HYDROLOGICAL ASSESSMENT OF THE

ST HELENA SHAFT

Project No. EIM-001

Version 2

October, 2018

HYDROLOGIC CONSULTING

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HYDROLOGICAL ASSESSMENT OF THE ST HELENA SHAFT

Prepared For

EIMS (PTY) LTD

Prepared By

Hydrologic Consulting (Pty) Ltd

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HYDROLOGICAL ASSESSMENT OF THE ST HELENA SHAFT

1 INTRODUCTION

1.1 BACKGROUND

Hydrologic Consulting (Pty) Ltd has been appointed by Environmental Impact Management Services (EIMS) to undertake a hydrological assessment of the Harmony Gold Mining Company Limited (Harmony) owned, St Helena 10 Mine Shaft mining right (FS 30/5/1/2/2 86MR), as part of a closure certificate application. The St Helena 10 Mine Shaft is located approximately 10km south of Welkom in the Free State Province. A rehabilitation action plan for the St Helena Mine Shaft was completed in September 2016 (Harmony, 2016) and provides supporting information regarding the closure of the shaft.

This hydrological assessment is undertaken at a level commensurate with a 'basic assessment' (as detailed in The National Environmental Management Act) and includes a conceptual storm water management plan aimed at ensuring compliance with Government Notice 704 (Government Gazette 20118 of June 1999 GN704).

1.2 SCOPE OF WORK

The scope of work was achieved by undertaking the following:

- Baseline Assessment – sourcing of baseline climatic and hydrological data. This included the interrogation of rainfall data, site specific deign rainfall (depth/duration/frequency), evaporation, soils, land-use, as well as a regional and local hydrological assessment;
- Site examination – The site was visited by Luke Wiles on the 24th May 2018. This was aimed to assist in a better understanding of the dominant hydrological flow regimes on site and to allow for the collection of water samples for laboratory analysis (where possible);
- Conceptual Storm Water Management Plan (SWMP) - this was developed based on South African best practice guidance and conceptualized through mapping and indicative design drawings;
- Hydrological Impact Assessment - this was undertaken using a recognised risk assessment methodology developed to enable effective communication of the potential consequences or impacts of activities on the hydrological (surface water) environment; and
- A technical report detailing the achieved scope of work.

1.3 REGIONAL SETTING AND LAYOUT

The St Helena 10 Mine Shaft is located at approximately 26° 44' 42" E and 28° 3' 31" S. Figure 1-1 illustrates the regional setting of the St Helena 10 Mine Shaft. The mine shaft and associated surface infrastructure has been historically operational, however, it has since been decommissioned with the majority of surface infrastructure being removed as part of the closure plan. Figure 1-2 illustrates the site's current layout, inclusive of the wider mining right boundary and area of works (hereafter referred to as the site as it is the focus of this assessment).

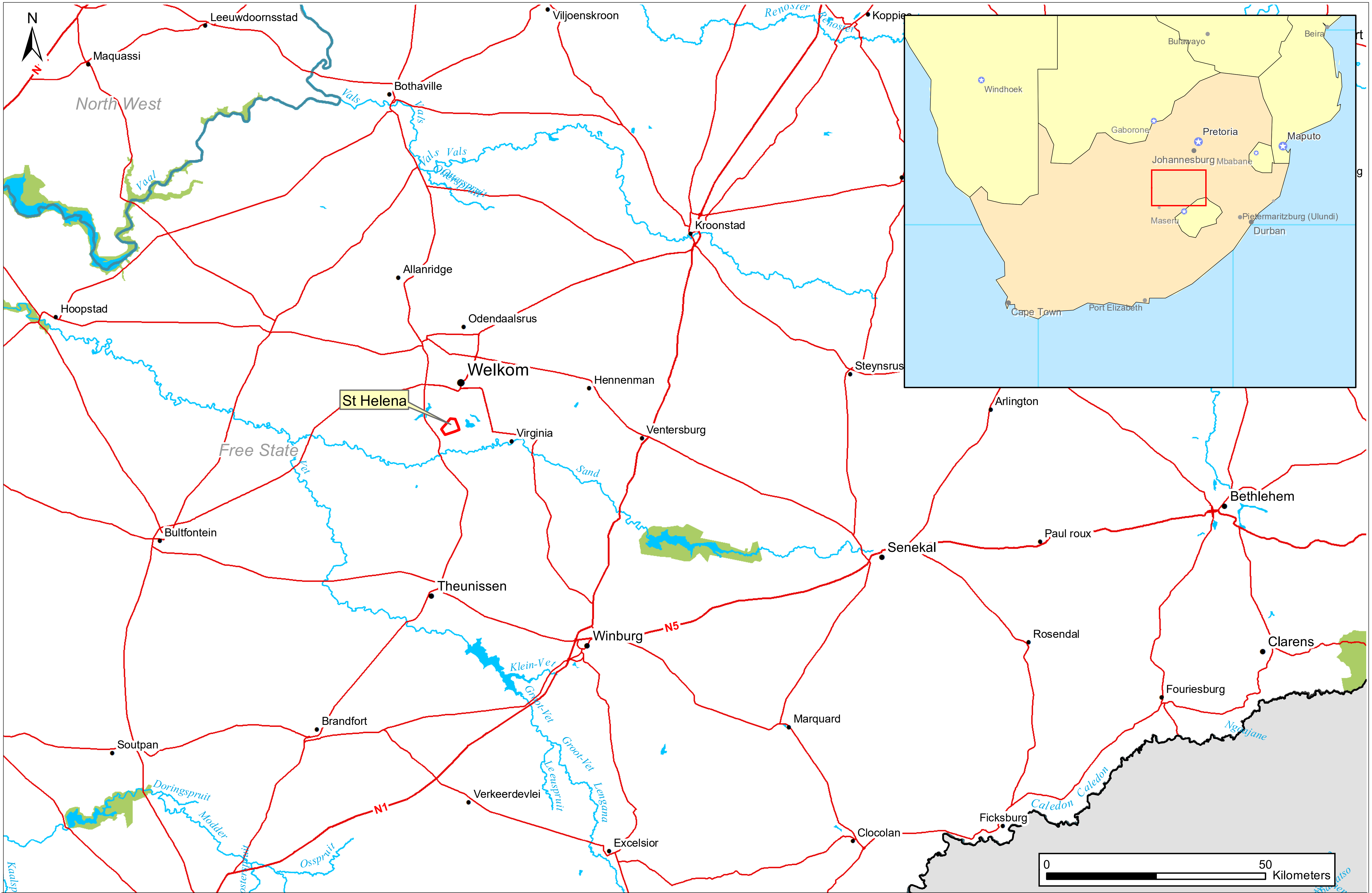

Figure 1-1 Regional Setting

Figure 1-2

Layout

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Most of the shaft's historical surface infrastructure has been removed and rehabilitated with only the waste rock dump (see Figure 1-3) and a containment area remaining. Back-filling of the old shaft as presented in Figure 1-4 was occurring at the time of the site visit and the site layout is consequently expected to change over time, with the potential for complete rehabilitation of all surface infrastructure including the waste rock dump. This hydrological assessment is, however, based on the state of the site during the site visit and on the latest google imagery available at the time of writing (capture date 31 December 2017).

FIGURE 1-3: BACKFILLING OF THE OLD SHAFT USING WASTE ROCK

FIGURE 1-4: WASTE ROCK AND EARTH MOVING NOTED DURING THE SITE VISIT

2 BASELINE INFORMATION

Baseline information in this section includes discussions on the rainfall, evaporation, design event rainfall, soils, vegetation and land cover, as well as site topography and regional and local catchment hydrology.

2.1 RAINFALL

Various weather stations managed by both the South African Weather Services (SAWS) and the Department of Water and Sanitation (DWS) are positioned about the site as illustrated in Figure 2-1. Both SAWS and DWS stations are present within 10km of the site. DWS stations were, however, prioritised as a source of rainfall data since DWS data is freely available compared to SAWS data which has an associated cost. The review of the three closest DWS stations (C4E004, C4E007 and C4E011) located approximately 6km, 9km and 13km respectively from the site reveal rainfall records that were either limited in length or dated (latest record for all three captured in 1974). This limitation in the freely available rainfall data meant that an alternative and site-specific source of rainfall data was used as provided by Lynch (2004) which was also used to illustrate the variation in mean annual precipitation (MAP) about the site as illustrated in Figure 2-1.

Lynch (2004) includes details on the development of a raster database of monthly rainfall data for Southern Africa. The resultant raster database utilises a geographically weighted regression which took account of factors including latitude, longitude, altitude, slope and distance from the sea when interpolating data from rainfall stations located throughout Southern Africa. Table 2-1 presents the average monthly rainfall estimates from Lynch (2004).

