kg
D [3,2]	39.7 μm
D [4,3]	205 μm

Result	
Span	3.381
Result Units	Volume
Dv (10)	26.0 μm
Dv (50)	132 μm
Dv (90)	473 μm

Frequency (compatible)



Result

Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under	Size (μm)	% Volume Under
0.0100	0.00	0.128	0.00	1.28	0.41	12.7	4.74	111	44.12	1110	99.12
0.0114	0.00	0.146	0.00	1.45	0.51	14.5	5.38	127	48.60	1260	99.47
0.0129	0.00	0.166	0.00	1.65	0.62	16.4	6.07	144	52.89	1430	99.70
0.0147	0.00	0.188	0.00	1.88	0.74	18.7	6.93	163	57.20	1630	99.83
0.0189	0.00	0.214	0.00	2.13	0.86	21.2	7.92	186	61.85	1850	99.90
0.0215	0.00	0.243	0.00	2.50	1.03	24.1	9.13	211	66.31	2100	99.94
0.0278	0.00	0.276	0.00	2.75	1.13	27.4	10.57	240	70.78	2390	99.98
0.0315	0.00	0.314	0.00	3.12	1.27	31.1	12.26	272	74.99	2710	100.00
0.0358	0.00	0.357	0.00	3.55	1.43	35.3	14.23	310	79.15	3080	100.00
0.0407	0.00	0.405	0.00	4.03	1.61	40.1	16.52	352	82.87	3500	100.00
0.0463	0.00	0.460	0.00	4.58	1.82	44.0	18.41	400	86.24		
0.0526	0.00	0.523	0.00	5.21	2.06	45.0	18.87	454	89.17		
0.0597	0.00	0.594	0.00	5.92	2.32	51.8	22.04	516	91.71		
0.0679	0.00	0.675	0.00	6.72	2.62	58.9	25.24	586	93.80		
0.0771	0.00	0.767	0.06	7.64	2.95	66.9	28.66	666	95.51		
0.0876	0.00	0.872	0.14	8.68	3.33	76.0	32.30	756	96.83		
0.0995	0.00	1.00	0.23	10.0	3.80	86.4	36.15	859	97.85		
0.113	0.00	1.13	0.31	11.2	4.22	98.1	40.12	976	98.59		

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Particle size distribution

Malvern Instruments

Measurement Details

Sample Name Average of '189395 A16 0.3M - Screened'
SDS 435
SOP File Name Default + 60us LV.msop

Measurement Details

Measurement Date Time 2022/10/21 14:33:58
Analysis Date Time 2022/10/21 14:33:58
Original Record Number 317

Analysis

Particle Name Default 1.0
Dispersant Name Water
Particle Absorption Index 1.000
Weighted Residual 0.15 %
Analysis Model General Purpose

Analysis

Particle Refractive Index 1.520
Dispersant Refractive Index 1.330
Laser Obscuration 9.28 %
Scattering Model Mie
Analysis Sensitivity Normal

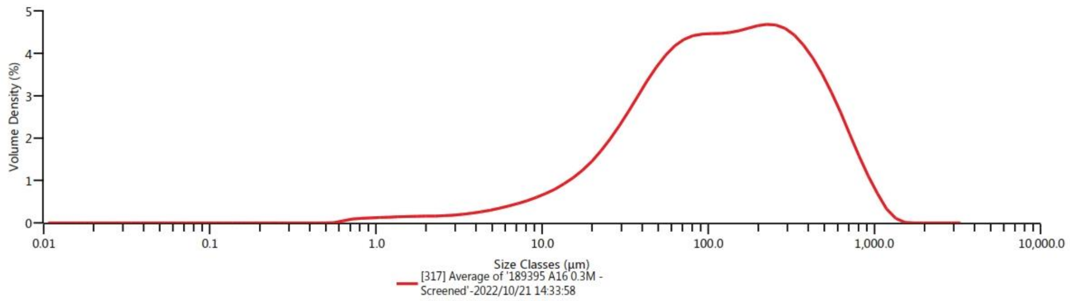
Result

Concentration 0.0418 %
Uniformity 1.190
Specific Surface Area 161.2 m^2/kg
D [3,2] 35.4 µm
D [4,3] 206 µm

