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Lehating

Lehating Mine Surface Water Management Plan

710.12015.0001

Report No. 1

June 2013

Lehating Mining (Pty) Ltd

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LEHATING MINE SURFACE WATER MANAGEMENT PLAN

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ACCRONYMS AND ABBREVIATIONS

Below a list of acronyms and abbreviations used in this report.

Acronyms / Abbreviations	**Definition**
AMSL	Above Mean Sea Level
DDF	Depth Duration Frequency
DWA	Department of Water Affairs
MAP	Mean Annual Precipitation
RLMA&SI	Regional L-Moment Algorithm and Scale Invariance
RMF	Regional Maximum Flood
RP	Return Period
SANRAL	South African National Road Agency Limited
SAWS	South African Weather Service
SDF	Standard Design Flood
TC	Time of Concentration

LEHATING MINE SURFACE WATER MANAGEMENT PLAN

1 INTRODUCTION

1.1 BACKGROUND

Lehating Mining (Pty) Ltd (Lehating) intends to develop an underground manganese mining operation near Hotazel town in the Northern Cape Province. The proposed project will involve the underground mining, crushing and screening of manganese ore and the resultant fines slurry will be disposed of at an on-site tailings storage facility (TSF). Lehating are currently conducting the pre- feasibility study for the proposed project.

In order to comply with applicable guidance, namely DWAF Government Notice 704 (GN704) and Best Practice Guidance (BPG 1), a stormwater management plan (SWMP) is required to be developed. As such, SLR Consulting (Africa) (Pty) Ltd was appointed to undertake the development of a SWMP for the Lehating site, including the diversion of clean water flows around the site, and the containment of dirty water on site.

A report detailing the potential flooding on site, and the primary drainage pathways was previously completed. The reader is directed to the SLR Africa report, 710.12015.0002 – Lehating Flooding Assessment – Report 1.

1.2 DWAF GOVERNMENT NOTICE 704

GN 704 was established 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.

The main principle conditions of GN 704 applicable to this study are:

- *Condition 4* which defines the area in which mine workings or associated structures may be located with reference to a watercourse and associated flooding. The 50-year flood-line and 100-year flood-line are used for defining suitable locations for mine workings (prospecting, underground mining or excavations) and associated structures respectively. Where the flood-line is less than 100 metres away from the watercourse, then a minimum watercourse buffer distance of 100 metres is required for both mine workings and associated structures.
- *Condition 5* which indicates that no residue or substance which causes or is likely to cause pollution of a water resource may be used in the construction of any dams, impoundments or embankments or any other infrastructure.

- *Condition 6* which describes the capacity requirements of clean and dirty water systems. Clean and dirty water systems must be kept separate and must be designed, constructed, maintained and operated such that these systems do not spill into each other more than once in 50 years

- *Condition 7* which describes the measures which must be taken to protect water resources. All dirty water or substances which cause or are likely to cause pollution of a water resource either through natural flow or by seepage are to be mitigated.

1.3 SITE LOCATION

The Lehating project area is centred at -27.048936° latitude and 22.872371° longitude, within the Northern Cape, approximately 265km north-west of Kimberley and approximately 95km south east of the Botswana border. See Figure 1.1 for the regional setting of the site.

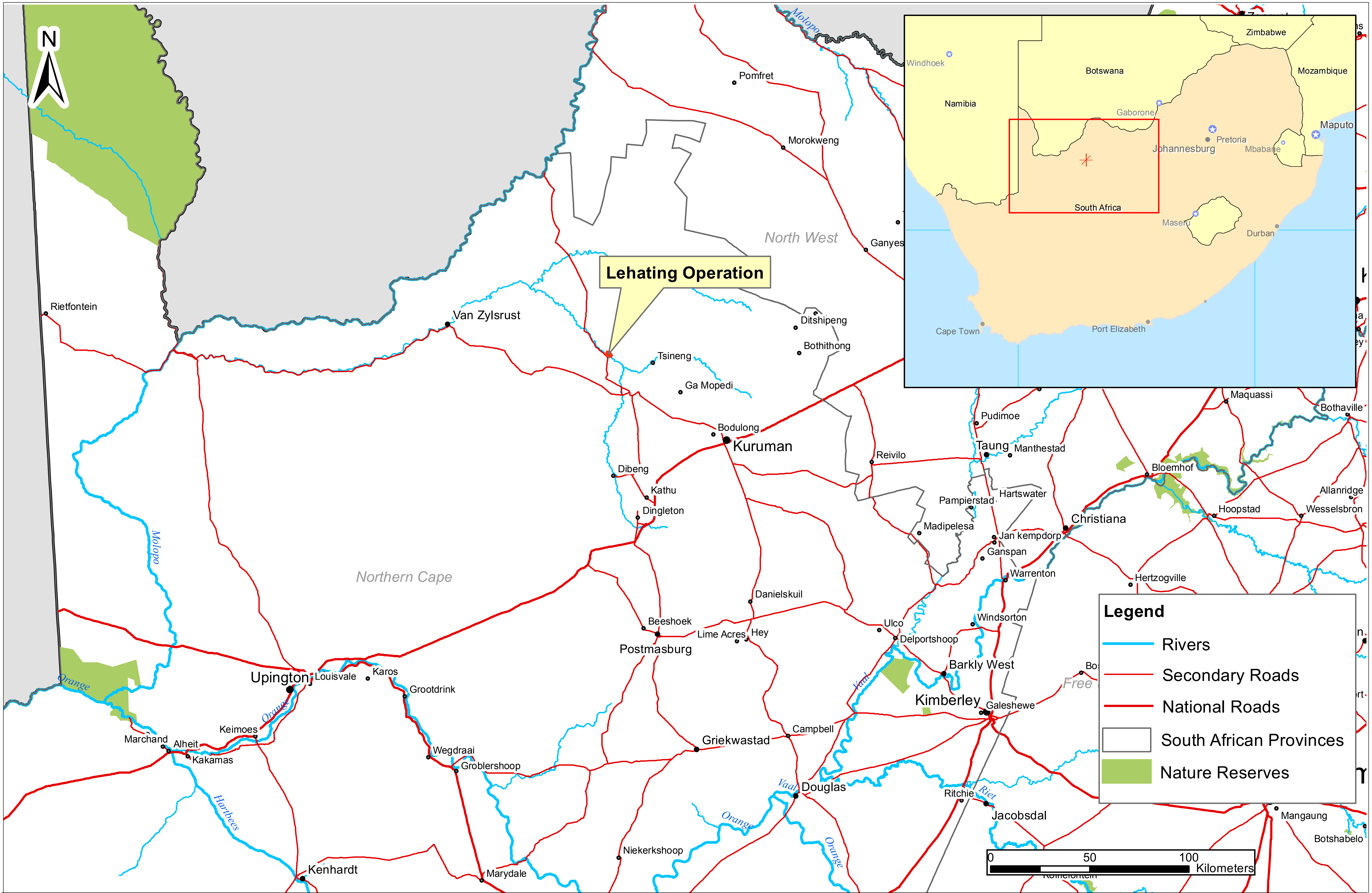


Figure 1-1 Regional Setting of the Proposed Lehating Opertation

2 BASELINE INFORMATION

2.1 REGIONAL CLIMATE

The proposed project site falls within the Northern Steppe climatic zone as defined by the South African Weather Bureau. This is a semi-arid region characterised by erratic rainfall, high evaporation levels, hot temperatures in summer and cold temperatures in winter. The regional average daily maximum temperature varies between 30°C and 33°C in January and in July it is approximately 17°C. The regional average daily minimum temperature is about 15°C in January and in July it is roughly 0°C. Other details of the regional climate pertaining to the hydrology, flood risk and stormwater management of the site include:

- 5 lightning flashes a year (Adamson TR102, lightning flash density per square kilometre)
- 50 thunder days a year (Alexander 2001, average number of thunder days a year)

2.2 RAINFALL

WR2005 (2009) indicates that the mean annual precipitation (MAP) for the site is approximately 320 mm/year. There are a number of South African Weather Service (SAWS) weather stations within 50km of the site, while the closest Department of Water Affairs (DWA) station is approximately 55km away. Table 2.1 presents the monthly totals of rainfall for the two SAWS gauges near the site; namely Winton and Milner located at 40.5km and 17.5km away respectively, and the DWA station, Kuruman (55km away).

