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# Hydrology Assessment for the Bundu Sands (Rietvalei) Mining Permit

## Report

**Version – Final 1**

**20 September 2024**

**Umhlaba Environmental Consulting CC**

**GCS Project Number: 23-0858**

**Client Reference: Bundu Sands (Rietvalei)**

**Report**
**Version – Final 1**

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## DOCUMENT ISSUE STATUS

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## DECLARATION OF INDEPENDENCE

GCS (Pty) Ltd was appointed to conduct this specialist hydrological study and to act as the independent hydrological specialist. GCS objectively performed the work, even if this resulted in views and findings that were not favourable. GCS has the expertise to conduct the specialist investigation and does not have a conflict of interest in undertaking 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:<br>(i) The specialist who prepares the reports; and<br>(ii) the expertise of that specialist to compile a specialist report, including a curriculum vitae | Document Issue (Page ii)<br>Appendix C. |
| (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 | Section 1. and 3. |
| (cA) Indication of the quality and age of base data used for the specialist report | Sections 1, 2 and 7. |
| (cB) A description of existing impacts on the site, cumulative impacts of the proposed development and levels of acceptable change | Section 7. |
| (d) Duration, Date and seasons of the site investigation and the relevance of the season to the outcome of the assessment | Section 1.2. |
| (e) Description of the methodology adopted in preparing the report or carrying out the specialised process, including equipment and modelling used | Section 2. |
| (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 | Sections 1, 2, 3 and 5. |
| (g) Identification of any areas to be avoided, including buffers | Section 9.1 |
| (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, 5 and 6. |
| (i) Description of any assumptions made and uncertainties or gaps in knowledge | Sections 1.3, 5.3, and 7. |
| (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 | Executive summary,<br>Section 7. |
| (k) Mitigation measures for inclusion in the EMPr | Section 9.1 |
| (l) Conditions for inclusion in the environmental authorisation | Refer to recommendations in Section 9. |
| (m) Monitoring requirements for inclusion in the EMPr or environmental authorisation | Refer to recommendations in Section 9. |
| (n) Reasoned opinion –<br>(i) as to whether the proposed activity, activities or portions thereof should be authorised.<br>(a) regarding the acceptability of the proposed activity or activities and<br>(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 | Section 9.3 |
| *(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.* |

# EXECUTIVE SUMMARY

GCS Water and Environment (Pty) Ltd (GCS) was appointed by Umhlaba Environmental Consulting CC (Umhlaba) to undertake a hydrology assessment to supplement the Water Use License (WUL) for the proposed Bundu Sands (Rietvalei) Mining Right (MR) Application, situated in the Kameeldrif West area, in Gauteng Province. The project falls within Quaternary catchment A211 of the Limpopo Water Management Area (WMA) (DWS, 2016).

The end client (Bundu Sands) wants to apply for a mining right at Bundu Sand Rietvalei, situated in the Kameeldrif West area in Gauteng Province. There are two drainage lines on either side of the application area that had to be evaluated, as these were pre-identified as potential watercourses.

Existing infrastructure entails a non-operational plant, one small-scale shovel (TLB and excavator) mining excavation, a stormwater dam and several settlement ponds which have been silted up due to historic mining activities. Rehabilitated sand mining operations that pre-dates Bundu mining are evident all over the project area.

Activities associated with the proposed Project include the addition of a proposed washing and settlement dam, which would be a shallow and deep opencast quarry, into the ridge. The client is currently developing a resource statement and mine plan based on the proposed area. Therefore, no formal mine plan is available for the proposed Project. The Client [Bundu Mining] indicated that the maximum mining depths would be 10m and 50m for the shallow and deep blasting operations. The estimated time to reach the 50m mark, which forms the LOM, is between 25 and 30 years. Groundwater and surface water will be used for dust suppression and to provide water to the sand-washing plant.

This hydrology assessment report was requested to supplement the Water Use License Application (WULA) and MR permit and to evaluate surface water drainage, stormwater and flooding risks associated with the project area and proposed activities.

This study found that:

- The project falls within quaternary catchment A21H of the Limpopo Water Management Area (WMA). Elevations for the site area range from 1200 to 1550 metres above mean sea level (mamsl).a
- The site is bound to the south by a steep hilltop, and two (2) dominant drainage lines exist, one towards the east and one towards the west of the hilltop, where valleys have been carved by erosion.

  - For the majority of the site, there are no recognised drainage lines or streams/rivers. The proposed Project area falls between the two drainage lines, and based on the topography and HRUs delineated, the activity will likely not impact the western drainage line and will further have a limited impact on the eastern drainage stream. From the site investigation, it is clear that free drainage takes place for the entire site, with occasional depressions where surface water collects shortly after rainfall events.
  - It is clear from the site walkover assessment that historic mining has changed the surface water flow paths, and micro-catchment style free drainage from higher to lower elevations takes place. The overall drainage direction is towards the north of the Swartspruit River. The Swartspruit River is situated about 1.04 km downstream of the site and flows towards the west to the Hartbeespoort Dam.
- Based on the flood lines generated for the project area, the mining right area, as well as the existing and proposed plant and operations, falls outside zones of inundation. No flooding issues are predicted.
- A surface water sample was taken from the existing stormwater dam at the site. The electrical conductance (EC) is low, and so are dissolved salts and metals. It is observed that the water quality falls well within the DWAF 1996 TWQR for potable use. The sodium absorption ratio (SAR) of the water sample suggests that stormwater used for dust suppression/irrigation will have no impact on the soils. Limited impacts in terms of water quality at the site are expected.
- A conceptual stormwater management plan was developed for the site and is available in Section 6. It was found that:
  - Based on the activity undertaken and proposed (sand and shallow rock mining) and considering the quality of the water at the stormwater dam, no dirty areas exist. Sedimentation may likely occur in active mining and operational areas, where sands will be excavated and where there will be heavy traffic.
  - The stormwater plan should focus on runoff containment and conveying of the stormwater back to the downstream environment. Stormwater from undisturbed areas would need to be controlled, and prevention of runoff outside of any excavations or work areas needs to be conveyed around the active work areas.

  - Temporary stormwater management measures are proposed for the site due to the dynamic nature of sand mines as well as the micro-catchment style free drainage associated with the site (refer to Section 6.6). However, based on the conceptual site layout plan, several more permanent measures can also be considered (refer to Section 6.7.).

- Several hydrological risks were identified and presented in Section 7, and several mitigation measures can be considered. A water monitoring plan is available in Section 8.

Based on the existing activities and mitigations to offset impacts, GCS believes that the authorisation of the activities should be considered. The final decision rests with the Government Authorities and should be based on the predicted hydrology impacts as well as the socio-economic value of the project. This statement is further founded on the assumption that the proposed mitigation measures and EMPr recommendations be implemented during the life of the project.

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# GENERAL LIST OF ACRONYMS

| Acronym | Description |
|---|---|
| **ADD** | Average Daily Demand |
| **BA** | Basic Assessment |
| **BOD** | Biological oxygen demand |
| **COD** | Chemical oxygen demand |
| **CM** | Concentrated Molasses |
| **CSWMP** | The conceptual stormwater management plan |
| **DEM** | Digital Elevation Model |
| **DWS** | Department of Water and Sanitation |
| **GCS** | GCS Water and Environment (Pty) Ltd. |
| **GN704** | General Notice 704 |
| **ha** | Hectare |
| **HRU** | Hydrological Response Unit |
| **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) |
| **PCD** | Pollution Control Dam |
| **PFD** | Process flow diagram |
| **SDF** | Standard design flood |
| **SAR** | Sodium Absorption Ratio |
| **SW** | Surface Water |
| **TDS** | Total dissolved solids |
| **TIN** | Triangulated Irregular Network |
| **WMA** | Water Management Area |
| **WR2012** | Water Resources of South Africa 2012 |
| **IFR** | Instream Flow Requirements |
| **EWR** | Ecological Water Requirements |
| **EIS** | Ecological Importance and Sensitivity |
| **MR** | Mining Right |

# 1 INTRODUCTION

GCS Water and Environment (Pty) Ltd (GCS) was appointed by Umhlaba Environmental Consulting CC (Umhlaba) to undertake a hydrology assessment to supplement the Water Use License (WUL) for the proposed Bundu Sands (Rietvalei) Mining Right (MR) Application, situated in the Kameeldrif West area, in Gauteng Province (refer to Figure 1-1). The project falls within Quaternary catchment A211 of the Limpopo Water Management Area (WMA) (DWS, 2016).

## 1.1 Background

The end client (Bundu Sands) wants to apply for a mining right at Bundu Sand Rietvalei, situated in the Kameeldrif West area in Gauteng Province. There are two drainage lines on either side of the application area that had to be evaluated, as these were pre-identified as potential watercourses.

The proposed mining right, as well as existing infrastructure at the site, is shown in Figure 1-1. Existing infrastructure entails a non-operational plant, one small-scale shovel (TLB and excavator) mining excavation, a stormwater dam and several settlement ponds which have been silted up due to historic mining activities. Rehabilitated sand mining operations that pre-dates Bundu mining are evident all over the project area.

Activities associated with the proposed Project include the addition of a proposed washing and settlement dam, which would be a shallow and deep opencast quarry, into the ridge. The client is currently developing a resource statement and mine plan based on the proposed area. Therefore, no formal mine plan is available for the proposed Project. The Client [Bundu Mining] indicated that the maximum mining depths would be 10m and 50m for the shallow and deep blasting operations. The estimated time to reach the 50m mark, which forms the LOM, is between 25 and 30 years. Groundwater and surface water will be used for dust suppression and to provide water to the sand-washing plant.

This hydrology assessment report was requested to supplement the Water Use License Application (WULA) and MR permit and to evaluate surface water drainage, stormwater and flooding risks associated with the project area and proposed activities.

## 1.2 Objectives

The objectives of this study were as follows:

- Identify natural and man-made drainage lines on a desktop level.
- Evaluate the site's hydrological setting (i.e., climate, rainfall, drainage, etc.).
- Determine the 1:10, 1:20, 1:50, and 1:100-year peak flows for the major rivers and drainage streams associated with the project area.
- Evaluate stormwater runoff potential at the site.
- Evaluate sedimentation risk and highlight high stormwater risk areas.

- Evaluate the existing stormwater management system.
- Indicate potential improvements to mitigate stormwater runoff and control sedimentation.
- Undertake a hydrological risk assessment and compile mitigation measures.
- Compile a surface water monitoring plan to monitor the impact on the receiving environment.

## 1.3 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 recognised geological and water resource databases for South Africa. Data generated during the time of this study is not seasonally bound, even though low and high flow yield estimates were evaluated, as average yearly data was applied where required and as scientifically acceptable.

## 1.4 Scope of work

The scope of work completed was as follows:

1. **Baseline Hydrology Review:**
    a. Hydro-meteorological data collection and analysis.
    b. Catchment delineation and drainage characteristics.
    c. Determination of catchment hydraulic and geometric parameters.
2. **Peak flows & flood line modelling:**
    a. Peak flood volume calculation for the 1:10, 1:20, 1:50, and 1:100-year recurring events.
    b. Flood line modelling using HEC-RAS hydraulic software – 1:50 and 1:100-year flood lines were presented.
    c. Analysis of the modelling results.
3. **Conceptual Storm Water Management Plan and Stormwater Monitoring:**
    a. Identification of stormwater sub-catchments (i.e., clean and dirty areas)
    b. Determination of stormwater flows and volumes (1:10, 1:20, 1:50 and 1:100-year return periods) were undertaken.
    c. Indications and explanations of the placement of stormwater attenuation infrastructure were offered.
    d. A stormwater monitoring system plan was drafted to ensure that the impact of stormwater discharge on the environment is managed and controlled.

4. **Risk assessment:**
    a. A hydrological risk assessment was undertaken to contextualize the project's potential surface water risk.
5. **Surface Water Monitoring Plan:**
    a. A surface water monitoring plan was developed.
6. **Reporting:**
    a. This report was compiled using the components above.

## 1.5 Limitations

- No formal mine plan is available for the proposed Project. Only the site layout plan was provided. The Client [Bundu Mining] indicated that the maximum mining depths would be 10m and 50m for the shallow and deep blasting operations. The estimated time to reach the 50m mark, which forms the Life of Mine (LOM), is between 25 and 30 years. The numerical simulations are based on the foreseen LOM of 30 years up to the maximum mining depth of 50m and assume closure thereafter. This limitation can only be overcome once a formal mine plan and mine block model is made available, indicating the sequence of mining, mining duration and depths associated with the Project.

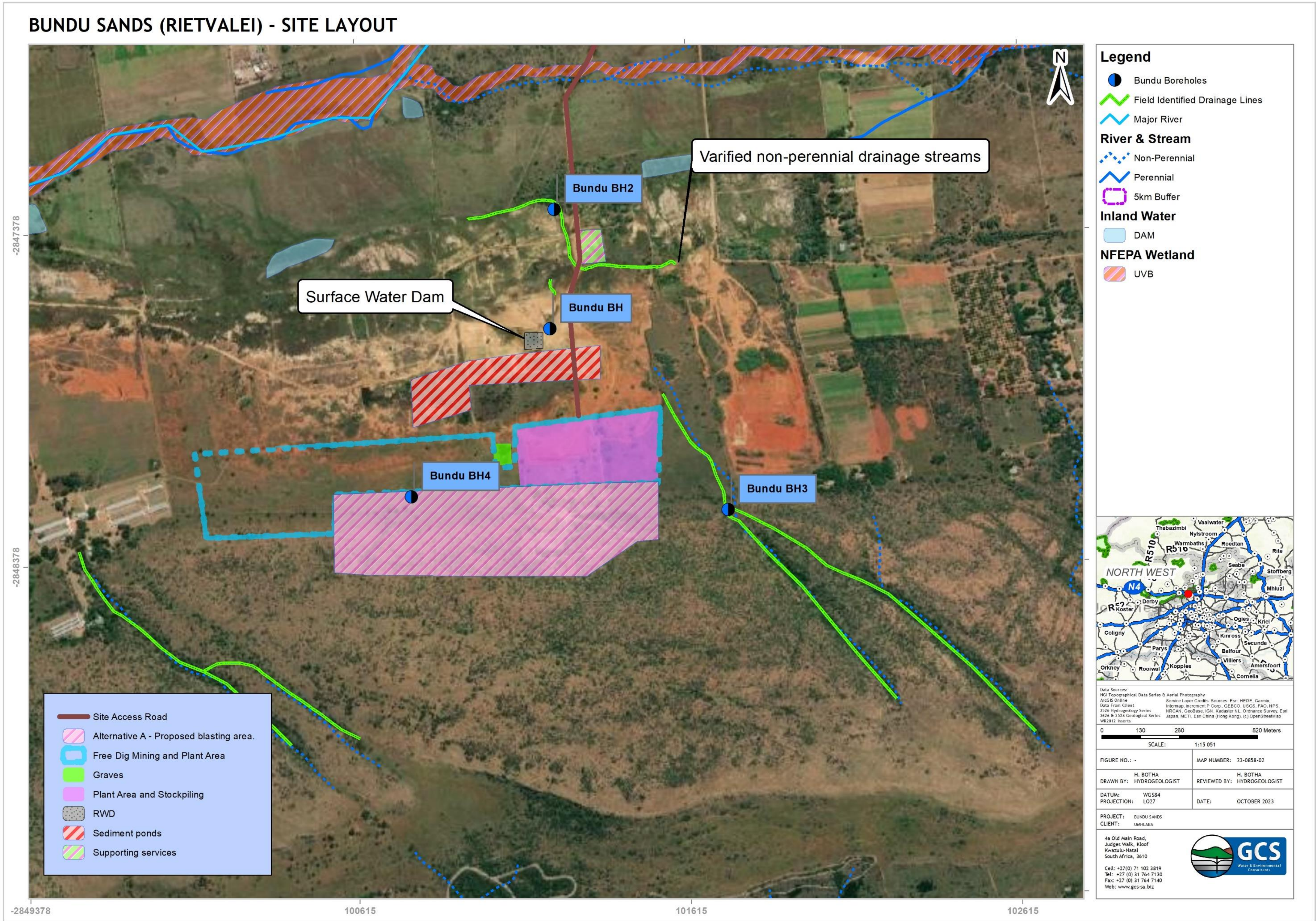



**Figure 1-1:** **Site layout**

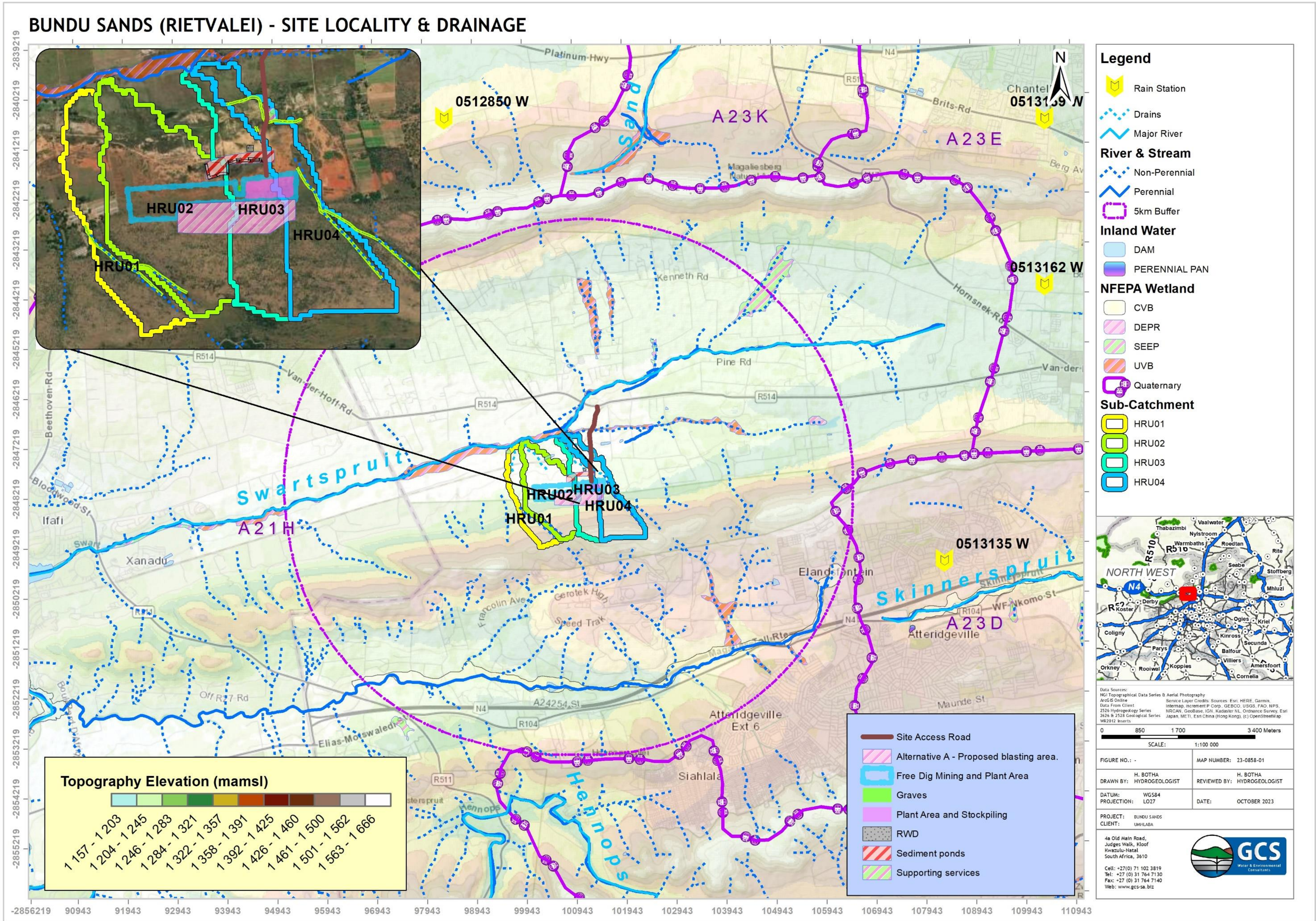



**Figure 1-2:** Site locality and drainage

# 2 METHODOLOGY

The methodological approach for the study is described in the sub-sections below.

## 2.1 Legal considerations

The National Water Act (Act 36 of 1998) (NWA) governs the use of water and protection of water resources in South Africa. The following legislation applies:

- Government Notice No. 704, 4 June 1999, National Water Act, 1998 (No. 36 of 1998): Regulations on the use of water for mining and related activities aimed at the protection of water resources (GN704).
- Government Notice No. 1352, 12 November 1999, National Water Act, 1998 (No. 36 of 1998): Regulations requiring that water use be registered.
- GNR.810 of 17 September 2010: Regulations for the Establishment of a Water Resource Classification System (Government Gazette No. 33541).
- GN R. 1036 of 31 October 2007: Regulations on financial assistance to resource-poor farmers (Government Gazette No. 30427).
- GNR.131 of 17 February 2017: Regulations requiring that the taking of water for irrigation purposes be measured, recorded, and reported (Government Gazette No. 40621).
- GNR. 267 of 24 March 2017: Regulations regarding the procedural requirements for water use licence applications and appeals (Government Gazette No. 40713).

In terms of Section 144 of the National Water Act of 1998 (Act 36 of 1998), a flood line, representing the highest elevation that would probably be reached during a storm with a return interval of 100 years, must be indicated on all plans for the establishment of townships. The term “establishment of townships” includes the subdivision of stands or farm portions in existing townships/development if the 100-year flood lines are not already indicated on these plans or when the land-use category of a particular portion of land is changed.

The National Environmental Management Act (Act 107 of 1998) (NEMA) stipulates that all relevant factors be considered for proposed developments to ensure that water pollution and environmental degradation are avoided. Section 2 of the Act establishes a set of principles that apply to the activities of all organs of the state that may significantly affect the environment. These include the following:

- Development must be sustainable.
- Pollution must be avoided or minimized and remedied.
- Waste must be avoided or minimized, reused, or recycled.
- Negative impacts must be minimized.

The requirements laid down by the National Building Regulations and Building Standards Act (Act 103 of 1977) in terms of development within the 1:50-year flood line area are based only on safety considerations without proper consideration and understanding of the underlying natural streamflow processes. The Town Planning and Townships Ordinance (Ordinance 15 of 1986) also makes provision in Regulation 44(3) for the extension of flood line areas up to 32 m from the centre of a stream in instances where the 1:50-year flood line is less than 62 m wide in total (CSIR, 2005). This regulation has also recently been replaced by SPLUMA and Municipal Bylaws and was evaluated accordingly for the project area.

Appendix 6 of GN 326 EIA Regulation 2017 further governs hydrology assessments for EIAs. This hydrology report conforms to Appendix 6 of the EIA regulations, which include the aspects listed in ***Table 1 (in front of this report).***

## 2.2 Hydrological overview

Hydrometeorological data for the study area were obtained from various sources, including the South African Water Resources Study WR2012 database (Bailey & Pitman, 2015), South African Atlas of Agrohydrology and Climatology (Schulze, 1997), and the Daily Rainfall Data Extraction Utility (Lynch, 2004). Moreover, sources such as the Köppen Climate Classification (Kottek, et al., 2006), World Climate Data CMIP6 V2.1 (Eyring, 2016), and Meteoblue (Meteoblue, 2023) were used to refine hydrological data.

These sources provided means of determining the Mean Annual Precipitation (MAP), Mean Annual Runoff (MAR), and Mean Annual Evaporation (MAE) of the study site as well as the design rainfall data. Data was applied to the site water balance calculations, runoff peak flow estimates for flood line modelling and stormwater runoff peak flow estimates for stormwater system sizing (where applicable to this study).

### *2.2.1 Catchment description and delineation*

A 30 m Digital Terrain Model (DTM) data from the Advanced Land Observing Satellite (ALOS) (JAXA, 2022) were used to delineate the area draining to the streams relevant to this study, sub-catchment flow path as well as to derive river geometry characteristics. These characteristics (area, slopes, and hydraulic parameters) are used to parameterise the site hydraulic model for flood line modelling, water balance modelling or stormwater modelling.

2022 South African (SA) National Land Cover Data (DFFE, 2021) was used to characterise the sub-catchment vegetation and derive Manning's surface roughness (n-values) coefficients.

### *2.2.2 Design rainfall and peak flow*

The Design Rainfall Estimation Software (Smithers & Schulze, 2002) data from the rainfall stations surrounding the study site were used to calculate the 24-hour design rainfall depths for various return periods. Critical storm durations for Rational Methods Alternative 3 were calculated using the Modified Hershfield Equation (Adamson, 1981).