TABLE 2-1: AVERAGE MONTHLY RAINFALL DISTRIBUTION (LYNCH, 2004)

Month	Rainfall (mm)
Jan	78
Feb	64
Mar	72
Apr	40
May	17
Jun	6
Jul	7
Aug	8
Sep	15
Oct	59
Nov	59
Dec	64
Total	**489**

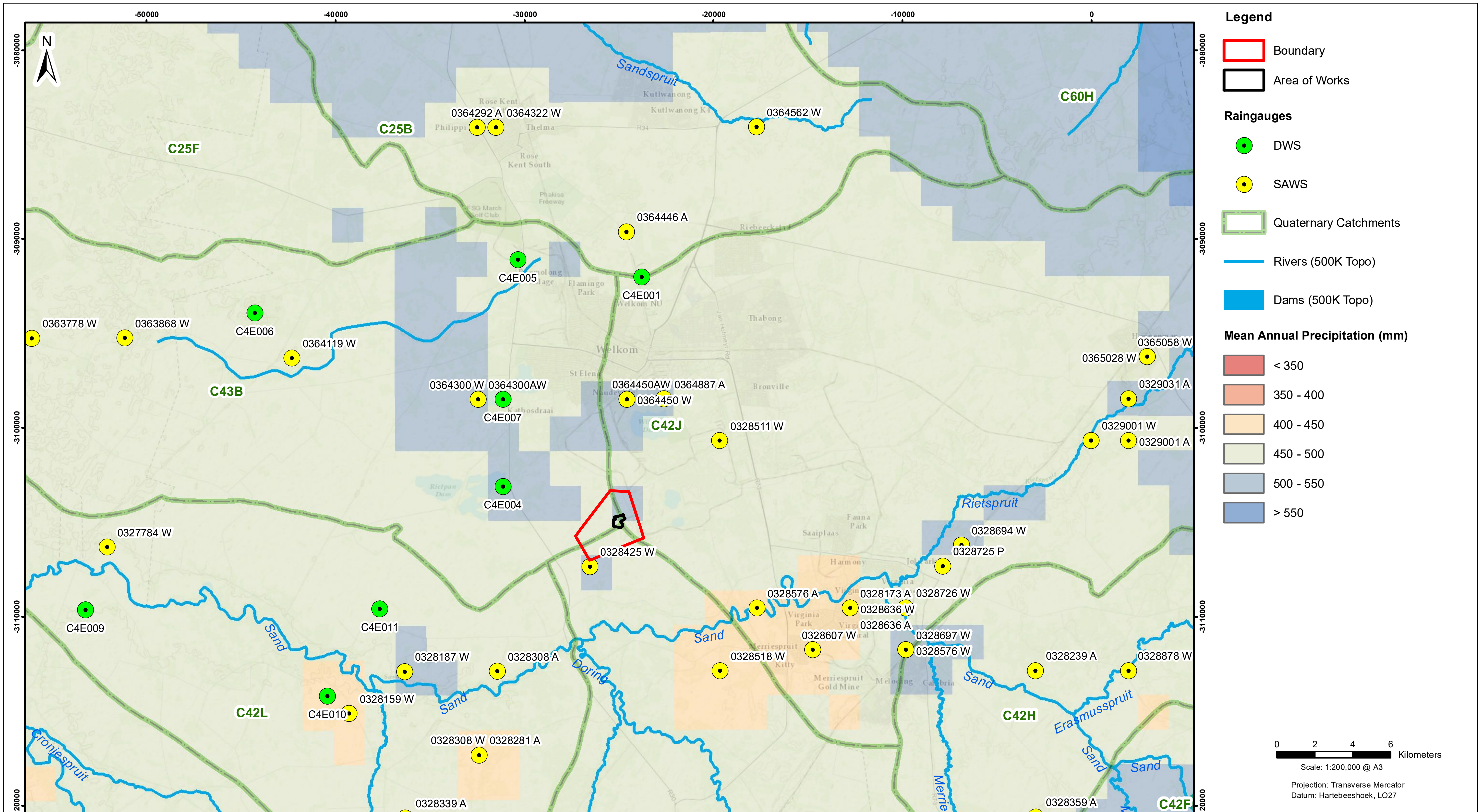

Figure 2-1

Weather Stations and Mean Annual Precipitation

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2.2 1-DAY DESIGN RAINFALL DEPTHS

For the development of a storm water management plan, design rainfall was the most important rainfall variable to consider as it is the driver behind peak flows.

Design storm estimates for various recurrence intervals (RI) and storm durations were sourced from the Design Rainfall Estimation Software for South Africa (DRESSA), developed by the University of Natal in 2002 as part of a WRC project K5/1060 (Smithers and Schulze, 2002). This method uses a Regional L-Moment Algorithm (RLMA) in conjunction with a Scale Invariance approach to provide site specific estimates of design rainfall (depth, duration and frequency), based on surrounding station records. WRC Report No. K5/1060 (WRC, 2002) provides more detail on the verification and validation of the method. Table 2-2 presents the DRESSA design storm estimates for the site.

TABLE 2-2: DRESSA 24-HOUR STORM DEPTH

Recurrence Interval (Years)	Rainfall Depth (24 hour) (mm)
2	58
5	79
10	93
20	107
50	126
100	141
200	156

*Estimates were sourced for the centre of the site

It is important to note, that no allowances for climate change have been made. A risk analysis using the expected life of a structure or process will indicate the relevance of considering climate change (i.e. as the expected life increases the influence of climate change increases).

2.3 EVAPORATION

Evaporation data was sourced from the South African Atlas of Climatology and Agrohydrology (Schulze and Lynch, 2006) in the form of A-Pan equivalent potential evaporation. The average monthly evaporation distribution is presented in Table 2-3 and shows the site has an annual potential evaporation of 2406mm.

TABLE 2-3: MONTHLY POTENTIAL EVAPOTRANSPIRATION (SCHULZE AND LYNCH, 2006)

Month	Evaporation(mm) A-Pan Equivalent
Jan	282
Feb	218
Mar	192
Apr	152
May	131
Jun	100
Jul	116
Aug	162
Sep	220
Oct	264
Nov	272
Dec	297
Total	**2406**

2.4 AVERAGE CLIMATE

The average climate for the site is presented in Figure 2-2 using the outcome of the investigation into rainfall and evaporation for the site. While evaporation is showing as greatly exceeding rainfall, this is representative of the maximum A-Pan equivalent potential evapotranspiration that could occur assuming no limitations are placed on evaporative demand. The combination of rainfall, evaporation and temperature result in a cold arid steppe climate according to the Köppen-Geiger climate classification[1].

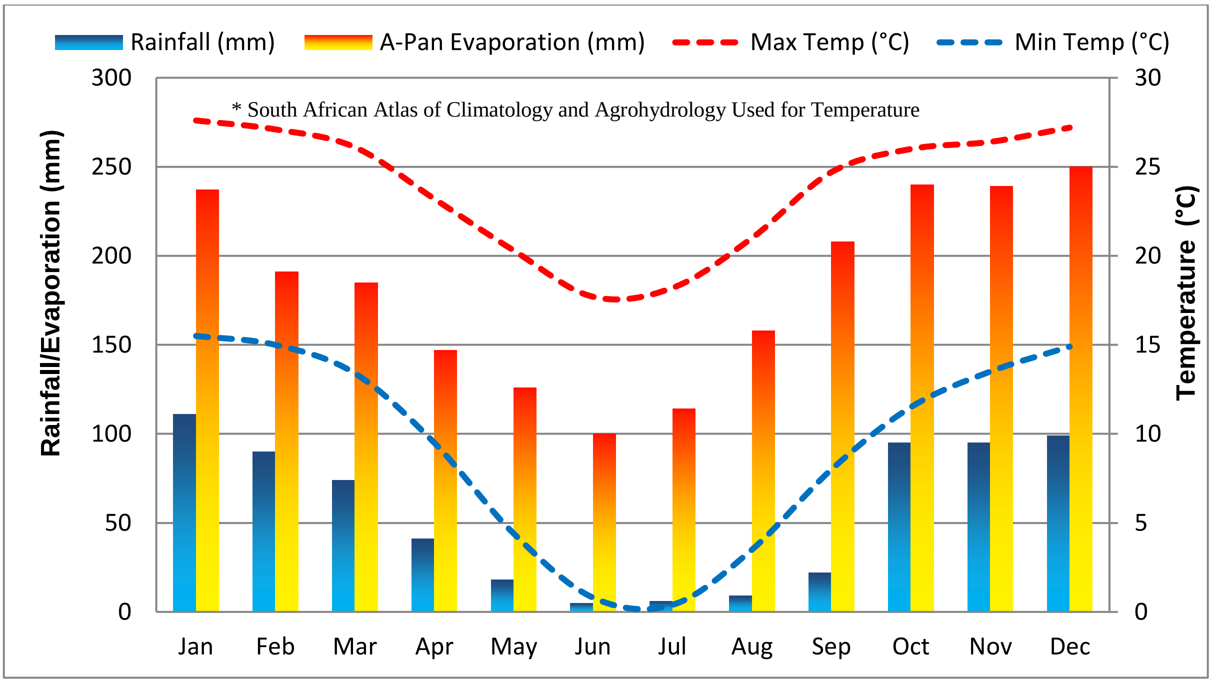

FIGURE 2-2: AVERAGE MONTHLY CLIMATE FOR THE SITE

[1] http://stepsa.org/climate_koppen_geiger.html

2.5 TOPOGRAPHY

No topographical (elevation) dataset was provided by the client and two freely available datasets were consequently used to assist in understanding the topographic variability of the site and surrounds, namely:

1. 30m SRTM[2] (Shuttle Radar and Topography Mission) in the form of a Digital Elevation Model (DEM); and
2. 5m contours extracted from the National Geo-spatial Information (NGI's) 1:50,000 topographical map data.

The SRTM30 DEM, with a cell size approximating 30x30m and a 1m vertical interval provides a coarse estimate of the topography of the site and surrounds while the 5m contour dataset enables the confirmation of the general topography. The available topographic data affects the accuracy of the SWMP included in this report, with alternative sources of elevation data such as Light Detection and Ranging (LiDAR) data providing a higher level of topographic detail and accuracy. The available topographic data is nevertheless considered sufficient for the purposes of this assessment.

