HYDROLOGICAL ASSESSMENT FOR THE PROPOSED LUSIKA INVEST URANIUM MINING OPERATION

Final

July 2025

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HYDROLOGICAL ASSESSMENT FOR THE PROPOSED LUSIKA INVEST URANIUM MINING OPERATION

Prepared For

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1 INTRODUCTION

1.1 BACKGROUND

Highlands Hydrology (Pty) Ltd was appointed by Aquatox Consulting (Pty) Ltd to undertake a hydrological assessment for a proposed Lusika Invest Uranium Mining Operation (hereafter referred to as '*the site*') located near Beaufort West in the Western Cape Province of South Africa. The aim of the assessment was to develop an appropriate flood model to identify areas of potential flood risk, develop a conceptual storm water management plan and to assess impacts related to the proposed mining operation. The specific areas considered in this assessment include Abante, Ryst Kuil Main, Ryst Kuil Extension and Hannekuil.

1.2 SCOPE OF WORK

The scope of work for the hydrological assessment included the following deliverables:

- *Site Examination* – the site was visited by Luke Wiles (PrSciNat registered hydrologist), on the 22nd of May 2025. This was to enable a better understanding of the dominant hydrological flow regimes and to confirm various model inputs;
- *Baseline Assessment* – baseline climatic and hydrological data were sourced for the site. This included the interrogation of rainfall data, site specific design rainfall (depth/duration/frequency), evaporation, soils, natural vegetation, land-cover, as well as a regional and local hydrology;
- *Flood Assessment* – this involved the development of a suitable hydrological/hydraulic model to identify areas with an associated flood risk for return periods of 1:50 and1:100 year recurrence intervals;
- *Conceptual Storm Water Management Assessment* – develop a storm water model and associated conceptual storm water management plan for the site;
- *Hydrological Impact Assessment* - Investigate hydrological impacts related to the proposed activity with associated mitigation measures recommended.
- A technical report detailing the achieved scope of work.

1.3 REGIONAL SETTING AND LAYOUT

The site's geographical extent necessitates its division into two distinct sections namely West and East. These sections are located at approximately 32° 41′ 01″ S, 22° 51′ 04″ E and 32° 36′ 05″ S, 23° 03′ 36″ E, respectively. For a regional overview, refer to Figure 1-1. The proposed infrastructure's layout is depicted in Figures 1-2, 1-3, and 1-4.