The streams/drainage sections that were modelled applying the three widely used methods were used to calculate 1:10, 1:20, 1:50, and 1:100-year peak flows. These are the Rational Method, Midgley and Pitman (MIPI), and the Standard Design Flood (SDF) methods. A brief description of each of the peak flow methods can be seen in Table 2-1.

Methodologies for using the applied peak flow models are explained broadly in the South African Drainage Manual (SANRAL, 2013). The calibration of the runoff coefficients for the drainage areas was guided by the manual, as well as the understanding of the runoff-generating processes and land cover attributes. The resulting peak flows calculated using the selected methods were evaluated, and conservative values were provided as inputs into the 1D HEC-RAS flood line model.

**Table 2-1: Summary of peak flow methods**

| |
|---|
| **Rational Method**<br>The rational method was developed in the mid-19th century and is one of the most widely used methods for the calculation of peak flows for small catchments (< 15 $km^2$). The formula indicates that Q = CIA, where I is the rainfall intensity, A is the upstream runoff area, and C is the runoff coefficient. Q is the peak flow. There are 3 alternatives to the Rational Method, which differ in the methodology used to calculate rainfall intensities. The first alternative (RM1) uses the depth-duration frequency relationships approach, the second uses the modified Hershfield equation, and the third alternative uses the Design Rainfall software for South Africa (SANRAL, 2013). |
| **Midgley and Pitman**<br>The Midgley and Pitman (MIPI) method is an empirical method that relates peak discharge to catchment size, slope, and distance from the drainage point to the centroid of the catchment (Campbell, 1986). The MIPI method uses 10-unit hydrographs for 10 zones in South Africa. The method does not consider overland flow as a component separate from streamflow but considers only the total longest flow path (Campbell, 1986). |
| **Standard Design Flood Method**<br>The Standard Design Flood (SDF) method was developed specifically to address the uncertainty in flood prediction under South African conditions (Alexander, 2002). The runoff coefficient (C) is replaced by a calibrated value based on the subdivision of the country into 26 regions or Water Management Areas (WMAs). The design methodology is slightly different and looks at the probability of a peak flood event occurring at any one of a series of similarly sized catchments in a wider region, while other methods focus on point probabilities (SANRAL, 2013). |

## 2.3 Flood line modelling

A 30 m ALOS digital terrain model (DTM) (JAXA, 2022) was used to derive the hydraulic and river geometry parameters. River/stream cross-sections and flow paths were prepared using RAS Mapper software and provided input into a 1D HEC-RAS (US Army Corps of Engineers, 2016) flood model. Visual assessment of riverbanks from the Google Earth Imagery and land cover types (DEA, 2020) was used to estimate Manning's 'n' coefficients along the river/streamlines. The 1:50 and 1:100-year flood lines were generated and mapped in Global Mapper and ArcGIS (ESRI, 2018).

## 2.4 Conceptual stormwater management plan (CSWMP)

The SWMP was designed in conjunction with the provided existing infrastructure layout plans and available topographical data. Dynamic stormwater modelling was undertaken using the EPA Stormwater Management Model (SWMM). Peak flows were modelled using meteorological data for the closest rainfall site. Stormwater infrastructure was sized based on the peak flows modelled and based on public topography data.

The conceptual SWMP was designed to consider relevant South African legislation – the National Water Act (1998) (NWA, 1998) and the Council for Scientific and Industrial Research (CSIR) Human Settlement Planning and Design guidelines (CSIR, 2005).

## 2.5 Hydrological risk assessment

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 2-2 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 2-3.

***[Consequence = (Duration + Extent + Irreplaceability of resource) x Severity]***
**Equation 1**

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

***[Environmental Significance = (Consequence x (Probability + Reversibility))]***
**Equation 2**

**Table 2-2: 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 impact extends beyond municipal boundaries. |
| | National (5) | The impact extends beyond more than 2 regional/provincial boundaries. |
| | International (6) | The impact extends beyond the country's 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. |
| | Medium-term (3) | The duration of the activity associated with the impact will last 18 months-5 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, 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 (7 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 2-3: 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 who 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. |
| 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 as 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.<br>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) 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 considered 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. |

## 2.6 Surface water monitoring plan

The monitoring network is based on the principles of a monitoring network design as described by the DWAF Best Practice Guidelines: G3 Monitoring (DWAF, 2007). The methodological approach that the monitoring plan follows is represented in Figure 2-1.

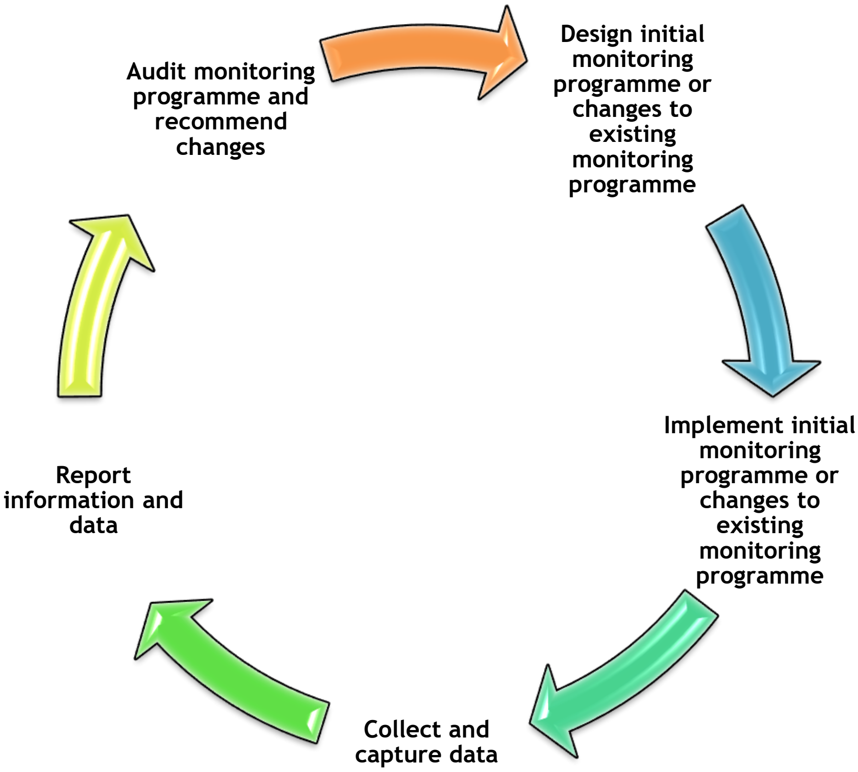



**Figure 2-1: Monitoring Process**

A surface water and stormwater monitoring plan was drafted and is based on the hydrological risks identified for the site.

# 3 SITE OVERVIEW AND HYDROLOGY

As mentioned previously, the project falls within the quaternary catchment A21H of the Limpopo Water Management Area (WMA) (DWS, 2016). Elevations for the site area range from 1200 to 1550 metres above mean sea level (mamsl).

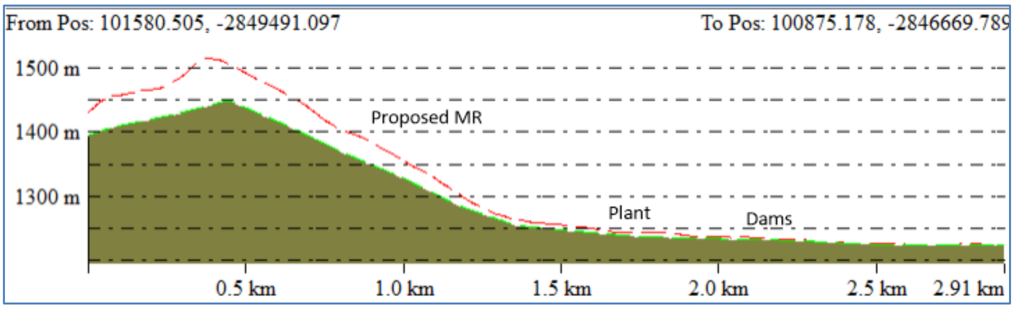



**Figure 3-1: Typical cross section from headwaters to the project area**

## 3.1 Sub-catchments/hydrological response units (HRUs)

Four (4) hydrological response units (HRUs) describe the natural drainage for the study area (using a 1:500 stream count and 30 m digital elevation model [DTM] fill) and describe the overall drainage flow paths based on the site topography.

The site is bound to the south by a steep hilltop, and two (2) dominant drainage lines exist, one towards the east and one towards the west of the hilltop, where valleys have been carved by erosion. For the majority of the site, there are no recognised drainage lines or streams/rivers. The proposed Project area falls between the two drainage lines, and based on the topography and HRUs delineated, the activity will likely not impact the western drainage line and will further have a limited impact on the eastern drainage stream. From the site investigation, it is clear that free drainage takes place for the entire site, with occasional depressions where surface water collects shortly after rainfall events.

It is clear from the site walkover assessment that historic mining has changed the surface water flow paths, and micro-catchment style free drainage from higher to lower elevations takes place. The overall drainage direction is towards the north of the Swartspruit River. The Swartspruit River is situated about 1.04km downstream of the site and flows towards the west to the Hartbeespoort Dam.

GCS undertook a site walkover assessment to confirm drainage lines and potential flow paths in the field. The field-identified drainage lines are shown in Figure 1-1, and the findings of the field walkover are summarised in Table 3-1.

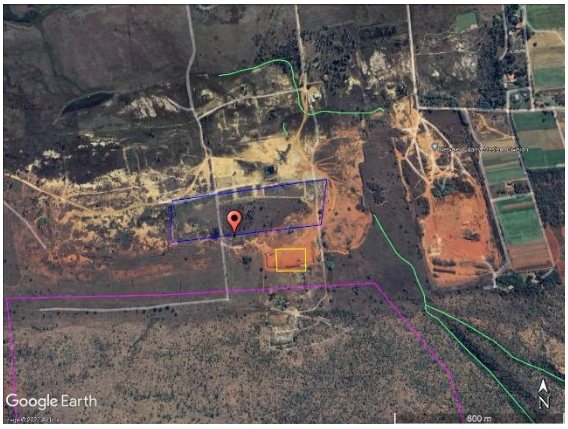
**Table 3-1: Summary of drainage lines identified in the project area**

| Photograph and observation | Location (indicated in red) |
|---|---|
|  Photograph of the eastern drainage line. Hard rock outcrops with limited soil cover are observed. The drainage line will act as an ephemeral system. |   |
|  Photograph of the eastern drainage line. Hard rock outcrops with more soil coverage were noted heading further downstream from the hilltop. The drainage line will act as an ephemeral system. |   |
|  Photograph of an old quarry in the Project area. No groundwater seepage or ponding of water was noted. |   |

Photograph of a man-made channel flowing past the Bundu mine office area. The channel originates towards the east (neighbouring mine) and disappears in what **<u>appears</u>** to be a depression wetland area west and downstream of the site (a very wet, water-logged area).


Photograph of the surface conditions observed across the site. No definable drainage lines occur, and stormwater runoff in **all directions** is evident **(sheet flow and free flow)**


Photograph of a series of what appears to be old settling dams. At least 4 were identified and appear to have been completely silted up.



Several man-made trenches are associated with these structures, as well as earth berms.

Photograph of the on-site stormwater dam downstream of the existing settling dams. There is a barge and abstraction system in place; however, it is not in use. A surface water sample was collected.


## 3.2 Land cover and slope

Natural grassland dominates the sub-catchments (DFFE, 2021) – refer to Figure 3-2. The slope rise (%) for the sub-catchment was determined using an ALOS 30 m DTM and can be seen in Figure 3-3. The sub-catchment parameters are captured in Table 3-2.

**Table 3-2: Sub-catchments parameters**

| Sub-Catchment | | HRU1 | HRU2 | HRU3 | HRU4 |
|---|---|---|---|---|---|
| Area (km²) | | 0.624 | 1.433 | 0.758 | 0.99 |
| Longest Drainage Line (km) | | 0.49 | 0.82 | 0.844 | 1.62 |
| Average Slope (%) | | 2.52% | 1.32% | 2.23% | 3% |
| Slope (%) | < 3 | 7.76% | 14.86% | 15.95% | 10.15% |
| | 3 - 10 | 43.68% | 38.43% | 30.49% | 29.69% |
| | 10 - 30 | 39.67% | 39.58% | 27.78% | 36.23% |
| | > 30 | 8.89% | 7.13% | 25.78% | 23.92% |
| Land Cover | Thick bush & plantation | 60.01% | 86.50% | 73.24% | 78.02% |
| | Light bush & farmlands | 4.26% | 8.60% | 18.31% | 11.90% |
| | Grasslands | 21.40% | 1.38% | 0.05% | 0.04% |
| | No Vegetation | 14.33% | 3.53% | 8.40% | 10.05% |

## 3.3 Local geology and soils

According to the 1:150 000 geology series (2526 Rustenburg & 2528 Pretoria) maps for the area (DMEA, 1981); (DMEA, 1998), the surface geology of the study is characterised by quaternary sands (Qb), intrusive diabase (di), quartzite (Vdq), and sediments of the Silverton and Hekpoort formations (shale, slate, hornfels, weathered andalusite, quartzite, basalt, tuff, shale and chert) of the Pretoria Supergroup, of the Transvaal Sequence - refer to Figure 3-4.

According to the Land Types of South Africa databases (ARC, 2006), the soils in the area fall within the Ib and Ba types. Soils associated with these groups typically entail:

- Ba (towards the plant and settlement dams area) - Freely drained, red and yellow, dystrophic/mesotrophic, apedal soils comprise > 40% of the land type (yellow soils < 10%)
- Ib (towards the mining right area)- Rock outcrops comprise > 60% of land type.

According to Soil Conservation Service (SCS) data for the project area, the soils are divided into B/C and type C soils. SCS curve number is a function of the ability of soils to allow infiltration of water, land use and the antecedent soil moisture condition. Table 3-3 provides a summary of the hydrological characteristics of the different SCS soil types.

**Table 3-3: Summary of SCS soil type hydrological characteristics (Muthu, 2015)**

| Hydrological Soil | Type of soil | Runoff Potential | Final Infiltration Rate (mm/hr) | Remarks |
|---|---|---|---|---|
| Group A | Deep, well-drained sands and gravels | Low | >7.5 | High rate of water transmission |
| Group B | Moderately deep, well-drained with moderately fine to coarse textures | Moderate | 3.8-7.5 | Moderate rate of water transmission |
| Group C | Clay loams, shallow sandy loam, soils with moderately fine to fine textures | Moderately high | 1.3-3.8 | Moderate rate of water transmission |
| Group D | Clay soils that swell significantly when wet, heavy plastic and soils with a permanent high water table | High | <1.3 | Low rate of water transmission |

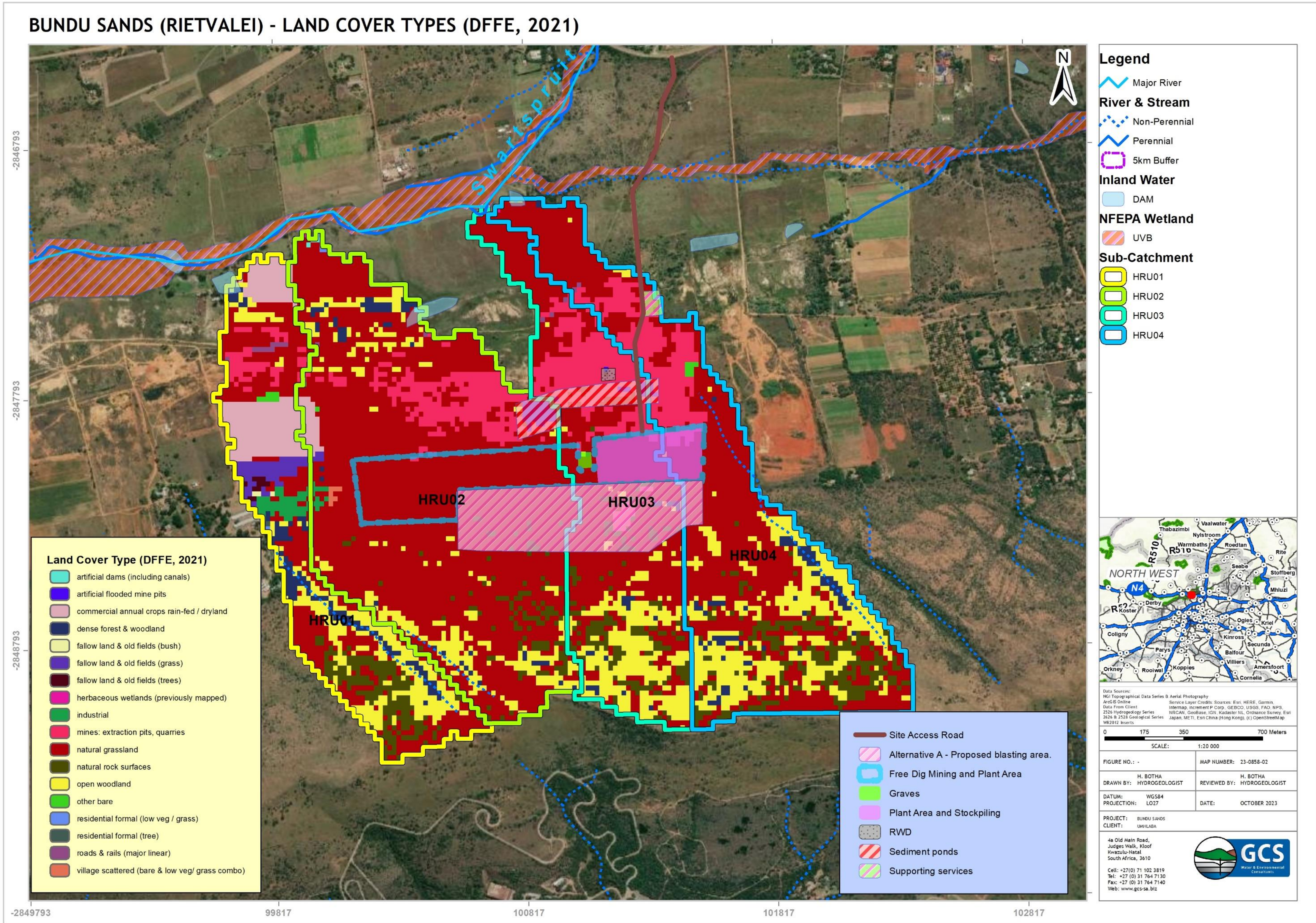



**Figure 3-2:** **Sub-catchments land cover types (DFFE, 2021)**

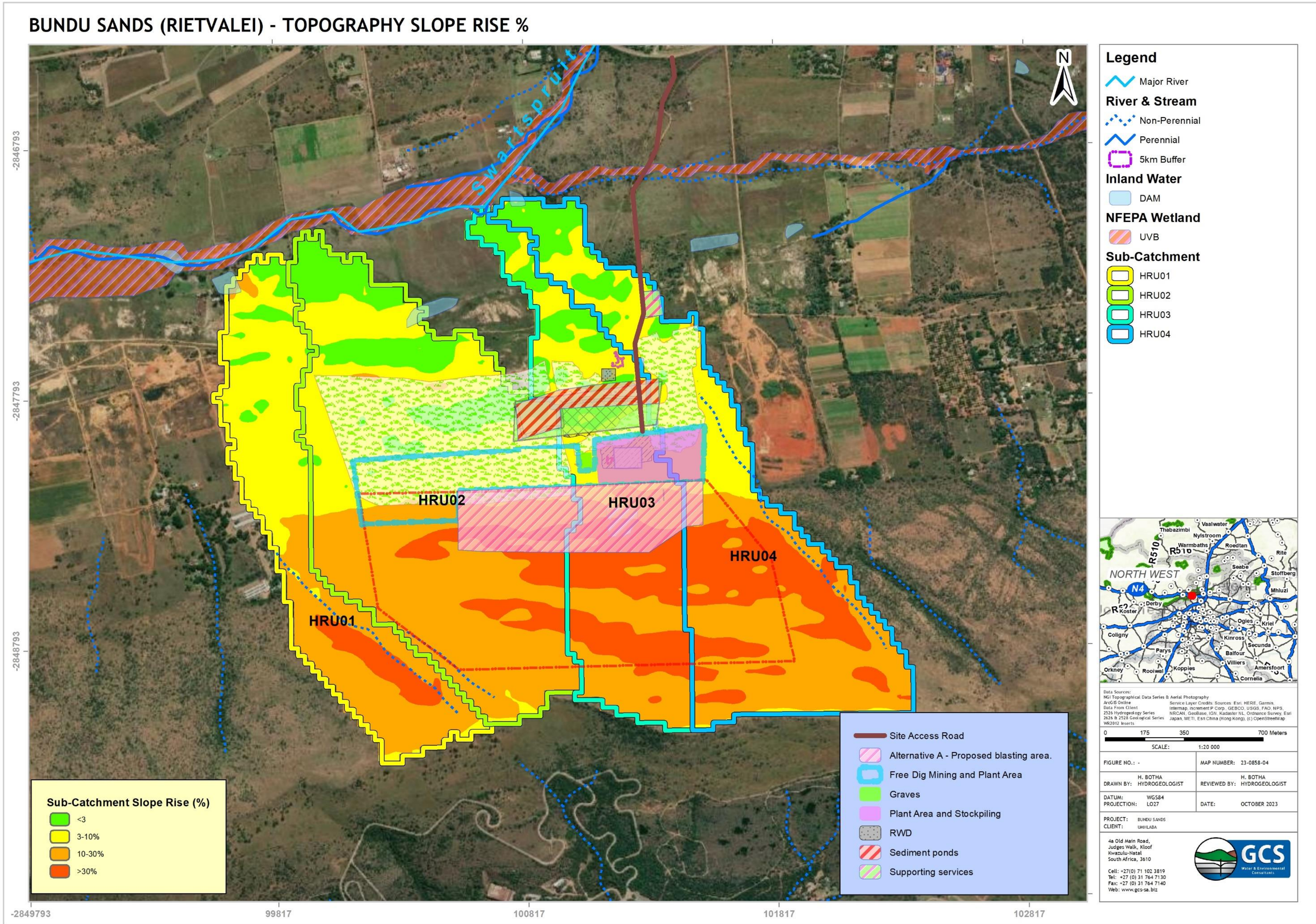



**Figure 3-3:** **Sub-catchments topography slope rise %**

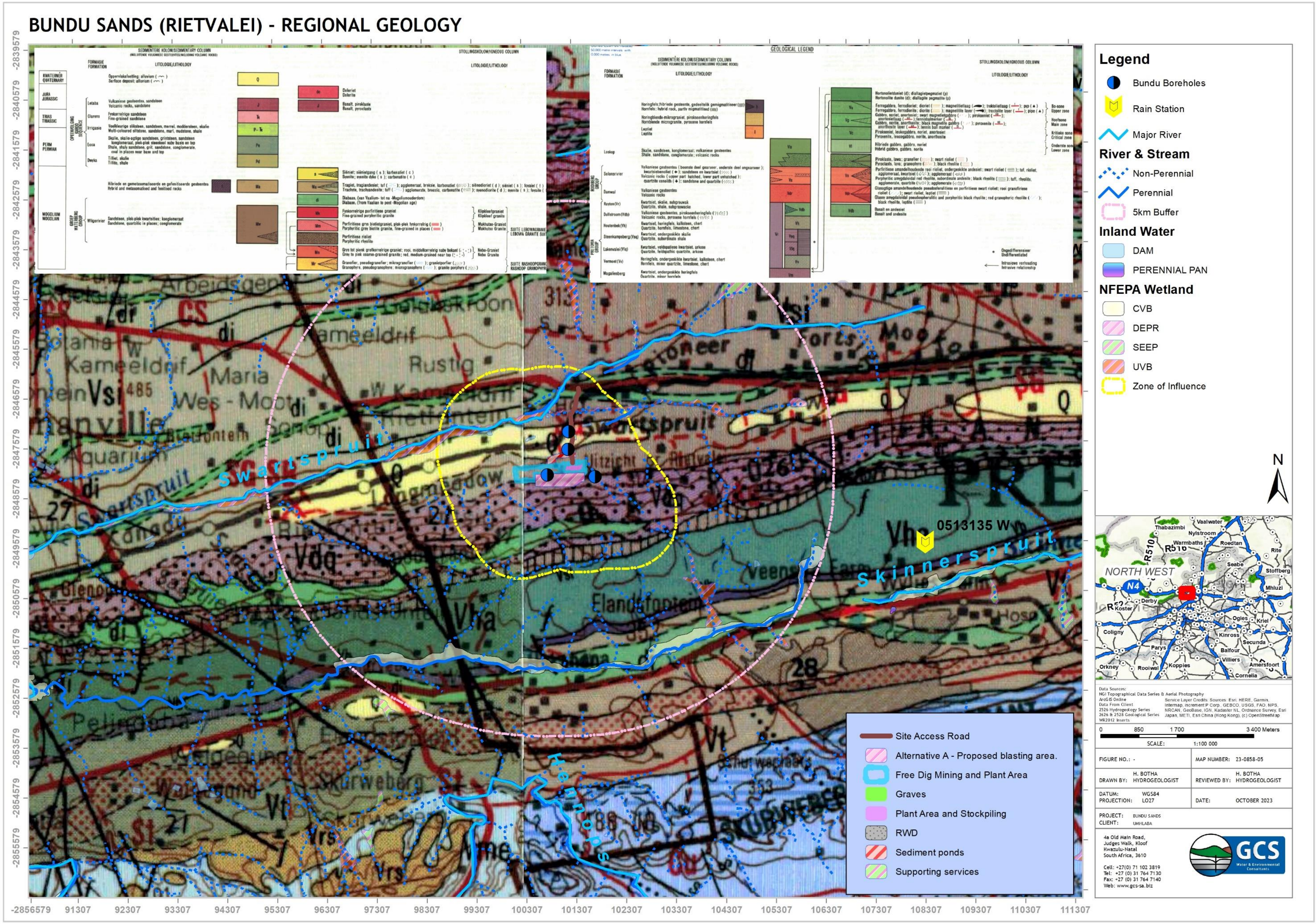



**Figure 3-4:** **Local surface geology**

## 3.4 Climate

Climate, amongst other factors, influences soil-water processes, runoff, and peak flows. 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.