Figure 2-3 illustrates the STRM30 DEM and 5m contour data for the site and surrounds with elevation on site approximating 1365m AMSL. Site slopes were also calculated with a variation in site slopes of under 3% and below 30%.

2.6 HYDROLOGY

Figure 2-3 illustrates the topographical and hydrological setting of the site, while Figure 2-1 presents the river network of the greater region. The site is positioned on the watershed of three quaternary catchments, *viz*; C42J, C42K and C43B. An analysis of site topography undertaken in Section 4 as part of the storm water management plan, reveals that the site drains to quaternary C24K (based upon SRTM30 data used). This variation from the quaternary catchments watersheds dataset is expected since the quaternary catchments for South Africa were derived using a low level of accuracy.

The primary river in the region about the site is the Sand River. A non-perennial river has its headwaters to the south of the site. This non-perennial river captures runoff from the site (which reaches it) and conveys it to the Sand River. A few small farm dams are located on this non-perennial river as indicated by the 1:50,000 topographical map data, with two of these farm dams located within the wider boundary of the site. Non-perennial pans are also located within the wider boundary of the site. During the site visit, both the non-perennial pans and two farm dams were found to be empty.

When considering the site (i.e. the area of works) two open reservoirs are noted according to the 1:50,000 topographical map data. The rehabilitation of the site has, however, removed the northern open reservoir and only the southern open reservoir remains.

The National Freshwater Ecosystems Priority Areas (NFEPA, 2011) dataset for South Africa also indicates that a wetland is located to the west of the site although a wetland assessment would be required to confirm the presence of this wetland or any other wetlands on the site.

[2] Data available from the U.S. Geological Survey

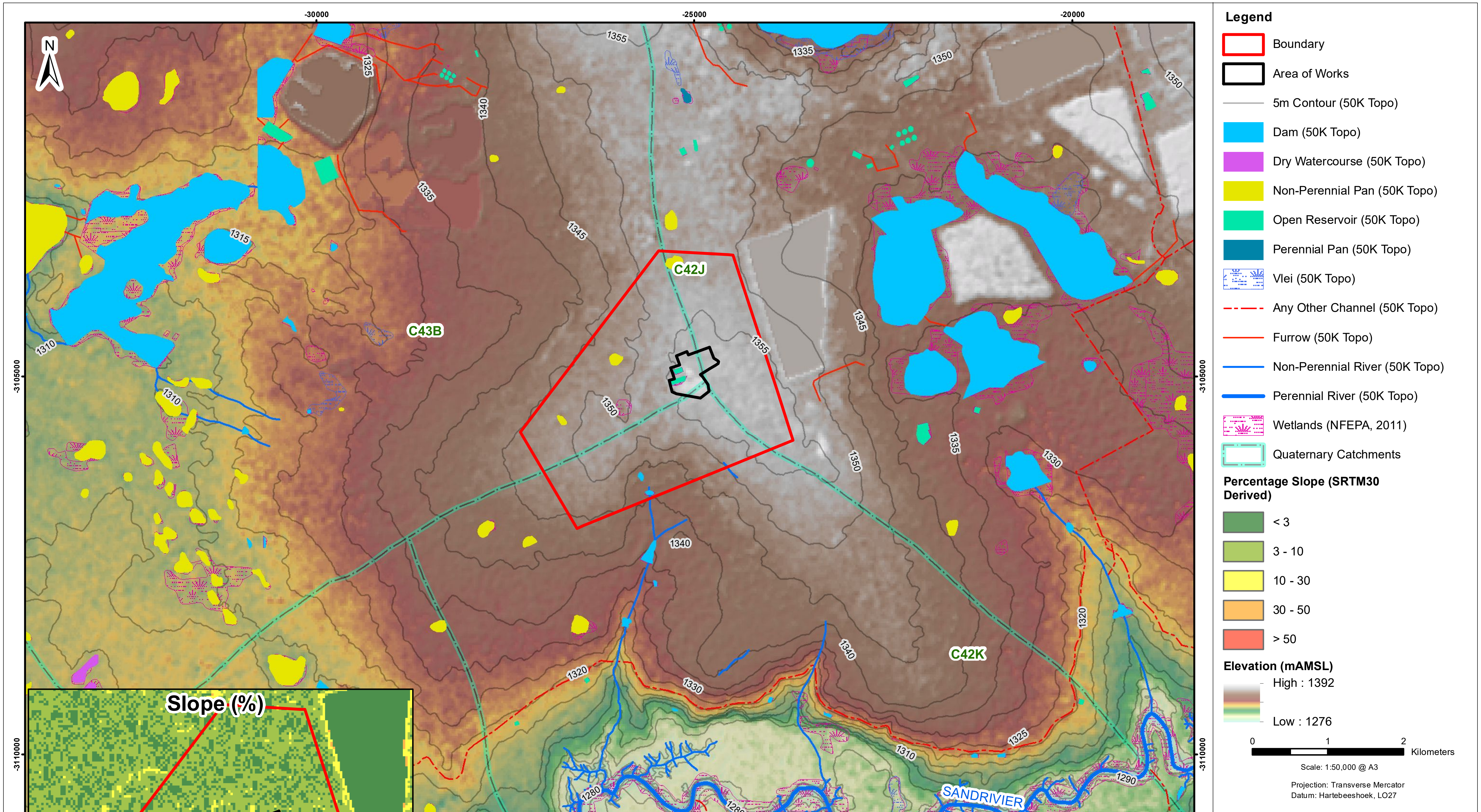

Figure 2-3

Hydrology and Topography

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2.7 SOILS, VEGETATION AND LAND-COVER

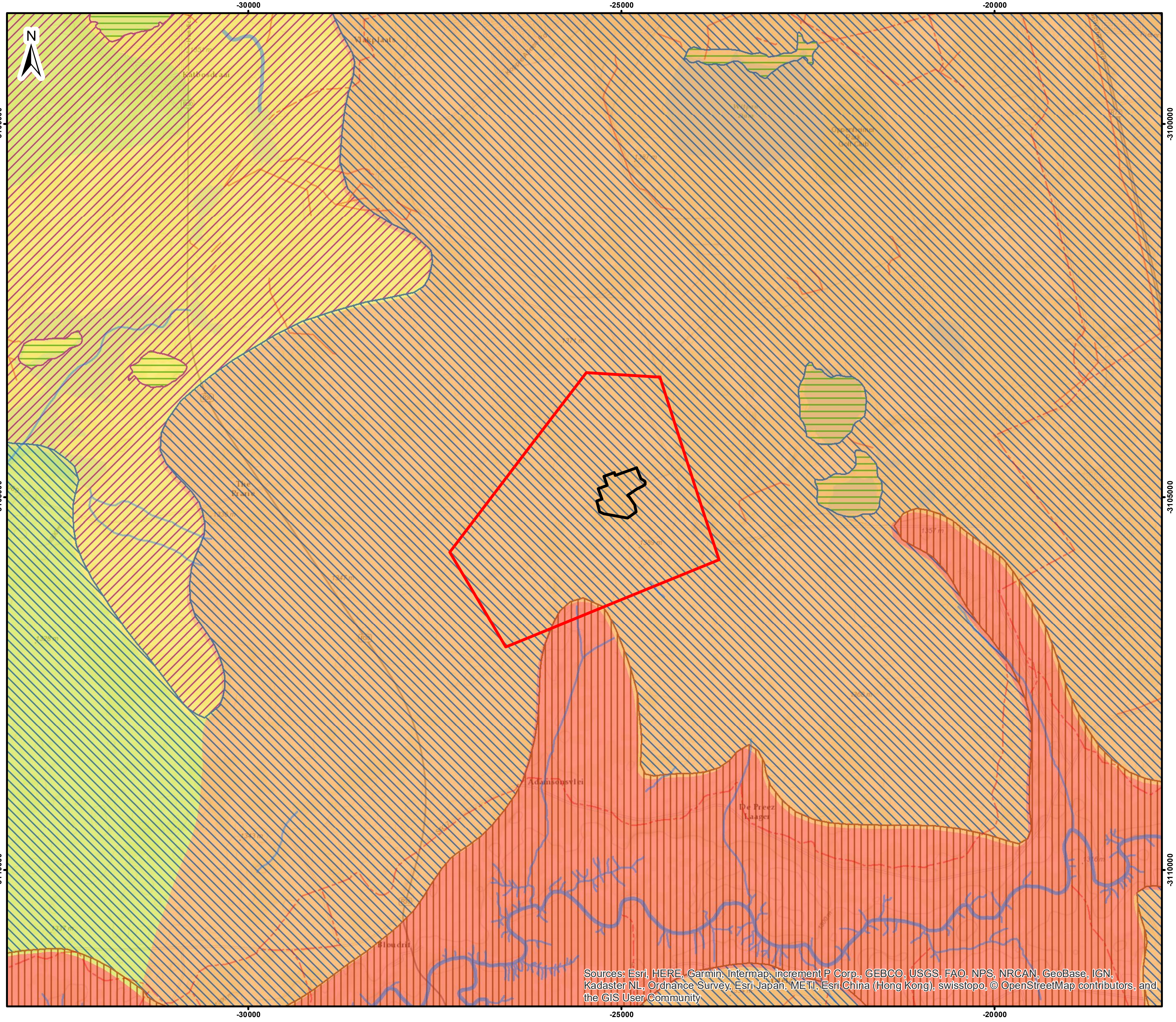
According to the high-level soils data included in the Water Resources of South Africa 2012 (WR2012) study (Bailey and Pitman, 2015), soils of the site and surrounds are classified as sandy loams to sandy clay loams. In considering the more detailed Soil Conservation Service for South Africa (SCS-SA) dataset of the site, soils are classified as being in hydrological soil group C (moderately high runoff potential).