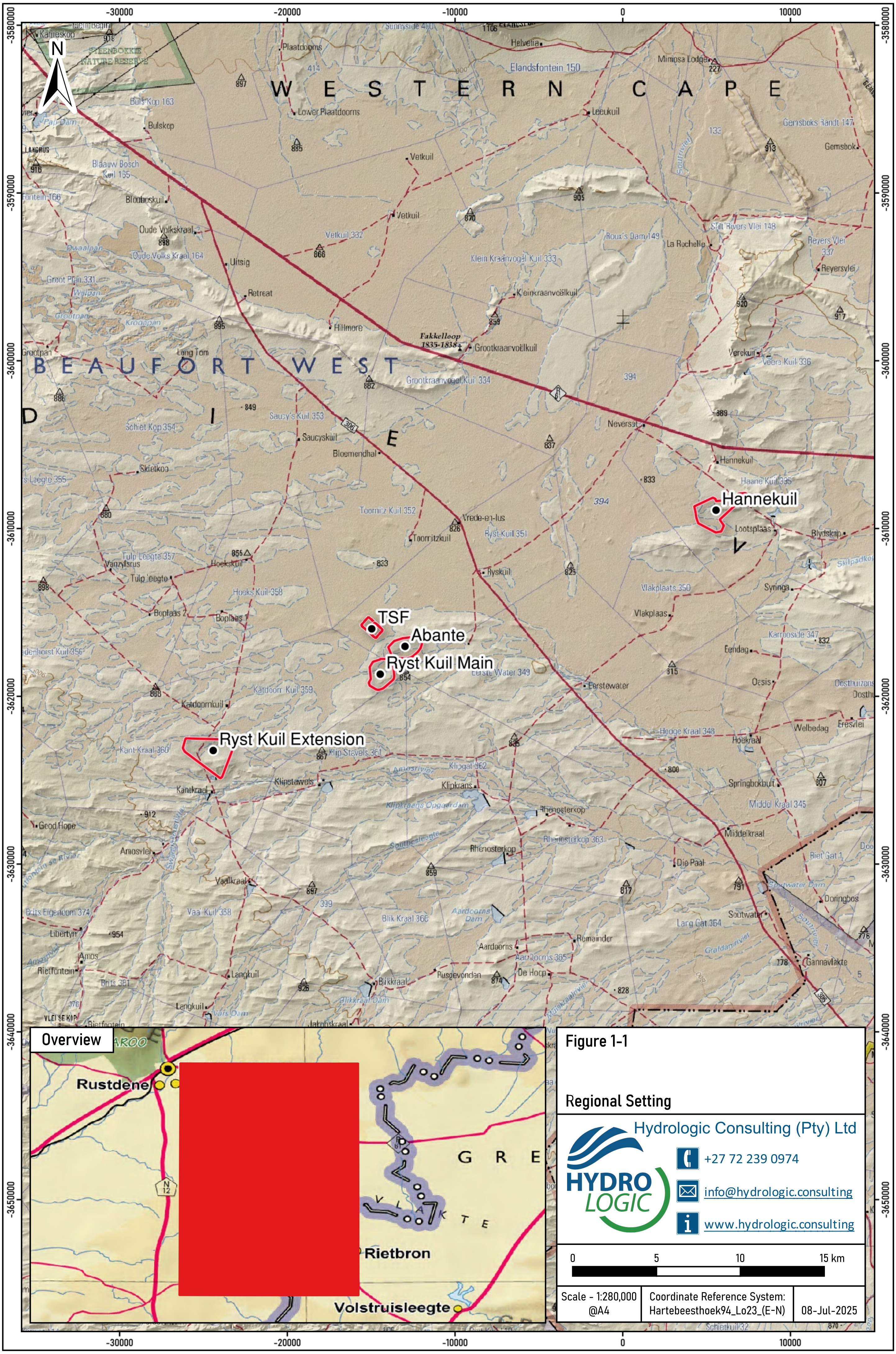

Figure 1-1

Regional Setting

Legend

- TSF - Phase 1
- TSF - Phase 2
- Abante
- Ryst Kuil Main
- CPP
- Open Pit
- ROM
- RWD
- Site Office, Stores & Changehouse
- Ancillary (CPP)
- Waste Rock Dump
- Site Road
- 100m Watercourse Buffer
- Dam (50K Topo)
- Dry Water Course (50K Topo)
- Furrow (50K Topo)
- Non-Perennial River (50K Topo)
- Footpath (50K Topo)