### *3.4.1 Temperature*

The average yearly temperature (refer to Figure 3-5) for the project area ranges from 20 to 35°C (high) and -5 to 3°C (Low). The study area is situated in a subtropical monsoon climate (Köppen: Cwa) with long, hot, rainy summers and short, dry and mild winters, as per the Köppen Climate Classification (Kottek, et al., 2006). The area is subjected to summer rainfall.

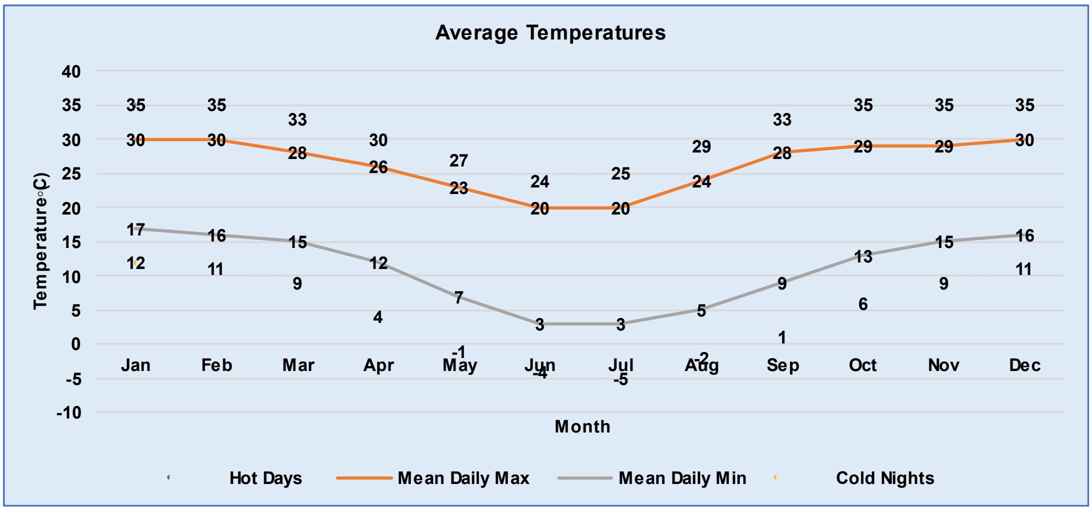



**Figure 3-5: Average yearly temperatures (Meteoblue, 2023)**

### *3.4.2 Wind speed and direction*

Figure 3-6 shows the modelled wind rose for the project area (Hilton used as reference) and presents the number of hours per year the wind blows from the indicated direction. Wind generally blows from W, N and E and more often from the direction between N and ENE at velocities > 19 km/h.

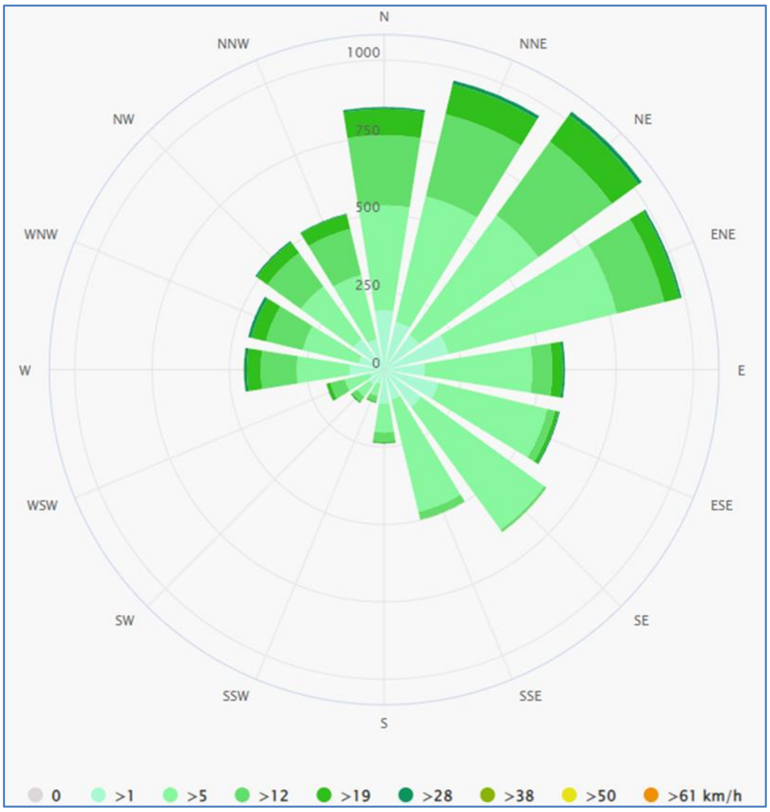



**Figure 3-6: Wind rose (Meteoblue, 2023)**

### *3.4.3 Rainfall and evaporation*

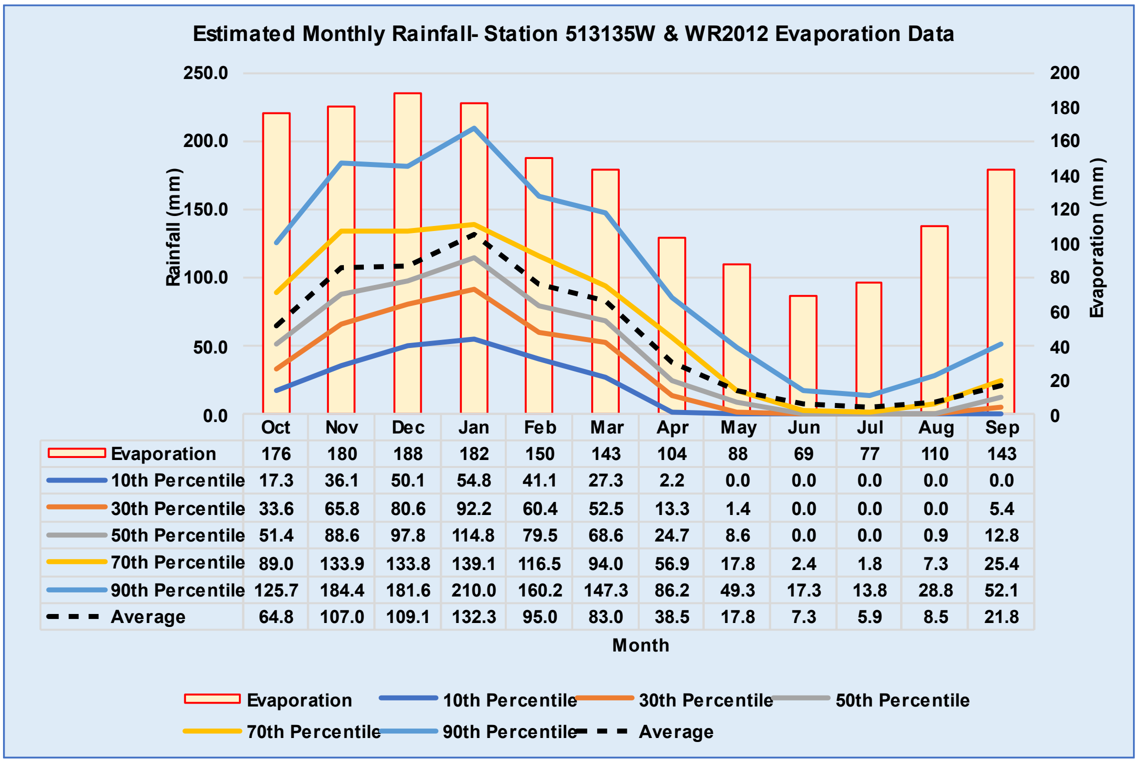
The project area is situated in rainfall zone A2C. The Mean Annual Precipitation (MAP) recorded at the nearest rainfall stations is summarised in Table 3-4 (WRC, 2015). The MAP for several sites is in the same order of magnitude.

**Table 3-4: Summary of MAP recorded at nearest rainfall stations**

| Station Name | ID | Record (Yr) | MAP (mm/yr) |
|---|---|---|---|
| WYLIE'S FARM | 0513135_W | 83 | 681 |
| PRETORIA-(POW) | 0513255_W | 75 | 687 |
| PRETORIA-VOORTREKERHOOG | 0513227_W | 71 | 709 |
| ZANDFONTEIN | 0513162_W | 38 | 691 |
| PRETORIA-WEST END PLTN | 0513254AW | 31 | 713 |
| PRETORIA-SKINNERSCOURT | 0513254_W | 58 | 713 |
| **Average** | | | **699** |

The monthly rainfall that represents the site was obtained from WR2012 rainfall station 0513135W (Wylies Farm). The rainfall record is for the period 1905 to 1988 (83 years). Monthly rainfall for the site is likely to be distributed, as shown in Figure 3-7. Available rainfall data suggest a MAP ranging from 405 (30$^{th}$ percentile) to 1258 (90$^{th}$ percentile) mm/yr. The average rainfall is in the order of 690 mm/yr.

The project area falls within evaporation zone 3A, of which Mean Annual Evaporation (MAE) ranges from 1 500 to 1 600 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 3-7.

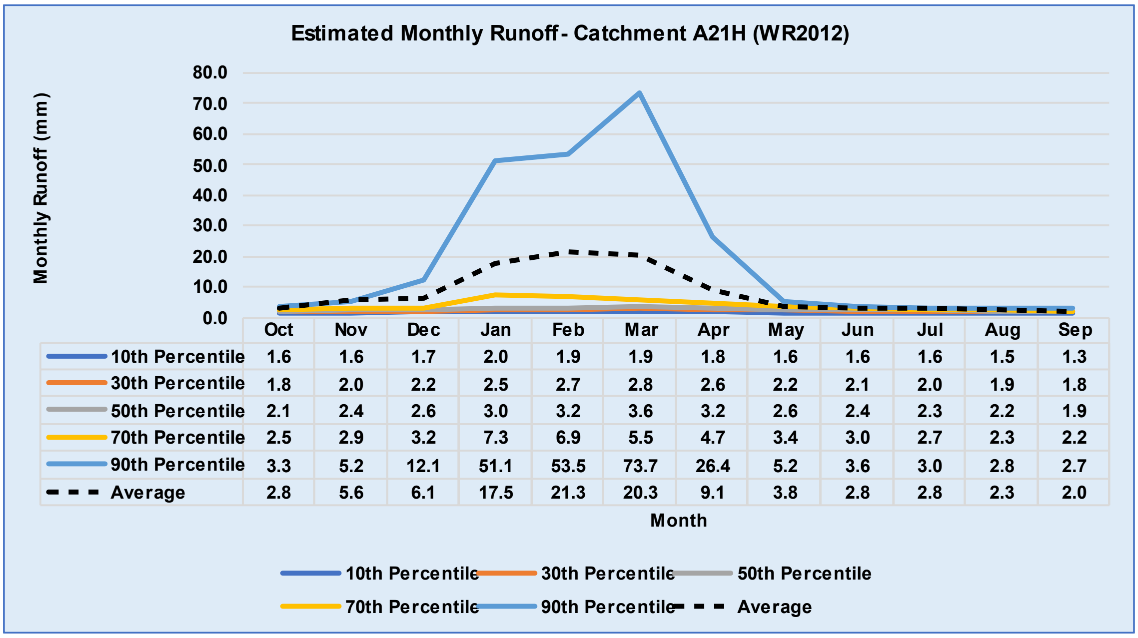



| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Evaporation | 176 | 180 | 188 | 182 | 150 | 143 | 104 | 88 | 69 | 77 | 110 | 143 |
| 10th Percentile | 17.3 | 36.1 | 50.1 | 54.8 | 41.1 | 27.3 | 2.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 30th Percentile | 33.6 | 65.8 | 80.6 | 92.2 | 60.4 | 52.5 | 13.3 | 1.4 | 0.0 | 0.0 | 0.0 | 5.4 |
| 50th Percentile | 51.4 | 88.6 | 97.8 | 114.8 | 79.5 | 68.6 | 24.7 | 8.6 | 0.0 | 0.0 | 0.9 | 12.8 |
| 70th Percentile | 89.0 | 133.9 | 133.8 | 139.1 | 116.5 | 94.0 | 56.9 | 17.8 | 2.4 | 1.8 | 7.3 | 25.4 |
| 90th Percentile | 125.7 | 184.4 | 181.6 | 210.0 | 160.2 | 147.3 | 86.2 | 49.3 | 17.3 | 13.8 | 28.8 | 52.1 |
| Average | 64.8 | 107.0 | 109.1 | 132.3 | 95.0 | 83.0 | 38.5 | 17.8 | 7.3 | 5.9 | 8.5 | 21.8 |

**Figure 3-7: Average rainfall for Station 0513135W & WR2012 evaporation**

### *3.4.4 Runoff*

Runoff from natural (unmodified) catchments for the quaternary A21A is simulated in WR2012 (WRC, 2015) as being equivalent to 96.5 mm/yr (or 14% of the MAP) - refer to Figure 3-8.




| | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10th Percentile | 1.6 | 1.6 | 1.7 | 2.0 | 1.9 | 1.9 | 1.8 | 1.6 | 1.6 | 1.6 | 1.5 | 1.3 |
| 30th Percentile | 1.8 | 2.0 | 2.2 | 2.5 | 2.7 | 2.8 | 2.6 | 2.2 | 2.1 | 2.0 | 1.9 | 1.8 |
| 50th Percentile | 2.1 | 2.4 | 2.6 | 3.0 | 3.2 | 3.6 | 3.2 | 2.6 | 2.4 | 2.3 | 2.2 | 1.9 |
| 70th Percentile | 2.5 | 2.9 | 3.2 | 7.3 | 6.9 | 5.5 | 4.7 | 3.4 | 3.0 | 2.7 | 2.3 | 2.2 |
| 90th Percentile | 3.3 | 5.2 | 12.1 | 51.1 | 53.5 | 73.7 | 26.4 | 5.2 | 3.6 | 3.0 | 2.8 | 2.7 |
| Average | 2.8 | 5.6 | 6.1 | 17.5 | 21.3 | 20.3 | 9.1 | 3.8 | 2.8 | 2.8 | 2.3 | 2.0 |

**Figure 3-8: Simulated natural (unmodified) runoff for A21H**

### 3.4.5 Considerations on climate change

Based on available climate change models for the project area, derived from World Climate Data CMIP6 V2.1 (Eyring, 2016), RCP 4.5 and 8.5 scenarios were chosen, and the following is predicted for the project area:

- Temperature:
  - 2021 - 2050: increases by as much as 2.1ºC
  - 2050 - 2100: increases by as much as 2.3ºC
- Annual average hot days:
  - 2021 - 2050: additional 0.16ºC extremely hot days.
  - 2050 - 2100: additional 0.9ºC extremely hot days.
- Annual rainfall totals (MAP):
  - 2021 - 2050: decrease in rainfall by as much as 89 mm/yr.
  - 2050 - 2100: decrease in rainfall by as much as 133 mm/yr.
- The annual average number of extreme rainfall days:
  - 2021 - 2050: decrease by as much as 2.1 days.
  - 2050 - 2100: decrease by as much as 3.1 days.

Based on the above, it is predicted that there will be future temperature increases with more frequent extreme temperatures, which will result in fewer days of rainfall. Based on the rainfall decrease projections, it is concluded that there will be less frequent storm events (though not extreme) to facilitate the projected decreases in annual rainfall.

## 3.5 Surface water and groundwater users in the study area

According to the Water Allocation Registration Management System (WARMS, 2019), there are only twenty-eight (28) WARMS users within a 5km buffer of the project area, of which none of them fall within the HRUs – refer to Figure 3-9. A review of SADAC GIP groundwater database boreholes further suggests several boreholes within a 5 km radius of the site with groundwater data available. The registry entry into WARMS for water use is summarised in Table 3-5, and SADAC GIP boreholes within a 5 km radius of the site are presented in Table 3-6.

98% of the WARMS users are boreholes, amounting to a total allocation in the order of 0.7 Mm³/yr, followed by 1 registered spring user and 1 surface water stream user. 1 groundwater user (WARMS ID: 26075176) is associated with the HRU of the site. 4 boreholes on site were identified during the GCS Hydrogeology Assessment (GCS, 2023), of which a borehole near the existing plant will be used for water supply (sand washing and dust suppression). The volume of water required has not yet been confirmed.

**Table 3-5: Summary of WARMS users within a 5 km radius of the site**

| ID | Latitude (WGS84) | Longitude (WGS84) | User | Resource Type | Resource | Register Status | Lawfulness Finding | Registered Volume (m³/yr.) |
|---|---|---|---|---|---|---|---|---|
| 26008800 | -25.71880 | 27.99010 | FOURCHAPS BOERDERY | BOREHOLE | NO NAME | ACTIVE | LAWFULNESS STILL TO BE DETERMINED | 17234 |
| 26010566 | -25.72010 | 27.98870 | FOURCHAPS BOERDERY | BOREHOLE | NO NAME | ACTIVE | LAWFULNESS STILL TO BE DETERMINED | 12720 |
| 26011672 | -25.77190 | 27.97950 | FOURCHAPS BOERDERY | RIVER/STREAM | SAARTJIESPRUIT | ACTIVE | LAWFULNESS STILL TO BE DETERMINED | 35520 |
| 26014394 | -25.72390 | 27.98690 | FOURCHAPS BOERDERY | BOREHOLE | NO NAME | ACTIVE | LAWFULNESS STILL TO BE DETERMINED | 21380 |
| 26014401 | -25.71550 | 27.96070 | FOURCHAPS BOERDERY | BOREHOLE | NO NAME | ACTIVE | LAWFUL | 40722 |
| 26015339 | -25.71000 | 28.02960 | FOURCHAPS BOERDERY | BOREHOLE | NO NAME | ACTIVE | LAWFULNESS STILL TO BE DETERMINED | 8000 |
| 26019399 | -25.71730 | 27.99110 | FOURCHAPS BOERDERY | BOREHOLE | NO NAME | ACTIVE | LAWFULNESS STILL TO BE DETERMINED | 18670 |
| 26020092 | -25.76000 | 27.98120 | FOURCHAPS BOERDERY | BOREHOLE | NO NAME | ACTIVE | LAWFULNESS STILL TO BE DETERMINED | 14700 |
| 26020163 | -25.70900 | 28.02450 | FOURCHAPS BOERDERY | BOREHOLE | NO NAME | ACTIVE | LAWFULNESS STILL TO BE DETERMINED | 24100 |
| 26021448 | -25.73290 | 28.02200 | FOURCHAPS BOERDERY | BOREHOLE | NO NAME | ACTIVE | LAWFULNESS STILL TO BE DETERMINED | 16980 |
| 26022214 | -25.72370 | 28.01670 | FOURCHAPS BOERDERY | BOREHOLE | NO NAME | ACTIVE | LAWFULNESS STILL TO BE DETERMINED | 69600 |
| 26023605 | -25.76694 | 27.98444 | FOURCHAPS BOERDERY | BOREHOLE | NO NAME | ACTIVE | LAWFULNESS STILL TO BE DETERMINED | 50000 |
| 26026540 | -25.70770 | 28.02970 | FOURCHAPS BOERDERY | BOREHOLE | NO NAME | ACTIVE | LAWFULNESS STILL TO BE DETERMINED | 12050 |
| 26026586 | -25.70990 | 28.03820 | FOURCHAPS BOERDERY | BOREHOLE | NO NAME | ACTIVE | LAWFULNESS STILL TO BE DETERMINED | 1800 |
| 26028334 | -25.77170 | 27.96190 | FOURCHAPS BOERDERY | BOREHOLE | NO NAME | ACTIVE | LAWFULNESS STILL TO BE DETERMINED | 11155 |
| 26041809 | -25.75000 | 28.05000 | FOURCHAPS BOERDERY | BOREHOLE | NO NAME | ACTIVE | LAWFUL | 15000 |
| 26046699 | -25.73806 | 27.96528 | FOURCHAPS BOERDERY | BOREHOLE | NO NAME | ACTIVE | LAWFULNESS STILL TO BE DETERMINED | 1543 |
| 26046797 | -25.71020 | 28.04120 | FOURCHAPS BOERDERY | BOREHOLE | NO NAME | ACTIVE | LAWFUL | 32486 |
| 26046804 | -25.71190 | 28.04200 | FOURCHAPS BOERDERY | BOREHOLE | NO NAME | ACTIVE | LAWFUL | 15399 |
| 26048054 | -25.74200 | 27.97090 | FOURCHAPS BOERDERY | BOREHOLE | NO NAME | ACTIVE | LAWFULNESS STILL TO BE DETERMINED | 100 |
| 26059675 | -25.77140 | 27.96560 | FOURCHAPS BOERDERY | SPRING/EYE | MONGWANE | ACTIVE | LAWFULNESS STILL TO BE DETERMINED | 27300 |
| 26060976 | -25.71330 | 27.97390 | FOURCHAPS BOERDERY | BOREHOLE | NO NAME | ACTIVE | LAWFULNESS STILL TO BE DETERMINED | 106560 |
| 26067247 | -25.72436 | 28.06094 | FOURCHAPS BOERDERY | BOREHOLE | NO NAME | ACTIVE | LAWFULNESS STILL TO BE DETERMINED | 96000 |
| 26068022 | -25.72710 | 28.05648 | FOURCHAPS BOERDERY | BOREHOLE | BOREHOLE | ACTIVE | LAWFULNESS STILL TO BE DETERMINED | 45720 |

| ID | Latitude (WGS84) | Longitude (WGS84) | User | Resource Type | Resource | Register Status | Lawfulness Finding | Registered Volume (m³/yr.) |
|---|---|---|---|---|---|---|---|---|
| 26069254 | -25.71150 | 28.02520 | FOURCHAPS BOERDERY | BOREHOLE | NO NAME | ACTIVE | LAWFULNESS STILL TO BE DETERMINED | 12000 |
| 26072473 | -25.70725 | 28.04361 | FOURCHAPS BOERDERY | BOREHOLE | SWART SPRUIT RIVER | ACTIVE | LAWFULNESS STILL TO BE DETERMINED | 36933 |
| 26075176 | -25.73758 | 27.99456 | FOURCHAPS BOERDERY | BOREHOLE | GROUNDWATER | ACTIVE | LAWFULNESS STILL TO BE DETERMINED | 9600 |
| 26075381 | -25.72569 | 28.03489 | FOURCHAPS BOERDERY | BOREHOLE | LONGSIDE BH1 | ACTIVE | LAWFUL | 14198 |