The natural vegetation of the site is classified as Vaal-Vet Sandy Grassland according to SANBI, (2012).

Land-cover of the site is classified as predominantly that of 'mines' with smaller areas of 'settlements', 'grasslands', 'bare ground', 'low shrubland', 'thicket/dense bush' and 'woodland/open bush' according to the Department of Environmental Affairs (DEA) 2014 dataset. Most of the area about the site (and within the wider site boundary) is classified as 'commercial annual crops non-pivot'. Figure 2-4 presents a photo of the surrounding 'commercial annual crops non-pivot'.

The distributions of the SCS soil types and natural vegetation are illustrated in Figure 2-5 while Figure 2-6 illustrates the land-cover in the region about the site.

FIGURE 2-4: 'COMMERCIAL ANNUAL CROPS NON-PIVOT' SURROUNDING THE SITE



Legend

- Boundary
- Area of Works
- Any Other Channel (50K Topo)
- Furrow (50K Topo)
- Non-Perennial River (50K Topo)
- Perennial River (50K Topo)

SANBI Vegetation Atlas (2012)

- Highveld Alluvial Vegetation
- Highveld Salt Pans
- Vaal-Vet Sandy Grassland
- Western Free State Clay Grassland

SCS Soils Runoff Potential

- A - Low Runoff Potential
- A/B
- B - Moderately Low Runoff Potential
- B/C
- C - Moderately High Runoff Potential
- C/D

0 2 Kilometers

Scale: 1:50,000 @ A3

Projection: Transverse Mercator
Datum: Hartebeeshoek, LO27

Figure 2-5

Soil and Vegetation

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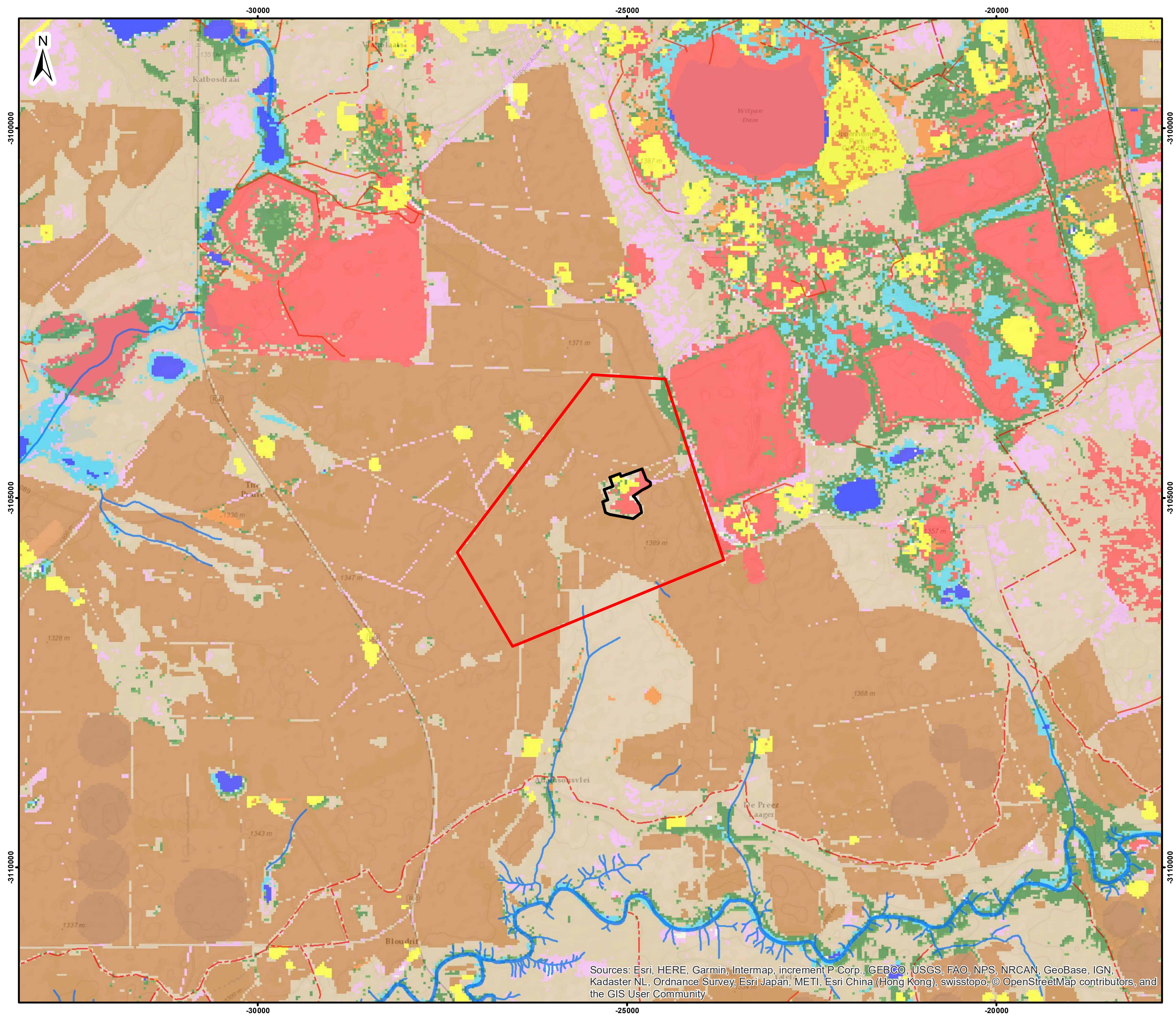

Legend

- Boundary
- Area of Works
- Any Other Channel (50K Topo)
- Furrow (50K Topo)
- Non-Perennial River (50K Topo)
- Perennial River (50K Topo)

Land-Cover (DEA, 2014)

- Thicket /Dense Bush
- Woodland/Open Bush
- Low Shrubland
- Plantations / Woodlots
- Commercial Annual Crops Non-Pivot
- Commercial Annual Crops Pivot
- Commercial Permanent Orchards
- Settlements
- Wetlands
- Grasslands
- Mines
- Waterbodies
- Bare Ground

0 1 2 Kilometers

Scale: 1:50,000 @ A3

Projection: Transverse Mercator
Datum: Hartebeeshoek, LO27

Figure 2-6

Land-Cover

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3 GOVERNMENT NOTICE 704

The aim of the conceptual SWMP as developed in Chapter 4 of this report, is to fulfil the requirements presented in Government Notice 704 (Government Gazette 20118 of June 1999), hereafter referred to as GN 704, and deals with the separation of clean and dirty water.

The Department of Water Affairs and Forestry (now the Department of Water and Sanitation), established GN 704 to provide regulations on the use of water for mining and related activities aimed at the protection of water resources. There are important definitions in the regulation which require understanding.

3.1 IMPORTANT DEFINITIONS IN GN 704

- **Clean water system:** This includes any dam, other form of impoundment, canal, works, pipeline and any other structure or facility constructed for the retention or conveyance of unpolluted water.
- **Dirty water system:** This includes any dam, other form of impoundment, canal, works, pipeline, residue deposit and any other structure or facility constructed for the retention or conveyance of water containing waste.
- **Dirty area:** This refers to any area at a mine or activity which causes, has caused or is likely to cause pollution of a water resource (i.e. polluted water).

3.2 APPLICABLE CONDITIONS IN GN 704

The principle conditions of GN 704 applicable to the development of a SWMP for the site are:

Condition 4 – Restrictions on locality – No person in control of a mine or activity may:

(a) locate or place any residue deposit, dam, reservoir, together with any associated structure or any other facility within the 1:100 year flood-line or within a horizontal distance of 100 metres from any watercourse or estuary, borehole or well, excluding boreholes or wells drilled specifically to monitor the pollution of groundwater, or on water-logged ground, or on ground likely to become water-logged, undermined, unstable or cracked;

(b) except in relation to a matter contemplated in regulation 10 (i.e. Additional regulations relating to winning sand and alluvial minerals from watercourse or estuary), carry on any underground or opencast mining, prospecting or any other operation or activity under or within the 1:50 year flood-line or within a horizontal distance of 100 metres from any watercourse or estuary, whichever is the greatest;

(c) place or dispose of any residue or substance which causes or is likely to cause pollution of a water resource, in the workings of any underground or opencast mine excavation, prospecting diggings, pit or any other excavation; or

(d) use any area or locate any sanitary convenience, fuel depots, reservoir or depots for any substance which causes or is likely to cause pollution of a water resource within the 1:50 year flood-line of any watercourse or estuary.

Condition 5 – Restrictions on use of material

No person in control of a mine or activity may use any residue or substance which causes or is likely to cause pollution of a water resource for the construction of any dam or other impoundment or any embankment, road or railway, or for any other purpose which is likely to cause pollution of a water resource.

Condition 6 - Capacity requirements of clean and dirty water systems

Every person in control of a mine or activity must:

(a) confine any unpolluted water to a clean water system, away from any dirty area;
(b) design, construct, maintain and operate any clean water system at the mine or activity so that it is not likely to spill into any dirty water system more than once in 50 years;
(c) collect the water arising within any dirty area, including water seeping from mining operations. outcrops or any other activity, into a dirty water system;
(d) design, construct, maintain and operate any dirty water system at the mine or activity so that it is not likely to spill into any clean water system more than once in 50 years; and
(e) design, construct, maintain and operate any dam or tailings dam that forms part of a dirty water system to have a minimum freeboard of 0.8 metres above full supply level, unless otherwise specified in terms of Chapter 12 of the Act.
(f) design, construct and maintain all water systems in such a manner as to guarantee the serviceability of such conveyances for flows up to and including those arising as a result of the maximum flood with an average period of recurrence of once in 50 years.