Figure 1-2

Layout Abante+RK Main

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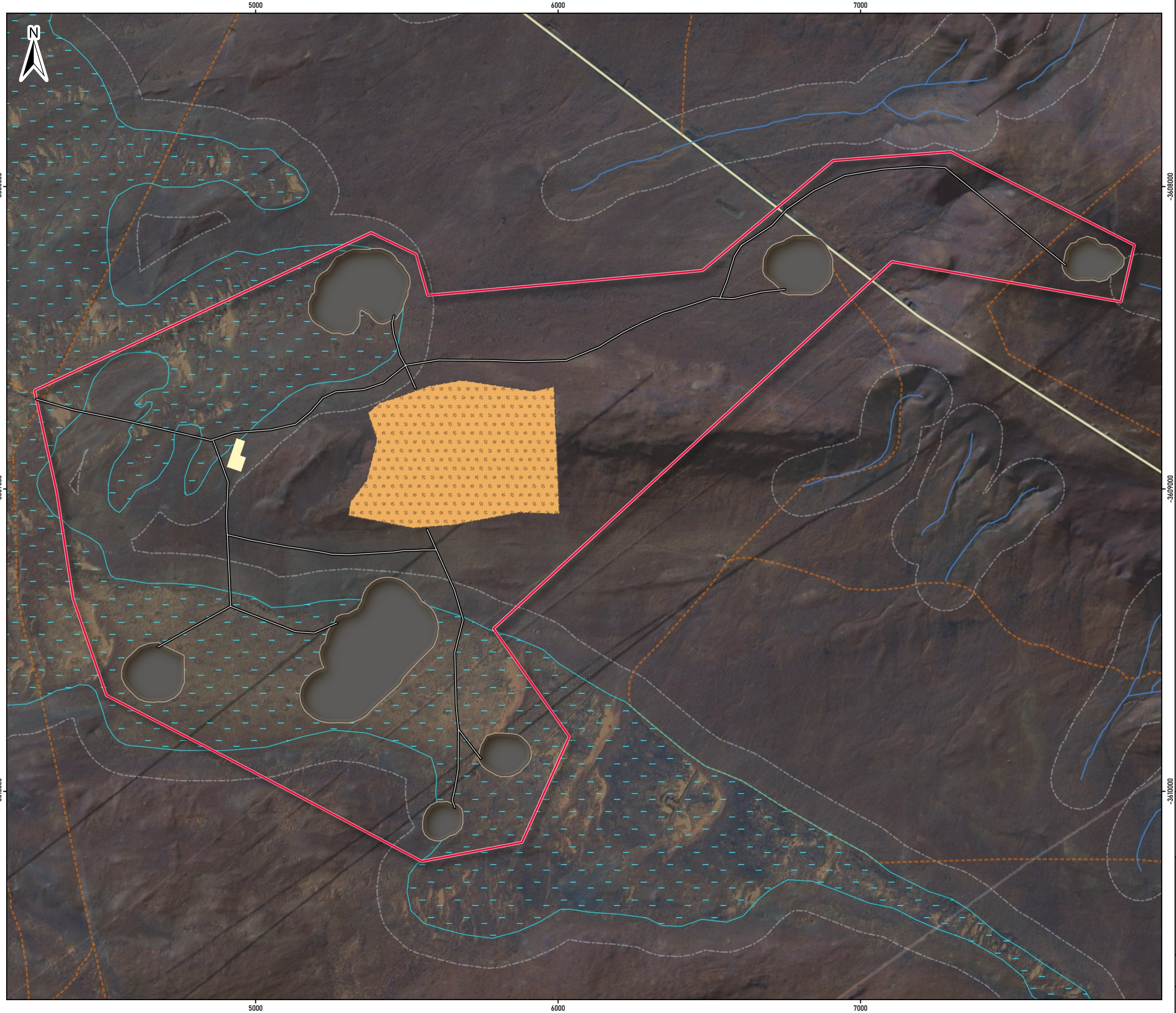
0 200 400 600 800 m

Scale - 1:17,000 @A3	Coordinate Reference System: Hartebeesthoek94_Lo23_(E-N)	10-Jul-2025



Legend

- Haanekuil
- Open Pit
- Site Office, Stores & Changehouse
- Waste Rock Dump
- Dry Water Course (50K Topo)
- Non-Perennial River (50K Topo)
- Site Road
- 100m Watercourse Buffer
- Footpath (50K Topo)
- Other Road (50K Topo)

Figure 1-3

Layout Hannekuil

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0 100 200 300 400 m

Scale - 1:11,709 @A3

Coordinate Reference System: Hartebeesthoek94_Lo23_(E-N)

10-Jul-2025

Legend

Layout Polygon

- Ryst Kuil Extension
- Open Pit
- Site Office, Stores & Changehouse
- Waste Rock Dump
- Site Road
- 500m Pan/Vlei Buffer
- 100m Watercourse Buffer
- Dam (50K Topo)
- Dry Pan (50K Topo)
- Dry Water Course (50K Topo)
- Furrow (50K Topo)
- Non-Perennial River (50K Topo)
- Footpath (50K Topo)
- Other Road (50K Topo)