**Table 3-6: Summary of SADAG GIP/NGA boreholes within a 5 km radius of the site**

| ID | Source | Latitude (WGS84) Decimal Degrees | Longitude (WGS84) Decimal Degrees | Elevation (mamsl) | Water Level (mbgl) |
|---|---|---|---|---|---|
| 673059 | SADAC GIP / NGA 2023 | -25.70133000 | 27.97500000 | 1318.5 | 5.5 |
| 673065 | | -25.70127000 | 27.97594000 | 1318.9 | 16.2 |
| 675536 | | -25.70250000 | 28.00922000 | 1269.2 | 22.9 |
| 675560 | | -25.70183000 | 28.01219000 | 1271.6 | 14.9 |
| 675584 | | -25.70153000 | 28.00925000 | 1272.0 | 27.4 |
| 675594 | | -25.72919000 | 28.04441000 | 1282.4 | 21.9 |
| 675894 | | -25.73846000 | 28.02369000 | 1310.9 | 30.5 |
| 677359 | | -25.77144000 | 28.01525000 | 1304.5 | 4 |
| 677360 | | -25.77377000 | 28.01953000 | 1309.9 | 8 |
| 677361 | | -25.77227000 | 28.01695000 | 1305.1 | 7 |
| 677362 | | -25.77169000 | 28.01023000 | 1305.9 | 11 |
| 677363 | | -25.77439000 | 28.00061000 | 1284.0 | 7 |
| 677364 | | -25.77004000 | 28.01804000 | 1310.6 | 9 |
| 121 | DWS RQS 2023 | -25.706111 | 27.983056 | 1310 | no data |

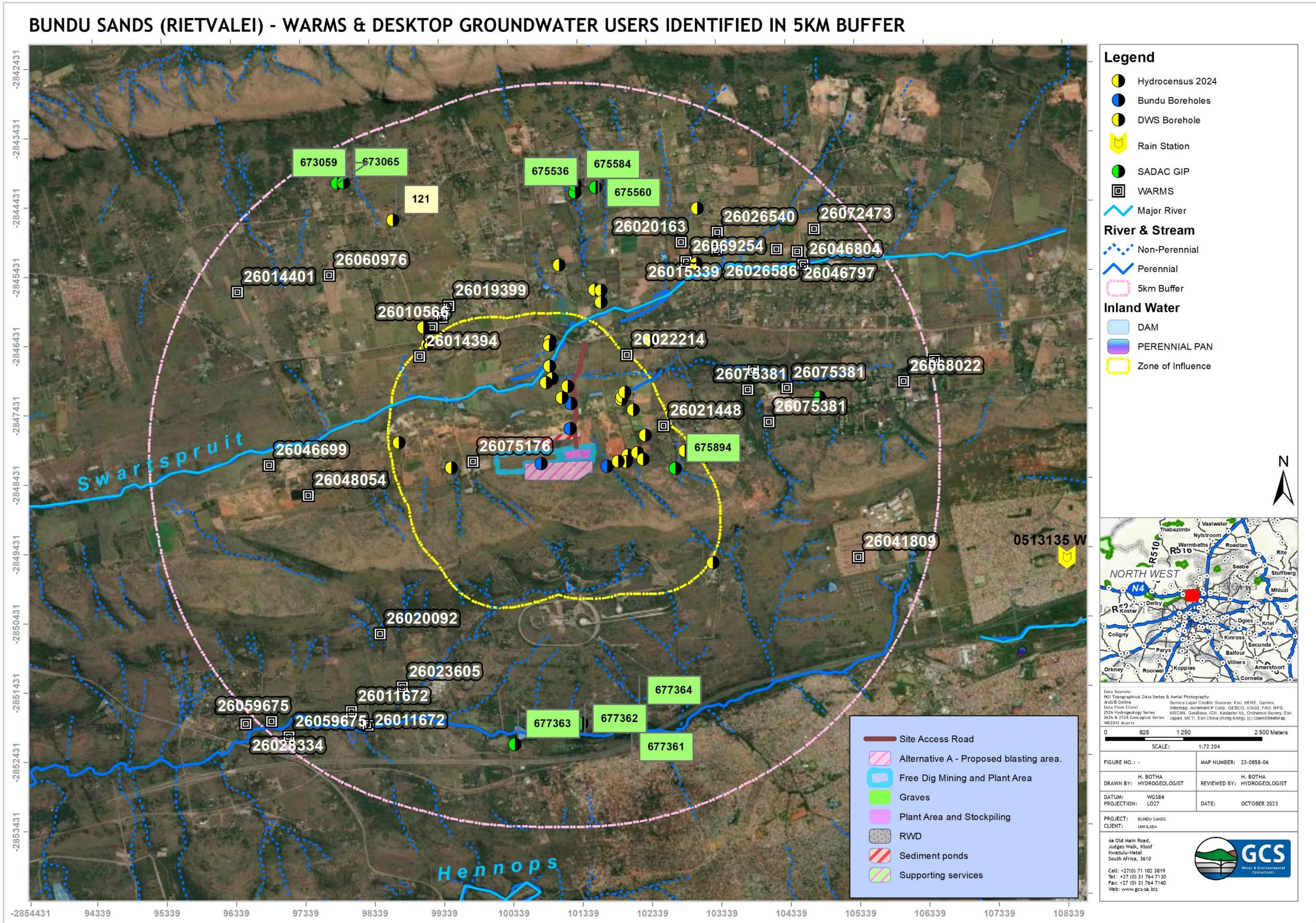



**Figure 3-9:** **WARMS and SADAG GIP users identified within a 5 km radius of the site**

## 3.6 Hydrogeology and depth to groundwater

According to the hydrogeology map for the study area (2526 Johannesburg - 1:500 000 hydrogeology series), the hydrogeology of the study area is characterised by meta-argillaceous rocs (shale and hornfels) and meta-arenaceous rocks (quartzite). Intrusive ultramafic rock (Diabase) is also known to occur in the project area.

Groundwater is generally associated with joints and fractures in competent arenaceous rocks relating to tensional or compressional stress and offloading, fault zones and along sedimentary or igneous rock contacts (either open, weathered or fractured) (King, 1998). Recharge to the aquifers in the region ranges from 3 to 8% of the MAP (King et al., 1998).

The aquifers underlying the study area are considered low-yielding aquifers (median yields of 0.5 to 2 l/sec – Class d3 aquifer and b2 aquifers). According to WR2012 (Bailey & Pitman, 2015) and DWAF GRAII (DWAF, 2006) data, the groundwater level in the study area, on average, is in the order of 16 mbgl (metre below ground level). Available literature and SADAC GIP data suggest that the groundwater table (weathered zone aquifer) generally follows the topography.

## 3.7 Desktop wetland and ecological areas

Based on available National Wetland Freshwater Ecosystem Priority Areas (NFEPA) (Van Deventer, 2018) evaluated on a desktop level, there are no wetland areas associated with the project area. However, based on the site investigation undertaken, several waterlogged areas were noted (specifically nearing the Swartspruit River).

In terms of river geo-hydrology, baseflow is considered the most important contributor to stream and wetland health. Baseflow (refer to Figure 3-10) is a non-process-related term that signifies low amplitude high-frequency flow in a river during dry or fair-weather periods. Baseflow is not a measure of the volume of groundwater discharged into a river or wetland, but it is recognised that groundwater contributes to the baseflow component of a river or wetland flow.

Available literature (WRC, 2015; DWAF, 2006) suggests groundwater contribution to baseflow ranges from 4.2 mm/yr (PITMAN MODEL) to 13 mm/yr (HUGHES MODEL). This relates to approximately 2% to 3% of rainfall.

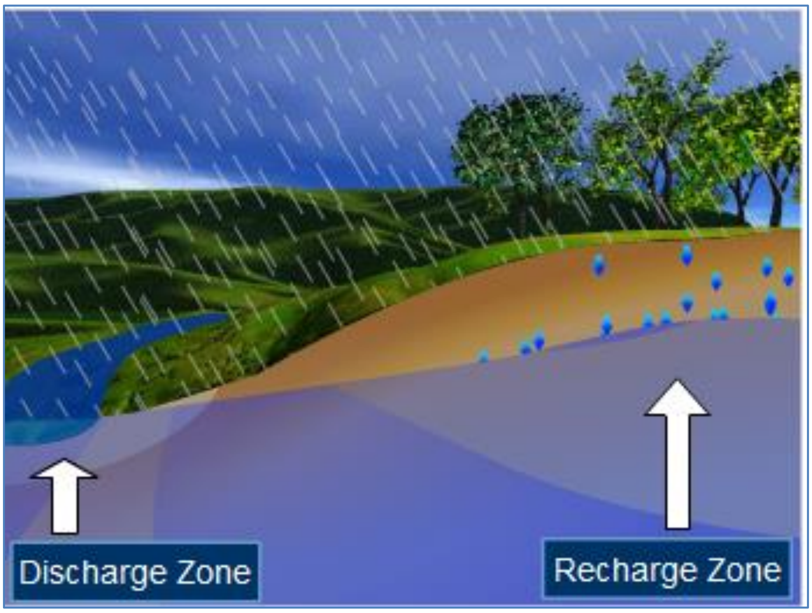



**Figure 3-10: Groundwater baseflow concept (DWS, 2011)**

## 3.8 Present ecological state (PES) and environmental sensitivity and ecological importance (EIS)

Table 3-7 provides a summary of the PES, EIS and EWR (as a percentage of the MAR) for the quaternary catchments associated with the project area. The same conditions are inferred to apply to delineated sub-catchments.

**Table 3-7: Summary of PES, EIS and EWR**

| Quat | PES | EIS | Reserve (EWR) % of NMAR | Source |
|---|---|---|---|---|
| A21H | C | Moderate | 28% | WR2012 |

### 3.9 Overview of site hydrological cycle

Based on the information attained for the study area (as presented in this section), existing groundwater and surface water users, climate, runoff and estimated baseflow to wetland/river areas, a sub-catchment-specific hydrological cycle was developed (refer to Figure 3-11). *The impact of the proposed/existing activities at the site on the cycle was considered in the hydrological impact assessment.*

With regards to the hydrological cycle for the combined sub-catchment area, the following are estimated:

- Average rainfall accounts for a volume in the order of 2.63 $Mm^3/yr$ (50% of the total water budget);
- Average runoff accounts for a volume in the order of 0.37 $Mm^3/yr$ (7% of the total water budget);
- The average groundwater contribution to baseflow to rivers/wetlands/streams is in the order of 0.02 $Mm^3/yr$ (0.3% of the total water budget).
- Evaporation accounts for a volume in the order of 2.02 $Mm^3/yr$ (38.4% of the total water budget);
- Groundwater use is estimated in the order of 0.00003 $Mm^3/yr$ (0.01% of the total water budget).
- WARMS surface water use is in the order of 0 $Mm^3/yr$ (0% of the total water budget).

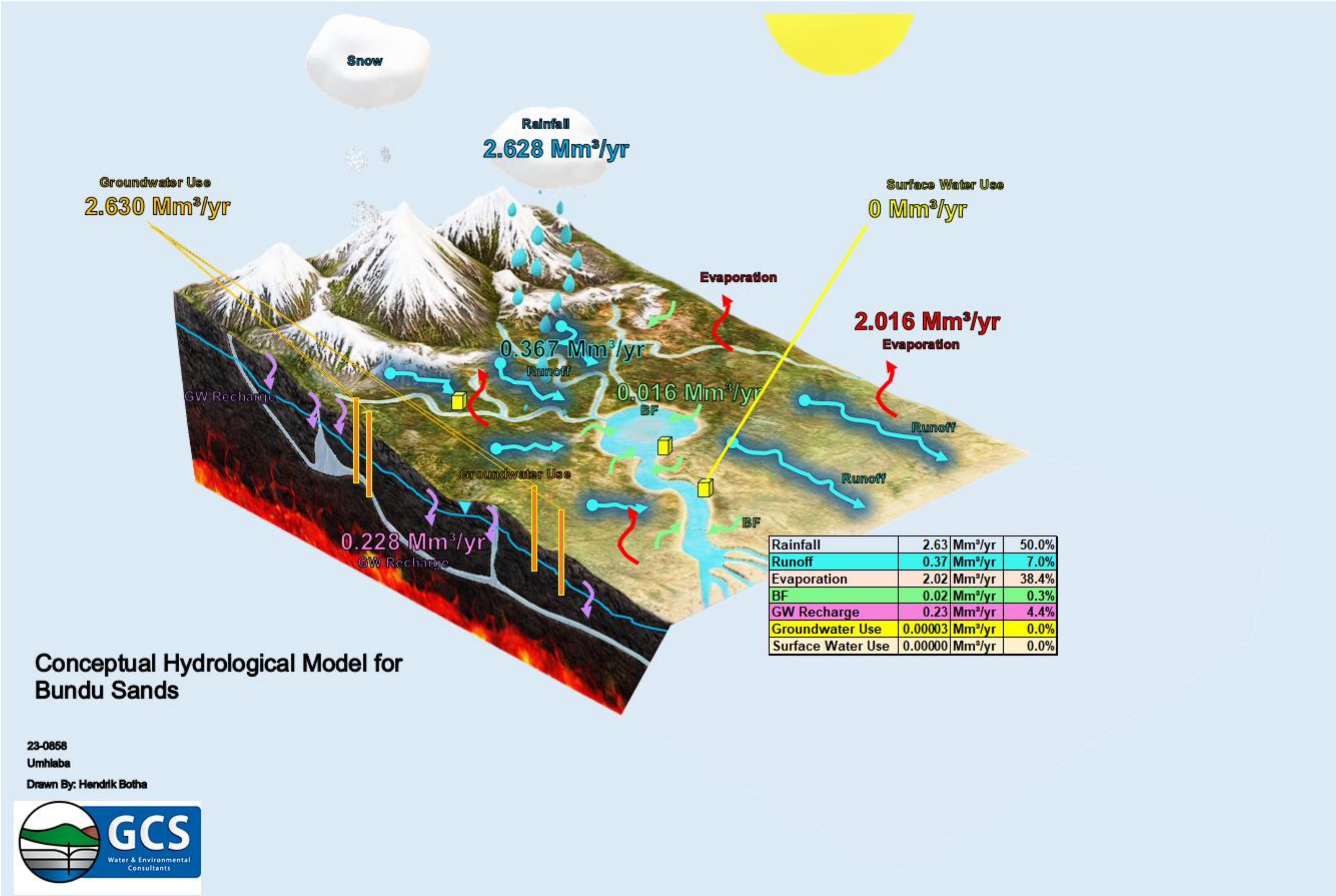



**Figure 3-11: Simplified overview of the hydrological cycle at the site (averages presented)**

# 4 SURFACE AND GROUNDWATER QUALITY

The groundwater quality for the region will be variable and will depend on the underlying geology and hydrogeology characteristics associated with groundwater recharge (i.e., older rock and aquifers with ion exchange will have higher EC, and recently recharged more permeable younger rocks will have lower EC). Literature and available hydrogeology maps for the area (refer to Figure 4-1) suggest that the electrical conductivity (EC) for the underlying aquifers generally ranges from 0 to 70 mS/m (milli Siemens/metre). The pH for the region ranges from 6 to 8. This means that groundwater abstracted from the aquifer can generally be used for domestic and recreational use (DWAF, 1996b). Where groundwater contributes to baseflow, similar water quality is expected.

In terms of surface water quality for the Swartspruit River, which is the end-receiver of the drainage network, DWS RQS resource water quality data suggest the following (DWS, 2023):

- Figure 4-2 shows the median of anions analysed at A2H058. The figure considers a data range from 1982 to 2018.
- The average total dissolved salts (TDS) are in the 552 mg/l.
- The electrical conductance (EC) of the water is in the order of 70.8 mS/m.
- pH is near neutral and, on average, in the order of 8.3.
- Alkalinity is in the order of 298 mg/l.
- The following averages are observed for salts:
    - Na – 54.6 mg/l
    - K – 7.41 mg/l
    - Ca – 47.9 mg/l
    - Mg – 28.1 mg/l
    - Cl – 54.1 mg/l
    - $SO_4$ – 48 mg/l
    - F – 0.392 mg/l
    - $PO_4$ – 0.571 mg/l
    - $NO_2$ + $NO_3$ – 0.308 mg/l

In terms of DWAF (1998) guidelines for drinking water (potable use), the water from the Swartspruit River is considered safe for human and livestock consumption. However, microbial screening would need to take place before humans consume water.

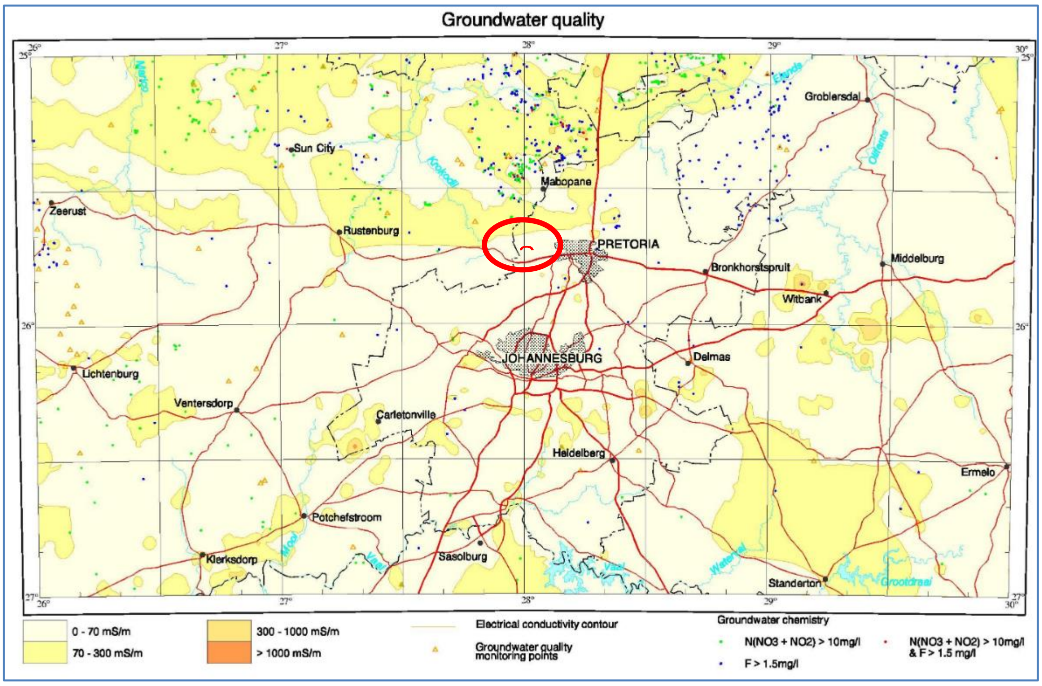



**Figure 4-1: Groundwater quality (King, 1998)**

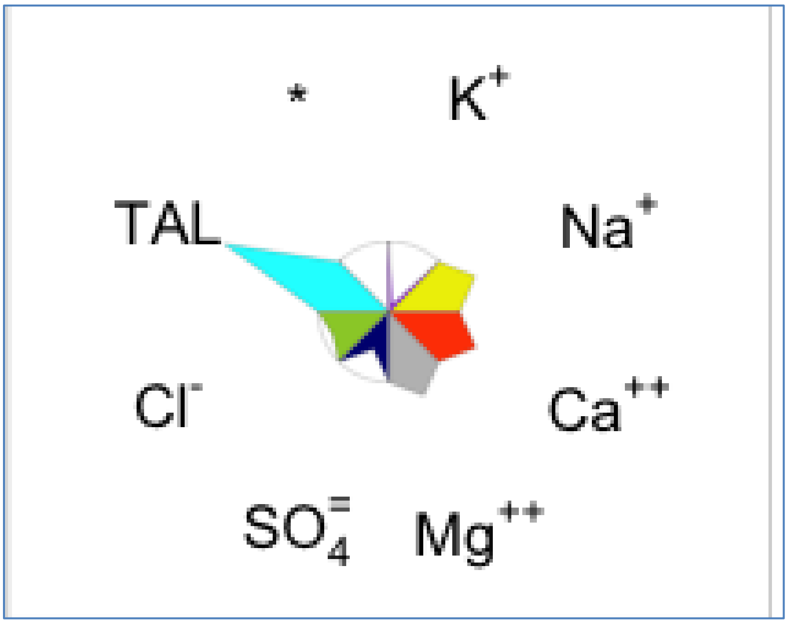



**Figure 4-2: Median of anions analysed at A2H058 – Ifafa 457 JQ at Rietfontein**

## 4.1 Site-gathered water quality data

A surface water sample was collected from the stormwater dam near the existing Bundu Sands plant to characterise the site's surface water quality. The sample was submitted to Aquatic Laboratories (SANS T0685) for analytical screening. Table 4-1 summarises the water quality results, and laboratory certificates are available in **Appendix B**. The analytical data is compared to DWAF 1996 target water quality values (TWQV) for domestic water use to contextualise the results (DWAF, 1996b). The results are summarized as follows:

- The surface water sample exhibits neutral pH conditions;
- Electrical conductance (EC) is low, as are dissolved salts and metals. It is observed that the water quality falls well within the DWAF 1996 TWQR for potable use.
- The sodium absorption ratio (SAR) of the water sample suggests that stormwater used for dust suppression/irrigation will have no impact on the soils.

**Table 4-1: Summary of surface hydrochemistry data**

| Constituent | Unit | SW-Dam | DWAF 1996 Domestic Use – TWQR |
|---|---|---|---|
| pH in water at 25ºC | - | 7.84 | 4 - 9 |
| Conductivity in mS/m @ 25ºC | mS/m | 12 | 0 - 70 |
| TDS | mg/l | 90 | 450 |
| Total Alkalinity as CaCO3 | mg/l | 71.3 | ns |
| Calcium | mg/l | 15.3 | 0 - 32 |
| Magnesium | mg/l | 7.74 | 0 - 30 |
| Potassium | mg/l | 2.53 | 0 - 50 |
| Sodium | mg/l | 4.21 | 0 - 100 |
| Chloride | mg/l | 1.01 | 0 - 100 |
| Fluoride | mg/l | 0.351 | 0 - 1 |
| Nitrate | mg/l | 0.303 | 0 - 6 |
| Sulphate | mg/l | <0.1 | 0 - 200 |
| Aluminium | mg/l | 0.035 | 0 - 0.15 |
| Copper | mg/l | <0.002 | <1 |
| Iron | mg/l | <0.002 | <0.1 |
| Manganese | mg/l | <0.002 | <0.05 |
| Sodium Adsorption Ratio (SAR) | Calculated | 0.22 | >8 |

ns = No Quality Range in Reference Guideline, Orange = Above DWAF (1996) Ideal Water Quality Ranges

# 5 PEAK FLOWS AND FLOOD LINE ASSESSMENT

Flood peak flows for the delineated sub-catchments were calculated using the Rational Method (RM3), Midgley and Pitman (MIPI) and the SDF methods (refer to **Appendix A**). Design rainfall was retrieved from station 513135W (Wylie's Farm) and used to calculate peak flow volumes. Table 5-1 provides a summary of the design rainfall data used to calculate peak flows.

The upper "U" rainfall intensity values were used, and catchment-based time concentration estimates were used in the estimation of the return period peak flows. It is noted that only HRU1 and HRU4 contribute to the runoff and peak flows of the drainage lines identified in the study area.