Condition 7 – Protection of water resources

Every person in control of a mine or activity must take reasonable measures to:

(a) prevent water containing waste or any substance which causes or is likely to cause pollution of a water resource from entering any water resource, either by natural flow or by seepage, and must retain or collect such substance or water containing waste for use, re-use, evaporation or for purification and disposal in terms of the Act;

(b) design, modify, locate, construct and maintain all water systems, including residue deposits, in any area so as to prevent the pollution of any water resource through the operation or use thereof and to restrict the possibility of damage to the riparian or in-stream habitat through erosion or sedimentation, or the disturbance of vegetation, or the alteration of flow characteristics;

(c) cause effective measures to be taken to minimise the flow of any surface water or floodwater into mine workings, opencast workings, other workings or subterranean caverns, through cracked or fissured formations, subsided ground, sinkholes, outcrop excavations, adits, entrances or any other openings;

(d) design, modify, construct, maintain and use any dam or any residue deposit or stockpile used for the disposal or storage of mineral tailings, slimes, ash or other hydraulic transported substances, so that the water or waste therein, or falling therein, will not result in the failure thereof or impair the stability thereof;

(e) prevent the erosion or leaching of materials from any residue deposit or stockpile from any area and contain material or substances so eroded or leached in such area by providing suitable barrier dams, evaporation dams or any other effective measures to prevent this material or substance from entering and polluting any water resources;

(f) ensure that water used in any process at a mine or activity is recycled as far as practicable, and any facility, sump, pumping installation, catchment dam or other impoundment used for recycling water, is of adequate design and capacity to prevent the spillage, seepage or release of water containing waste at any time;

(g) at all times keep any water system free from any matter or obstruction which may affect the efficiency thereof; and

(h) cause all domestic waste, including wash-water, which cannot be disposed of in a municipal sewage system, to be disposed of in terms of an authorisation under the Act.

The Minister of Water Affairs and Forestry (now Water and Sanitation) may in writing, authorise an exemption to the requirements of regulation 5, 6 and 7 which is likely necessary given the current mining operation's position over a few non-perennial rivers. An audit of the mining operation with regards to GN704 would be necessary to establish all instances of GN704 contravention.

4 CONCEPTUAL STORM WATER MANAGEMENT PLAN

Previous and current operation of the site has altered the natural environmental state, thereby affecting the generation of storm water and possibly degrading downstream rivers due to unmitigated control of dirty areas in some locations on site. Owing to the shaft closure, most of surface infrastructure of the shaft has been removed and rehabilitated, although a waste rock dump is still present which is currently not being adequately managed with regards to GN704. The purpose of this section is therefore to produce a conceptual level SWMP by which dirty water generating areas are firstly identified and then managed appropriately.

This storm water management plan complies with the principles presented in the DWS Best Practice Guideline G1 for Storm Water Management (BPG1).

It should be noted that the location and sizing for the diversions/containment included in this conceptual SWMP have been based on STRM30 elevation data. This elevation data only provides a general understanding of flow accumulation on site and inaccuracies are anticipated. The use of recent aerial imagery (31 December 2017) has offset the limitations of the SRTM30 data to some degree.

4.1 MANAGEMENT APPROACH

Figure 4-1 presents the dirty area on the site requiring storm water management.

The majority of the site's previous surface infrastructure has been removed with subsequent rehabilitation. These rehabilitated areas are considered clean areas for the purposes of this SWMP (assuming adequate rehabilitation), and no storm water infrastructure is proposed for their management. The only dirty area on site is the currently operational waste rock dump and mine shaft (currently being backfilled) for which containment is required with regards to storm water. Two open reservoirs are noted as being present within the area of works (site) according to the 1:50,000 topographical map data, although only the open reservoir to the south remains (as the northern one has been rehabilitated). The southern 'open reservoir' as illustrated in Figure 4-1, is not formally utilised and is not a reservoir in function, instead functioning as an informal containment area. The existence of this underutilised containment area lends itself to the storm water management of the waste rock dump and mine shaft (currently being backfilled), which are situated immediately to the east. Diversions to route water into this containment area are proposed, resulting in the containment area being reclassified as a pollution control dam (PCD) for the purposes of this SWMP.

Current rehabilitation of the site includes the backfilling of the mine shaft and may result in the removal of the waste rock dump. Once full site rehabilitation has occurred (including PCD removal where relevant), the recommendations in this report with regards to the SWMP will no longer be applicable as all areas will defined as 'clean' with regards to GN704.

Legend

- Boundary
- Area of Works
- Old Shaft
- 5m Contour (50K Topo)
- Furrow (50K Topo)
- Non-Perennial River (50K Topo)
- Dam (50K Topo)
- Non-Perennial Pan (50K Topo)
- Open Reservoir (50K Topo)
- Flow Path (SRTM30 Derived)
- Quaternary Catchments
- Subcatchment (SRTM30 Derived)
- 100m River Buffer
- Rehabiliated Area (Clean)
- Waste Rock Dump (Dirty)

0 400 800 Meters

Scale: 1:15,200 @ A3

Projection: Transverse Mercator
Datum: Hartebeeshoek, LO27

Figure 4-1

Dirty Area

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4.1.1 HYDROCARBONS AND CHEMICALS

The storage/handling of hydrocarbons (e.g. fuel and lubricants) and chemicals is not expected to be relevant in time due to closure of shaft although earth moving machinery is currently operating on site and may be a source of potential hydrocarbons with regards to leaking of fuel/oils. The storage/handling of fuel, lubricants and chemicals (where relevant) requires special attention due to their hazardous nature. These areas are required to be managed on impermeable floors with appropriate bunding, sumps and roofing. This is regarded as localised management and does not form part of this conceptual SWMP.

4.2 STORM WATER MANAGEMENT INFRASTRUCTURE

Stormwater management infrastructure has been conceptually designed in this report as per the requirements of GN 704 and BPG1 and utilised the 1:50 RI rainfall event for design. No account has been taken of climate change and any potential future increases in rainfall depth or intensity.

Figures 4-2 illustrates the conceptual SWMP, while Appendix A presents details relating to the development of the SWMP using PCSWMM, which is based on the Storm Water Management Model (Rossman, 2008).

4.2.1 AVAILABLE INFORMATION

The following information was used to develop the (SWMP):

- Climate Data: Specifically design rainfall depths;
- Elevation Data: STRM30 DEM as outlined in Section 2.5 was used to define flow routes and subcatchment divisions; and
- Catchment characteristics: Soil characteristics, land-cover and site slopes were used to define catchment characteristics.

4.2.2 CLEAN WATER SYSTEM - DIVERSIONS

The purpose of a clean water system is to divert upstream/upslope clean water (utilising a channel) which would otherwise flow into the dirty area, while a berm running alongside the channel ensures containment of dirty water within dirty areas. The use of a clean water system has not been proposed for this SWMP since the sites position over a watershed means that clean water areas upslope of the site are limited in size (and therefore their potential generation of runoff is also limited).

Partitioning of clean and dirty water areas will instead be managed using the dirty water system only.

Legend

- Area of Works
- Old Shaft
- Rehabiliated Area (Clean)
- Waste Rock Dump (Dirty)
- Flow Path (SRTM30 Derived)
- Subcatchment (SRTM30 Derived)
- Junctions
- berm/channel
- Storages
- PCD
- Dirty Area

0 100 Meters

Scale: 1:3,400 @ A3

Projection: Transverse Mercator
Datum: Hartebeeshoek, LO27

Figure 4-2

Storm Water Management Plan (Conceptual)

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4.2.3 DIRTY WATER SYSTEM – DIVERSIONS

The use of embanked dirty water diversions (i.e. channels with a berm on the side as illustrated in Figure 4-3) will be sufficient to limit the ingress of any clean water originating from the rehabilitated portion of the site or clean areas upslope of the site, due to the limited size of the potential upslope clean water areas. Furthermore, the SRTM30 data indicates that the primary flow path from the site routes water away from the waste rock dump and therefore away from the defined dirty area.