Figure 1-4

Layout Ryst Kuil Extension

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0 100 200 300 400 m

Scale - 1:13,000 @A3	Coordinate Reference System: Hartebeesthoek94_Lo23_(E-N)	10-Jul-2025

2 BASELINE INFORMATION

Baseline information in this section includes rainfall, evaporation, design event rainfall, terrain, soils, vegetation and land-cover, as well regional and local topography 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. The closest SAWS station to the proposed infrastructure on the west side is SAWS station 70735 W (Klipkrans) located approximately 7km south-east of Ryst Kuil Main. This SAWS station has a record length of at least 79 years with a Mean Annual Precipitation (MAP) of 178mm. The closest SAWS station to the proposed infrastructure on the east site is SAWS station 71121 W (Verekuil) located approximately 8km north of Hannekuil. This SAWS station has a record length of at least 48 years with a Mean Annual Precipitation (MAP) of 207mm. There are no DWS rainfall stations in close proximity to the site.

The potential for rainfall distributions to change over distance can be significant as illustrated in Figure 2-1. There is also risk associated with reliance on a single rain gauge due to any potential error which may be associated with the data at a particular monitoring station. As such, an alternative and site-specific source of rainfall data was used to provide average monthly rainfall values for the actual site (west and east) as per Pegram *et al* (2016). This eliminates any risk associated with relying on a single rainfall station which may or may not be representative of the site.

Pegram *et al* (2016) includes details on the development of a raster database of monthly rainfall data for Southern Africa. Table 2-1 presents the site specific average monthly rainfall estimates from Pegram *et al* (2016) indicating a MAP of 205mm and 222mm for the west and east side of the site respectively, comparing well to the distribution of rainfall as illustrated in Figure 2-1, as well as SAWS stations in close proximity. Table 2-1 presents the average monthly rainfall estimates from Pegram *et al* (2016) for the site. This data has been used as the preferred monthly distribution of rainfall for the site.

TABLE 2-1: AVERAGE MONTHLY RAINFALL DISTRIBUTION (MM)

Month	Rainfall (mm)	
	West	East
Jan	20	22
Feb	26	29
Mar	32	35
Apr	21	22
May	13	13
Jun	8	7
Jul	8	9
Aug	10	11
Sep	10	11
Oct	16	18
Nov	21	23
Dec	19	22
Total	**205**	**222**

*Estimates were sourced for the points (32° 41′ 01" S, 22° 51′ 04" E and 32° 36′ 05" S, 23° 03′ 36" E)