Result

Span 3.849
Result Units Volume
Dv (10) 22.5 µm
Dv (50) 126 µm
Dv (90) 508 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.128	0.00	1.28	0.52	12.7	5.44	111	46.26	1110	99.65
0.0114	0.00	0.146	0.00	1.45	0.64	14.5	6.24	127	50.19	1260	99.92
0.0129	0.00	0.166	0.00	1.65	0.76	16.4	7.09	144	53.87	1430	100.00
0.0147	0.00	0.188	0.00	1.88	0.89	18.7	8.16	163	57.53	1630	100.00
0.0189	0.00	0.214	0.00	2.13	1.02	21.2	9.34	186	61.49	1850	100.00
0.0215	0.00	0.243	0.00	2.50	1.19	24.1	10.76	211	65.32	2100	100.00
0.0278	0.00	0.276	0.00	2.75	1.30	27.4	12.42	240	69.27	2390	100.00
0.0315	0.00	0.314	0.00	3.12	1.45	31.1	14.32	272	73.09	2710	100.00
0.0358	0.00	0.357	0.00	3.55	1.62	35.3	16.50	310	77.01	3080	100.00
0.0407	0.00	0.405	0.00	4.03	1.81	40.1	18.99	352	80.69	3500	100.00
0.0463	0.00	0.460	0.00	4.58	2.03	44.0	21.01	400	84.19		
0.0526	0.00	0.523	0.00	5.21	2.28	45.0	21.50	454	87.41		
0.0597	0.00	0.594	0.00	5.92	2.57	51.8	24.85	516	90.35		
0.0679	0.00	0.675	0.04	6.72	2.90	58.9	28.17	586	92.91		
0.0771	0.00	0.767	0.12	7.64	3.28	66.9	31.64	666	95.09		
0.0876	0.00	0.872	0.21	8.68	3.71	76.0	35.25	756	96.83		
0.0995	0.00	1.00	0.31	10.0	4.28	86.4	38.96	859	98.15		
0.113	0.00	1.13	0.41	11.2	4.79	98.1	42.65	976	99.07		

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Particle size distribution

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Measurement Details

Sample Name	Average of '189397 A17 0.0.3M - Screened'
SDS	436
SOP File Name	Default + 60us LV.msop
Measurement Date Time	2022/10/21 14:40:29
Analysis Date Time	2022/10/21 14:40:29
Original Record Number	321

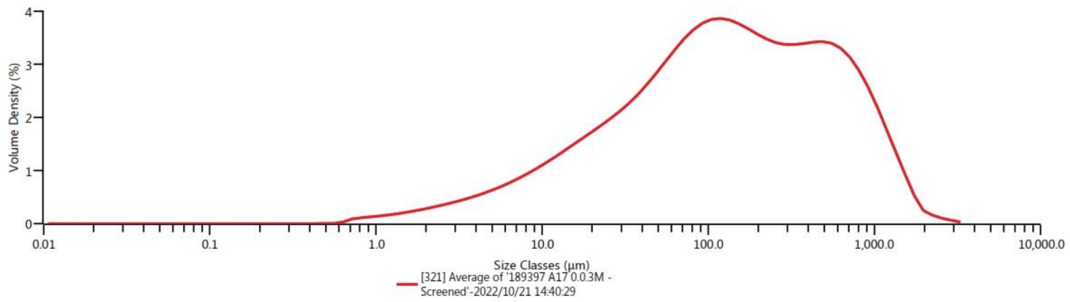
Analysis

Particle Name	Default 1.0
Dispersant Name	Water
Particle Absorption Index	1.000
Weighted Residual	0.18 %
Analysis Model	General Purpose
Particle Refractive Index	1.520
Dispersant Refractive Index	1.330
Laser Obscuration	10.52 %
Scattering Model	Mie
Analysis Sensitivity	Normal