The mean annual rainfall measured at the nearby Winton and Milner weather stations ranges between 330mm and 362mm respectively. Rainfall is typically in the form of thunderstorms during the summer months of October to March. The peak rainy period occurs between the months of January to March. Rainfall is erratic and may vary significantly from year to year. The weather stations presented in Table 2.1 have their positions illustrated in Figure 2.2

TABLE 2.1: MONTHLY RAINFALL FOR WEATHER STATIONS NEAR THE SITE

	STATIONS		
Station name	**Winton**	**Milner**	**Kuruman**
Station No.	392148 W	393083 W	D4E004
Latitude	27°29' S	27°22' S	27°28' S
Longitude	22°37' E	23°02' E	23°26' E
Distance to site (km)	55	40	75
Altitude (m)	1180	1118	1320
Years of Record	72	67	54
	RAINFALL (mm)		
January	62.1	66.1	85.6
February	61.2	61.4	82.9
March	58.0	66.4	86.5
April	31.8	35.5	45.1
May	13.9	16.1	21.5
June	4.2	6.0	7.4
July	2.5	1.9	2.8
August	4.9	4.2	9.8
September	6.2	6.2	7.8
October	16.2	19.0	26.3
November	25.7	32.0	45
December	43.3	46.8	44.9
Annual	330.1	361.6	465.7

2.2.1 RAINFALL DEPTHS

Design rainfall depths for various return periods (RP) and storm durations were sourced from the Design Rainfall Estimation Software for South Africa, 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 in conjunction with a Scale Invariance (RLMA&SI) approach to provide site specific estimates of depth-duration-frequency (DDF) rainfall, based on surrounding observed records. This method of DDF rainfall estimation is considered more robust than previous single site methods. The Water Research Commission (WRC) Report No. K5/1060 provides further detail on the verification and validation of the method.

For comparative purposes, HRU (1978) was considered. The HRU method is a simplistic empirical method which uses the mean annual precipitation (MAP) of a site, combined with a locational setting to estimate design rainfall. The HRU method resulted in lower estimates, thereby placing greater confidence in the RLMA&SI estimates with regard to their use in design. Table 2.2 presents the results of the RLMA&SI and HRU estimates for the site.

TABLE 2.2: RAINFALL DEPTH FOR VARIOUS METHODOLOGIES AND RETURN PERIODS FOR THE 1-HOUR AND 24-HOUR STORM

Methodology	Rainfall Depth (mm) for associated Return Periods in relation to a 1-hour rainfall duration						
	2	5	10	20	50	100	200
RLMA&SI (standard)	26.2	37.3	45.1	52.9	63.6	72.1	80.9
HRU 1978	18.86	24.8	30.6	37.6	49.5	61.0	75.1
	Rainfall Depth (mm) for associated Return Periods in relation to a 24-hour rainfall duration						
	2	5	10	20	50	100	200
RLMA&SI (standard)	58.3	82.8	100.3	117.6	141.4	160.3	179.8
HRU 1978	32.2	42.2	52.08	64.1	84.2	103.9	127.9

2.3 EVAPORATION

WR2005 (2009) shows a range in annual evaporation for the site of greater than 2600mm (A-Pan estimate). A correction factor of approximately 0.65(based upon the annual average for monthly correction factors) allows for the translation of the A-Pan estimate to the evaporation estimate for a very shallow body of water (Lake), equivalent to 1695mm.

Table 2.3 presents evaporation data sourced from the DWA station (Kuruman) closest to the site.

TABLE 2.3: MONTHLY EVAPORATION FOR KURUMAN WEATHER STATION

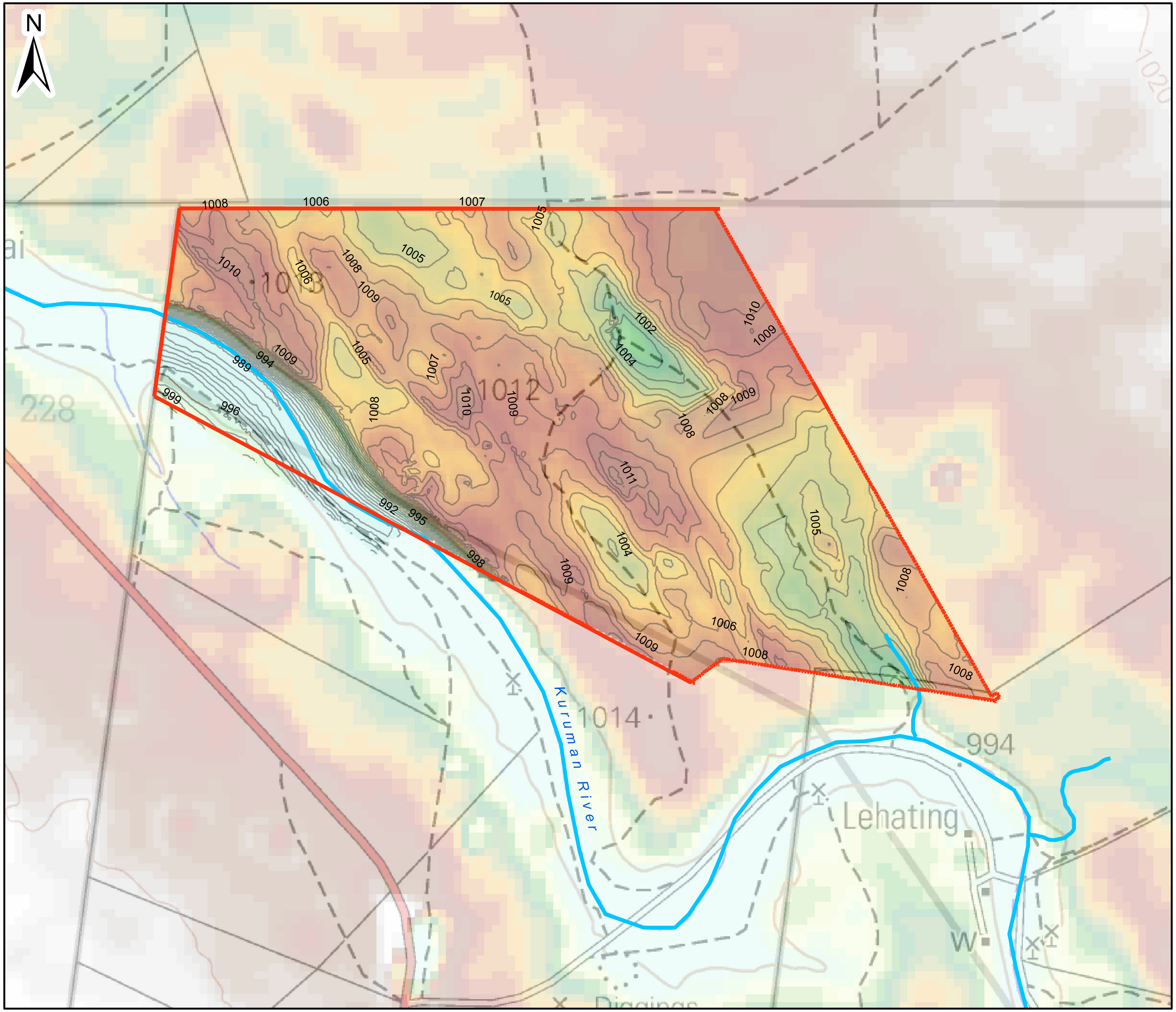
Month	Mean Monthly A-Pan Evaporation (mm)	Mean Monthly Lake Evaporation (mm)
Jan	259.0	169.7
Feb	208.4	144.9
Mar	161.3	112.1
Apr	122.3	83.9
May	113.2	76.8
Jun	82.5	56.1
Jul	99.1	63.3
Aug	131.2	81.8
Sep	188.5	109.9
Oct	236.3	135.9
Nov	243.6	157.8
Dec	272.7	183.3
Total	**2118.1**	**1375.7**

2.4 TOPOGRAPHY AND LAND COVER

The topography of the mine and surrounding area is illustrated in Figure 2.1. The proposed site is located at 1005m AMSL, with a variation in elevation of approximately 5m. The site and its surroundings are characterised by flat sandy plains with slopes under 10%. As presented in Figure 2.1, survey elevation data was only available for the site. Consequently, the elevation about the site was sourced from the ASTER GDEM with a cell size of 30m (ASTER is a product of METI and NASA). The ASTER GDEM estimates seem to approximate those of the survey, although a -10m vertical variation was evident.

The site is characterised by natural land cover consisting of semi-arid scrub. The vegetation of the site is defined as Kathu Bushveld and Southern Kalahari Mekgacha (Mucina & Rutherford 2006).

Both the topography and land cover of the sites are regarded as important considerations in the determination of runoff generated during storm events.