The Dirty area diversion has been designed to ensure dirty water generated on the site is contained. A minimum channel dimension of 0.5m channel depth and 1.0m channel base breadth has been used to simplify design. The channel component has been sized using PCSWMM stormwater modelling software to meet the requirement of accommodating the 1:50 year RI event. A Manning's 'n' roughness coefficient of 0.015 (cement) was used in sizing of the diversion channels as presented in Figure 4-3, where:

- a = Channel Depth
- b = Channel Base Breadth

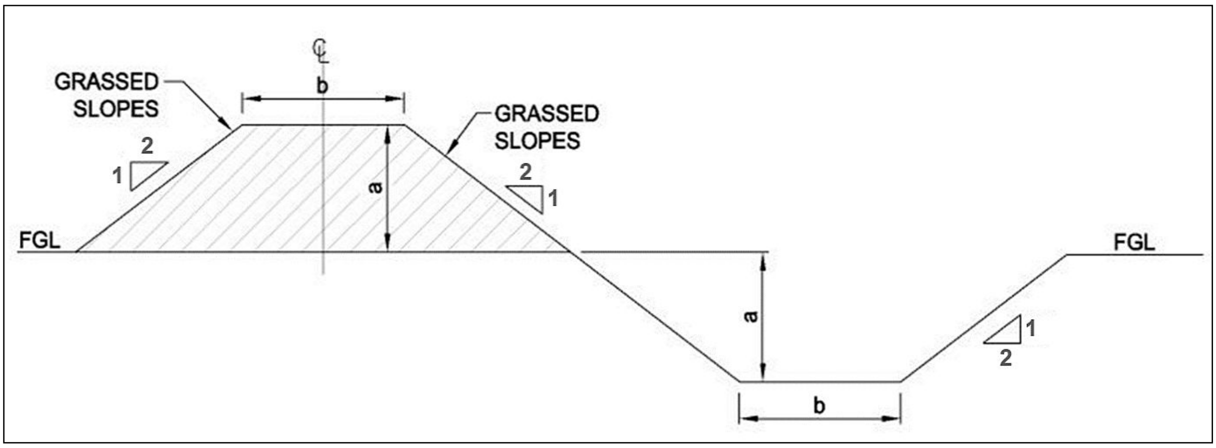

FIGURE 4-3: TYPICAL BERM AND CHANNEL FOR STORMWATER DIVERSION SYSTEM

Table 4-1 presents the dimensions of the dirty area diversion, including the average longitudinal slope. Average longitudinal slopes were used in the modelling of the channel since the detail needed to determine variations in channel slope requires a more accurate DEM than was available. The indicated construction dimensions and peak flows may differ from final, depending on the construction method, the location of diversions and the additional detail included in the detailed design. The channel dimensions should consequently be reviewed during the detailed design phase. All diversions include the accumulation of flow from upslope subcatchments where applicable.

TABLE 4-1: DIMENSIONS FOR DIRTY AREA DIVERIONS (1:50 RI EVENT)

Diversion	Depth(m)	Width (m)	Average Longitudinal Slope (%)	Peak Flow (m^3/s)
J1 to J2	0.5	1.0	1.2	1.2
J3 to J4	0.5	1.0	0.8	0.8

The design of the dirty diversion routing water exceeds the necessary capacity as a result of the simplification in diversion design, however, this is of benefit due to uncertainty with regards to the routing of water (i.e. the division between 'D1' and 'D2' dirty areas may been inaccurate with a higher proportion of runoff going to one diversion).

4.2.4 DIRTY WATER SYSTEM – POLLUTION CONTROL DAM

Condition 6 of GN 704 states that clean and dirty water systems must be kept separate and must be designed, constructed, maintained and operated such that these clean and dirty water systems do not spill into each other as a result of storm events below and including the 1:50 year event. A minimum freeboard of 0.8 m above full supply level must also be maintained as per the requirements of GN 704.

The necessary capacity of the PCD included in the SWMP was calculated based on the summation of the 1:50 year design rainfall (24 hour) event for the dirty water area **and** the highest monthly rainfall (January) falling over the dirty water area, **less** the corresponding monthly evaporation (January) taking place over the surface area of the PCD. PCSWMM was used to model the containment of water, with the volume of runoff associated with monthly rainfall calculated using the Rational Method and set as an initial depth in the PCD.

Figure 4-2 illustrates the position of the PCD which utilises the southern open reservoir (per 1:50,000 topographical map data) as it is appropriately situated to capture runoff from the waste rock dump and mine shaft (currently being backfilled) and is already able to contain a significant volume of water (thereby reducing construction costs).

Table 4-2 presents the volume requirements for the PCD based upon a constant surface area (i.e. vertical PCD walls). These volumes do not account for any additions of process water, dewatering, spillages, wash water or the like. Table 4-2 should be evaluated and revised (if necessary) as part of the detailed design phase to include additional water requirements.

TABLE 4-2: POLLUTION CONTROL DAM VOLUME REQUIREMENTS

	Surface Area (m^2)	Average Depth when Full (m)	Minimum Volume (m^3)	Recommended Volume (m^3)
PCD1	9,900	0.96	8,200	9,500

Although the PCD has been sized according to GN704 (i.e. using the 1:50 RI event), it is possible that the DWS may agree to a reduced sizing based upon the design of a sediment trap (e.g. using the 1:10 RI event) to only undertake sediment control of the waste rock dump (since the mine shaft is being backfilled and should be rehabilitated in the short term). Furthermore, waterproof lining for a PCD is usually required to prevent seepage of polluted water into the soil and subsequently into surface or ground water resources and may also be omitted if agreed upon by the DWS. These less stringent requirements would be more likely assuming the waste rock was to also be removed in its entirety within the short term (e.g. within a year) and that the area was to be rehabilitated.

4.3 REHABILITATED AREA

The rehabilitated areas on site have been delineated according to Figures 4-1 and 4-2, with dirty areas ‘D1-1’ and D1-2’ representing the area to be contained with regards to surface runoff. Areas falling outside of the defined dirty area are assumed to be adequately rehabilitated and defined as clean areas. All residual waste rock, excavated or other material with the potential to leach contaminants into the surface water environment is expected to have been removed from both the historical area of works and the site as a whole (i.e. the site boundary). This would include spillage from the transport of material via either railway or road.

5 HYDROLOGICAL IMPACTS AND MITIGATION MEASURES

An impact is essentially any change (positive or negative) to a resource or receptor brought about by the presence of the project component or by the execution of a project related activity.

The potential impacts of the project have been evaluated using a recognised risk assessment methodology developed to ensure communication of the potential consequences or impacts of activities on the hydrological (surface water) environment as set out in the National Environmental Management Act (NEMA). A quantitative approach was taken in determining environmental significance since this enables a cross-disciplinary assessment of impact whereby the interpretation of impact significance is the same (i.e. a high impact on the surface water environment has the same interpretation as a high impact on ecology).

5.1 METHOD OF ASSESSING IMPACTS

The broad approach to the significance rating methodology is to determine the environmental risk (ER) by considering the consequence (C) of each impact (comprising Nature, Extent, Duration, Magnitude, and Reversibility) and relate this to the probability/likelihood (P) of the impact occurring. This determines the environmental risk. In addition other factors, including cumulative impacts, public concern, and potential for irreplaceable loss of resources, are used to determine a prioritisation factor (PF) which is applied to the ER to determine the overall significance (S).

5.1.1 DETERMINATION OF ENVIRONMENTAL RISK

The significance (S) of an impact is determined by applying a prioritisation factor (PF) to the environmental risk (ER).

The environmental risk is dependent on the consequence (C) of the particular impact and the probability (P) of the impact occurring. Consequence is determined through the consideration of the Nature (N), Extent (E), Duration (D), Magnitude (M), and reversibility (R) applicable to the specific impact.

For the purpose of this methodology the consequence of the impact is represented by:

$$C = \frac{E + D + M + R}{4} \times N$$

Each individual aspect in the determination of the consequence is represented by a rating scale as defined in Table 5-1.

TABLE 5-1: CRITERIA FOR DETERMINING IMPACT CONSEQUENCE

Aspect	Score	Definition
Nature	- 1	Likely to result in a negative/ detrimental impact
	+1	Likely to result in a positive/ beneficial impact
Extent	1	Activity (i.e. limited to the area applicable to the specific activity)
	2	Site (i.e. within the development property boundary),
	3	Local (i.e. the area within 5 km of the site),
	4	Regional (i.e. extends between 5 and 50 km from the site
	5	Provincial / National (i.e. extends beyond 50 km from the site)
Duration	1	Immediate (<1 year)
	2	Short term (1-5 years),
	3	Medium term (6-15 years),
	4	Long term (the impact will cease after the operational life span of the project),
	5	Permanent (no mitigation measure of natural process will reduce the impact after construction).
Magnitude/ Intensity	1	Minor (where the impact affects the environment in such a way that natural, cultural and social functions and processes are not affected),
	2	Low (where the impact affects the environment in such a way that natural, cultural and social functions and processes are slightly affected),
	3	Moderate (where the affected environment is altered but natural, cultural and social functions and processes continue albeit in a modified way),
	4	High (where natural, cultural or social functions or processes are altered to the extent that it will temporarily cease), or
	5	Very high / don't know (where natural, cultural or social functions or processes are altered to the extent that it will permanently cease).
Reversibility	1	Impact is reversible without any time and cost.
	2	Impact is reversible without incurring significant time and cost.
	3	Impact is reversible only by incurring significant time and cost.
	4	Impact is reversible only by incurring prohibitively high time and cost.
	5	Irreversible Impact

Once the C has been determined the ER is determined in accordance with the standard risk assessment relationship by multiplying the C and the P. Probability is rated/scored as per Table 5-2.

TABLE 5-2: PROBABILITY SCORING

Probability Score	Description
1	Improbable (the possibility of the impact materialising is very low as a result of design, historic experience, or implementation of adequate corrective actions; <25%),
2	Low probability (there is a possibility that the impact will occur; >25% and <50%),
3	Medium probability (the impact may occur; >50% and <75%),
4	High probability (it is most likely that the impact will occur- > 75% probability), or
5	Definite (the impact will occur),

The result is a qualitative representation of relative ER associated with the impact. ER is therefore calculated as follows:

$$ER = C \: x \: P$$

TABLE 5-3: DETERMINATION OF ENVIRONMENTAL RISK

Consequence	5	5	10	15	20	25
	4	4	8	12	16	20
	3	3	6	9	12	15
	2	2	4	6	8	10
	1	1	2	3	4	5
		1	2	3	4	5
	Probability					

The outcome of the environmental risk assessment will result in a range of scores, ranging from 1 through to 25. These ER scores are then grouped into respective classes as described in Table 5-4.