**Table 5-1: Summary of design rainfall data used for peak flow estimates**

| Duration | Return Period (years) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2 | 5 | 10 | 20 | 50 | 100 | 200 |
| 5 min | 12 | 16.6 | 20.1 | 23.9 | 29.4 | 34.1 | 39.3 |
| 10 min | 17.7 | 24.5 | 29.6 | 35.1 | 43.2 | 50.2 | 57.9 |
| 15 min | 22.2 | 30.7 | 37.1 | 44 | 54.2 | 62.9 | 72.6 |
| 30 min | 28 | 38.7 | 46.7 | 55.5 | 68.3 | 79.3 | 91.5 |
| 45 min | 32.1 | 44.3 | 53.5 | 63.6 | 78.2 | 90.8 | 104.7 |
| 1 hr | 35.3 | 48.7 | 58.9 | 70 | 86.1 | 100 | 115.3 |
| 1.5 hr | 40.4 | 55.8 | 67.5 | 80.1 | 98.6 | 114.5 | 132 |
| 2 hr | 44.5 | 61.4 | 74.3 | 88.2 | 108.5 | 126 | 145.3 |
| 4 hr | 52.4 | 72.4 | 87.5 | 103.9 | 127.8 | 148.5 | 171.2 |
| 6 hr | 57.7 | 79.7 | 96.3 | 114.4 | 140.7 | 163.4 | 188.4 |
| 8 hr | 61.7 | 85.3 | 103.1 | 122.4 | 150.6 | 174.9 | 201.7 |
| 10 hr | 65.1 | 89.9 | 108.7 | 129 | 158.8 | 184.4 | 212.6 |
| 12 hr | 68 | 93.9 | 113.5 | 134.7 | 165.8 | 192.5 | 222 |
| 16 hr | 72.7 | 100.5 | 121.5 | 144.2 | 177.5 | 206.1 | 237.6 |
| 20 hr | 76.7 | 105.9 | 128 | 152 | 187.1 | 217.2 | 250.5 |
| 24 hr | 80.1 | 110.6 | 133.7 | 158.7 | 195.3 | 226.8 | 261.5 |
| 1 day | 66.6 | 92 | 111.2 | 132 | 162.4 | 188.6 | 217.5 |
| 2 days | 80.4 | 111.1 | 134.3 | 159.4 | 196.2 | 227.8 | 262.7 |
| 3 days | 89.8 | 124 | 149.9 | 178 | 219.1 | 254.4 | 293.3 |
| 4 days | 99 | 136.7 | 165.2 | 196.2 | 241.4 | 280.3 | 323.2 |
| 5 days | 106.7 | 147.4 | 178.1 | 211.5 | 260.3 | 302.2 | 348.5 |
| 6 days | 113.5 | 156.7 | 189.4 | 224.9 | 276.8 | 321.4 | 370.6 |
| 7 days | 119.5 | 165.1 | 199.6 | 236.9 | 291.6 | 338.6 | 390.4 |

## 5.1 Calculated flood peak flows

Calculated peak flows are summarised in Table 5-2. The Geometric Mean of the dataset was applied to the HEC-RAS model. The flood line assessment is aimed at providing a worst-case inundation scenario to evaluate potential flooding risks associated with recognised rivers and streams associated with the study area.

**Table 5-2: Summary of design peak flows for the delineated sub-catchments ($m^3/s$)**

| Catchment | Method | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | RM (3) | | | SDF | | | MIPI | | | Geometric Mean | | |
| | 1:20yr | 1:50yr | 1:100yr | 1:20yr | 1:50yr | 1:100yr | 1:20yr | 1:50yr | 1:100yr | 1:20yr | 1:50yr | 1:100yr |
| | *($m^3/s$)* | | | | | | | | | | | |
| HRU1 | 18 | 23 | 29 | 12 | 18 | 22 | 12 | 16 | 21 | 14 | 19 | 24 |
| HRU2 | 19 | 25 | 31 | 19 | 28 | 36 | 21 | 29 | 37 | 20 | 27 | 34 |
| HRU3 | 14 | 18 | 22 | 12 | 17 | 21 | 13 | 18 | 22 | 13 | 18 | 22 |
| HRU4 | 14 | 18 | 22 | 12 | 17 | 22 | 14 | 19 | 24 | 13 | 18 | 23 |

## 5.2 Post-development peak flows

The flood lines generated are based on the existing land use, and no increases or decreases are anticipated. Considering the position of the infrastructure proposed and the mining right area, no increases in peak flows are expected. It should also be noted that proposed stormwater measures will likely further reduce runoff velocities, which could further prevent sedimentation or bank erosion. It should also be noted that only HRU1 and HRU4 contribute to the flow of the drainage lines east and west of the site.

## 5.3 Flood line modelling

### *5.3.1 Software*

HEC-RAS 6.4.1 was used to model the flood elevation profile for the 1:50 and 1:100-year flood events. HEC-RAS is a hydraulic programme designed to perform one-dimensional hydraulic calculations for a range of applications, from a single watercourse to a full network of natural or constructed channels. The software is used worldwide and has consequently been thoroughly tested through numerous case studies.

### *5.3.2 Topography profile data*

A triangulated irregular network (TIN) from the 30 m DTM (JAXA, 2023) formed the foundation for the HEC-RAS model and was used to extract elevation data for the river profile together with the river cross-sections. Furthermore, the TIN was used to determine placement positions for the cross-sections along with the river profile so that the watercourse could be accurately modelled to the resolution of the provided topographical data. The positions of the river sections were further refined by evaluating Google Earth Imagery and its correlation to the DTM elevations (i.e., does the actual position of a river/stream correlate to the sub-catchment drainage line generated).

#### *5.3.3 Manning's roughness coefficients*

Manning's roughness factor (n) is used to describe the channel and adjacent floodplain's resistance to flow. A Manning's factor of 0.02 to 0.03 best represents the frictional characteristics of the sub-catchment drainage areas, streams, and riverbank areas. This is due to isolated flow paths noted in the field, with a mixture of dense shrubs and bushels.

#### *5.3.4 Inflow and boundary conditions*

Based on the HRUs and the confirmed drainage lines/streams in the project area, a total of two (2) HEC-RAS rivers was defined, consisting of both critical depth (upstream) and normal depth slope boundary conditions. The normal depth slope was determined based on the ALOS DTM slope rise for the given sub-catchment drainage line.

#### *5.3.5 Hydraulic structures*

Hydraulic structures were not incorporated into the HEC-RAS model. Modelling these hydraulic structures would have been hampered by the lack of good-resolution topographical data (better than 30 m ALOS data). As such, including these structures would have been ineffective in the hydraulics of the streams as well as ineffective areas that were raised (i.e., roads, dam walls, buildings, culverts, etc.). Similarly, canals and diversion canals could not be modelled due to them not being captured by accurate topography elevation or lidar survey data.

#### *5.3.6 Model assumptions*

In line with the development of the flood lines, the following assumptions were made:

- The topographic data provided was of sufficient accuracy and coverage to enable hydraulic modelling at a suitable level of detail.
- The Manning's 'n' values used are considered suitable for use in the flooding events modelled, representing all the channels and floodplains.
- No abstractions or discharges into the stream sections were considered during the modelling.
- Hydraulic structures, other than the water storage dams, were not included in the model due to the resolution of available topography data.
- Steady-state hydraulic modelling was undertaken, which assumes the flow is continuous at the peak rate.
- A mixed flow regime that is tailored to both subcritical and supercritical flows was selected for running the steady-state model.

## 5.4 Model results

The 1:50 and 1:100-year flood areas modelled for the recognised field drainage lines are shown in Figure 5-1. The mining right area, as well as the existing and proposed plant and operations, fall outside zones of inundation. No flooding issues are predicted.

## 5.5 Site-specific sensitivity & buffers (avoidance areas)

A moderate to high probability of erosion of the banks of the rivers/streams associated with the project area is anticipated. *The 1:100-year flood line should be considered an avoidance area (buffer area) for any future developments that may take place.* Care should be taken if the development or linear infrastructure is expanded into the demarcated flooding areas. If development does take place in the exclusion zone, proper flooding protocols and erosion prevention measures should be implemented.

## 5.6 Limitations

Steady-state flood modelling was undertaken, which is a conservative approach as it ignores the effect of storage within the system and, therefore, produces higher flood levels than would be expected to occur. A steady-state model will result in worst-case (conservative) estimates of flooding, and resultant flood levels and floodplain extents would decrease if unsteady state modelling were undertaken using an inflow hydrograph as opposed to continuous peak flow.

Despite the above-mentioned Manning’s ‘n’ coefficients for the vegetation observed and the medium-low resolution topographic data, the flood risk to the surface infrastructure has been adequately assessed for the project area. No further flood modelling work is considered necessary and would only be considered necessary when more detailed topographical data is available.

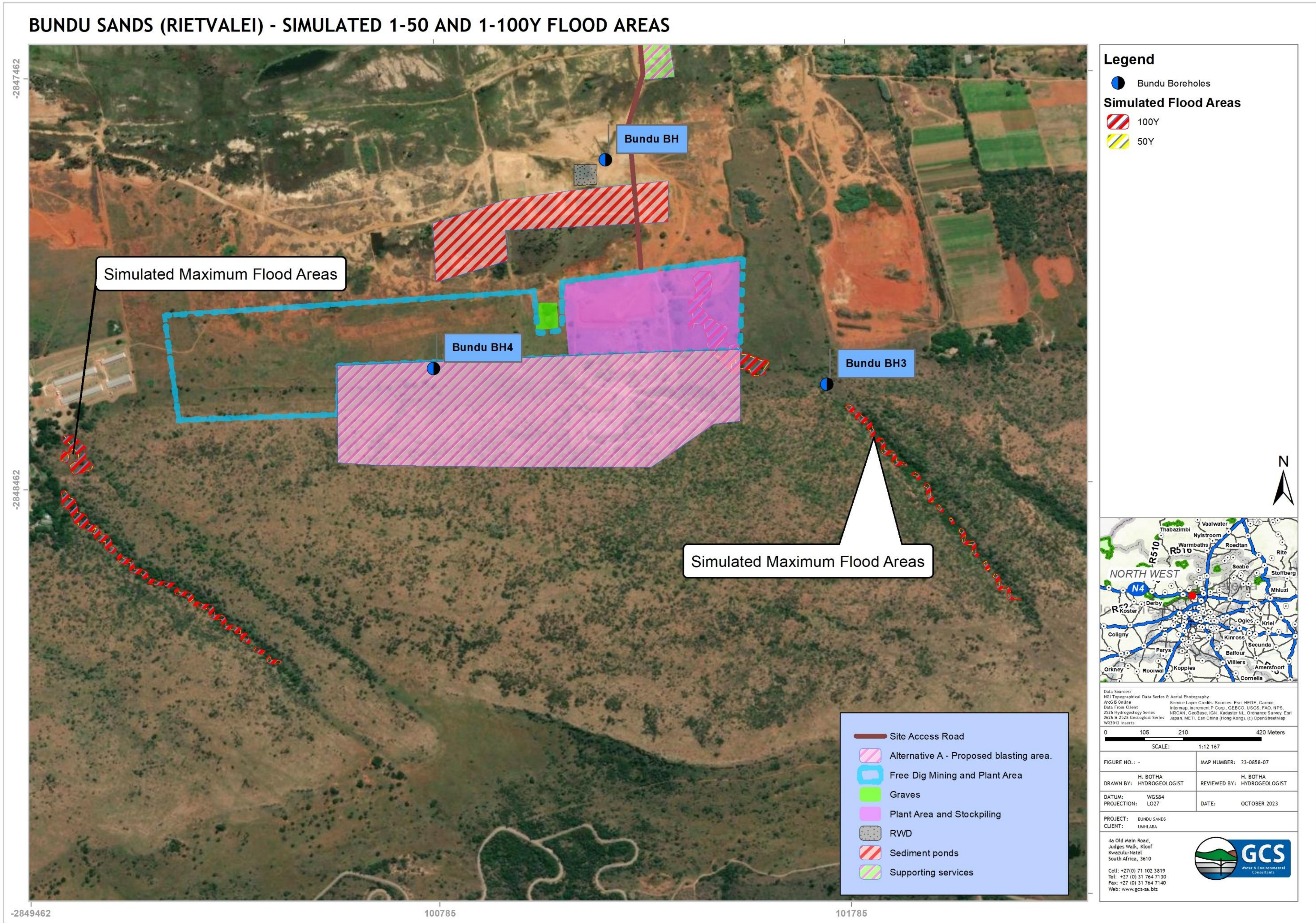



**Figure 5-1:** **Simulated 1-50- and 1-100-year flooding areas for recognised drainage lines**

# 6 STORMWATER MANAGEMENT

The following section describes the CSWMP developed and is based on available hydrological data, the walkover assessment data gathered and available site layout data.

## 6.1 Aim of the stormwater management plan

The CSWMP aims to:

- Illustrate likely stormwater sub-catchments (HRUs) and preferential overland runoff flow paths.
- Determine likely dirty and clean water HRUs (if any).
- Provide water containment and diversion systems to prevent the mixing of clean and dirty water, as well as soil erosion and flooding.
- Attenuate stormwater back to the natural environment.

## 6.2 Existing stormwater infrastructure

Limited stormwater infrastructure currently exists at the site, and the following was observed during the GCS site walkover assessment:

- Earth berms along the sides of the existing plan, as well as small diameter (< 225 mm) drains that discharge water accumulated at the plant to the downstream environment.
- Earth trenches downstream of the sedimentation dams, as well as several berms along the dams to control runoff. It appears as though the sedimentation dams have been compartmentalised.

As expressed earlier in this report, free drainage across the site occurs. There are also no recognised drainage lines, rivers or streams associated with the active mining areas. Mining and rehabilitation activities appear to have changed the drainage of the overall area and likely pre-dates that of the existing Bundu mining operations. Micro-sub catchment style drainage occurs, where rainwater that does not run off to the downstream environment ponds and seeps into the soils.

## 6.3 Delineation of clean and dirty water areas

Based on the activity undertaken and proposed (sand and shallow rock mining) and considering the quality of the water at the stormwater dam, no dirty areas exist. Sedimentation may likely occur in active mining and operational areas, where sands will be excavated and where there will be heavy traffic.

Focus of sotmrwater managment should be on the containment of runoff and conveying of the stormwater back to the downstream environment after trapping sediments that become suspended in the stormwater runoff. Stormwater from undisturbed areas would need to be controlled, and prevention of runoff outside of any excavations or work areas needs to be conveyed around the active work areas. The areas that will contribute to stormwater runoff based on the site layouts provided are shown in Figure 6-1.

## 6.4 Assumptions and limitations

The following assumptions pertain to the CSWMP:

- The ALOS DTM is used to delineate the stormwater drainage areas and is assumed to be of sufficient resolution to accurately describe the runoff from the site(s).
- Conceptual stormwater modelling and sizing were undertaken, as well as the application of the RM (3) methods to determine 1-10 and 1-100-year stormwater peak flows.
- No dynamic engineering level stormwater modelling or stormwater sizing was undertaken (not part of this scope). It is assumed that the concepts presented in this report will be modelled and developed by a professional civil engineer and integrated into the mine master layout plan.

## 6.5 Stormwater peak flows

The rational method was used to calculate the stormwater peak flows for the stormwater sub-catchments. 24-hour design rainfall for the closest rainfall station (513135W) is available in Table 6-1. The soils in the study area have an SCS rating of B/C soil types (runoff coefficient in the order of 53%), with an erodibility rating of 7.

Considering the vegetation cover observed on-site, the land cover translates to a run-off coefficient (C) in the order of 0.8 (80%). 1:2, 1:10, 1:50 and 1:100 yr return periods are presented and are tabulated in Table 6-2. The values presented represent the peak runoff volumes at the recurrence interval, which can be expected within each micro-sub-catchment.

**Table 6-1: Design rainfall – 24-hour storm – Rainfall station 513135W**

| Duration | Return Period (years) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2 | 5 | 10 | 20 | 50 | 100 | 200 |
| 24 hr | 80.1 | 110.6 | 133.7 | 158.7 | 195.3 | 226.8 | 261.5 |

**Table 6-2: Stormwater return period estimates**

| Storm HRU | Q2 -m³/s | Q10 -m³/s | Q50 -m³/s | Q100 -m³/s |
|---|---|---|---|---|
| HRU-OC | 0.875 | 1.461 | 2.135 | 2.479 |
| HRU-Plant | 0.183 | 0.306 | 0.446 | 0.518 |
| HRU-Shallow Mine | 0.575 | 0.962 | 1.408 | 1.633 |

## 6.6 Proposed stormwater management measures

Based on the proposed activities and considering the runoff patterns associated with the site, temporary stormwater management is proposed as an overall stormwater management strategy. This would involve using temporary berms, sandbags, gabion walls, revegetation of eroded areas, silt fences and temporary drainage trenches to convey stormwater around active mining areas and to the downstream environment. The proposed settlement dams are also situated downstream of the mining operations and will likely capture sediment runoff from the site, with little additional stormwater management required.

As part of the dynamic nature of typical sand and shallow rock mining operations, fixed stormwater management structures would be difficult to implement. The following would need to be considered as part of the stormwater management strategy:

- **Assess the site constraints and any site-specific concerns, including:**
  - Specific vegetation that may need to be identified and/or isolated from the site disturbance.
  - Highly erodible soils may require additional erosion control measures.
  - The type of activity should consider landforms.
  - Up-slope drainage catchments that may need to be diverted around the work site – *which is currently being done*.
  - Workspace limitations may require site-specific sediment control measures and/or the extensive use of skips or bins for material storage and waste management.
  - Expected rainfall intensity during the period of disturbance (wet season vs dry season).
- **Stabilise the site entry/exit points:**
  - A stabilised site access must be established and, if possible, limited to one point only. The access allows vehicles to enter the work area of goods while preventing the unnecessary tracking of sediment onto the nearby environment from multiple locations. A stabilised entry/exit point normally consists of a stabilised rock pad.
- **Prevent erosion & manage stockpiles:**

- Suitable material storage areas must be located up-slope of the main sediment barrier (e.g., sediment fence).
- Stockpiles kept on site for more than two weeks will require an impervious cover (e.g., builder's plastic or geofabric) to protect against raindrop impact. Stockpiles of sandy topsoil material located behind a sediment fence will only need a protective cover if the stockpiles are likely to be exposed to strong winds and erosion.

## 6.7 Other stormwater considerations

Based on the conceptual site layout plan, the following can be considered in terms of more permanent stormwater management (refer to Figure 6-1):

- Install a temporary earth-filled berm (0.8 m high, base 2 m) upstream of the deep mining operations towards the southwestern flank to intercept any runoff from the hilltop.
- Install vegetated swales (about 0.8m to 1.4m and 0.6m across, 1:4 slope rise) with gabion walls along the eastern flank of the operations to capture and release any stormwater runoff from the hilltop. Gabion wall structures should be positioned in the grassed swale from upstream to downstream to decrease flow velocity and act as sediment traps. Upstream gabion structures will need to be cleaned annually. Release via a reno mattress or re-enforced vegetated area at the swale outflow is recommended.
- Install a concrete-lined (about 0.8m to 1.2m and 0.6m across, 1:4 slope rise) V-drain upstream and along the southern border of the deep mining area, as well as along the shallow mining area. The V-drains should converge and discharge collected stormwater to the downstream environment. The outflow can either be stabilised with an attenuation pond (~5000 $m^3$ storage and surface area of 0.00235 $km^2$, depth of 2m, unlined) and overflow system or direct discharge via a stabilised gabion wall and reno mattress structure. Alternatively, a chute/step drain can be considered for the outflow.
- Towards the eastern flank of the shallow mining, and to prevent any accidental runoff towards the poultry farm, it is proposed that an earth berm (0.8 m high, base 2 m) be constructed.
- For the plant area, a trap drain system flowing into the settling dams is proposed (refer to Figure 6-1).
- Stormwater collected in the deep excavation should be collected in the lowest portion of the pit – towards the east) in a sump or free collection. The accumulated stormwater will need to be pumped to the proposed attenuation pond or the settling dams. Groundwater inflow should be pumped to the RWD, and as an alternative, all accumulated water in the pit (stormwater, runoff and groundwater) can be pumped to the RWD.

The concepts discussed above will be subjected to changes as the mine layout plan is formalised. The following factors also need to be considered during the preparation, operational, and closure phases of the site.

- Ensure that all stormwater systems are kept clean of any debris and silt to reduce flooding risk.
- Ensure that eroded areas are re-vegetated to reduce sedimentation risk and runoff volumes in the streams.
- Have fuel/oil spill kits on-site for immediate clean-up of any hydrocarbons during the proposed activities. Park vehicles in dedicated areas with drip trays to manage potential leakages.
- Regular inspections and maintenance of the site should be conducted to ensure that vegetation cover is adequate and no rivulets are generated.

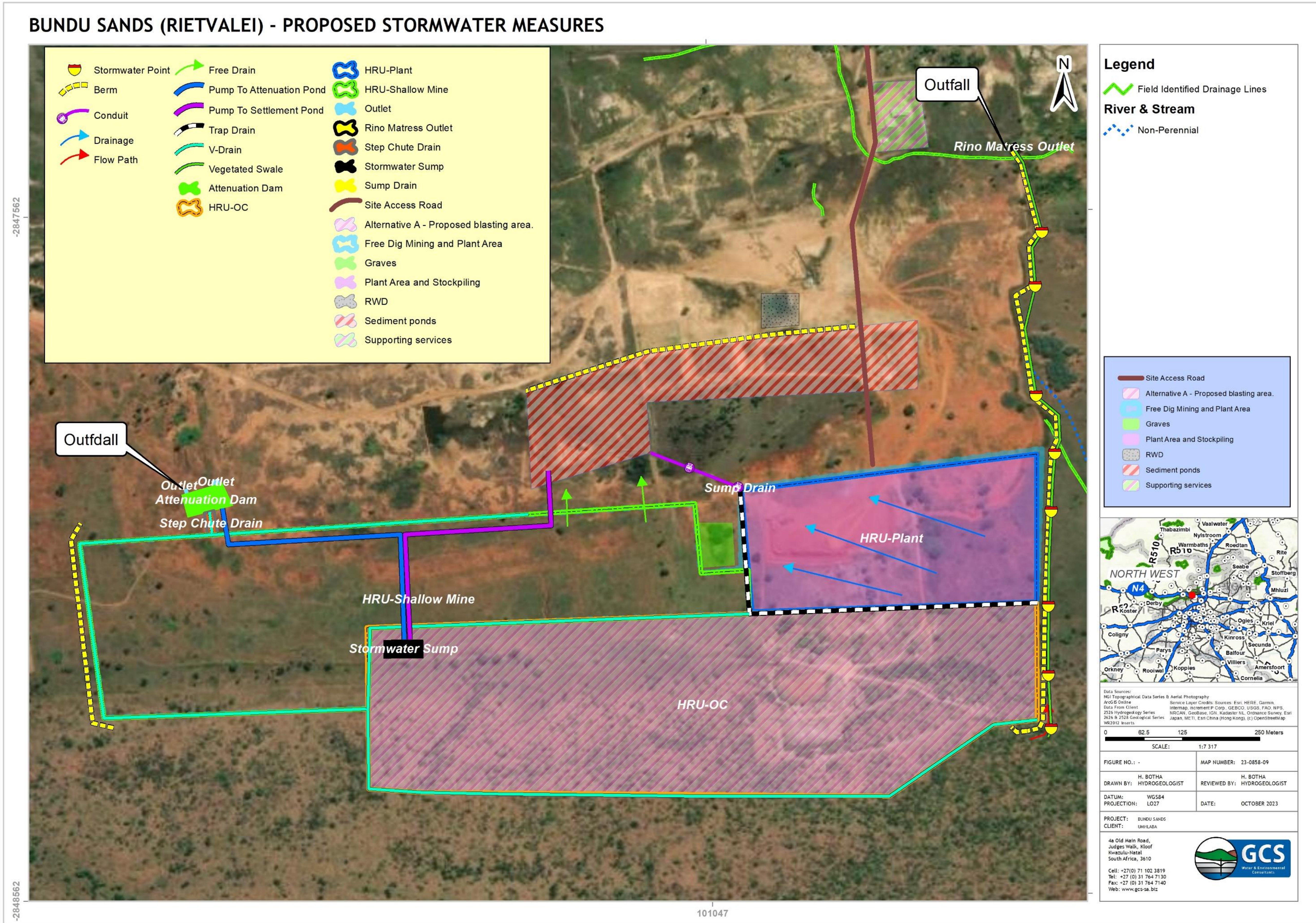



**Figure 6-1:** **Stormwater catchments & proposed stormwater measures**

# 7 HYDROLOGICAL RISK ASSESSMENT

The anticipated hydrological risk concerning the preparation, operational and closure phase of the proposed project was evaluated. The activities entail:

- Movement of heavy machinery and equipment at the site can potentially cause soil pollution (i.e., hydrocarbon spills) and promote erosion/compaction associated with haul roads.
- Opencast excavations using excavators within the Project area (impact on vadose zone soils).
- Stockpiling of sand at the washing plant for transportation (could lead to sedimentation during stormwater events).
- Solid sand settlement in the proposed settlement dams.
- Groundwater and surface water abstraction (from the stormwater dam) is used to wash the sand and suppress dust. *The volumes required have not yet been determined.*

The source-pathway-receptor (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***

The environmental significance of an impact was determined by multiplying the consequence by probability. The risk significance rating is summarised in Table 7-1.

**Table 7-1: Risk rating scale**

| Criteria | Rating Scales |
|---|---|
| Significance | Very high – negative (-48 to -66) |
| | High – negative (-36 to -48) |
| | Moderate – negative (-24 to -36) |
| | Low – negative (-12 to -24) |
| | Neutral - Very low (0 to -12) |
| | Low–positive (0 to 12) |
| | Moderate–positive (12 to 24) |
| | High–positive (24 to 48) |
| | Very high – positive (48 to 66) |

Several hydrological risks were identified and are listed in Table 7-2 (preparation phase), Table 7-3 (operational phase) and Table 7-4 (closure phase).