Key:

- Site Boundary
- 1m Contour
- Non-Perennial Rivers (50K Dataset)

Elevation (m AMSL)

High : 1010

Low : 980

This map makes use of ASTER GDEM Data.
ASTER is a product of METI and NASA.

0 200 400 600 Meters

Scale: 1:12,700 @ A3

Projection: Transverse Mercator
Datum: Hartebeeshoek, LO27

Lehating Mining (Pty) Ltd

Figure 2-1

Site Topography and Hydrology

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M Bollaert	L024-01	April 2012

2.5 GEOLOGY AND SOILS

The site is underlain by predominantly Kalahari geology which is a combination of Sand and Limestone lithology.

Soils in the region of the proposed project site are typically Kalahari sediments of gravels, clays, calcrete and aeolian sand. The project area is made up largely of deep Hutton and Clovelly soils (± 90%) with a small percentage of rock outcrops and shallow Mispah soils. The soils are well drained and have a low clay content.

2.6 RIVER SYSTEMS

The site is located in the Orange River Basin, in quaternary catchment D41M. With reference to Figure 2.2, the ephemeral Kuruman River runs to the south of the site from east to west. A large catchment of approximately 13,780km^2 feeds the Kuruman River, and consequently when the river is in flood, flows can become considerable. The Kuruman River is, however, considered ephemeral as the river only exists during periods of heavy precipitation.

A minor tributary joins the Kuruman River to the south of the site. This river is only defined as having a length of 400m according to the 1:50,000 topographical map for the site. The ASTER data indicates that a catchment area of approximately 58km^2 drains to this tributary during heavy rainfall events. A secondary elevation SRTM dataset (Shuttle Radar Topography Mission) indicates that this catchment is only 20km^2. This disparity is due to the coarse topographic data from which the drainage pathways are being derived as well as the flat slopes of the area (which add error into the calculation of drainage pathways). The presence of a second minor tributary 500m upstream of site tributary is the alternate drainage pathway to which a part the 58km^2 of catchment may flow. To maintain a conservative approach, a 58km^2 catchment area is assumed. Section 2.8 provides further detail on the noted SRTM and ASTER difference.

2.7 HYDROLOGICAL REGIME

The Kuruman catchment is large but sparsely vegetated and features freely draining soils which indicates that minor rainfall events would infiltrate to groundwater as opposed to generating significant volumes of runoff. This understanding is supported by the fact that numerous road crossings and houses are situated within or immediately adjacent to the channel which suggests that the watercourse does not flow on a regular basis. Anecdotal evidence suggests that no flow has been observed within the watercourse in this locality for some years.

The Kuruman River in this locality is meandering and features a low longitudinal gradient (approximately 1:1050) indicating that any flows are likely to be relatively deep but slow moving. The Kuruman River and the site tributary are ephemeral in nature only flowing during periods of heavy rainfall. In this regard, the site tributary will only require incident rainfall to fall over its catchment area, whereas the Kuruman River could come into flood due to rainfall occurring somewhere else in its catchment.

There is a contributing catchment upslope of the site of a significant size (approximately 12.5km^2). This catchment area drains towards the site, although the precise proportion of catchment draining to any one point is not possible to estimate due to nature of the coarse elevation data away from the site. Nevertheless, there remains the potential for preferential flowpaths that will route surface water towards the site during a significant rainfall event.

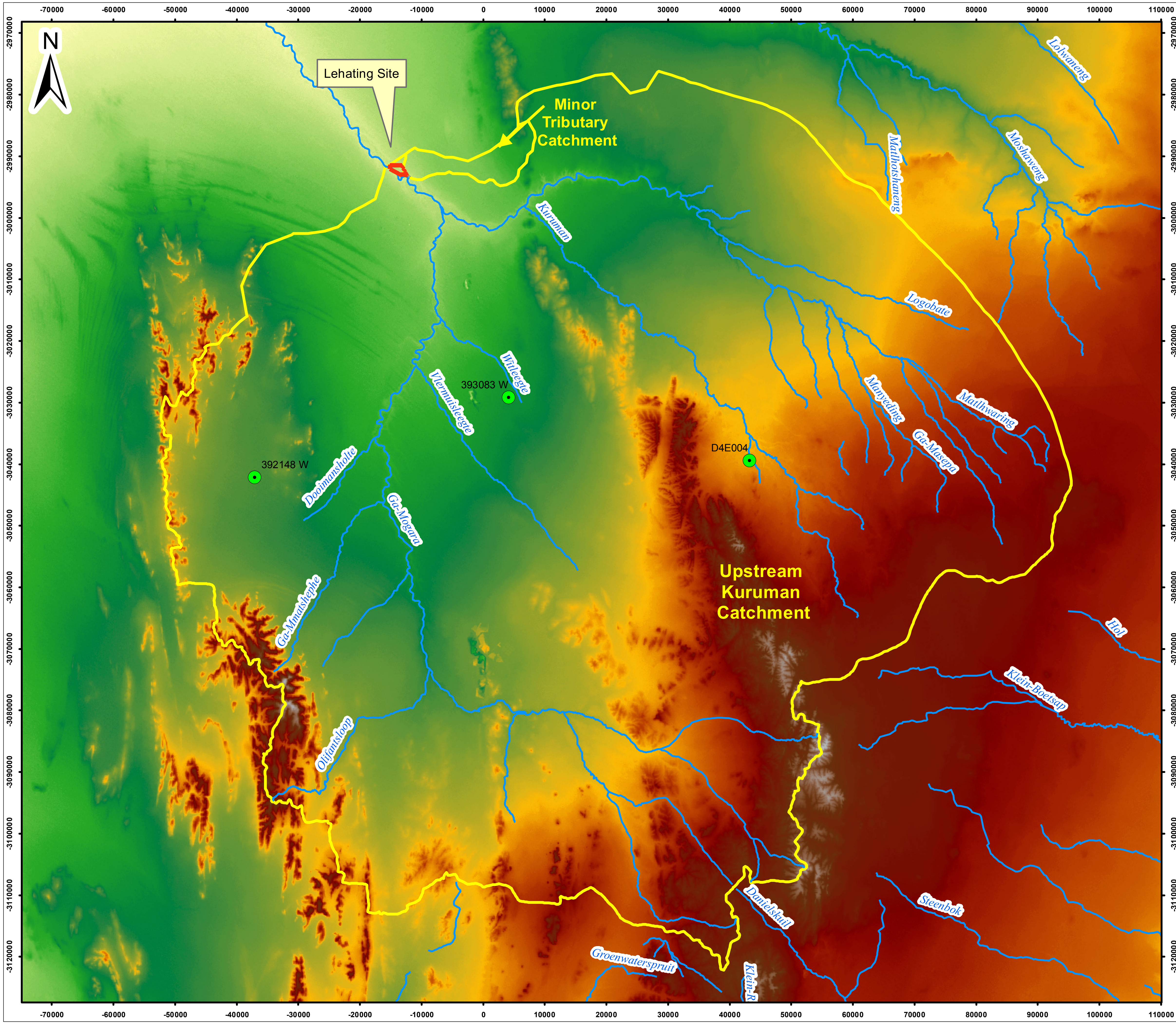
2.8 PREFERENTIAL FLOWPATHS

The site was assessed with regards to preferential flowpaths as illustrated in Figure 2.3. Site survey data shows a clear channel running along the eastern side of the site. This channel is a preferential flowpath since surface water will flow along the channel from upslope regions before flowing into the site tributary and on into the Kuruman River (during heavy rainfall events).

Figure 2.3 presents the results of two elevation datasets (ASTER and SRTM). These datasets were used to calculate the likely preferential flowpaths on and into the site. Since both of these datasets have coarse elevation data, there remains a level of uncertainty as to their accuracy. This is highlighted in the case of points A and B. According to the ASTER dataset, approximately 58km^2 of upstream catchment drains to point A, versus the SRTM which shows this upstream catchment primarily draining to point B.

Remaining ASTER derived flowpaths on site have smaller catchment areas, with a total contributing area of approximately 12.5km^2 being noted upstream of point C.

A precautionary approach should therefore be adopted on site with regards to the preferential flowpaths, since while these flowpaths are not defined as watercourses, the potential for flooding as a result of concentrated overland flow is still present.