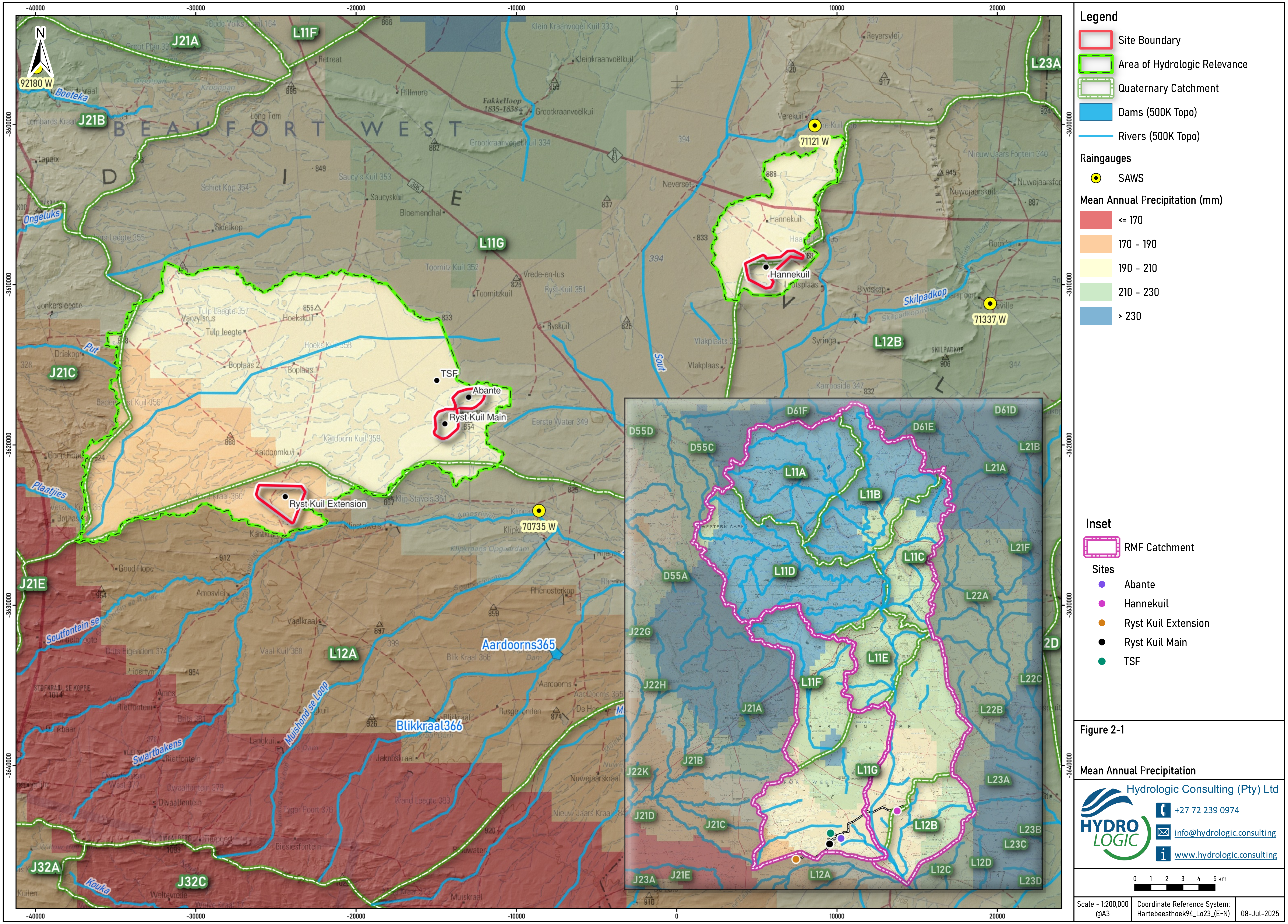


Figure 2-1

Mean Annual Precipitation

2.2 1-DAY DESIGN RAINFALL DEPTHS

For modelling flooding, design rainfall is one of the most important variables to consider as it is the driver behind runoff volumes and 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 design rainfall depths for the site at both West and East. Tables 2-3 and 2-4 present the design rainfall values for West and East across different times for the flood modelling, the data was obtained from DRESSA. Variations in design rainfall in the large catchments were noted and accounted for in modelling during the study. It is important to note, that no allowances for climate change have been made in this study. 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 potentially increases).

TABLE 2-2: 24-HOUR RAINFALL DEPTH

Recurrence Interval (Years)	DRESSA Rainfall Depth (24-hour) (mm)	
	West	East
2	34.7	40.2
5	51	59.1
10	62.9	72.9
20	75.2	87.3
50	92.6	107.4
100	106.8	123.8
200	121.9	141.3

* Estimates were sourced for the regions of relevance.

TABLE 2-3: 24-HOUR DESIGN RAINFALL DEPTH (MM) AT WEST

Recurrence Interval (Years)	DRESSA Rainfall Depth (mm)									
	5 m	10 m	15 m	30 m	60 m	2 h	3 h	6 h	12 h	24 h
2	5.8	8.3	10.3	12.7	14.3	15.6	17.6	19.2	22.7	25
5	8.5	12.3	15.2	18.7	21.1	23	26	28.3	33.4	36.7
10	10.5	15.1	18.7	23	26	28.4	32	34.9	41.1	45.3
20	12.6	18.1	22.4	27.6	31.1	33.9	38.3	41.8	49.2	54.2
50	15.5	22.3	27.6	33.9	38.3	41.8	47.1	51.4	60.6	66.7
100	17.9	25.7	31.8	39.1	44.2	48.1	54.4	59.2	69.8	76.9
200	20.4	29.4	36.3	44.7	50.4	55	62.1	67.6	79.7	87.8

* Estimates were sourced at West and represent average values (not upper or lower limits).