## 7.1 Preparation phase

The following activities are anticipated during the construction phase of the project:

- Typical earthworks are required to clear the areas.
- Construction of access roads, housing foundations and buildings.
- Excavation for the proposed settlement dams.
- Establish service platforms, material handling areas, and other temporary infrastructure.
- Dust suppression of access roads.
- Placing of topsoil in designated areas; and
- Constructing laydown areas and temporary stormwater systems and berms.

The identified possible hydrology impacts for the preparation phase include (refer to Table 7-2):

- The destruction of the vadose zone sediments by clearing activities. This impact is permanent and is therefore not included in the impact table, as no mitigation measures can be recommended. This could lead to sediment runoff and surface water contamination.
- Clearing topsoil from footprint areas will influence the rate of infiltration of water to the shallow groundwater system and/or baseflow component to shallow streams.
- Handling waste and transporting material can cause various types of spills (domestic waste, sewage water, hydrocarbons), which can infiltrate and contaminate the soils and groundwater system.
- Oil and fuel spills and leakages at vehicle park areas and in the project areas may cause poor-quality seepage and soil contamination.

Visual monitoring of the site on an ongoing (monthly) basis will serve as a 1$^{st}$ order detection system for any soil and water pollution that may take place. If required, a surface water monitoring plan should be established to monitor the impact on the nearby surface water receptors. The collected information should be used as part of an active water management system and act as an early warning system for the application of mitigation measures. The identified impacts are not likely to negatively affect the commencement of the proposed projects.

## 7.2 Operational phase

The possible hydrological impacts for the operational phase of the project are likely to be (refer to Table 7-3):

- The destruction of the vadose zone sediments by mining activities.
- Stockpiling of washed sands that could lead to sediment runoff during storm events.
- Oil and fuel spillages associated with service and mining vehicles accessing and undertaking maintenance work at the site.
- Sediment stormwater discharges during flooding events.

In general, the operational phase risk associated with the project is predicted to be low, and it is foreseen that the impacts can be managed. This is based on the type of project that is proposed.

## 7.3 Closure and decommissioning phases

The closure and decommissioning phases will be per an agreed and approved closure plan for the Bundun Mining operations. The potential risks are captured in Table 7-4 and summarised as follows:

- Cessation of mining operations and rehabilitation;
- Backfill and rehabilitate mining excavations.
- Rehabilitation of the settlement dams; and
- Decommission the plant and other supporting infrastructure.

Closure of the site is predicted to be beneficial to the area and will enable long-term stabilisation of the mined areas. The area would need to be sloped as per pre-mining conditions and rehabilitated with vegetation grown on site. Stabilisation of the area is required due to the high sediment and erosion potential of the soils in the project area.

## 7.4 Alternatives considerations

No alternatives were considered during this assessment, as the application is for a mine permit. However, it is advised that the demarcated flooding area be considered in the final mine layout and plan. Offsets will likely not be possible, as the area in question needs to be mined to tap the sand resource.

## 7.5 Cumulative impacts and impacts on the hydrological cycle

Based on the unique hydrology conditions of the site and proposed stormwater management options, no impacts to the hydrological cycle are anticipated. Runoff will still be allowed to enter the watercourses as well as stormwater to maintain ecological water requirements, and the impact of increased evaporation is considered marginal on a sub-catchment scale.

In terms of the preparation and operational phase, there are expected cumulative impacts on the soils associated with the site. The impact is predicted to improve at the closure of the mine and if rehabilitation is rolled out. The sub-catchments in which the mining will take place are isolated from other mines and activities in the area, and hence, cumulative impacts on a larger scale will be limited.

**Table 7-2: Hydrological impacts during the preparation phase**

| Component Being Impacted On | Activity Which May Cause the Impact | Activity | Pre- Mitigation | | | | | | | Recommended Mitigation Measures | Post Mitigation | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 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 |
| Vadose zone soils and subsequent aquifer (groundwater table) | Disturbing vadose zone during soil excavations/construction activities. | Net Result of Earthworks and Mining | Medium Term (3) | Site (2) | Yes (1) | Moderate (-2) | Slightly detrimental (-7 to -12)<br><br>(-12) | Definite (2) | Low – negative (-13 to -24)<br><br>(-24) | - Only excavated areas apply to the project area.<br>- Backfill the material in the same order it was excavated to reduce contamination of deeper soils with shallow, oxidised soils.<br>- Cover excavated soils with a temporary liner to prevent contamination.<br>- Retain as much indigenous vegetation as possible.<br>- Exposed soils are to be protected using a suitable covering or revegetating. | Medium Term (3) | Site (2) | Yes (1) | Low (-1) | Negligible (-6 to 0)<br><br>(-6) | Probable (1) | Neutral/ Negligible (0 to -12)<br><br>(-6) |
| | Poor quality seepage from machinery used to excavate soils. Oil, grease, and fuel leaks could lead to hydrocarbon contamination of the vadose zone - which could percolate into the shallow aquifer. | Net Result of Earthworks and Mining | Medium Term (3) | Site (2) | Yes (1) | Moderate (-2) | Slightly detrimental (-7 to -12)<br><br>(-12) | Definite (2) | Low – negative (-13 to -24)<br><br>(-24) | - Park heavy machinery in lined areas and place drip trays under vehicles at the site.<br>- Visual soil assessments for signs of contamination during construction (monthly) | Medium Term (3) | Site (2) | Yes (1) | Low (-1) | Negligible (-6 to 0)<br><br>(-6) | Probable (1) | Neutral/ Negligible (0 to -12)<br><br>(-6) |
| Primary Surface Water Receivers<br>- Swartspruit River is about 1km downstream of the site.<br>- No other recognised rivers/streams are associated with the site. | Erosion and sedimentation runoff may enter the river (worst case); however, due to the distance from the site, it is very unlikely. | Net Result of Earthworks and Mining | Medium Term (3) | Site (2) | Yes (1) | Low (-1) | Negligible (-6 to 0)<br><br>(-6) | Probable (1) | Neutral/ Negligible (0 to -12)<br><br>(-6) | - Use temporary or permanent stormwater systems (as per this report) to prevent erosion and manage sediment runoff.<br>- Visual inspections of all vehicles entering and operating at the site. | Medium Term (3) | Site (2) | Yes (1) | Low (-1) | Negligible (-6 to 0)<br><br>(-6) | Probable (1) | Neutral/ Negligible (0 to -12)<br><br>(-6) |

**Table 7-3: Hydrological impacts during the operational phase**

| Component Being Impacted On | 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vadose zone soils | Disturbing vadose zone during soil mining | Net Result of Earthworks and Mining | Medium Term (3) | Site (2) | Yes (1) | Moderate (-2) | Slightly detrimental (-7 to -12)<br>(-12) | Definite (2) | Low – negative (-13 to -24)<br>(-24) | - Keep excavations as small as possible.<br>- Ensure that sediment barriers are in place at mining sites to prevent sediment runoff and erosion. | Medium Term (3) | Site (2) | Yes (1) | Low (-1) | Negligible (-6 to 0)<br>(-6) | Probable (1) | Neutral/ Negligible (0 to -12)<br>(-6) |
| | Poor quality seepage from machinery used to excavate soils. Oil, grease, and fuel leaks could lead to hydrocarbon contamination of the vadose zone - which could percolate into the shallow aquifer and enter the stormwater system. | Net Result of Earthworks and Mining | Medium Term (3) | Site (2) | Yes (1) | Moderate (-2) | Slightly detrimental (-7 to -12)<br>(-12) | Definite (2) | Low – negative (-13 to -24)<br>(-24) | - Park heavy machinery in lined areas and place drip trays under vehicles at the site.<br>- Visual soil assessments for signs of contamination during construction (monthly) | Medium Term (3) | Site (2) | Yes (1) | Low (-1) | Negligible (-6 to 0)<br>(-6) | Probable (1) | Neutral/ Negligible (0 to -12)<br>(-6) |
| | Sediment runoff because of dust suppression and movement of vehicles at the site | Net Result of Earthworks and Mining | Medium Term (3) | Site (2) | Yes (1) | Moderate (-2) | Slightly detrimental (-7 to -12)<br>(-12) | Definite (2) | Low – negative (-13 to -24)<br>(-24) | - Park heavy machinery in lined areas and place drip trays under vehicles at the site.<br>- Visual soil assessments for signs of contamination during construction (monthly) | Medium Term (3) | Site (2) | Yes (1) | Low (-1) | Negligible (-6 to 0)<br>(-6) | Probable (1) | Neutral/ Negligible (0 to -12)<br>(-6) |
| | Poor quality runoff into the environment (if hydrocarbon contamination takes place at the site). The impact will be on local soils as there are no watercourses associated with the site. | Net Result of Earthworks and Mining | Medium Term (3) | Site (2) | Yes (1) | Moderate (-2) | Slightly detrimental (-7 to -12)<br>(-12) | Definite (2) | Low – negative (-13 to -24)<br>(-24) | - Have fuel cleanup kits available on site.<br>- Ensure that stormwater is monitored annually for contaminants. | Medium Term (3) | Site (2) | Yes (1) | Low (-1) | Negligible (-6 to 0)<br>(-6) | Probable (1) | Neutral/ Negligible (0 to -12)<br>(-6) |
| Primary Surface Water Receivers<br>- Swartspruit River is about 1km downstream of the site.<br>- No other recognised rivers/streams are associated with the site. | Erosion and sedimentation runoff may enter the river (worst case); however, due to the distance from the site, it is very unlikely. | Net Result of Earthworks and Mining | Medium Term (3) | Site (2) | Yes (1) | Low (-1) | Negligible (-6 to 0)<br>(-6) | Probable (1) | Neutral/ Negligible (0 to -12)<br>(-6) | - Use temporary or permanent stormwater systems (as per this report) to prevent erosion and manage sediment runoff.<br>- Visual inspections of all vehicles entering and operating at the site. | Medium Term (3) | Site (2) | Yes (1) | Low (-1) | Negligible (-6 to 0)<br>(-6) | Probable (1) | Neutral/ Negligible (0 to -12)<br>(-6) |

**Table 7-4: Hydrological impacts during the closure phase/decommissioning phase**

| Component Being Impacted On | Activity Which May Cause the Impact | Activity | Pre- Mitigation | | | | | | | Recommended Mitigation Measures | Post Mitigation | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 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 |
| Vadose zone soils and subsequent aquifer (groundwater table) | Rehabilitation of mining operations. | Rehabilitation | Medium Term (3) | Site (2) | Yes (1) | High (3) | Moderately beneficial (7 to 18)<br>(18) | Definite (2) | High–positive (24 to 48)<br>(36) | | | | | | | | |
| | Poor quality seepage from machinery used to decommission and rehabilitate the mine operations. | Rehabilitation | Medium Term (3) | Site (2) | Yes (1) | Moderate (-2) | Slightly detrimental (-7 to -12)<br>(-12) | Definite (2) | Low – negative (-13 to -24)<br>(-24) | - Park heavy machinery in lined areas and place drip trays under vehicles at the site.<br>- Visual soil assessments for signs of contamination during rehabilitation (monthly) | Medium Term (3) | Site (2) | Yes (1) | Low (-1) | Negligible (-6 to 0)<br>(-6) | Probable (1) | Neutral/ Negligible (0 to -12)<br>(-6) |
| | Rehabilitation of settlement dams will stabilise the soils in the project area. | Rehabilitation | Medium Term (3) | Site (2) | Yes (1) | High (3) | Moderately beneficial (7 to 18)<br>(18) | Definite (2) | High–positive (24 to 48)<br>(36) | | | | | | | | |
| Regional groundwater table/groundwater aquifer | Cession of mining activity and rebound of the groundwater table. | Decommissioning | Medium Term (3) | Site (2) | Yes (1) | High (3) | Moderately beneficial (7 to 18)<br>(18) | Definite (2) | High–positive (24 to 48)<br>(36) | | | | | | | | |
| | Decommissioning of the borehole used for groundwater supply. | Decommissioning | Medium Term (3) | Site (2) | Yes (1) | High (3) | Moderately beneficial (7 to 18)<br>(18) | Definite (2) | High–positive (24 to 48)<br>(36) | | | | | | | | |

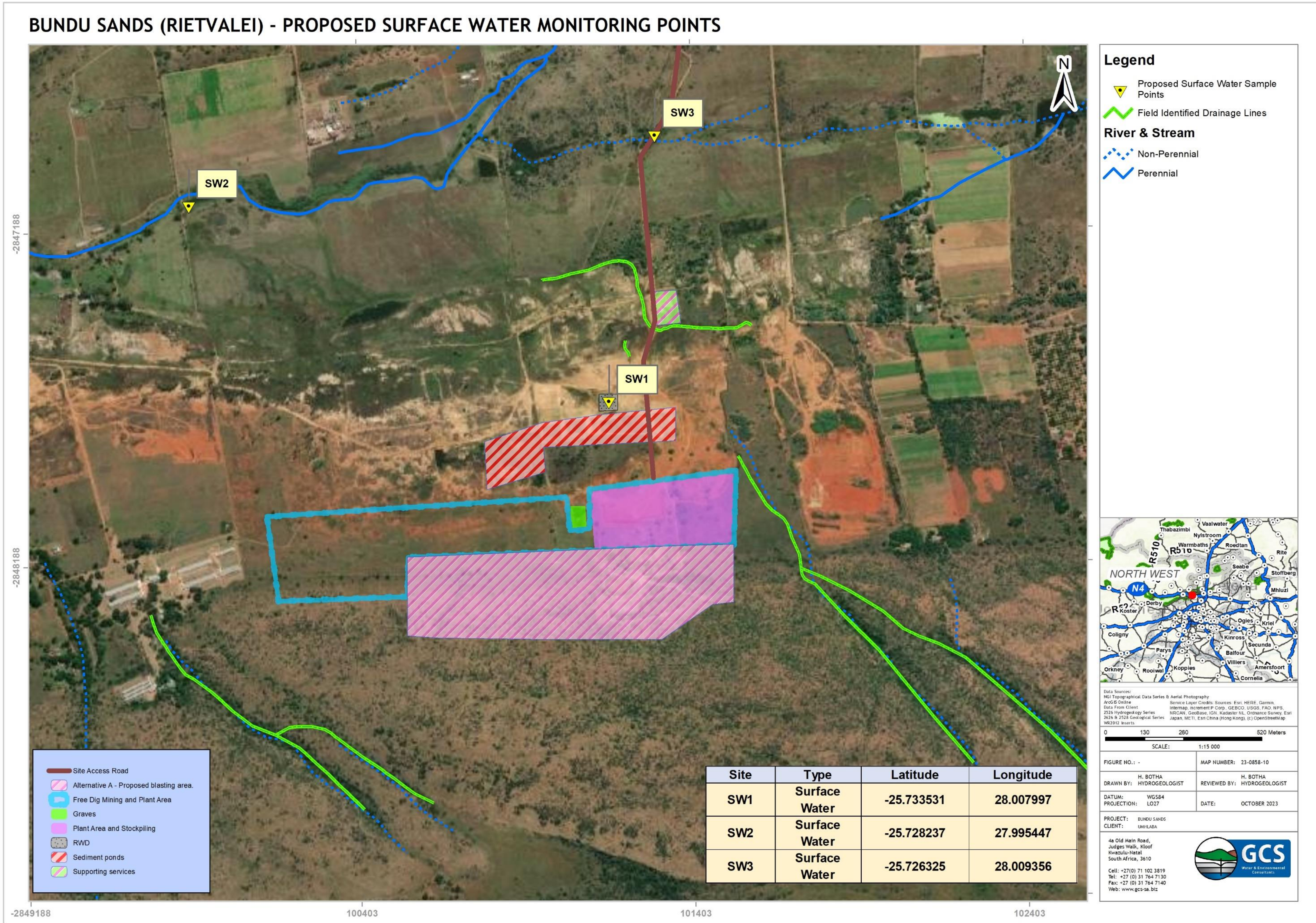
# 8 SURFACE WATER QUALITY MONITORING

Currently, no surface water monitoring is being done. It is proposed that a proper monitoring programme be implemented to monitor both the water quality and quantity in the project area. This would be important for both the construction and the operational phases of the project.

Three (3) phases of monitoring are proposed:

1. Monthly visual assessments in work areas are associated with the preparation, operational, and closure phase activities. If visual and monitoring observations show areas of concern (i.e., where pollution is observed during the operational phase or in the wetland units), then mitigation measures should be formulated based on the scale of impact observed. Soil and water quality samples may also be required and will need to be determined in the field and based on the observations made at the time of site evaluation. No formal monitoring points are proposed as part of this phase.
2. It is proposed that three (3) surface water sample points be established as the project approaches the operational phase.
    a. The positions of the proposed surface water streams are from upstream to downstream in the downstream watercourse, and the aim is to assess the long-term impact on the stream and wetland system. The positions and coordinates of the proposed surface water sample sites are available in Figure 8-1.
    b. Annual water quality sampling is proposed.
    c. The following constituents should be screened, and more detailed screening may be required if non-compliance in terms of DWAF (1996) Water Quality Guidelines Volume 7: Aquatic Ecosystems is noted:
        i. pH, EC, Total Dissolved Solids, Turbidity, Oil and Grease, Biological oxygen demand (BOD), and chemical oxygen demand (COD).
        ii. Ca, Mg, Na, K, Cl, F, $NO_3$, $SO_4$, Fe, Mn, Al.
3. Stormwater monitoring requires a visual component where the stormwater system is visually assessed every month to identify issues (i.e., clogged systems, erosion and sedimentation) and then rectify the issues observed. No dedicated stormwater monitoring points have been proposed. Visual stormwater monitoring is proposed quarterly and weekly during rainy months. Stormwater quality monitoring is also not proposed and is based on the expected water quality as observed in the existing stormwater dam.

It is proposed that the developer/land owner undertake the water quality program. The results should be reported to DWS on an annual basis if required. Otherwise, the results should be kept on record if DWS audits the site.




| Site | Type | Latitude | Longitude |
|---|---|---|---|
| SW1 | Surface Water | -25.733531 | 28.007997 |
| SW2 | Surface Water | -25.728237 | 27.995447 |
| SW3 | Surface Water | -25.726325 | 28.009356 |

**Figure 8-1: Proposed surface water monitoring network**

# 9 CONCLUSIONS

Based on the investigation undertaken, the following conclusions are made:

- The project falls within quaternary catchment A21H of the Limpopo Water Management Area (WMA). Elevations for the site area range from 1200 to 1550 metres above mean sea level (mamsl).
- The site is bound to the south by a steep hilltop, and two (2) dominant drainage lines exist, one towards the east and one towards the west of the hilltop, where valleys have been carved by erosion.
    - For the majority of the site, there are no recognised drainage lines or streams/rivers. The proposed Project area falls between the two drainage lines, and based on the topography and HRUs delineated, the activity will likely not impact the western drainage line and will further have a limited impact on the eastern drainage stream. From the site investigation, it is clear that free drainage takes place for the entire site, with occasional depressions where surface water collects shortly after rainfall events.
    - It is clear from the site walkover assessment that historic mining has changed the surface water flow paths, and micro-catchment style free drainage from higher to lower elevations takes place. The overall drainage direction is towards the north of the Swartspruit River. The Swartspruit River is situated about 1.04km downstream of the site and flows towards the west to the Hartbeespoort Dam.
- Based on the flood lines generated for the project area, the mining right area, as well as the existing and proposed plant and operations, falls outside zones of inundation. No flooding issues are predicted.
- A surface water sample was taken from the existing stormwater dam at the site. The electrical conductance (EC) is low, and so are dissolved salts and metals. It is observed that the water quality falls well within the DWAF 1996 TWQR for potable use. The sodium absorption ratio (SAR) of the water sample suggests that stormwater used for dust suppression/irrigation will have no impact on the soils. Limited impacts in terms of water quality at the site are expected.
- A conceptual stormwater management plan was developed for the site and is available in Section 6. It was found that:
    - Based on the activity undertaken and proposed (sand and shallow rock mining) and considering the quality of the water at the stormwater dam, no dirty areas exist. Sedimentation may likely occur in active mining and operational areas, where sands will be excavated and where there will be heavy traffic.

- The stormwater plan should focus on runoff containment and conveying of the stormwater back to the downstream environment. Stormwater from undisturbed areas would need to be controlled, and prevention of runoff outside of any excavations or work areas needs to be conveyed around the active work areas.
- Temporary stormwater management measures are proposed for the site due to the dynamic nature of sand mines as well as the micro-catchment style free drainage associated with the site (refer to Section 6.6). However, based on the conceptual site layout plan, several more permanent measures can also be considered (refer to Section 6.7.).

- Several hydrological risks were identified and presented in Section 7, and several mitigation measures can be considered. A water monitoring plan is available in Section 8.

## 9.1 Avoidance areas

The 1:100-year flood line should be considered an avoidance area (buffer area) for any future developments that may take place. Care should be taken if the development or linear infrastructure is expanded into the demarcated flooding areas. If development does take place in the exclusion zone, proper flooding protocols and erosion prevention measures should be implemented.

## 9.2 Mitigation measures for inclusion in the EMPr

The following mitigation measures can be implemented as part of the EMPr to further reduce the risk of flooding on site and contribute to stormwater generation potential:

- **Assess the site constraints and any site-specific concerns, including:**
  - Specific vegetation that may need to be identified and/or isolated from the site disturbance.
  - The type of construction should consider landform. Avoid slab-on-ground construction on steep sites.
  - Up-slope drainage catchments that may need to be diverted around the work site.
  - Workspace limitations may require site-specific sediment control measures and/or the extensive use of skips or bins for material storage and waste management.
  - Expected rainfall intensity during the period of disturbance (wet season vs dry season).
- **Stabilise the site entry/exiting points:**

- A stabilised site access must be established and, if possible, limited to one point only. The access allows for construction vehicles to enter the work area while preventing the unnecessary tracking of sediment onto the nearby environment from multiple locations. A stabilised entry/exit point normally consists of a stabilised rock pad.

- **Prevent erosion & manage stockpiles:**
  - Suitable material storage areas must be located up-slope of the main sediment barrier (e.g., sediment fence).
  - Stockpiles kept on site for more than two weeks will require an impervious cover (e.g., builder's plastic or geofabric) to protect against raindrop impact. Stockpiles of sandy material located behind a sediment fence will only need a protective cover if the stockpiles are likely to be exposed to strong winds.
  - On steep sites and sites with limited available space, erodible materials may need to be stored in commercial-sized bins or mini-skips before use.
- **Manage site waste:**
  - Adequate waste containers must be provided on-site and maintained in a way that potential and actual environmental harm resulting from such material waste is minimised.
  - Building activities must be carried out on a pervious surface, such as grass or open soil, or in such a manner that all sediment-laden runoff is prevented from discharging into a water body.
- Ensure that eroded areas are re-vegetated to reduce sedimentation risk and runoff volumes in the streams.
- Ensure that all stormwater attenuation dams/ponds are operated with enough freeboard to prevent spillages and withstand 1:100-year flooding events.

## 9.3 Reasoned opinion on whether the activity should be authorized

Based on the existing activities and mitigations to offset impacts, GCS believes that the authorisation of the activities should be considered. The final decision rests with the Government Authorities and should be based on the predicted hydrology impacts as well as the socio-economic value of the project. This statement is further founded on the assumption that the proposed mitigation measures and EMPr recommendations be implemented during the life of the project.