Key:

Rivers (500K DWA Dataset)

Weather Stations Used

This map makes use of SRTM Data

0 20 Kilometers

Scale: 1:575,000 @ A3

Projection: Transverse Mercator
Datum: Hartebeeshoek, LO27

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Figure 2-2

Regional Hydrology and Weather Stations Used

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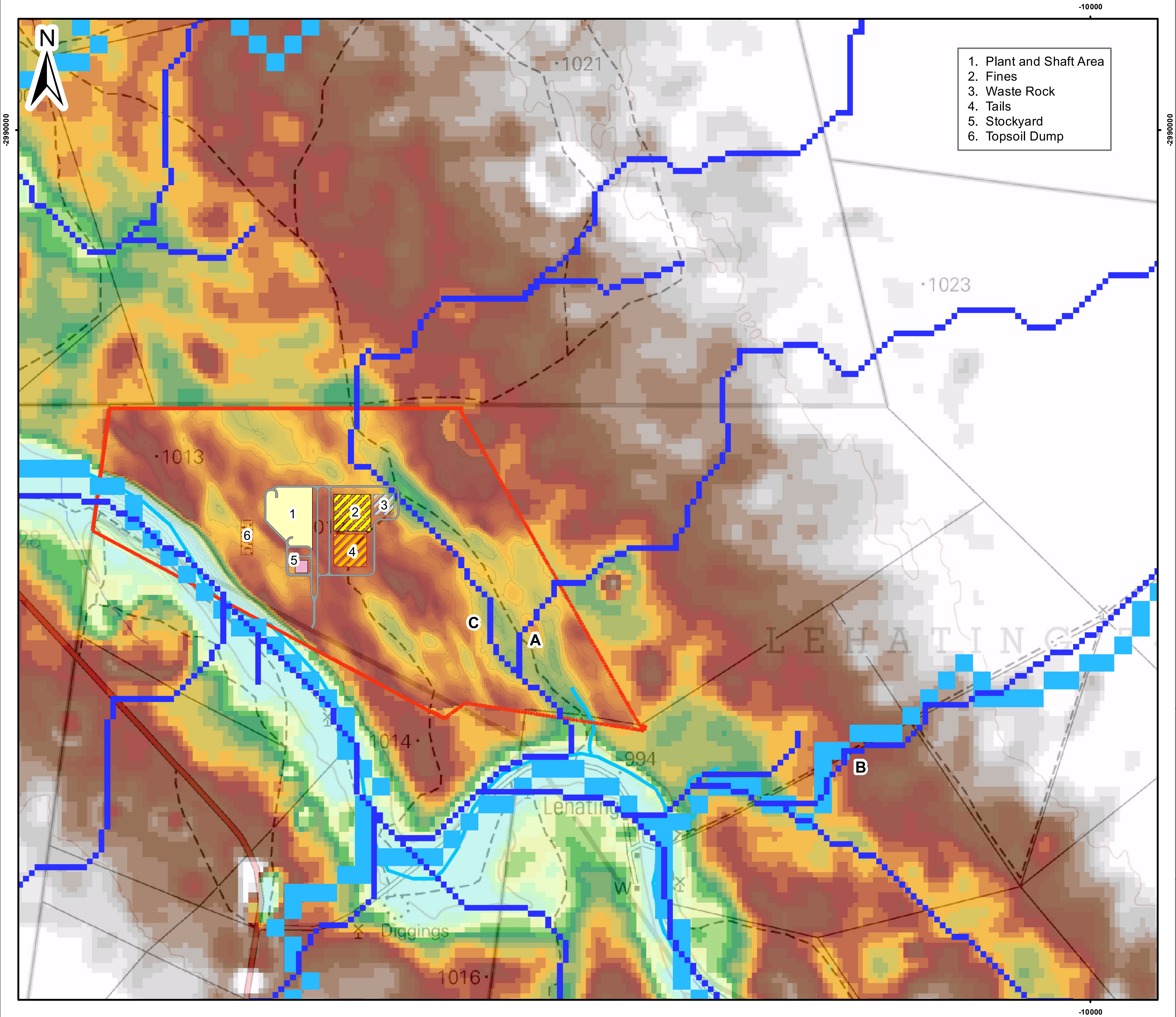

Key:

- Site Boundary
- 1m Contour

Elevation (m AMSL)

- High : 1020
- Low : 995

- Flowpath (SRTM Derived)
- Flowpath (Aster Derived)

This map makes use of ASTER GDEM Data.
ASTER is a product of METI and NASA.

0 500 1 000 Meters

Scale: 1:19,000 @ A3

Projection: Transverse Mercator
Datum: Hartebeeshoek, LO27

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Figure 2-3

Preferential Flowpaths

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3 STORMWATER MANAGEMENT PLAN

The proposed SWMP was developed according to the site layout as provided by Lehating Mining, an in particular the design drawing Gridlines and Contours-8 Rev 2.dwg

3.1 DWAF GOVERNMENT NOTICE 704

GN 704 was published 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, and these are discussed below.

3.1.1 IMPORTANT DEFINITIONS

Some important definitions from GN 704 appropriate to this project include:

- **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.
- **Dam:** This includes any settling dam, slurry dam, evaporation dam, catchment or barrier dam and any other form of impoundment used for the storage of unpolluted water or water containing waste (i.e. polluted water)
- **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)
- **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.

3.1.2 APPLICABLE CONDITIONS

The four main principle conditions of GN 704 applicable to this project are:

- *Condition 4,* which defines the area in which mine workings or associated structures may be located with reference to a watercourse and associated flooding. The 50-year floodline and 100-year flood line are used for defining suitable locations for mine workings (prospecting, underground mining or excavations) and associated structures respectively. Where the floodline is less than 100 metres away from the watercourse, then a minimum watercourse buffer distance of 100 metres is required for both mine workings and associated structures.

- *Condition 5,* which indicates that no residue or substance which causes or is likely to cause pollution of a water resource may be used in the construction of any dams, impoundments or embankments or any other infrastructure.

- *Condition 6,* which describes the capacity requirements of clean and dirty water systems. Clean and dirty water systems must be kept separate and must be designed, constructed, maintained and operated such that these systems do not spill into each other more than once in 50 years

- *Condition 7,* which describes the measures which must be taken to protect water resources. All dirty water or substances which cause or are likely to cause pollution of a water resource either through natural flow or by seepage are to be mitigated.

3.2 CLEAN AND DIRTY WATER AREAS

In Figure 3-1, the dirty water catchments for the site have been delineated according to the surface layout provided by Lehating Mining. All other areas are considered clean water areas. Of note is the clean water, preferential flowpaths that will direct surface water run-on towards the site during a large storm event.

In the case of the soil stockpiles, there is no chemical pollution potential as traditionally associated with dirty water areas. Instead, there is a sedimentation potential, whereby heavy rainfall events will result in sediment being entrained within surface water runoff, and subsequently finding its way into the natural watercourse. The implication of this entrainment means that the sediment load in the watercourse would increase, thereby resulting in a potentially adverse change to the river water quality. As per BPG 1, it is the recommendation that a sediment control approach be implemented with regards to soil stockpiles.

The access road to the site has the potential to result in the addition of pollutants into the environment. The SWMP does not consider this in detail as standard site practices are expected to be implemented in mitigating these areas (e.g. roadside drainage).

The vent shaft and associated infrastructure (winders, fans and evaporation pond) are also positioned outside the dirty water area since these areas are not expected to contribute a significant amount of potential pollutants such that the area would be classified as dirty. Standard site practices may nonetheless be required, such as the mitigation of pollutants arising from hydrocarbons due to maintenance of the winders and vent shaft.