Result

Concentration	0.0369 %
Uniformity	1.762
Specific Surface Area	208.0 m²/kg
D [3,2]	27.5 µm
D [4,3]	284 µm
Span	5.812
Result Units	Volume
Dv (10)	13.4 µm
Dv (50)	132 µm
Dv (90)	783 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.128	0.00	1.28	0.55	12.7	9.51	111	45.54	1110	95.71
0.0114	0.00	0.146	0.00	1.45	0.70	14.5	10.69	127	48.94	1260	97.19
0.0129	0.00	0.166	0.00	1.65	0.88	16.4	11.89	144	52.08	1430	98.32
0.0147	0.00	0.188	0.00	1.88	1.09	18.7	13.27	163	55.13	1630	99.09
0.0189	0.00	0.214	0.00	2.13	1.32	21.2	14.68	186	58.29	1850	99.52
0.0215	0.00	0.243	0.00	2.50	1.66	24.1	16.23	211	61.22	2100	99.71
0.0278	0.00	0.276	0.00	2.75	1.88	27.4	17.88	240	64.14	2390	99.84
0.0315	0.00	0.314	0.00	3.12	2.21	31.1	19.62	272	66.93	2710	99.93
0.0358	0.00	0.357	0.00	3.55	2.59	35.3	21.49	310	69.81	3080	99.98
0.0407	0.00	0.405	0.00	4.03	3.00	40.1	23.51	352	72.60	3500	100.00
0.0463	0.00	0.460	0.00	4.58	3.46	44.0	25.10	400	75.44		
0.0526	0.00	0.523	0.00	5.21	3.98	45.0	25.48	454	78.26		
0.0597	0.00	0.594	0.00	5.92	4.55	51.8	28.06	516	81.13		
0.0679	0.00	0.675	0.02	6.72	5.19	58.9	30.62	586	83.96		
0.0771	0.00	0.767	0.10	7.64	5.89	66.9	33.34	666	86.72		
0.0876	0.00	0.872	0.19	8.68	6.67	76.0	36.24	756	89.33		
0.0995	0.00	1.00	0.30	10.0	7.64	86.4	39.30	859	91.74		
0.113	0.00	1.13	0.42	11.2	8.48	98.1	42.43	976	93.88		

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Particle size distribution

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Measurement Details	
Sample Name	Average of '189398 A17 1.3-1.5M - Screened'
SDS	437
SOP File Name	Default + 60us LV.msop

Measurement Details	
Measurement Date Time	2022/10/21 14:47:14
Analysis Date Time	2022/10/21 14:47:14
Original Record Number	325

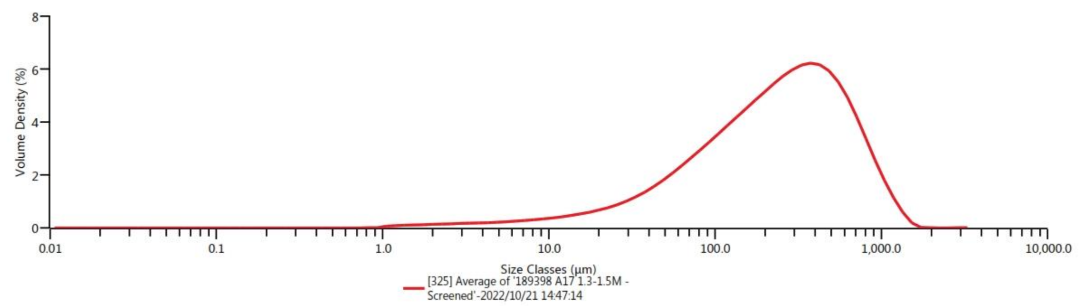
Analysis	
Particle Name	Default 1.0
Dispersant Name	Water
Particle Absorption Index	1.000
Weighted Residual	0.24 %
Analysis Model	General Purpose

Analysis	
Particle Refractive Index	1.520
Dispersant Refractive Index	1.330
Laser Obscuration	7.22 %
Scattering Model	Mie
Analysis Sensitivity	Normal

Result	
Concentration	0.0565 %
Uniformity	0.848
Specific Surface Area	92.73 m^2/kg
D [3,2]	61.6 µm
D [4,3]	317 µm

Result	
Span	2.724
Result Units	Volume
Dv (10)	42.3 µm
Dv (50)	243 µm
Dv (90)	703 µm

Frequency (compatible)