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# APPENDIX A: CALCULATED PEAK FLOWS FOR SUB-CATCHMENTS

## HRU01

| RATIONAL METHOD 3 | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Description of catchment** | | HRU1 | | | | | |
| **River detail** | Unnamed Tributary | | | | | | |
| **Calculated by** | Hendrik Botha | | | Date | Thursday, 02 November 2023 | | |
| **Physical characteristics** | | | | | | | |
| Size of catchment (A) | 0.624 | $km^2$ | | Rainfall region | | A2C | |
| Longest watercourse (L) | 0.49 | km | | **Area distribution factors** | | | |
| Average slope ($S_{av}$) | 0.0252 | m/m | | Rural (α) | Urban (β) | Lakes (γ) | |
| Dolomite area (D%) | 0 | % | | 1 | 0 | 0 | |
| Mean annual rainfall(MAR) | 690 | mm | | | | | |
| **Rural** | | | | **URBAN** | | | |
| **Surface slope** | **%** | **Factor** | **$C_s$** | **Description** | **%** | **Factor** | **C2** |
| Vleis and pans (<3%) | 7.76 | 0.03 | 0.23 | **Lawns** | | | |
| Flat areas (3 - 10%) | 43.68 | 0.08 | 3.49 | Sandy,flat<2% | 0 | 0.08 | 0 |
| Hilly (10 - 30%) | 39.67 | 0.16 | 6.35 | Sandy,steep>7% | 0 | 0.16 | 0 |
| Steep Areas (>30%) | 8.89 | 0.26 | 2.31 | Heavy s,flat<2% | 0 | 0.15 | 0 |
| Total | 100.00 | 0.53 | 12.39 | Heavy s,steep>7% | 0 | 0.3 | 0 |
| **Permeability** | **%** | **Factor** | **$C_p$** | **Residential Areas** | | | |
| Very permeable | 80 | 0.04 | 3.20 | Houses | 0 | 0.5 | 0 |
| Permeable | 20 | 0.08 | 1.60 | Flats | 0 | 0.6 | 0 |
| Semi-permeable | 0 | 0.16 | 0.00 | Industry | | | |
| Impermeable | 0 | 0.26 | 0.00 | Light industry | 0 | 0.6 | 0 |
| Total | 100 | 0.54 | 4.80 | Heavy industry | 0 | 0.7 | 0 |
| **Vegetation** | **%** | **Factor** | **$C_v$** | **Business** | | | |
| Thick bush & plantation | 60.01 | 0.04 | 2.40 | City centre | 0 | 0.8 | 0 |
| Light bush & farm-lands | 4.26 | 0.11 | 0.47 | Suburban | 0 | 0.65 | 0 |
| Grasslands | 21.4 | 0.21 | 4.49 | Streets | 0 | 0.75 | 0 |
| No vegetation | 14.33 | 0.25 | 3.58 | Max flood | 0 | 1 | 0 |
| | | | 10.95 | Total (C2) | 0 | | 0 |
| $$T_C = 0.604\left(\frac{rL}{\sqrt{S_{av}}}\right)^{0.467}$$ of con | | $$T_c = \left[\frac{0.87\,L^2}{1000\,S_{AV}}\right]^{0.385}$$ | | Use Defined watercourse | | | |
| 0.666 hours | | 0.158 | hours | | | | |
| **Run-off coefficient** | | | | | | | |
| **Return Period (years)** | **2** | **5** | **10** | **20** | **50** | **100** | **PMF** |
| Run-off coefficient, $C_1$ | 0.281 | 0.281 | 0.281 | 0.281 | 0.281 | 0.281 | 0.900 |
| Adjusted for dolomitic areas, $C_{1D}$ | 0.281 | 0.281 | 0.281 | 0.281 | 0.281 | 0.281 | 0.900 |
| Adj factor for initial saturation, $F_t$ | 0.75 | 0.8 | 0.85 | 0.9 | 0.95 | 1 | 1.00 |
| Adjusted run - off coefficient, $C_{1T}$ | 0.21098475 | 0.2250504 | 0.23911605 | 0.253 | 0.267 | 0.281 | 0.900 |
| Combined run - off coefficient, $C_T$ | 0.21098475 | 0.2250504 | 0.23911605 | 0.253 | 0.267 | 0.281 | 0.900 |
| **Rainfall** | | | | | | | |
| **Return Period (years)** | **2** | **5** | **10** | **20** | **50** | **100** | **PMF** |
| Point rainfall (mm), $P_T$ | 30.73 | 42.43 | 51.23 | 60.89 | 74.89 | 86.96 | 100.29 |
| Point Intensity (mm/h), $P_{it}$ | 194.51 | 268.56 | 324.25 | 385.43 | 474.04 | 550.41 | 634.80 |
| Area reduction factor (%),$ARF_T$ | 1.069 | 1.069 | 1.069 | 1.069 | 1.069 | 1.069 | 1.069 |
| Average intensity (mm/hour),$I_T$ | 207.926 | 287.082 | 346.619 | 412.018 | 506.735 | 588.372 | 678.579 |
| **Return Period (years)** | **2** | **5** | **10** | **20** | **50** | **100** | **PMF** |
| Peak flow (m3/s) | 7.604 | 11.199 | 14.366 | 18.081 | 23.473 | 28.69 | 105.86 |

| STANDARD DESIGN FLOOD (SDF) METHOD | | | | | | | |
|---|---|---|---|---|---|---|---|
| Description of catchment | | HRU1 | | | | | |
| River detail | Unnamed Tributary | | | | | | |
| Calculated by | Hendrik Botha | | | Date | 2023/11/02 | | |
| Physical characteristics | | | | | | | |
| Size of catchment (A) | 0.624 | $km^2$ | Days of thunder per year (R) | | 30 | days | |
| Longest watercourse (L) | 0.49 | km | Time of concentration, t | | 9.479 | minutes | |
| Average slope ($S_{av}$) | 0.025 | m/m | Time of concentration, $T_c$ | $T_c = \left[\frac{0.87\, L^2}{1000\, S_{AV}}\right]^{0.385}$ | | 0.1580 | |
| SDF Basin | 1 | | | | | | |
| 2-year return period rainfall (M) | 56 | mm | | | | | |
| TR102 n-day rainfall data | | | | | | | |
| Weather Service Station | | | MAP | | 690 | mm | |
| Weather Service Station no. | | | Coordinates | | | | |
| Duration | Return Period (years) | | | | | | |
| | 2 | 5 | 10 | 20 | 50 | 100 | 200 |
| | | | | | | | |
| Rainfall | | | | | | | |
| **Return Period (years), T** | **2** | **5** | **10** | **20** | **50** | **100** | **200** |
| Point precipitation depth (mm) $P_{t,T}$ | 12.0 | 20.3 | 26.5 | 32.8 | 41.1 | 47.3 | 53.6 |
| Area reduction factor (%), $ARF_T$ | 1.069 | 1.069 | 1.069 | 1.069 | 1.069 | 1.069 | 1.069 |
| Average intensity (mm/hour), $I_T$ | 81.4 | 137.3 | 179.6 | 221.9 | 277.8 | 320.1 | 362.4 |
| Run-off coefficient | | | | | | | |
| Calibration factors $C_2$ (%) | 10 | | $C_{100}$ (%) | 40 | | | |
| **Return Period (years), T** | **2** | **5** | **10** | **20** | **50** | **100** | **200** |
| Return period factors ($Y_T$) | 0 | 0.84 | 1.28 | 1.64 | 2.05 | 2.33 | 2.58 |
| Run-off coefficient, $C_T$ | 0.100 | 0.208 | 0.265 | 0.311 | 0.364 | 0.400 | 0.432 |
| Peak flow (m3/s) | 1.41 | 4.95 | 8.24 | 11.97 | 17.53 | 22.19 | 27.15 |

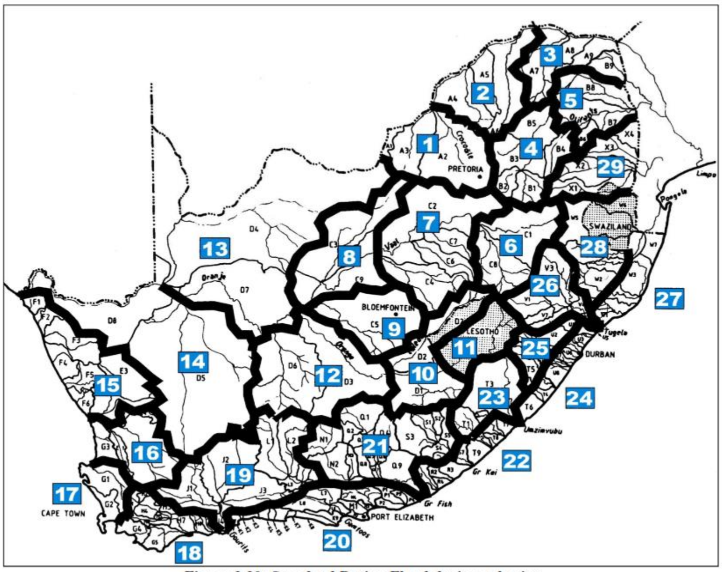



Figure 3.30: Standard Design Flood drainage basins

| MIDGLEY & PITMAN (MIPI) METHOD | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| River Detail | Catchment Area | MAP | S | L | Lc | Constant $K_T$ | | | | Catchment Parameter | Peak Flows | | | |
| | ($km^2$) | (mm) | m/m | km | km | 1:10 year | 1:20 Year | 1: 50 year | 1: 100 year | (Dimensionless) | 1:10 year | 1:20 Year | 1: 50 year | 1: 100 year |
| HRU1 | 0.624 | 690 | 0.0252 | 0.49 | 1.66 | 0.67 | 0.91 | 1.26 | 1.6 | 0.1218 | 8.62 | 11.71 | 16.21 | 20.58 |

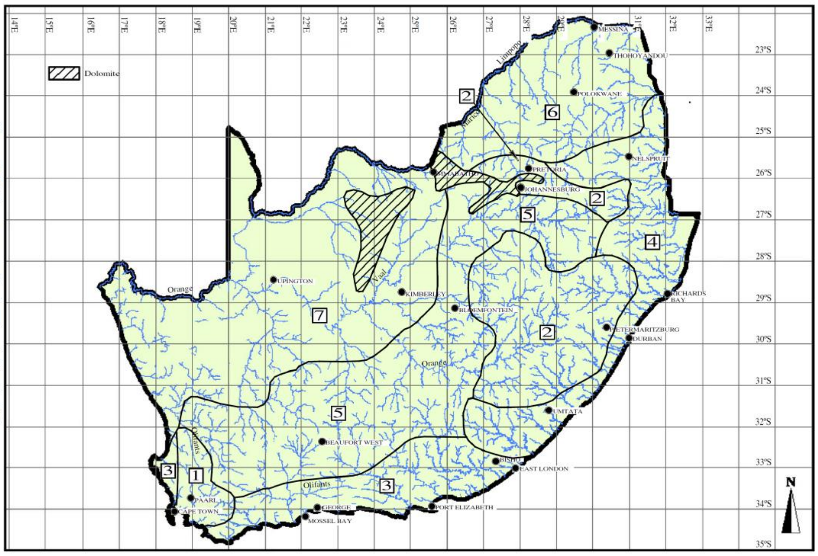


Figure 3.35: Homogeneous flood regions in South Africa

## HRU02

| RATIONAL METHOD 3 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Description of catchment | HRU2 | | | | | | |
| River detail | Unnamed Tributary | | | | | | |
| Calculated by | Hendrik Botha | | | | Date | Thursday, 02 November 2023 | |
| Physical characteristics | | | | | | | |
| Size of catchment (A) | 1.433 | $km^2$ | | Rainfall region | | A2C | |
| Longest watercourse (L) | 0.82 | km | | Area distribution factors | | | |
| Average slope ($S_{av}$) | 0.0132 | m/m | | Rural (α) | Urban (β) | Lakes (γ) | |
| Dolomite area (D%) | 0 | % | | 1 | 0 | 0 | |
| Mean annual rainfall(MAR) | 690 | mm | | | | | |
| Rural | | | | URBAN | | | |
| **Surface slope** | **%** | **Factor** | **$C_s$** | **Description** | **%** | **Factor** | **C2** |
| Vleis and pans (<3%) | 14.86 | 0.03 | 0.45 | **Lawns** | | | |
| Flat areas (3 - 10%) | 38.43 | 0.08 | 3.07 | Sandy,flat<2% | 0 | 0.08 | 0 |
| Hilly (10 - 30%) | 39.58 | 0.16 | 6.33 | Sandy,steep>7% | 0 | 0.16 | 0 |
| Steep Areas (>30%) | 7.13 | 0.26 | 1.85 | Heavy s,flat<2% | 0 | 0.15 | 0 |
| Total | 100.00 | 0.53 | 11.71 | Heavy s,steep>7% | 0 | 0.3 | 0 |
| **Permeability** | **%** | **Factor** | **$C_p$** | **Residential Areas** | | | |
| Very permeable | 80 | 0.04 | 3.20 | Houses | 0 | 0.5 | 0 |
| Permeable | 20 | 0.08 | 1.60 | Flats | 0 | 0.6 | 0 |
| Semi-permeable | 0 | 0.16 | 0.00 | Industry | | | |
| Impermeable | 0 | 0.26 | 0.00 | Light industry | 0 | 0.6 | 0 |
| Total | 100 | 0.54 | 4.80 | Heavy industry | 0 | 0.7 | 0 |
| **Vegetation** | **%** | **Factor** | **$C_v$** | **Business** | | | |
| Thick bush & plantation | 86.5 | 0.04 | 3.46 | City centre | 0 | 0.8 | 0 |
| Light bush & farm-lands | 8.6 | 0.11 | 0.95 | Suburban | 0 | 0.65 | 0 |
| Grasslands | 1.38 | 0.21 | 0.29 | Streets | 0 | 0.75 | 0 |
| No vegetation | 3.53 | 0.25 | 0.88 | Max flood | 0 | 1 | 0 |
| Total | 100.01 | 0.61 | 5.58 | Total (C2) | 0 | | 0 |

Time of concentration (TC)

$$T_C = 0.604\left(\frac{rL}{\sqrt{S_{av}}}\right)^{0.467}$$

$$T_c = \left[\frac{0.87\,L^2}{1000\,S_{AV}}\right]^{0.385}$$

Use Defined watercourse

| | | | |
|---|---|---|---|
| 0.986 | hours | 0.301 | hours |

| Run-off coefficient | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Return Period (years)** | **2** | **5** | **10** | **20** | **50** | **100** | **PMF** |
| Run-off coefficient, $C_1$ | 0.221 | 0.221 | 0.221 | 0.221 | 0.221 | 0.221 | 0.900 |
| Adjusted for dolomitic areas, $C_{1D}$ | 0.221 | 0.221 | 0.221 | 0.221 | 0.221 | 0.221 | 0.900 |
| Adj factor for initial saturation, $F_t$ | 0.75 | 0.8 | 0.85 | 0.9 | 0.95 | 1 | 1.00 |
| Adjusted run - off coefficient, $C_{1T}$ | 0.16563825 | 0.1766808 | 0.18772335 | 0.199 | 0.210 | 0.221 | 0.900 |
| Combined run - off coefficient, $C_T$ | 0.16563825 | 0.1766808 | 0.18772335 | 0.199 | 0.210 | 0.221 | 0.900 |
| **Rainfall** | | | | | | | |
| **Return Period (years)** | **2** | **5** | **10** | **20** | **50** | **100** | **PMF** |
| Point rainfall (mm), $P_T$ | 35.12 | 48.45 | 58.59 | 69.64 | 85.65 | 99.48 | 114.70 |
| Point Intensity (mm/h), $P_{it}$ | 116.57 | 160.83 | 194.50 | 231.16 | 284.32 | 330.21 | 380.74 |
| Area reduction factor (%),$ARF_T$ | 1.053 | 1.053 | 1.053 | 1.053 | 1.053 | 1.053 | 1.053 |
| Average intensity (mm/hour),$I_T$ | 122.782 | 169.394 | 204.857 | 243.467 | 299.458 | 347.798 | 401.013 |
| **Return Period (years)** | **2** | **5** | **10** | **20** | **50** | **100** | **PMF** |
| Peak flow (m3/s) | 8.095 | 11.913 | 15.308 | 19.263 | 25.009 | 30.58 | 143.66 |

| STANDARD DESIGN FLOOD (SDF) METHOD | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Description of catchment** | | HRU2 | | | | | |
| **River detail** | Unnamed Tributary | | | | | | |
| **Calculated by** | Hendrik Botha | | | Date | 2023/11/02 | | |
| **Physical characteristics** | | | | | | | |
| Size of catchment (A) | 1.433 | $km^2$ | Days of thunder per year (R) | | 30 | days | |
| Longest watercourse (L) | 0.82 | km | Time of concentration, t | | 18.075 | minutes | |
| Average slope ($S_{av}$) | 0.013 | m/m | Time of concentration, $T_c$ | $T_c = \left[\frac{0.87 L^2}{1000 S_{AV}}\right]^{0.385}$ | | 0.3013 | |
| SDF Basin | 1 | | | | | | |
| 2-year return period rainfall (M) | 56 | mm | | | | | |
| **TR102 n-day rainfall data** | | | | | | | |
| Weather Service Station | | | MAP | | 690 | mm | |
| Weather Service Station no. | | | Coordinates | | | | |
| **Duration** | **Return Period (years)** | | | | | | |
| | **2** | **5** | **10** | **20** | **50** | **100** | **200** |
| | | | | | | | |
| **Rainfall** | | | | | | | |
| **Return Period (years), T** | **2** | **5** | **10** | **20** | **50** | **100** | **200** |
| Point precipitation depth (mm) $P_{t,T}$ | 16.2 | 27.4 | 35.8 | 44.3 | 55.4 | 63.9 | 72.3 |
| Area reduction factor (%),$ARF_T$ | 1.053 | 1.053 | 1.053 | 1.053 | 1.053 | 1.053 | 1.053 |
| Average intensity (mm/hour),$I_T$ | 56.8 | 95.8 | 125.3 | 154.8 | 193.9 | 223.4 | 252.9 |
| **Run-off coefficient** | | | | | | | |
| Calibration factors / $C_2$ (%) | 10 | | $C_{100}$ (%) | | 40 | | |
| **Return Period (years), T** | **2** | **5** | **10** | **20** | **50** | **100** | **200** |
| Return period factors ($Y_T$) | 0 | 0.84 | 1.28 | 1.64 | 2.05 | 2.33 | 2.58 |
| Run-off coefficient, $C_T$ | 0.100 | 0.208 | 0.265 | 0.311 | 0.364 | 0.400 | 0.432 |
| Peak flow (m3/s) | 2.26 | 7.94 | 13.21 | 19.18 | 28.08 | 35.57 | 43.51 |

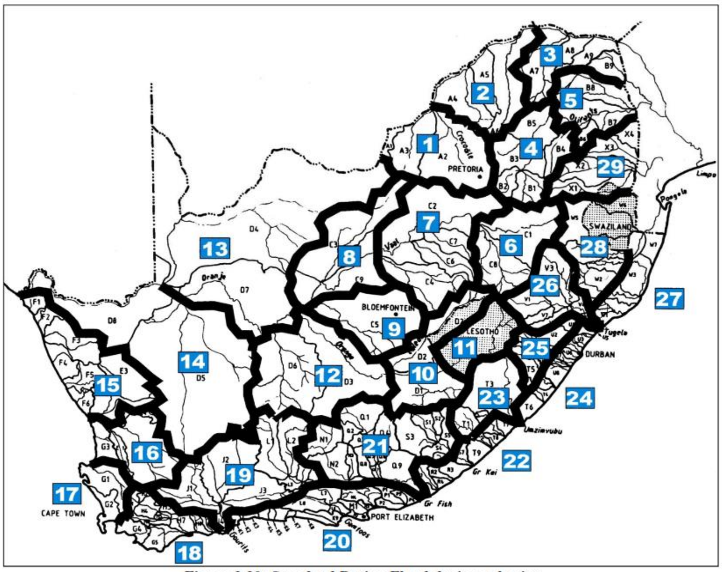


**Figure 3.30: Standard Design Flood drainage basins**

| MIDGLEY & PITMAN (MIPI) METHOD | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **River Detail** | **Catchment Area** | **MAP** | **S** | **L** | **Lc** | **Constant $K_T$** | | | | **Catchment Parameter** | **Peak Flows** | | | |
| | ($km^2$) | (mm) | m/m | km | km | 1:10 year | 1:20 Year | 1: 50 year | 1: 100 year | (Dimensionless) | 1:10 year | 1:20 Year | 1: 50 year | 1: 100 year |
| HRU2 | 1.433 | 690 | 0.0132 | 0.82 | 1.13 | 0.67 | 0.91 | 1.26 | 1.6 | 0.1777 | 15.31 | 20.79 | 28.79 | 36.56 |

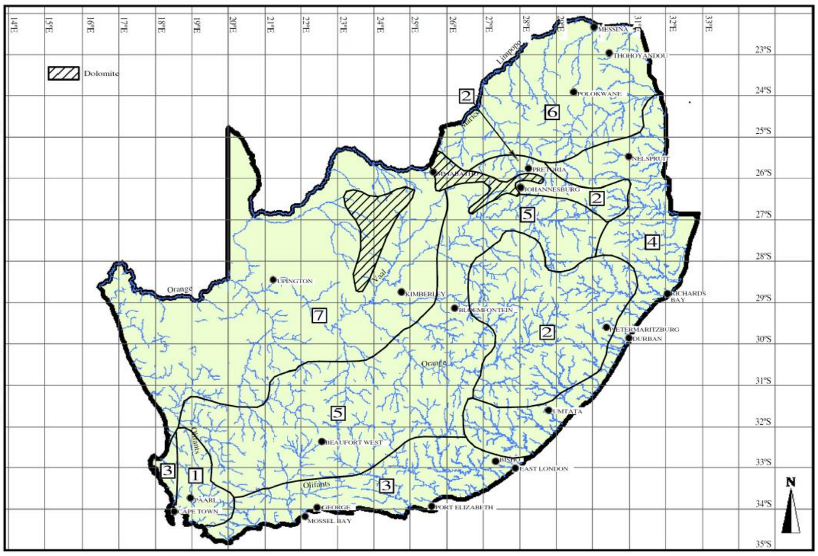



Figure 3.35: Homogeneous flood regions in South Africa

## HRU03

| RATIONAL METHOD 3 | | | | | | | |
|---|---|---|---|---|---|---|---|
| Description of catchment | HRU3 | | | | | | |
| River detail | Unnamed Tributary | | | | | | |
| Calculated by | Hendrik Botha | | | | Date | Thursday, 02 November 2023 | |
| Physical characteristics | | | | | | | |
| Size of catchment (A) | 0.758 | $km^2$ | | Rainfall region | | A2C | |
| Longest watercourse (L) | 0.844 | km | | Area distribution factors | | | |
| Average slope ($S_{av}$) | 0.0223 | m/m | | Rural (α) | Urban (β) | Lakes (γ) | |
| Dolomite area (D%) | 0 | % | | 1 | 0 | 0 | |
| Mean annual rainfall(MAR) | 690 | mm | | | | | |
| Rural | | | | URBAN | | | |
| Surface slope | % | Factor | $C_s$ | Description | % | Factor | C2 |
| Vleis and pans (<3%) | 15.95 | 0.03 | 0.48 | Lawns | | | |
| Flat areas (3 - 10%) | 30.49 | 0.08 | 2.44 | Sandy,flat<2% | 0 | 0.08 | 0 |
| Hilly (10 - 30%) | 27.78 | 0.16 | 4.44 | Sandy,steep>7% | 0 | 0.16 | 0 |
| Steep Areas (>30%) | 25.78 | 0.26 | 6.70 | Heavy s,flat<2% | 0 | 0.15 | 0 |
| Total | 100.00 | 0.53 | 14.07 | Heavy s,steep>7% | 0 | 0.3 | 0 |
| Permeability | % | Factor | $C_p$ | Residential Areas | | | |
| Very permeable | 80 | 0.04 | 3.20 | Houses | 0 | 0.5 | 0 |
| Permeable | 20 | 0.08 | 1.60 | Flats | 0 | 0.6 | 0 |
| Semi-permeable | 0 | 0.16 | 0.00 | Industry | | | |
| Impermeable | 0 | 0.26 | 0.00 | Light industry | 0 | 0.6 | 0 |
| Total | 100 | 0.54 | 4.80 | Heavy industry | 0 | 0.7 | 0 |
| Vegetation | % | Factor | $C_v$ | Business | | | |
| Thick bush & plantation | 73.24 | 0.04 | 2.93 | City centre | 0 | 0.8 | 0 |
| Light bush & farm-lands | 18.31 | 0.11 | 2.01 | Suburban | 0 | 0.65 | 0 |
| Grasslands | 0.05 | 0.21 | 0.01 | Streets | 0 | 0.75 | 0 |
| No vegetation | 8.4 | 0.25 | 2.10 | Max flood | 0 | 1 | 0 |
| Total | 100 | 0.61 | 7.05 | Total (C2) | 0 | | 0 |
| Time of concentration (TC) | | | | | | | |
| Overland flow | Defined watercourse | | | | | | |
| $T_C = 0.604\left(\frac{rL}{\sqrt{S_{av}}}\right)^{0.467}$ | $T_c = \left[\frac{0.87\,L^2}{1000\,S_{AV}}\right]^{0.385}$ | | | Use Defined watercourse | | | |
| 0.884 hours | 0.252 | hours | | | | | |
| Run-off coefficient | | | | | | | |
| Return Period (years) | 2 | 5 | 10 | 20 | 50 | 100 | PMF |
| Run-off coefficient, $C_1$ | 0.259 | 0.259 | 0.259 | 0.259 | 0.259 | 0.259 | 0.900 |
| Adjusted for dolomitic areas, $C_{1D}$ | 0.259 | 0.259 | 0.259 | 0.259 | 0.259 | 0.259 | 0.900 |
| Adj factor for initial saturation, $F_t$ | 0.75 | 0.8 | 0.85 | 0.9 | 0.95 | 1 | 1.00 |
| Adjusted run - off coefficient, $C_{1T}$ | 0.19439625 | 0.207356 | 0.22031575 | 0.233 | 0.246 | 0.259 | 0.900 |
| Combined run - off coefficient, $C_T$ | 0.19439625 | 0.207356 | 0.22031575 | 0.233 | 0.246 | 0.259 | 0.900 |
| Rainfall | | | | | | | |
| Return Period (years) | 2 | 5 | 10 | 20 | 50 | 100 | PMF |
| Point rainfall (mm), $P_T$ | 33.82 | 46.66 | 56.40 | 67.03 | 82.44 | 95.73 | 110.38 |
| Point Intensity (mm/h), $P_{it}$ | 134.34 | 185.37 | 224.05 | 266.30 | 327.50 | 380.33 | 438.53 |
| Area reduction factor (%),$ARF_T$ | 1.076 | 1.076 | 1.076 | 1.076 | 1.076 | 1.076 | 1.076 |
| Average intensity (mm/hour),$I_T$ | 144.620 | 199.547 | 241.186 | 286.674 | 352.553 | 409.420 | 472.077 |
| Return Period (years) | 2 | 5 | 10 | 20 | 50 | 100 | PMF |
| Peak flow (m3/s) | 5.919 | 8.712 | 11.188 | 14.081 | 18.279 | 22.34 | 89.46 |