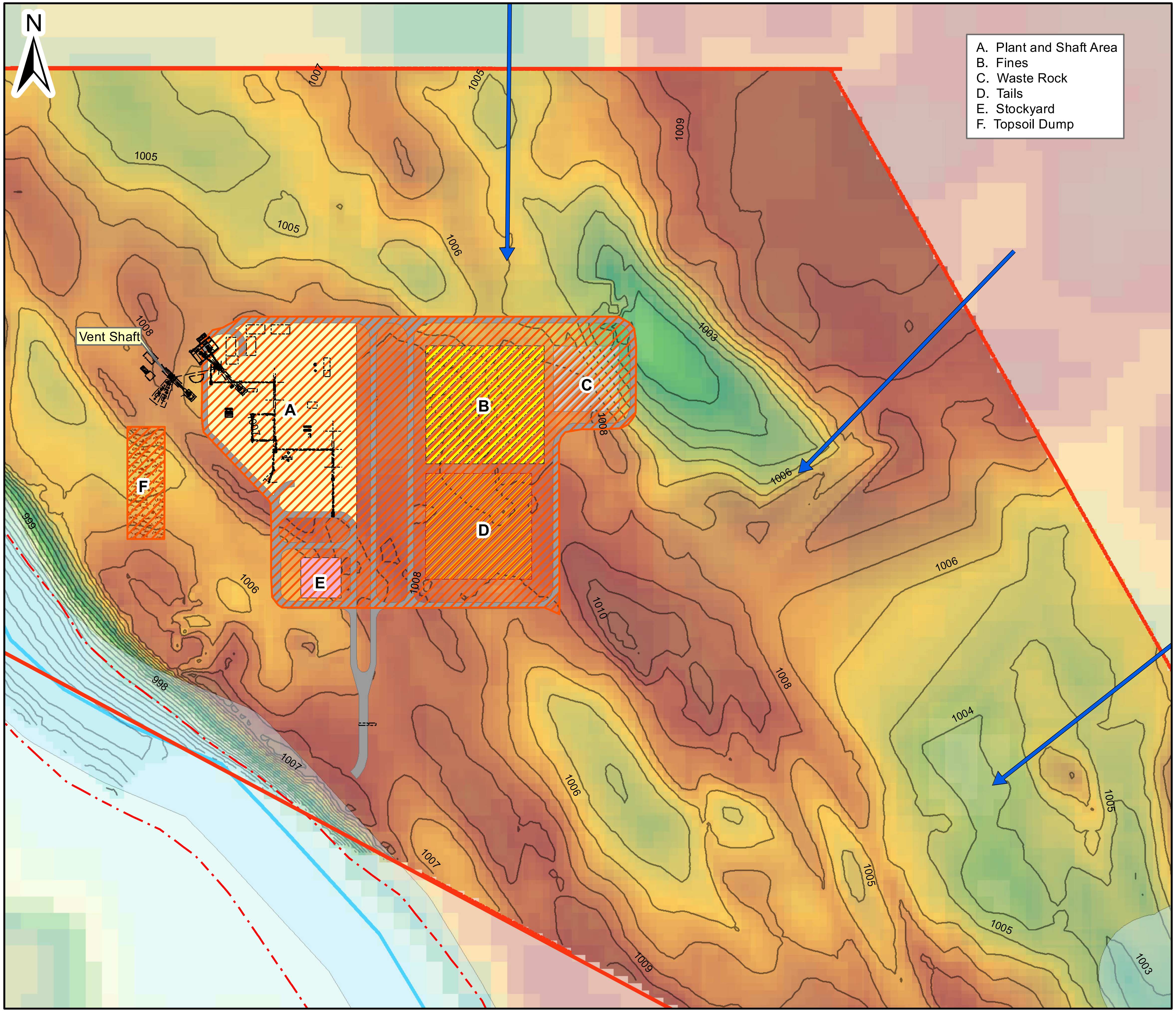

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Figure 3-1

Dirty Water Area

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3.3 ASSESSMENT OF FLOODING POTENTIAL

Previous flood modelling was undertaken in order to define the extent of flooding as a result of both the 1 in 50 year and 1 in 100 year storm events. The results of this modelling are presented in the SLR Africa report, 710.12015.0002 – Lehating Flooding Assessment – Report 1.

The modelled floodlines show that both the 1 in 50 or 1 in 100 year do not exceed the eroded floodplain of the Kuruman River. Figure 3-1 presents the 1 in 100 year flood extent and 100m river buffer, along with the site layout. As illustrated in the figure, the proposed site layout does not intersect either the floodline or the river buffer and fluvial flooding is consequently not considered an issue with regards to the location of the proposed area of works.

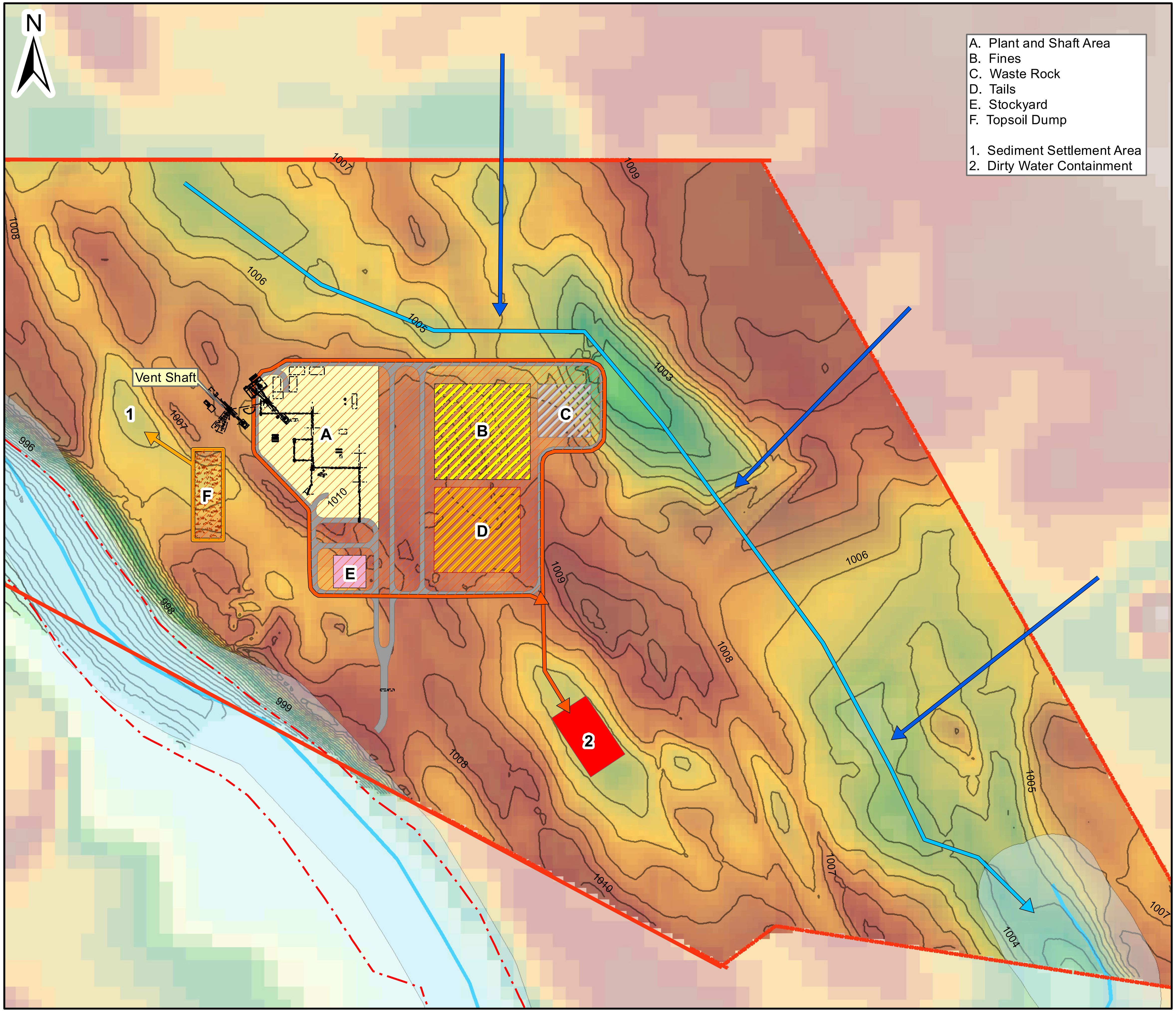
Depression storage of surface water may occur in those areas where depressions exist on site, as indicated by the site survey data. Cognisance should therefore be taken of the potential for prolonged periods of flooding in these natural 'dry ponds'. This is particularly the case with the depression in the north east of the site (and the proposed waste rock dump), which is also coincident with a preferential flowpath contributing area of approximately $12.5km^2$.

Additional depressions are evident on site, however, without significant contributing areas upslope, these depressions are not expected to have much in the way of surface run-on, runoff or storage.

3.4 PROPOSED STORMWATER MANAGEMENT INFRASTRUCTURE

The site has been classified as clean or dirty, as shown in Figure 3-1. The proposed conceptual SWMP is presented in Figure 3-2, and includes the following key features include:

- Dirty stormwater from the plant area, shaft area, fines, waste rock and stock yard will be collected by a perimeter diversion, and conveyed to a containment dam;
- Clean water from the upslope catchment will be diverted around the site via natural drainage pathways where possible;
- Sediment laden water associated with the soil stockpile will be diverted to a low point to allow for settling; and
- The tailings storage facility has its own stormwater management infrastructure (return water dam), which has been independently sized. The tailings storage facility has consequently not been considered in this SWMP.



Key:

Site Boundary

1m Contour

Elevation (m AMSL)

High : 1010

Low : 980

Roads

Non-Perennial Rivers (50K Dataset)

100m River Buffer

100-Year Floodline

Preferential Flowpath

Diversion (Clean Water)

Diversion (Dirty Water)

Diversion (Sediment)

Dirty Water Area

This map makes use of ASTER GDEM Data. ASTER is a product of METI and NASA.