Result

Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under	Size (µm)	% Volume Under
0.0100	0.00	0.128	0.00	1.28	0.13	12.7	3.33	111	26.14	1110	98.43
0.0114	0.00	0.146	0.00	1.45	0.21	14.5	3.73	127	29.53	1260	99.38
0.0129	0.00	0.166	0.00	1.65	0.30	16.4	4.15	144	32.97	1430	99.87
0.0147	0.00	0.188	0.00	1.88	0.40	18.7	4.65	163	36.62	1630	100.00
0.0189	0.00	0.214	0.00	2.13	0.51	21.2	5.20	186	40.77	1850	100.00
0.0215	0.00	0.243	0.00	2.50	0.66	24.1	5.83	211	45.00	2100	100.00
0.0278	0.00	0.276	0.00	2.75	0.75	27.4	6.56	240	49.58	2390	100.00
0.0315	0.00	0.314	0.00	3.12	0.89	31.1	7.39	272	54.26	2710	100.00
0.0358	0.00	0.357	0.00	3.55	1.03	35.3	8.35	310	59.37	3080	100.00
0.0407	0.00	0.405	0.00	4.03	1.19	40.1	9.46	352	64.48	3500	100.00
0.0463	0.00	0.460	0.00	4.58	1.35	44.0	10.41	400	69.69		
0.0526	0.00	0.523	0.00	5.21	1.53	45.0	10.63	454	74.80		
0.0597	0.00	0.594	0.00	5.92	1.72	51.8	12.26	516	79.77		
0.0679	0.00	0.675	0.00	6.72	1.92	58.9	13.99	586	84.37		
0.0771	0.00	0.767	0.00	7.64	2.15	66.9	15.93	666	88.50		
0.0876	0.00	0.872	0.00	8.68	2.40	76.0	18.12	756	91.98		
0.0995	0.00	1.00	0.01	10.0	2.71	86.4	20.58	859	94.81		
0.113	0.00	1.13	0.06	11.2	2.99	98.1	23.27	976	96.94		

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APPENDIX C: HYDROPEDOLOGY RISK ASSESSMENT METHODOLOGY

Due to the assessment forming part of a larger risk assessment for the study area, the potential impacts and the determination of impact significance were assessed. The process of assessing the potential impacts of the project encompasses the following four activities:

1. Identification and assessment of potential impacts.
2. Prediction of the nature, magnitude, extent, and duration of potentially significant impacts.
3. Identification of mitigation measures that could be implemented to reduce the severity or significance of the impacts of the activity; and
4. Evaluation of the significance of the impact after the mitigation measures have been implemented i.e., the significance of the residual impact.

Per GNR 982 of the EIA Regulations (2014), the significance of potential impacts was assessed in terms of the following criteria:

I. Cumulative impacts.
II. Nature of the impact.
III. The extent of the impact.
IV. Probability of the impact occurring.
V. The degree to which the impact can be reversed.
VI. The degree to which the impact may cause irreplaceable loss of resources; and
VII. The degree to which the impact can be mitigated.

Table 6-1 provides a summary of the criteria used to assess the significance of the potential impacts identified. An explanation of these impact criteria is provided in Table 6-2.

Consequence = (Duration + Extent + Irreplaceability of resource) x Severity

And the environmental significance of an impact was determined by multiplying consequence by probability.

Table 6-1: Proposed Criteria and Rating Scales to be used in the Assessment of the Potential Impacts

Criteria	Rating Scales	Notes
Nature	Positive (+)	An evaluation of the effect of the impact related to the proposed development.
	Negative (-)	
Extent	Footprint (1)	The impact only affects the area in which the proposed activity will occur.
	Site (2)	The impact will affect only the development area.
	Local (3)	The impact affects the development area and adjacent properties.
	Regional (4)	The effect of the impact extends beyond municipal boundaries.
	National (5)	The effect of the impact extends beyond more than 2 regional/provincial boundaries.
	International (6)	The effect of the impact extends beyond country borders.
Duration	Temporary (1)	The duration of the activity associated with the impact will last 0-6 months.
	Short-term (2)	The duration of the activity associated with the impact will last 6-18 months.