| STANDARD DESIGN FLOOD (SDF) METHOD | | | | | | | |
|---|---|---|---|---|---|---|---|
| Description of catchment | | HRU3 | | | | | |
| River detail | Unnamed Tributary | | | | | | |
| Calculated by | Hendrik Botha | | | Date | 2023/11/02 | | |
| Physical characteristics | | | | | | | |
| Size of catchment (A) | 0.758 | $km^2$ | Days of thunder per year (R) | | 30 | days | |
| Longest watercourse (L) | 0.844 | km | Time of concentration, t | | 15.103 | minutes | |
| Average slope ($S_{av}$) | 0.022 | m/m | Time of concentration, $T_c$ | $T_c = \left[ \frac{0.87 L^2}{1000 S_{AV}} \right]^{0.385}$ | | 0.2517 | |
| SDF Basin | 1 | | | | | | |
| 2-year return period rainfall (M) | 56 | mm | | | | | |
| TR102 n-day rainfall data | | | | | | | |
| Weather Service Station | | | MAP | | 690 | mm | |
| Weather Service Station no. | | | Coordinates | | | | |
| | Return Period (years) | | | | | | |
| Duration | 2 | 5 | 10 | 20 | 50 | 100 | 200 |
| | | | | | | | |
| Rainfall | | | | | | | |
| Return Period (years), T | 2 | 5 | 10 | 20 | 50 | 100 | 200 |
| Point precipitation depth (mm) $P_{t,T}$ | 15.1 | 25.4 | 33.3 | 41.1 | 51.4 | 59.3 | 67.1 |
| Area reduction factor (%),$ARF_T$ | 1.076 | 1.076 | 1.076 | 1.076 | 1.076 | 1.076 | 1.076 |
| Average intensity (mm/hour),$I_T$ | 64.5 | 108.7 | 142.2 | 175.7 | 220.0 | 253.5 | 287.0 |
| Run-off coefficient | | | | | | | |
| Calibration factors $C_2$ (%) | 10 | | $C_{100}$ (%) | 40 | | | |
| Return Period (years), T | 2 | 5 | 10 | 20 | 50 | 100 | 200 |
| Return period factors ($Y_T$) | 0 | 0.84 | 1.28 | 1.64 | 2.05 | 2.33 | 2.58 |
| Run-off coefficient, $C_T$ | 0.100 | 0.208 | 0.265 | 0.311 | 0.364 | 0.400 | 0.432 |
| Peak flow (m3/s) | 1.36 | 4.77 | 7.93 | 11.51 | 16.86 | 21.35 | 26.12 |

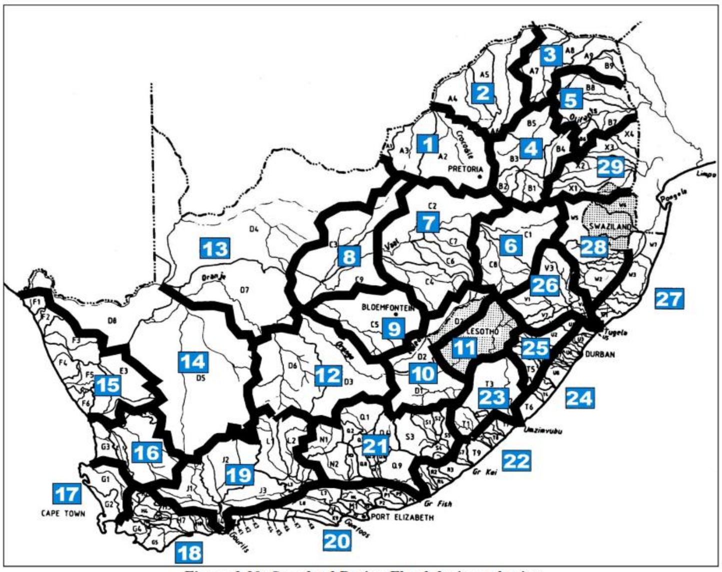
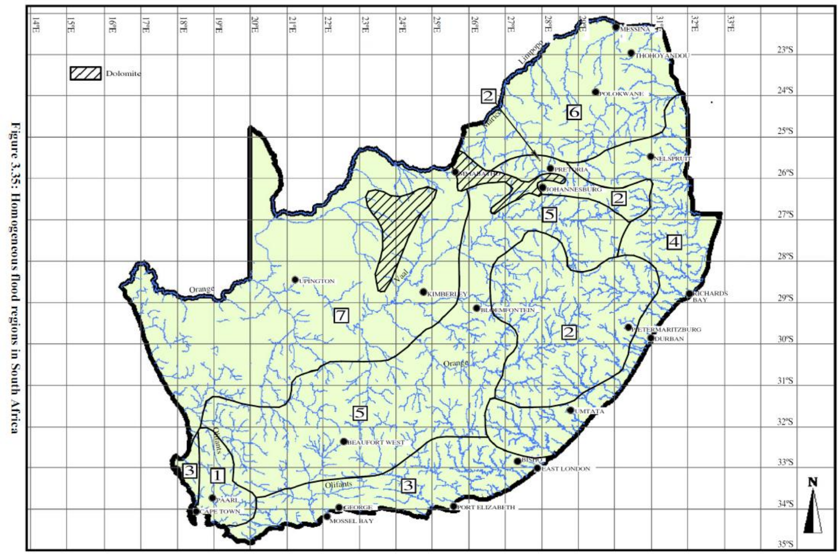



**Figure 3.30: Standard Design Flood drainage basins**

| MIDGLEY & PITMAN (MIPI) METHOD | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| River Detail | Catchment Area | MAP | S | L | Lc | Constant $K_T$ | | | | Catchment Parameter | Peak Flows | | | |
| | ($km^2$) | (mm) | m/m | km | km | 1:10 year | 1:20 Year | 1: 50 year | 1: 100 year | (Dimensionless) | 1:10 year | 1:20 Year | 1: 50 year | 1: 100 year |
| HRU3 | 0.758 | 690 | 0.0223 | 0.84 | 1.29 | 0.67 | 0.91 | 1.26 | 1.6 | 0.1040 | 9.39 | 12.75 | 17.65 | 22.41 |



## HRU04

| RATIONAL METHOD 3 | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Description of catchment** | | HRU4 | | | | | |
| **River detail** | Unnamed Tributary | | | | | | |
| **Calculated by** | Hendrik Botha | | | | Date | Thursday, 02 November 2023 | |
| **Physical characteristics** | | | | | | | |
| Size of catchment (A) | 0.99 | $km^2$ | | Rainfall region | | A2C | |
| Longest watercourse (L) | 1.62 | km | | **Area distribution factors** | | | |
| Average slope ($S_{av}$) | 0.0300 | m/m | | Rural (α) | Urban (β) | Lakes (γ) | |
| Dolomite area (D%) | 0 | % | | 1 | 0 | 0 | |
| Mean annual rainfall(MAR) | 690 | mm | | | | | |
| **Rural** | | | | **URBAN** | | | |
| **Surface slope** | **%** | **Factor** | **$C_s$** | **Description** | **%** | **Factor** | **C2** |
| Vleis and pans (<3%) | 10.15 | 0.03 | 0.30 | **Lawns** | | | |
| Flat areas (3 - 10%) | 29.69 | 0.08 | 2.38 | Sandy,flat<2% | 0 | 0.08 | 0 |
| Hilly (10 - 30%) | 36.23 | 0.16 | 5.80 | Sandy,steep>7% | 0 | 0.16 | 0 |
| Steep Areas (>30%) | 23.92 | 0.26 | 6.22 | Heavy s,flat<2% | 0 | 0.15 | 0 |
| Total | 99.99 | 0.53 | 14.70 | Heavy s,steep>7% | 0 | 0.3 | 0 |
| **Permeability** | **%** | **Factor** | **$C_p$** | **Residential Areas** | | | |
| Very permeable | 80 | 0.04 | 3.20 | Houses | 0 | 0.5 | 0 |
| Permeable | 20 | 0.08 | 1.60 | Flats | 0 | 0.6 | 0 |
| Semi-permeable | 0 | 0.16 | 0.00 | Industry | | | |
| Impermeable | 0 | 0.26 | 0.00 | Light industry | 0 | 0.6 | 0 |
| Total | 100 | 0.54 | 4.80 | Heavy industry | 0 | 0.7 | 0 |
| **Vegetation** | **%** | **Factor** | **$C_v$** | **Business** | | | |
| Thick bush & plantation | 78.02 | 0.04 | 3.12 | City centre | 0 | 0.8 | 0 |
| Light bush & farm-lands | 11.9 | 0.11 | 1.31 | Suburban | 0 | 0.65 | 0 |
| Grasslands | 0.04 | 0.21 | 0.01 | Streets | 0 | 0.75 | 0 |
| No vegetation | 10.05 | 0.25 | 2.51 | Max flood | 0 | 1 | 0 |
| Total | 100.01 | 0.61 | 6.95 | Total (C2) | 0 | | 0 |
| Time of concentration (TC) | | | | | | | |
| Overland flow | Defined watercourse | | | | | | |
| $T_C = 0.604\left(\frac{rL}{\sqrt{S_{av}}}\right)^{0.467}$ | $T_c = \left[\frac{0.87\,L^2}{1000\,S_{AV}}\right]^{0.385}$ | | | Use Defined watercourse | | | |
| 1.118 hours | 0.371 | hours | | | | | |
| **Run-off coefficient** | | | | | | | |
| **Return Period (years)** | **2** | **5** | **10** | **20** | **50** | **100** | **PMF** |
| Run-off coefficient, $C_1$ | 0.264 | 0.264 | 0.264 | 0.264 | 0.264 | 0.264 | 0.900 |
| Adjusted for dolomitic areas, $C_{1D}$ | 0.264 | 0.264 | 0.264 | 0.264 | 0.264 | 0.264 | 0.900 |
| Adj factor for initial saturation, $F_t$ | 0.75 | 0.8 | 0.85 | 0.9 | 0.95 | 1 | 1.00 |
| Adjusted run - off coefficient, $C_{1T}$ | 0.198348 | 0.2115712 | 0.2247944 | 0.238 | 0.251 | 0.264 | 0.900 |
| Combined run - off coefficient, $C_T$ | 0.198348 | 0.2115712 | 0.2247944 | 0.238 | 0.251 | 0.264 | 0.900 |
| **Rainfall** | | | | | | | |
| **Return Period (years)** | **2** | **5** | **10** | **20** | **50** | **100** | **PMF** |
| Point rainfall (mm), $P_T$ | 36.51 | 50.38 | 60.94 | 72.39 | 89.06 | 103.44 | 119.26 |
| Point Intensity (mm/h), $P_{it}$ | 98.41 | 135.81 | 164.26 | 195.14 | 240.07 | 278.82 | 321.47 |
| Area reduction factor (%),$ARF_T$ | 1.078 | 1.078 | 1.078 | 1.078 | 1.078 | 1.078 | 1.078 |
| Average intensity (mm/hour),$I_T$ | 106.078 | 146.390 | 177.060 | 210.344 | 258.776 | 300.541 | 346.511 |
| **Return Period (years)** | **2** | **5** | **10** | **20** | **50** | **100** | **PMF** |
| Peak flow (m3/s) | 5.786 | 8.517 | 10.946 | 13.768 | 17.879 | 21.86 | 85.76 |

| STANDARD DESIGN FLOOD (SDF) METHOD | | | | | | | |
|---|---|---|---|---|---|---|---|
| Description of catchment | | HRU4 | | | | | |
| River detail | Unnamed Tributary | | | | | | |
| Calculated by | Hendrik Botha | | | Date | 2023/11/02 | | |
| Physical characteristics | | | | | | | |
| Size of catchment (A) | 0.99 | $km^2$ | | Days of thunder per year (R) | | 30 | days |
| Longest watercourse (L) | 1.62 | km | | Time of concentration, $t_c$ | | 22.259 | minutes |
| Average slope ($S_{av}$) | 0.030 | m/m | | Time of concentration, $T_c$ | $T_c = \left[ \frac{0.87 L^2}{1000 S_{AV}} \right]^{0.385}$ | | 0.3710 |
| SDF Basin | 1 | | | | | | |
| 2-year return period rainfall (M) | 56 | mm | | | | | |
| TR102 n-day rainfall data | | | | | | | |
| Weather Service Station | | | | MAP | | 690 | mm |
| Weather Service Station no. | | | | Coordinates | | | |
| Duration | Return Period (years) | | | | | | |
| | 2 | 5 | 10 | 20 | 50 | 100 | 200 |
| | | | | | | | |
| Rainfall | | | | | | | |
| Return Period (years), T | 2 | 5 | 10 | 20 | 50 | 100 | 200 |
| Point precipitation depth (mm) $P_{t,T}$ | 17.6 | 29.7 | 38.8 | 48.0 | 60.1 | 69.2 | 78.4 |
| Area reduction factor (%), $ARF_T$ | 1.078 | 1.078 | 1.078 | 1.078 | 1.078 | 1.078 | 1.078 |
| Average intensity (mm/hour), $I_T$ | 51.2 | 86.3 | 112.9 | 139.5 | 174.6 | 201.2 | 227.8 |
| Run-off coefficient | | | | | | | |
| Calibration factors $C_2$ (%) | 10 | | $C_{100}$ (%) | | 40 | | |
| Return Period (years), T | 2 | 5 | 10 | 20 | 50 | 100 | 200 |
| Return period factors ($Y_T$) | 0 | 0.84 | 1.28 | 1.64 | 2.05 | 2.33 | 2.58 |
| Run-off coefficient, $C_T$ | 0.100 | 0.208 | 0.265 | 0.311 | 0.364 | 0.400 | 0.432 |
| Peak flow (m3/s) | 1.41 | 4.94 | 8.22 | 11.93 | 17.47 | 22.13 | 27.07 |

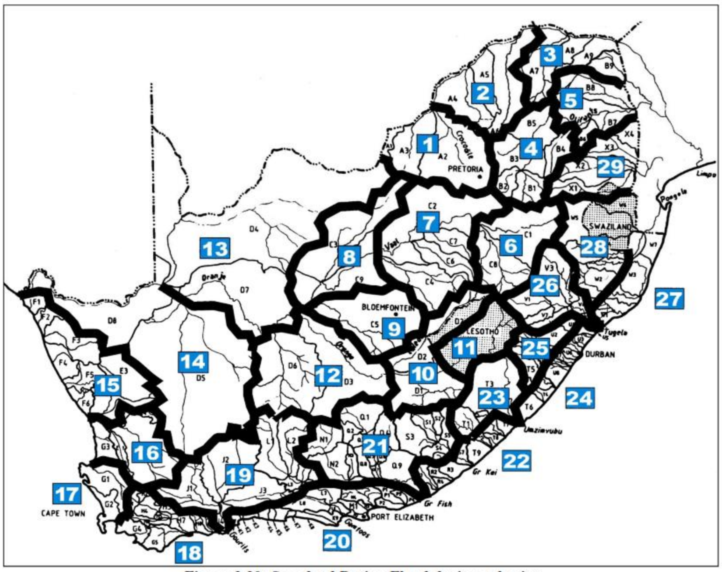
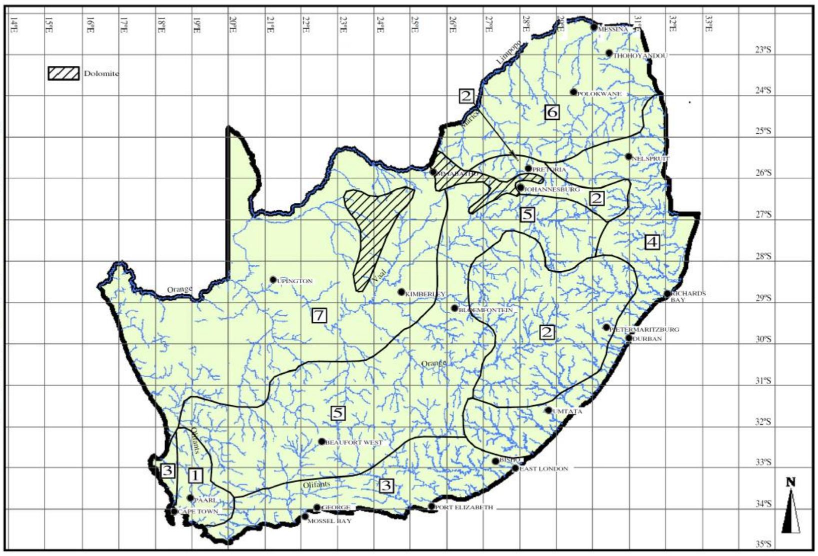



**Figure 3.30: Standard Design Flood drainage basins**

| MIDGLEY & PITMAN (MIPI) METHOD | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| River Detail | Catchment Area | MAP | S | L | Lc | Constant $K_T$ | | | | Catchment Parameter | Peak Flows | | | |
| | (km$^2$) | (mm) | m/m | km | km | 1:10 year | 1:20 Year | 1: 50 year | 1: 100 year | (Dimensionless) | 1:10 year | 1:20 Year | 1: 50 year | 1: 100 year |
| HRU4 | 0.99 | 690 | 0.0300 | 1.62 | 1.539 | 0.67 | 0.91 | 1.26 | 1.6 | 0.0688 | 10.14 | 13.78 | 19.07 | 24.22 |

Figure 3.35: Homogeneous flood regions in South Africa



## APPENDIX B: LABORATORY CERTIFICATE

aquatico Laboratories (Pty). Ltd.

sanas Testing Laboratory T0685

**Test Report** Page 1 of 1

| | | | |
|---|---|---|---|
| **Client:** | Groundwater Consulting Services (GCS) | **Date of report:** | 19 October 2023 |
| **Address:** | 63 Wessel Road, Woodmead, 2191 | **Date accepted:** | 06 October 2023 |
| **Report no:** | 166152 | **Date completed:** | 19 October 2023 |
| **Project:** | GCS | **Date received:** | 06 October 2023 |

| | | | | | |
|---|---|---|---|---|---|
| **Lab no:** | | | | | 330046 |
| **Date sampled:** | | | | | 06-Oct-23 |
| **Aquatico sampled:** | | | | | No |
| **Sample type:** | | | | | Water |
| **Locality description:** | | | | | SW-Dam |
| | | **Analyses** | **Unit** | **Method** | |
| A | AQL | pH @ 25°C | pH | ALM 20 | 7.84 |
| A | AQL | Electrical conductivity (EC) @ 25°C | mS/m | ALM 20 | 12.0 |
| A | AQL | Total Dissolved solids @ 180°C | mg/l | ALM 24 | 90 |
| A | AQL | Total Alkalinity | mg $CaCO_3$/l | ALM 01 | 71.3 |
| A | AQL | Chloride (Cl) | mg/l | ALM 02 | 1.01 |
| A | AQL | Sulphate ($SO_4$) | mg/l | ALM 03 | <0.141 |
| A | AQL | Nitrate ($NO_3$) as N | mg/l | ALM 06 | 0.303 |
| A | AQL | Total oxidised nitrogen as N | mg/l | ALM 06 | 0.303 |
| A | AQL | Fluoride (F) | mg/l | ALM 08 | 0.351 |
| A | AQL | Calcium (Ca) | mg/l | ALM 30 | 15.3 |
| A | AQL | Magnesium (Mg) | mg/l | ALM 30 | 7.74 |
| A | AQL | Acid Soluble Sodium (Na) | mg/l | ALM 30 | 9.87 |
| A | AQL | Sodium (Na) | mg/l | ALM 30 | 4.21 |
| A | AQL | Acid Soluble Potassium (K) | mg/l | ALM 30 | 2.53 |
| A | AQL | Aluminium (Al) | mg/l | ALM 31 | 0.035 |
| A | AQL | Manganese (Mn) | mg/l | ALM 31 | <0.001 |
| A | AQL | Copper (Cu) | mg/l | ALM 31 | <0.002 |
| A | AQL | Turbidity | NTU | ALM 21 | 1.67 |
| A | AQL | Sodium Adsorption Ratio | SAR | ALM 26 | 0.22 |
| A | AQL | Total suspended solids (TSS) | mg/l | ALM 25 | <4.5 |
| A | AQL | Iron (Fe) | mg/l | ALM 92 | <0.000001 |

A = Accredited N = Non accredited Sub = Sub-contracted NR = Not requested RTF = Results to follow NATD = Not able to determine ATR = Alternative test report ; Results relate only to the items received and tested ; Results reported against the limit of detection; Results marked 'Non SANAS Accredited' in this report are not included in the SANAS Schedule of Accreditation for this laboratory; Uncertainty of measurement available on request for all methods included in the SANAS Schedule of Accreditation; The report shall not be reproduced except in full without approval of the laboratory

M. Swanepoel
Technical Signatory

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AQK 28 Karee ave, Kathu, Northern Cape, South Africa Tel: +27 53 880 0208 www.aquatico.co.za

## APPENDIX C: DISCLAIMER AND DECELERATION OF INDEPENDENCE

The opinions expressed in this Report have been based on site /project information supplied to GCS (Pty) Ltd by Umhlaba Environmental Consulting cc (Umhlaba) and are based on public domain 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 D: 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**

| |
|---|
| Hydrology Assessment for the Bundu Sands (Rietvalei) Mining Permit |

SPECIALIST INFORMATION

| | | | | |
|---|---|---|---|---|
| Specialist Company Name: | GCS SA (Pty) Ltd | | | |
| 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)<br>BSc Hons. Environmental Sciences (Hydrology)<br>BSc. Geology and Chemistry | | | |
| Professional affiliation/registration: | PR SCI NAT 400139/17 | | | |
| Physical address: | 20 Jack Hindon Road, Sasolburg, Free-State | | | |
| Postal address: | | | | |
| Postal code: | 1947 | 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.

20/09/2024
6:10:15
Pr.Sci.Nat (400139/17)

Signature of the Specialist

GCS SA (Pty) Ltd

Name of Company:

20 September 2024

Date

## APPENDIX E: 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
- Malawi

### PROFILE

Hendrik (Henri) Botha is currently the Technical Director at GCS Water and Environment. He holds an MSc in Environmental Science in Geohydrology & Geochemistry, and a BSc Hons. Degree in Hydrology. He is registered as a SACNASP Professional Natural Scientist in the Earth Science Field. 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:**

- Project Management of water and environmental projects for mining, industrial and agriculture sectors.
- Integrated Water Investigations
- Waste classification and Impact Assessments
- Aquifer vulnerability assessments
- Geochemical sampling, data interpretation and modelling
- 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)
- Conceptual Stormwater Management Assessments
- Surface Water Yield Assessments
- Water and Salt Balances

SCAN ME
PROJECT RECORD