0 200 400 Meters

Scale: 1:7,500 @ A3

Projection: Transverse Mercator
Datum: Hartebeeshoek, LO23

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Figure 3-2

Surface Water Management Plan

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3.5 PEAK FLOWS

Flood peak flows for the dirty water and clean water catchments of the site draining past the site were determined using the Soil Conservation Service (SCS) method.

The SCS method was implemented through the HydroCAD 10.0 software. Additional routing and storage calculations were also performed with the HydroCAD software.

3.5.1 METHODOLOGY

The SCS method is intended for the estimation of design flood volume and peak discharge from small catchments (i.e. < 30 km²). While originally developed for the US, the method was adapted for use in southern Africa by Schulze and Arnold (1979) and by Schmidt and Schulze (1987). This resulted in the SCS-SA method which has subsequently been extensively used in southern Africa.

The SCS method takes into account, many of the factors that affect runoff. These include variations in rainfall quantity, time distribution and duration, as well as variation in land use, soil type, soil moisture and catchment characteristics (SANRAL, 2006).

3.5.2 MODEL INPUTS

For each of the catchments modelled, parameters were determined in order to implement the SCS method.

The time of concentration (TC) for each of the catchments identified in was calculated using the TR-55 method. The TR-55 method uses catchment and river characteristics such as catchment slope, surface roughness, river length and river slope by which to estimate TC. Table 3.1 presents the estimates for TC. Lag time as used by the SCS method was calculated as 0.6 x TC.

TABLE 3.1: CALCULATED TIME OF CONCENTRATION AND LAG TIME

	Catchment		
	Dirty Water Area (Main)	**Dirty Water Area (Soil)**	**Clean Water Area**
Time of Concentration (min)	35	20	140
Lag Time (min)	21	12	84

3.5.3 RAINFALL-RUNOFF RESPONSE

The SCS curve number method is the assumption that the ratio of actual soil retention after runoff begins, to potential maximum retention, is equal to the ratio of direct runoff to available rainfall. The sandy soils and land cover of the site were used to estimate the SCS curve numbers as presented in Table 3.2.

TABLE 3.2: CURVE NUMBER ESTIMATES

	Dirty Water Area (Main)	Dirty Water Area (Soil)	Clean Water Area
Area (km^2)	0.264	0.011	12.500
Curve Number	77	60	45

Slopes over the catchments of interest are below 30% and verify the applicability of the SCS method with regards to slope, since the SCS method was developed using catchments with slopes below 30%.

3.6 DEPTH-DURATION-FREQUENCY RAINFALL AND STORM DISTRIBUTION

It was necessary to calculate design rainfall depths associated with each catchment. This required that both *duration* and *frequency* of rainfall be determined in order to arrive at a design rainfall *depth*. Frequency direcly relates to the Return Period (*T*) of the event. *Duration* is defined through the estimation of the critical storm duration for each subcatchment, estimated by calculating the TC (and by association the lag time for the SCS method) for individual catchments.

In the case of the SCS method, these rainfall depths are determined according to the selected storm type distribution and the lag time of the catchment of interest, and are estimated from the 24-hour storm depths as presented in Table 2.2. The development of a hydrograph in the SCS method uses the storm type distribution to distribute the total rainfall depth over time, with longer durations of rainfall being distributed over a longer period of time, resulting in reduced rainfall intensity. The smaller the storm type distribution number (storm type distributions number 1 to 4), the greater the distribution of rainfall over time. These rainfall distributions are presented in Figure 3.3. For the Lehating site, a storm type distribution of 3 was used.

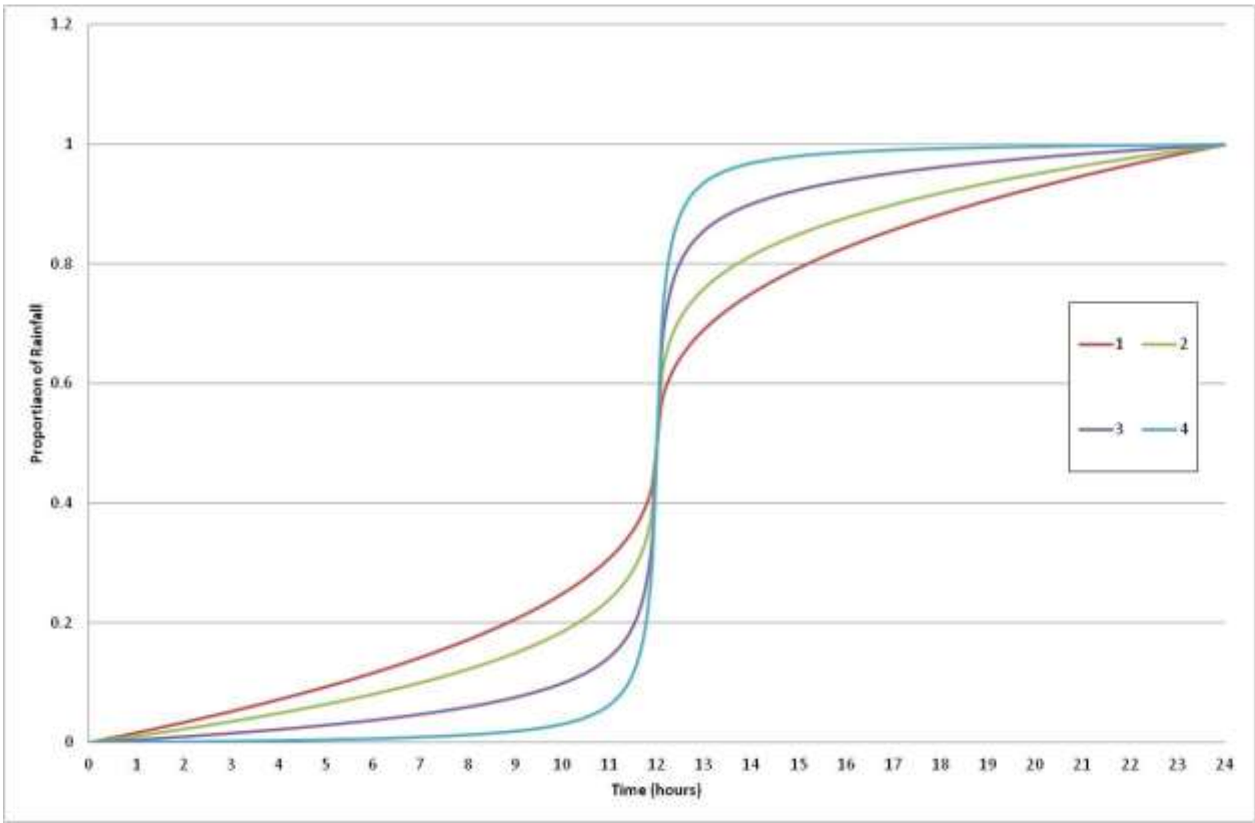

FIGURE 3.3: SCS-SA STORM TYPE DISTRIBUTIONS

3.7 PEAK FLOW ESTIMATES FOR FLOOD MODELLING

The resulting peak flows developed for flood modelling are presented in Table 3.3 presents the peak flow estimates for the catchments modelled.

TABLE 3.3: PEAK FLOW ESTIMATES

Return Period (Years)	Dirty Water Area (Main)	Dirty Water Area (Soil)	Clean Water Area
1:50	203.9	203.7	370.5

3.8 CLEAN WATER DIVERSIONS

The stormwater management plan includes a clean water diversion as illustrated in Figure 3-2. This clean water diversion consists of a berm and channel component (compacted earth fill). Clean water diversion berms are designed to divert upstream clean water around dirty water generating areas (i.e. intercepting clean water runoff and diverting this water around mining activities). The clean water diversion for the site has been sized to cater for 1 in 50 year flood event and will serve two main purposes:

- The channel section will divert upstream clean water which would otherwise flow into the identified dirty areas. In the case of the Lehating site, the channel serves a secondary purpose of routing surface water around the site and on into the non-perennial watercourse to the south east.

- The berm section will add to the effectiveness of the diversion by elevating the ground level towards the site, through the fill material excavated for the channel. It is important, however, that the berm be constructed such that clean water runoff into the channel from the south of the diversion is still possible.

The clean water diversion is coincident with a large depression adjacent the proposed waste rock dump. The presence of this depression (along with other more minor depression along the course of the proposed clean water diversion), will result in potential ponding in the event of a significant rainfall event. Site works are expected, such that the waste rock dump will be raised above the clean water diversion and the potential maximum level of ponding.