Criteria	Rating Scales	Notes
	Medium-term (3)	The duration of the activity associated with the impact will last 18 months-5 or years.
	Long-term (4)	The duration of the activity associated with the impact will last more than 5 years.
Severity	Low (1)	Where the impact affects the environment in such a way that natural, cultural and social functions and processes are minimally affected.
	Moderate (2)	Where the affected environment is altered but natural, cultural and social functions and processes continue albeit in a modified way; and valued, important, sensitive, or vulnerable systems or communities are negatively affected.
	High (3)	Where natural, cultural, or social functions and processes are altered to the extent that the natural process will temporarily or permanently cease; and valued, important, sensitive, or vulnerable systems or communities are substantially affected.
Potential for impact on irreplaceable resources	No (0)	No irreplaceable resources will be impacted.
	Yes (1)	Irreplaceable resources will be impacted.
Consequence	Extremely detrimental (-25 to -33)	A combination of extent, duration, intensity, and the potential for impact on irreplaceable resources.
	Highly detrimental (-19 to -24)	
	Moderately detrimental (-13 to -18)	
	Slightly detrimental (-7 to -12)	
	Negligible (-6 to 0)	
	Slightly beneficial (0 to 6)	
	Moderately beneficial (13 to 18)	
	Highly beneficial (19 to 24)	
	Extremely beneficial (25 to 33)	
Probability (the likelihood of the impact occurring)	Improbable (0)	It is highly unlikely or less than 50% likely that an impact will occur.
	Probable (1)	It is between 50 and 70% certain that the impact will occur.
	Definite (2)	It is more than 75% certain that the impact will occur, or the impact will occur.
Significance	Very high - negative (-49 to -66)	A function of Consequence and Probability.
	High - negative (-37 to -48)	
	Moderate - negative (-25 to -36)	
	Low - negative (-13 to -24)	
	Neutral - Very low (0 to -12)	
	Low-positive (0 to 12)	
	Moderate-positive (13 to 24)	
	High-positive (24 to 48)	
	Very high - positive (49 to 66)	

Table 6-2: Explanation of Assessment Criteria

Criteria	Explanation
Nature	This is an evaluation of the type of effect the construction, operation, and management of the proposed development would have on the affected environment. Will the impact of change on the environment be positive, negative, or neutral?
Extent or Scale	This refers to the spatial scale at which the impact will occur. The extent of the impact is described as footprint (affecting only the footprint of the development), site (limited to the site), and regional (limited to the immediate surroundings and closest towns to the site). The extent of scale refers to the actual physical footprint of the impact, not to the spatial significance. It is acknowledged that some impacts, even though they may be of a small extent, are of very high importance, e.g., impacts on species of very restricted range. To avoid "double counting, specialists have been requested to indicate spatial significance under "intensity" or "impact on irreplaceable resources" but not under "extent" as well.
Duration	The lifespan of the impact is indicated as temporary, short, medium, and long-term.
Severity	This is a relative evaluation within the context of all the activities and the other impacts within the framework of the project. Does the activity destroy the impacted environment, alter its functioning, or render it slightly altered?
Impact on irreplaceable resources	This refers to the potential for an environmental resource to be replaced, should it be impacted. A resource could be replaced by natural processes (e.g., by natural colonization from surrounding areas), through artificial means (e.g., by reseeding disturbed areas or replanting rescued species) or by providing a substitute resource, in certain cases. In natural systems, providing substitute resources is usually not possible, but in social systems, substitutes are often possible (e.g., by constructing new social facilities for those that are lost). Should it not be possible to replace a resource, the resource is essentially irreplaceable e.g., red data species that are restricted to a particular site or habitat to a very limited extent.
Consequence	The consequence of the potential impacts is a summation of the above criteria, namely the extent, duration, intensity, and impact on irreplaceable resources.

Criteria	Explanation
Probability of occurrence	The probability of the impact occurring is based on the professional experience of the specialist with environments of a similar nature to the site and/or with similar projects. It is important to distinguish between the probability of the impact occurring and the probability that the activity causing a potential impact will occur. Probability is defined as the probability of the impact occurring, not as the probability of the activities that may result in the impact.
Significance	Impact significance is defined to be a combination of the consequence (as described below) and the probability of the impact occurring. The relationship between consequence and probability highlights that the risk (or impact significance) must be evaluated in terms of the seriousness (consequence) of the impact, weighted by the probability of the impact occurring. In simple terms, if the consequence and probability of an impact are high, then the impact will have a high significance. The significance defines the level to which the impact will influence the proposed development and/or environment. It determines whether mitigation measures need to be identified and implemented and whether the impact is important for decision-making.
Degree of confidence in predictions	Specialists and the EIR team were required to indicate the degree of confidence (low, medium, or high) that there is in the predictions made for each impact, based on the available information and their level of knowledge and expertise. The degree of confidence is not taken into account in the determination of consequence or probability.
Mitigation measures	Mitigation measures are designed to reduce the consequence or probability of an impact or to reduce both consequence and probability. The significance of impacts has been assessed both with mitigation and without mitigation.

APPENDIX D: DISCLAIMER AND DECELERATION OF INDEPENDENCE

The opinions expressed in this Report have been based on site/project information supplied to GCS (Pty) Ltd by Kangra Coal (Pty) Ltd and are based on public domain data, field data and data supplied to GCS by the client. GCS has acted and undertaken this assessment objectively and independently.