TABLE 5-4: SIGNIFICANCE CLASSES

Environmental Risk Score	Description
< 9	Low (i.e. where this impact is unlikely to be a significant environmental risk),
≥9 & <17	Medium (i.e. where the impact could have a significant environmental risk),
≥ 17	High (i.e. where the impact will have a significant environmental risk).

The impact ER will be determined for each impact without relevant management and mitigation measures (pre-mitigation), as well as post implementation of relevant management and mitigation measures (post-mitigation). This allows for a prediction in the degree to which the impact can be managed/mitigated.

5.1.2 IMPACT PRIORITISATION

In accordance with the requirements of Regulation 31 (2)(l) of the EIA Regulations (GNR 543), and further to the assessment criteria presented in the Section above it is necessary to assess each potentially significant impact in terms of:

- Cumulative impacts; and
- The degree to which the impact may cause irreplaceable loss of resources.

In addition, it is important that the public opinion and sentiment regarding a prospective development and consequent potential impacts is considered in the decision-making process.

To ensure that these factors are considered, an impact prioritisation factor (PF) will be applied to each impact ER (post-mitigation). This prioritisation factor does not aim to detract from the risk ratings but rather to focus the attention of the decision-making authority on the higher priority/significance issues and impacts. The PF will be applied to the ER score based on the assumption that relevant suggested management/mitigation impacts are implemented.

TABLE 5-5: CRITERIA FOR DETERMINING PRIORITISATION

Public Response (PR)	Low (1)	Issue not raised in public response.
	Medium (2)	Issue has received a meaningful and justifiable public response.
	High (3)	Issue has received an intense meaningful and justifiable public response.
Cumulative Impact (CI)	Low (1)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change.
	Medium (2)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is probable that the impact will result in spatial and temporal cumulative change.
	High (3)	Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is highly probable/definite that the impact will result in spatial and temporal cumulative change.
Irreplaceable Loss of Resources (LR)	Low (1)	Where the impact is unlikely to result in irreplaceable loss of resources.
	Medium (2)	Where the impact may result in the irreplaceable loss (cannot be replaced or substituted) of resources but the value (services and/or functions) of these resources is limited.
	High (3)	Where the impact may result in the irreplaceable loss of resources of high value (services and/or functions).

The value for the final impact priority is represented as a single consolidated priority, determined as the sum of each individual criteria represented in Table 5-5. The impact priority is therefore determined as follows:

$$Priority = PR + CI + LR$$

The result is a priority score which ranges from 3 to 9 and a consequent PF ranging from 1 to 2 (Refer to Table 5-6).

TABLE 5-6: DETERMINATION OF PRIORITISATION FACTOR

Priority	Ranking	Prioritisation Factor
3	Low	1
4	Medium	1.17
5	Medium	1.33
6	Medium	1.5
7	Medium	1.67
8	Medium	1.83
9	High	2

In order to determine the final impact significance the PF is multiplied by the ER of the post mitigation scoring. The ultimate aim of the PF is to be able to increase the post mitigation environmental risk rating by a full ranking class, if all the priority attributes are high (i.e. if an impact comes out with a medium environmental risk after the conventional impact rating, but there is significant cumulative impact potential, significant public response, and significant potential for irreplaceable loss of resources, then the net result would be to upscale the impact to a high significance).

TABLE 5-7: FINAL ENVIRONMENTAL SIGNIFICANCE RATING

Rating	Description
< 10	Low (i.e. where this impact would not have a direct influence on the decision to develop in the area),
≥10 & <20	Medium (i.e. where the impact could influence the decision to develop in the area),
≥ 20	High (i.e. where the impact must have an influence on the decision process to develop in the area).

5.2 IDENTIFIED IMPACTS

5.2.1 EROSION OF SOILS

Eroded soils have the potential to cause sedimentation of downstream watercourses.

The mine shaft previously had surface infrastructure, most of which has been removed except for the waste rock dump and mine shaft (currently being backfilled). Areas which were associated with surface infrastructure have largely been rehabilitated. These rehabilitated areas have the potential to be eroded if soils are not stabilised by the introduction of plants (e.g. grass) or using other erosion control methods (e.g. biodegradable soil blankets).

Disturbance of vegetation and soil has also recently occurred due to a need to rehabilitate portions of the site (e.g. a borrow pit was noted during the site visit as per Figure 5-1). All disturbed areas should likewise be stabilised and vegetation reintroduced or erosion control methods used.

Harmony (2016) presents a rehabilitation plan for the site inclusive of topsoil replacement, a re-vegetation strategy and maintenance/aftercare and should be consulted with regards to prevention of erosion.

FIGURE 5-1: SOIL BORROW PIT

TABLE 5-8: IMPACT TABLE – EROSION OF SOILS

Impact Name	**Erosion of Soils**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature	-1	-1	Magnitude	3	1
Extent	3	2	Reversibility	3	2
Duration	3	1	Probability	4	2
Environmental Risk (Pre-mitigation)					-12.00
Mitigation Measures					
• *Harmony (2016) provides details on the rehabilitation plan for the site (inclusive of erosion control) and should be consulted.* • *Disturbed areas or areas rehabilitated with soils should be stabilised as soon as possible using plants (e.g. grass) or other mechanical methods (e.g. profiling or erosion control blankets).*					
Environmental Risk (Post-mitigation)					-3.00
Degree of confidence in impact prediction:					Medium
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					1
Low: Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change. The site's presence over a watershed means that there is no cumulative impact since no surface water interaction is anticipated with adjacent areas (i.e. no run-on to the site).					
Degree of potential irreplaceable loss of resources					1
Low: Where the impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.00
Final Significance					-3.00

5.2.2 POLLUTANTS ENTERING THE SURFACE WATER ENVIRONMENT

The mine shaft is no longer operational with supporting surface infrastructure reduced to the current waste rock dump and the mine shaft (currently being backfilled). The waste rock dump and backfill material around the mine shaft have the potential to leach pollutants into the environment with current site operations (i.e. earth moving) potentially mobilising pollutants. Section 4 of this report details the proposed SWMP which will mitigate this potential source of contamination (i.e. the waste rock dump).

Operation of earth moving machinery on site (including the possible storage or handling of hydrocarbons) poses a potential source of contamination with regards to the surface water environment.

Harmony (2016) presents a rehabilitation plan for the site which considers hydrocarbon spills and surface water monitoring and should be consulted.

TABLE 5-9: IMPACT TABLE – POLLUTANTS ENTERING THE SURFACE WATER ENVIRONMENT

Impact Name	**Pollutants Entering the Surface Water Environment**				
Environmental Risk					
Attribute	**Pre-mitigation**	**Post-mitigation**	**Attribute**	**Pre-mitigation**	**Post-mitigation**
Nature	-1	-1	Magnitude	3	1
Extent	3	3	Reversibility	3	3
Duration	4	1	Probability	4	1
Environmental Risk (Pre-mitigation)					-13.00
Mitigation Measures					
• *Implement the SWMP as outlined in this report.* • *Ensure vehicles are regularly serviced so that hydrocarbon leaks are limited.* • *Store hydrocarbons off site where possible, or otherwise ensure suitable storage and handling.* • *Handle hydrocarbons carefully to limit spillage.* • *Designate a single location for refuelling and maintenance where possible.* • *Keep a spill kit on site to deal with any hydrocarbon leaks.* • *Remove soil from the site which has been contaminated by hydrocarbon spillage.* *Undertake surface water monitoring to enable change detection related to contaminants originating from the site (outlined in Section 6).*					
Environmental Risk (Post-mitigation)					-2.00
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					1
Low: Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change. The site's presence over a watershed means that there is little cumulative impact since no surface water interaction is anticipated with adjacent areas (i.e. no run-on to the site).					
Degree of potential irreplaceable loss of resources					1
Low: Where the impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.00
Final Significance					-2.00

5.2.3 DECREASE IN RUNOFF

The proposed containment of runoff originating from the waste rock dump will remove approximately 10ha from its associated catchment. This is a negligible change (with regards to volume of runoff contained) that may be limited by the potential for runoff from the waste rock dump to enter (and be contained) by the existing 'open reservoir' (which is to be converted to a PCD). The mitigation of this impact is consequently unnecessary and impractical as it is the intention to contain and thereby decrease runoff.

TABLE 5-10: IMPACT TABLE – DECREASE IN RUNOFF

Impact Name	Decrease in Runoff				
Alternative	Alternative 3				
Environmental Risk					
Attribute	Pre-mitigation	Post-mitigation	Attribute	Pre-mitigation	Post-mitigation
Nature	-1	-1	Magnitude	1	1
Extent	1	1	Reversibility	2	2
Duration	4	4	Probability	5	5
Environmental Risk (Pre-mitigation)					-10.00
Mitigation Measures					
• *No mitigation possible*					
Environmental Risk (Post-mitigation)					-10.00
Degree of confidence in impact prediction:					High
Impact Prioritisation					
Public Response					1
Low: Issue not raised in public responses					
Cumulative Impacts					1
Low: Considering the potential incremental, interactive, sequential, and synergistic cumulative impacts, it is unlikely that the impact will result in spatial and temporal cumulative change. The site's presence over a watershed means that there is no cumulative impact since no surface water interaction is anticipated with adjacent areas (i.e. no run-on to the site).					
Degree of potential irreplaceable loss of resources					1
Low: Where the impact is unlikely to result in irreplaceable loss of resources.					
Prioritisation Factor					1.00
Final Significance					-10.00

5.3 ADDITIONAL REQUIREMENTS AND RECOMMENDATION

The hydrological impacts of the proposed infrastructure are medium to medium without mitigation. When mitigation is included, these impacts are reduced to low for 'erosion of soils' and 'pollutants entering the surface water environment'. A medium impact is defined for the 'decrease in runoff' with and without mitigation.