Figure 3.4 represents a typical clean water containment earth berm and channel as recommended by SLR Africa. The berm component will be constructed from the material excavated from the channel and supplemented by topsoil stockpiling if required. The side slopes for all berms and channels will be kept constant at 1 vertical: 2 horizontal. The channel component has been sized using Manning's equation for trapezoidal channels to meet the requirements of the 1 in 50 year flood. A Manning's 'n of 0.035 was used in the calculations, associated with a cropped grass earth channel.

In Figure 3.4:

- a = Channel Depth
- b = Channel base breadth

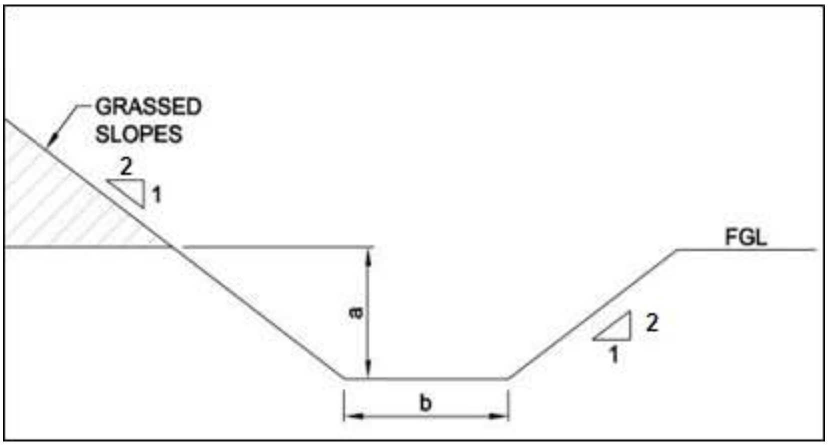

FIGURE 3.4: TYPICAL BERM AND CHANNEL FOR CLEAN STORMWATER DIVERSION SYSTEM

Table 3.4 presents the dimensions for the berm and channel associated with the clean water area.

TABLE 3.4: BERM AND CHANNEL DIMENSIONS FOR CLEAN STORMWATER

Diversion	a (m)	b (m)	Average Slope (m/m)
Clean Water	2.0	6.0	0.002

A single clean water diversion has been sized to accommodate the 1 in 50 year design flows from the estimated 12.5km^2 clean water catchment north of the site. Coarse topographic data for the site means that the precise catchment areas and locations at which different contributing preferential flow paths intersect the proposed clean water diversion are not known. Consequently, a single diversion has been sized which will accommodate the full 12.5km^2 area. An additional catchment area joins the site at point A in Figure 2.3 and potentially accounts for a further 58km^2 of catchment area. The design of clean water diversion should consequently take this potential addition of flow into account with regards to erosion. The proximity of this inflow at point A to the Kuruman River resulted in the adoption of the 12.5km^2 over the full length of the clean water diversion, since the excess surface water will be able to be contained by the natural topography at this location.

The velocity of flow estimated within some of the channels will approach 2m/s during the design event. It is therefore recommended that the detailed designs of the channels consider suitable erosion protection measures including channel stepping, internal check weirs / velocity reduction bunds, blockstone or riprap protection. The impacts of these measures on the Manning's 'n' value of the channel and consequently the channel dimensions should be considered during the detailed engineering design of the scheme.

3.9 DIRTY WATER DIVERSIONS

As per the clean water diversions, dirty water containment systems have been designed to ensure dirty water generated on the site is contained. These systems will also consist of a berm and channel component. Unlike the earthen clean water diversions, these channels will be lined with an impermeable liner such as concrete and/or soilcrete (filled in cells), with specific details to be determined in the detailed design phase. The berm and channel component have been designed to accommodate the 1 in 50 year flood and serve two main purposes:

- Diverting upstream clean water which would otherwise flow into the identified dirty areas.
- Contain dirty water in the identified dirty areas and direct towards the appropriate dirty water containment facility.

The main assumption in the dirty water diversion layout is that all water generated in the dirty area will be able to drain under gravity, to the area allocated for the dirty water containment facility. The proposed works are expected to level out much of the site, while site drainage is expected to facilitate the drainage of all areas into the proposed dirty water diversions.

Figure 3.5 represents a typical dirty water containment berm and channel as recommended by SLR Africa. The berm component will be constructed from the material excavated from the channel and supplemented by topsoil stockpiling if required. The side slopes for all berms and channels will be kept constant at 1 vertical: 2 horizontal. The channel component has been sized using Manning's equation for trapezoidal channels to meet the requirements of the 1 in 50 year flood. A Manning's 'n' value of 0.02 was used in the calculations, associated with a concrete lined channel. A lined channel is necessary to ensure there is no seepage of pollutants into the soil substrate.

In Figure 3.5:

- a = Channel Depth
- b = Channel base breadth

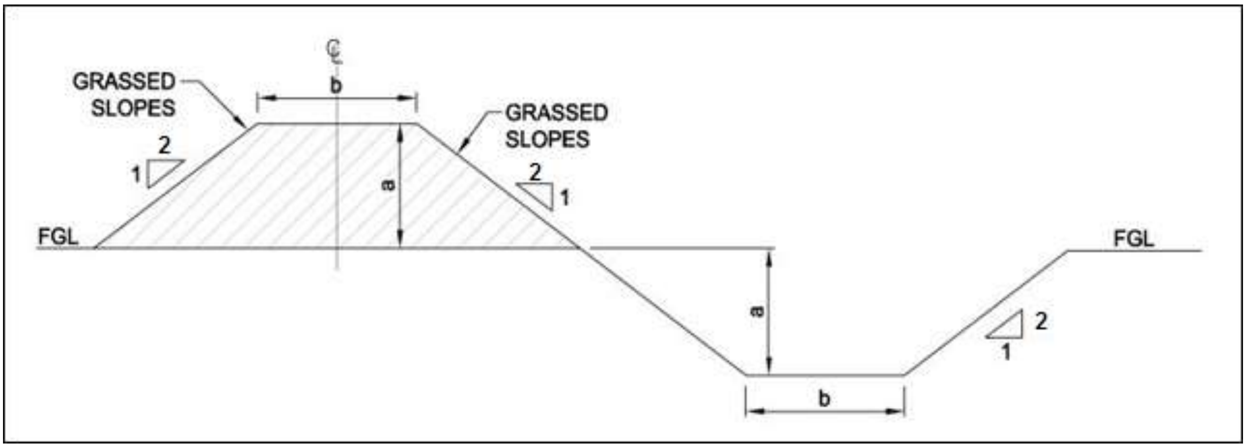

FIGURE 3.5: TYPICAL BERM AND CHANNEL FOR DIRTY STORMWATER DIVERSION SYSTEM

Table 3.5 presents the dimensions for each of the berms and channels associated with the clean water area.

TABLE 3.5: BERM AND CHANNEL DIMENSIONS FOR DIRTY STORMWATER

Diversion	a (m)	b (m)	Average Slope (m/m)
Clean Water	1.0	1.6	0.002

3.10 SEDIMENT DIVERSIONS AND CONTAINMENT

The soil stockpiles on site require some form of stormwater management in order to mitigate the sedimentation of watercourses that could otherwise occur. It is usually the case that only sediment loss needs to be managed, unless the soil stockpile is likely to leach out other contaminants. Control of sediment is commonly achieved through the inclusion of stormwater settling facilities (also known as silt traps). Unlike chemically contaminated waters, silt laden waters (with high total suspended solids) require a slowing down of the water in order for the suspended solids to ‘drop out’. It is therefore not necessary to fully contain the design storm events associated with ‘chemically’ dirty water areas (i.e. the 1 in 50 event). Rather, a smaller design storm can be considered when dealing with sediment generating areas.

Guidance on the appropriate design of silt traps differs. A paper presented by Ferreria and Waywood at the 2009 International Mine Water Conference, references the standards used by the Province of British Columbia (1996). These standards are as follows:

- Design flow for removal of suspended solids in sedimentation ponds should correspond to the 10-year, 24-hour flood flow.
- Easy removal of sediment at regular intervals

- Preferred shape of sedimentation ponds is generally rectangular with ratio of length to width of about 5 to 1.
- Unless there are mitigating factors, the pond should be sized to provide not less than a 20 hour detention time for a 1 in 10 year flood flow.