GCS has exercised all due care in reviewing the supplied information. Whilst GCS has compared key supplied data with expected values, the accuracy of the results and conclusions are entirely reliant on the accuracy and completeness of the supplied data. GCS does not accept responsibility for any errors or omissions in the supplied information and does not accept any consequential liability arising from commercial decisions or actions resulting from them.

Opinions presented in this report, apply to the site conditions, and features as they existed at the time of GCS's investigations, and those reasonably foreseeable. These opinions do not necessarily apply to conditions and features that may arise after the date of this report, about which GCS had no prior knowledge nor had the opportunity to evaluate.

APPENDIX E: DETAILS OF THE SPECIALIST, DECLARATION OF INTEREST AND UNDERTAKING UNDER OATH

Application for authorisation in terms of the National Environmental Management Act, Act No. 107 of 1998, as amended and the Environmental Impact Assessment (EIA) Regulations, 2014, as amended (the Regulations)

PROJECT TITLE

Hydropedology Assessment for the Proposed Co-Disposal Facility & Water Treatment Plant at Kangra Maquasa East Operations

SPECIALIST INFORMATION

Specialist Company Name:	GCS Environmental SA			
B-BBEE	Contribution level (indicate 1 to 8 or non-compliant)	2	Percentage Procurement Recognition	
Specialist name:	Hendrik Botha			
Specialist Qualifications:	MSc Environmental Sciences (Geohydrology & Geochemistry) BSc Hons. Environmental Sciences (Hydrology) BSc. Geology and Chemistry			
Professional affiliation/registration:	PR SCI NAT 400139/17			
Physical address:	1 Karbochem Road, Newcastle, KZN			
Postal address:				
Postal code:	2940	Cell:		
Telephone:	071 102 3819	Fax:		
E-mail:	hendrikb@gcs-sa.biz			

DECLARATION BY THE SPECIALIST

I, Hendrik Botha, declare that –

- I act as the independent specialist in this application.
- I will perform the work relating to the application objectively, 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 concerning 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 48 and is punishable in terms of section 24F of the Act.

09/11/2022
1:49:53
Pr.Sci.Nat (400139/17)

Signature of the Specialist

GCS

Name of Company:

17 November 2023

Date

APPENDIX F: CV OF SPECIALIST

Hendrik Botha

Technical Director

LinkedIn:

CORE SKILLS

- Project management
- Analytical and numerical groundwater modelling
- Geochemical assessments and geochemical modelling
- Hydropedology, hydrological assessments & yield assessments
- Hydrology, floodline modelling & storm water management
- Groundwater vulnerability, impact, and risk assessments
- Technical report writing
- GIS and mapping

DETAILS

Qualifications

- BSc Chemistry and Geology (Environmental Sciences) (2012)
- BSc Hons Hydrology (Environmental Sciences) (2013)
- MSc Geohydrology and Hydrology (Environmental Sciences) (2014-2016)

Membership

- Groundwater Division of GSSA
- Groundwater Association of KwaZulu Natal Member
- International Mine Water Association (IMWA)

Languages

- Afrikaans – Speak, read, write.
- English – Speak, read, write.

Projects undertaken in

- South Africa
- Nigeria
- Namibia
- Liberia

PROFILE

Hendrik (Henri) Botha is currently the manager of the GCS Newcastle Office and occupies the role of principal hydrogeologist. Groundwater, geochemistry and surface hydrology, as well as knowledge of water chemistry together with GIS, and analytical and numerical modelling skills, are some of his sought-after expertise. General and applied logical knowledge are his key elements in problem-solving.

Professional Affiliations:

SACNASP Professional Natural Scientist (400139/17)

Areas of Expertise:

- Waste classification and Impact Assessments
- Aquifer vulnerability assessments
- Geochemical sampling, data interpretation and modelling
- Geophysical surveys and data interpretation
- GIS
- Water quality sampling and data interpretation
- Groundwater impact and risk assessments
- Numerical and Conceptual Visual Modelling (Visual Modflow, ModflowFLEX, Voxler, RockWorks, Surfer and Excel)
- Hydropedology (Hydrological Soil Types) & Soils Assessments
- Floodline Modelling (HEC-RAS)
- Stormwater Management Systems and Modelling
- Surface Water Yield Assessments
- Water and Salt Balances

SCAN ME
PROJECT RECORD

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