The mitigation indicated within Section 5 should form part of the shafts closure plan to reduce the impact of the site on the surface water environment. Surface water monitoring requirements are addressed in the following section.

6 SURFACE WATER MONITORING

Surface water sampling for the site was attempted during the site visit on the 24th May 2018. Initial comment by the site supervisor suggested that there would be no suitable sampling locations on site. A site walkover to the non-perennial pans and two small dams within the site boundary as per Figure 2-3, confirmed the site supervisor's suspicions with no standing or running water located. The reason for there being no water for sampling is likely due to the date of the site visit, which occurred in the dry season (where rainfall for the month of May is estimated to be 17mm as per Table 2-1) and due to the site's position on a watershed (which limits the contributing area that can generate streamflow or fill dams). Surface water sampling within the site boundary would have a higher chance of success in January when rainfall is at its highest. A farm is present south of the site and may be a location at which more permanent running or standing water may be present, however, access was not possible during the site visit.

A review of past sampling undertaken by Harmony provided in seven excel spreadsheets indicated no sampling locations or results for the SRTM30 derived catchment containing the area of works as per Figure 6-1. Surface water sampling points were noted in other areas adjacent the site, however, these were associated with different mining operations and consequently cannot be used to distinguish the water quality originating from the site (assuming that the SRTM30 derived catchments are inaccurate and runoff were to be routed into the adjacent catchments to the north, east and west instead of to the south).

When considering future sampling locations, Figure 6-1 illustrates the identified catchment containing the area of works. Two sampling locations are proposed, with the one within the site boundary likely not being suitable during the dry season, while the other location is situated further downstream in an adjacent farm for which access would have to be negotiated. Sampling locations within the site boundary and as close as possible to the area of works are preferential due to the potential for dilution the further away a sample point is located and the possibility of other land uses (e.g. mining or farming) limiting the potential for change detection resulting from the water quality changes at the site alone. This is not merely limited to surface water runoff since groundwater contributions may cause the impact of adjacent areas (such as the mining operation to the east) to be evident in the surface water quality of the site's catchment due to the potential difference between surface water and groundwater catchments.

Legend

- Boundary
- Area of Works
- Old Shaft
- Containing Catchment
- Potential Sampling Location
- 5m Contour (50K Topo)
- Any Other Channel (50K Topo)
- Furrow (50K Topo)
- Non-Perennial River (50K Topo)
- Dam (50K Topo)
- Non-Perennial Pan (50K Topo)
- Open Reservoir (50K Topo)
- Vlei (50K Topo)
- Flow Path (SRTM30 Derived)
- Quaternary Catchments
- Rehabiliated Area (Clean)
- Waste Rock Dump (Dirty)

0 400 800 Meters

Scale: 1:23,500 @ A3

Projection: Transverse Mercator
Datum: Hartebeeshoek, LO27

Figure 6-1

Potential Sampling Locations

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M Bollaert		October 2018

6.1 MONITORING PROGRAMME

The monitoring programme for the site (as managed by Harmony) should consequently focus on the two sampling locations identified (assuming the SRTM30 derived catchment is accurate).

Sampling should take place on a quarterly basis (in line with Harmony, 2016) although frequency of monitoring should also be agreed with the DWS. Any waters that will be discharged into the natural environment must be tested and comply with the relevant water quality limits. If necessary, the water will be treated prior to discharge. This is specifically applicable to the PCD which may fill over time, necessitating removal of water.

Parameters that need to be monitored should include (but are not limited) to those in Table 6-1. This table can be refined through the focus on contaminants of concern if known or as they become identified over time (i.e. if a potential contaminant is shown to be constantly below effluent limits, then its monitoring can be reduced/excluded in favour of contaminants that are more relevant).

TABLE 6-1: MONITORING PARAMETERS

In field measurements		
pH	Electrical conductivity	Total dissolved solids
Laboratory analysis		
pH	Ammonium	Copper
Electrical conductivity	Alkalinity as $CaCO_3$	Mercury
Boron	Sulphate	Chloride
Selenium	Cobalt	Fluoride
Arsenic	Phosphate	Magnesium
Nitrate	Total dissolved solids (TDS)	Zinc
Bicarbonate	Cadmium	Potassium
Sodium	Calcium	Barium
Chrome	Chrome VI	Iron
Aluminum	Lead	Manganese

Bi-annual monitoring reports should, as a minimum, include the following:

- Comparison of water samples to differentiate seasonal variations and general trends due to the historic mining activities;
- Comparison of water samples to standards and guidelines set by the Department of Water and Sanitation (DWS); and
- Analysis of parameters over time so that trends can be established.

Applicable effluent standards are provided in the '*Revision of General Authorisations in Terms of Section 39 of the National Water Act, 1998 (Act No. 36 of 1998)'* published under Government Notice 665 in Government Gazette 36820, dated 6 September 2013, while the Water Research Commission (WRC) provides gold mine specific guidance[3].

[3] *A Manual to Assess and Manage the Impact of Gold Mining Operations on the Surface Water Environment* by W. Pulles, R. Heath and M. Howard, Water Research Commission Report No. TT 79/96.

7 CONCLUSIONS AND RECOMMENDATIONS

Baseline information including rainfall, evaporation, design event rainfall, soils, vegetation and land cover, as well as site topography and regional and local catchment hydrology have been considered for the St Helena 10 Mine Shaft mining right (FS 30/5/1/2/2 86MR).

A conceptual storm water management plan has been developed based on the requirements of GN 704 and best practice guidance. The location and sizing for the diversions/containment included in this conceptual SWMP are based upon STRM30 data and informed by aerial imagery and the site layout. Inaccuracies or limited detail in the STRM30 data could potentially cause inaccuracies in the SWMP as modelled, however, aerial imagery has been used to inform the model approach to reduce this potential error.

The management of stormwater on the site is limited to the waste rock dump and mine shaft undergoing backfilling, for which two dirty diversions and a single PCD are recommended. The PCD has been sized according to the 1:50 RI event and the balance of the wettest months (January) rainfall and evaporation. Lining requirements and the potential to utilise a smaller design event for sizing (e.g. the 1:10 RI event) should be discussed and agreed with the DWS.

During the site visit it was evident that rehabilitation of the site was ongoing, which is assumed to be in accordance with the mines rehabilitation plan. It is unconfirmed as to how much of the existing waste rock will be used to backfill the shaft or what will be done with the remaining waste rock post backfilling. Modifications to the SWMP will likely be possible once rehabilitation is complete with the potential for removal of all storm water management infrastructure (i.e. diversions and PCD) assuming all areas including the waste rock dump are rehabilitated.

Surface water impacts for the current rehabilitation of the site and continued existence of the waste rock dump (inclusive of the proposed SWMP) were identified and assessed as part of this study. Table 7-1 presents a summary of these impacts with and without mitigation.

TABLE 7-1: IMPACT SIGNIFICANCE WITH AND WITHOUT MITIGATION

Impact	Without Mitigation	Residual Impact (with Mitigation)
Erosion of Soils	Medium (-12)	Low (-3)
Pollutants Entering the Surface Water Environment	Medium (-13)	Low (-2)
Decrease in Runoff	Medium (-10)	Medium (-10)

Lastly, a surface water monitoring programme was recommended although no water quality sampling was possible at the time of the site visit due to it being the dry season.

Harmony (2016) should be consulted along with this report as it contains information relevant to the surface water environment with regards to rehabilitation of the site.

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APPENDIX A: STORM WATER CALCULATIONS

8.1 A.1 MODEL CHOICE

PCSWMM is a model package that makes use of the USEPA Stormwater Management Model (SWMM), which is a computer program that computes dynamic rainfall-runoff from developed urban and undeveloped or rural areas (Rossman, 2008). The SWMM model suits application to this project since it can account for:

- Time-varying rainfall;
- Rainfall interception in depression storage;
- Infiltration of rainfall into unsaturated soil layers;
- Evaporation of standing surface water;
- Routing of overland flow; and
- Capture and retention of rainfall/runoff.

The development of SWMP's using SWMM have been undertaken for many thousands of studies through the world including (Rossman, 2008) South Africa.

8.2 A.2 DESIGN HYDROGRAPHS

8.2.1 A.2.1 DESIGN STORM

The SCS Type 3 design storm for South Africa was used to define the rainfall distribution according to the RLMA (Smithers /Schulze) 24-hour design rainfall depth for the 1:50 RI events (see Table 2.2).

8.2.2 A.2.2 MODEL PARAMETERISATION

SRTM30 was used to separate dirty and clean areas (draining by gravity). Land cover parameters were estimated according to the surface infrastructure layout and satellite imagery with the baseline land cover and soil type being set according Section 2.7

8.3 A.3 MODEL RUN

Dynamic wave routing was set for the model run along with a variable time step. The resulting runoff continuity error was 0% while the routing continuity error was 0% which is optimum. The resulting peak flows and characteristics for the dirty and clean areas is presented in Table A-1.

TABLE A-1: DIRTY AREA CHARACTERISTICS FOR THE 1:50 YEAR EVENT

Name	Area (ha)	Precipitation (mm)	Infiltration (mm)	Runoff Coefficient	Runoff Volume (ML)	Peak Runoff (m^3/s)
D1-1	6.1	126	57	0.54	4.1	1.3
D1-2	3.1	126	56	0.54	2.8	0.9