As per the dirty water containment, sediment diversion systems have been designed to ensure sediment laden water generated on the site is temporarily contained to allow the ‘dropping out’ of sediment. These systems also consist of a berm and channel component. Unlike the concrete dirty water diversions, the channels are not required to be lined (as seepage of pollutants into the underlying soil is not a concern). The berm and channel component have been designed to accommodate the 1 in 10 year flood and serve two main purposes:

- Diverting upstream clean water which would otherwise flow into the identified dirty areas.
- Contain sediment laden water in the identified soil stockpile areas and direct towards the appropriate silt trap.

Figure 3.5 represents a typical sediment diversion berm and channel as recommended by SLR Africa. The berm component will be constructed from the material excavated from the channel and supplemented by topsoil stockpiling if required. The side slopes for all berms and channels will be kept constant at 1 vertical: 2 horizontal. The channel component has been sized using Manning’s equation for trapezoidal channels to meet the requirements of the 1 in 10 year flood. A Manning’s ‘n of 0.035 was used in the calculations, associated with a cropped grass earth channel.

In Figure 3.6:

- a = Channel Depth
- b = Channel base breadth

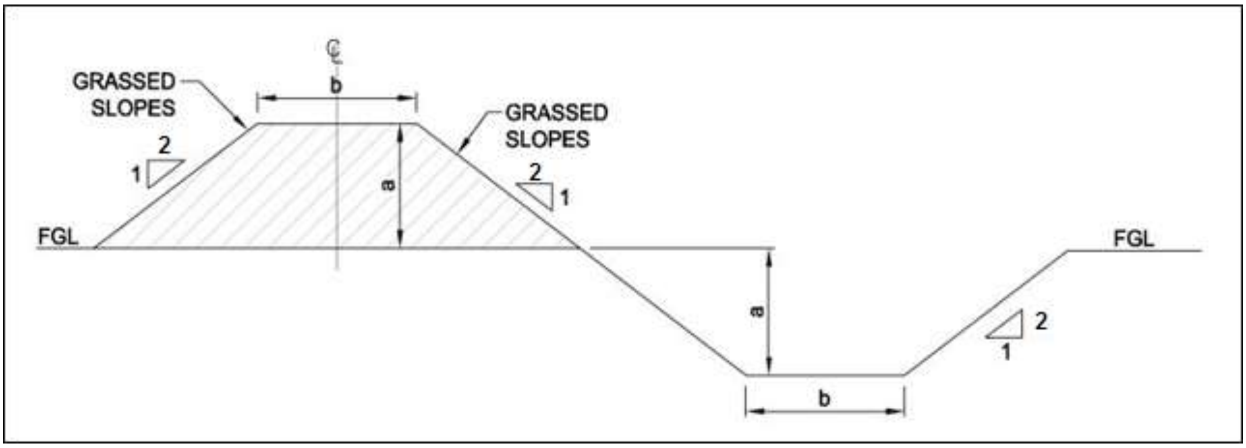

FIGURE 3.6: TYPICAL BERM AND CHANNEL FOR SEDIMENT CONTORL STORMWATER DIVERSION SYSTEM

Table 3.4 presents the dimensions for each of the berms and channels associated with the soil stockpile areas.

TABLE 3.6: BERM AND CHANNEL DIMENSIONS FOR SEDIMENT CONTROL STORMWATER

Diversion	a (m)	b (m)	Average Slope (m/m)
Clean Water	0.3	1.0	0.002

A minimum design with a = 0.3m and b = 1.0m has been used. This simplifies construction and enables a small front end loader to scrape the diversion (with regards to construction and maintenance).

Sizing of the sediment traps was also undertaken according to a 1 in 10 year 24-hour design storm. These volume estimates are presented in Table 3.7. It is important to note that a depression already exists to the west of the proposed soil stockpile. This depression will easily contain the required silt trap volume. As such, it is the recommendation that a diversion be put in place around the soil stockpile with water being diverted to the depression whereupon sediments can settle out.

TABLE 3.7: SILT TRAP VOLUME ESTIMATES

Diversion	Silt Trap Volume (m^3)
Soil Stockpile	293

3.11 DIRTY WATER CONTAINMENT (CONTAINMENT FACILITY)

Condition 6 of GN 704, deals with the capacity requirements of clean and dirty water systems, and 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 in 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. Water accumulated in this containment facility during the wet season should be used as a priority in the process water circuit where possible, to ensure the capacity requirements are not compromised during periods of heavy/extended rainfall.

In this project, the capacity of the dirty water containment facilities were calculated based on the summation of the 1 in 50 year design rainfall (24 hour) event for the catchment area **and** the highest monthly rainfall (March) falling over the catchment, **less** the corresponding monthly evaporation (March) taking place over the surface area of the proposed containment facility. Runoff coefficients used were determined according to the return period of interest, such that maximum monthly rainfall event was associated with a smaller runoff coefficient than the 1 in 50 year design rainfall event.

In the case of the Lehating operation, only a single containment facility is proposed which will contain all dirty water generated from the area of works (with the exception of the TSF). Additional storage is required for the groundwater dewatering volumes which are estimated at 293m^3 per a day. Groundwater storage requirements have consequently been factored to accommodate 1 month of dewatering (9,052m^3).

There is an assumption that the containment facility will operate empty, or close to empty. While the inclusion of a months preceding rainfall provides some leeway, failure to operate with sufficient available capacity will result in the containment facilities gradually filling over the year, to a point where it will be unable to accommodate the required design storm event. This would result in spillage for events under the 1 in 50 year design storm (with the potential for spillage during moderate rainfall events). It is therefore anticipated that a minimum storage volume will be available at any one time, as per Table 3.8. In order to allow for this, excess water will need to be removed from the containment facilities at regular intervals. This water should be incorporated into the plant process water system where possible or treated and discharged if not.

The volume of the containment facility was calculated based on an average depth of 1 meter (to estimate evaporative loss).

Table 3.8 presents the volume requirements for the dirty water containment facility.

TABLE 3.8: DIRTY WATER CONTAINMENT VOLUME REQUIREMENTS FOR 1 IN 50 YEAR FLOOD EVENT

Containment Facility	Total Volume (m^3)	Dewatering (m^3)	Minimum Volume Required (m^3)
Dirty Water (Main)	33,364	9,052	22,465

In accordance with Condition 7 of GN 704, the dirty water containment dam will require a liner to prevent infiltration of dirty water into the groundwater environment. The required freeboard allowance of 0.8m has not been included in the aforementioned volumes and will be necessary to include in the detailed design.

3.12 ADDITIONAL RECOMMENDED DRAINAGE MEASURES

In accordance with Condition 7 of GN 704, it is recommended that polluting activities including storage of mining fleet, equipment wash down facilities and vehicle maintenance yards are restricted to the workshop areas and are undertaken on impermeable hard standing surfaces, which are formally drained to the dirty water drainage system at the site.

It is recommended that dirty water drainage channels be concrete lined to prevent infiltration of dirty water into the groundwater environment, which would otherwise be likely to cause pollution of the groundwater environment. Furthermore, it is recommended that drainage of 'dirty' hard standing areas is formalised by installing perimeter kerbing to convey dirty runoff directly to the lined dirty water channels, and prevent uncontrolled spillage onto unlined surfaces including grass, sand or gravel.

All fuels and chemicals stored or used on site should be contained within fit for purpose containers and stored within designated storage areas. In order to prevent pollution of the surrounding environment during an accidental spillage, the designated storage areas should be situated on an impermeable surface and should feature a perimeter bund and a drainage sump. The volume of the bund and sump should be sized to contain at least 110% of the total volume of the fuel and chemicals being stored within the designated storage area. The storage areas should feature a roof to prevent inflow of rainwater, which would require the sump to be emptied frequently.

4 CONCLUSION

The baseline conditions of the site and surroundings including rainfall, evaporation, depth duration frequency rainfall events, topography, soils types and land cover have been provided.

A review of the existing surface infrastructure was undertaken in the context of GN 704 to inform the stormwater design principles for the site. Clean and dirty runoff producing areas of the site were identified while natural drainage flowpaths were assessed. With this understanding, a stormwater management plan for the site was developed with a single clean water diversion to divert clean water from upstream, around the site and into the Kuruman River. A single diversion has also been proposed for the routing of dirty water into a single dirty water containment facility for the site.

A single diversion has also been proposed for the soil stockpile in order to divert sediment laden water into an area of containment to allow sediment to settle out. No formal sediment trap has been proposed, since the natural depression in the vicinity of the soil stockpile will serve the same function as a sediment trap.

The peak flows draining into each channel (clean, dirty and sediment) have been estimated along with the associated channel dimensions required to convey design flows. The containment facility associated with the dirty water area has also been appropriately sized to accommodate the 1 in 50 year design event as per the guidance of GN 704.

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