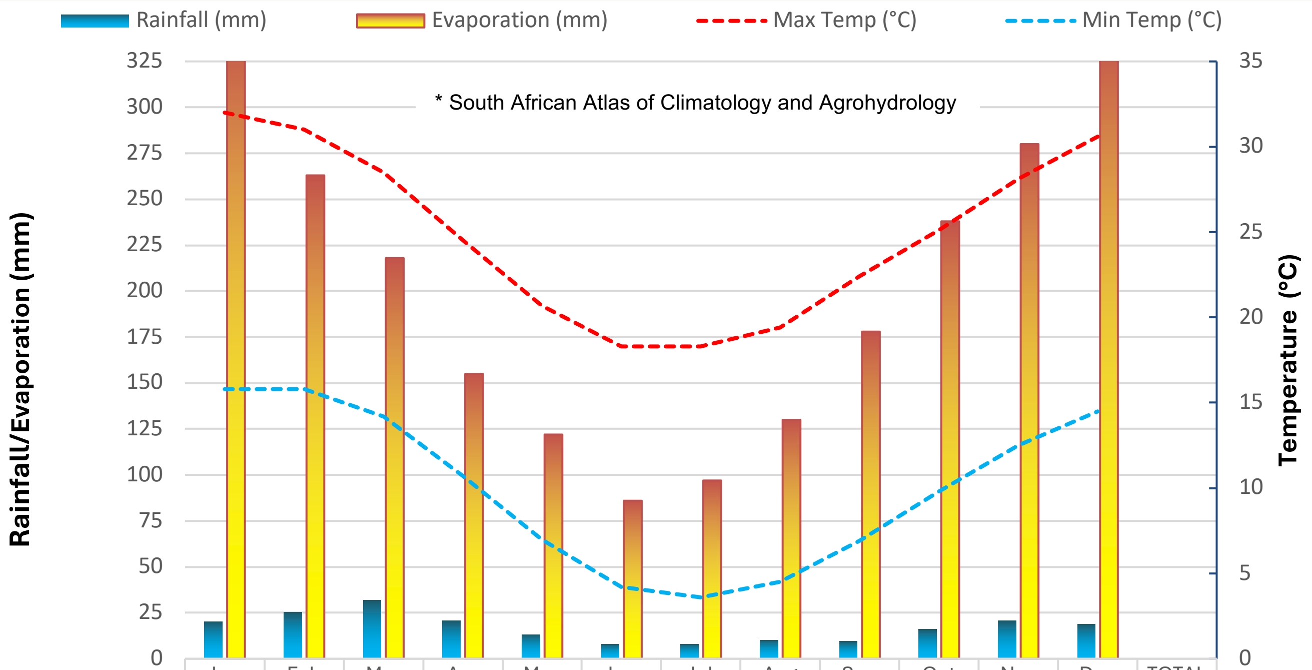
TABLE 2-4: 24-HOUR DESIGN RAINFALL DEPTH (MM) AT EAST

Recurrence Interval (Years)	DRESSA Rainfall Depth (mm)									
	5	10	15	30	60	2	3	6	12	24
	m	m	m	m	m	h	h	h	h	h
2	5.9	8.4	10.3	12.9	14.7	16.2	18.5	20.3	24.6	27.5
5	8.6	12.3	15.1	19	21.7	23.8	27.2	29.9	36.1	40.4
10	10.6	15.2	18.7	23.4	26.7	29.4	33.5	36.8	44.6	49.8
20	12.7	18.1	22.3	28	32	35.1	40.1	44.1	53.3	59.6
50	15.6	22.3	27.5	34.5	39.3	43.2	49.4	54.2	65.6	73.4
100	18	25.7	31.7	39.7	45.4	49.8	56.9	62.5	75.7	84.6
200	20.6	29.4	36.1	45.4	51.8	56.9	65	71.4	86.4	96.6

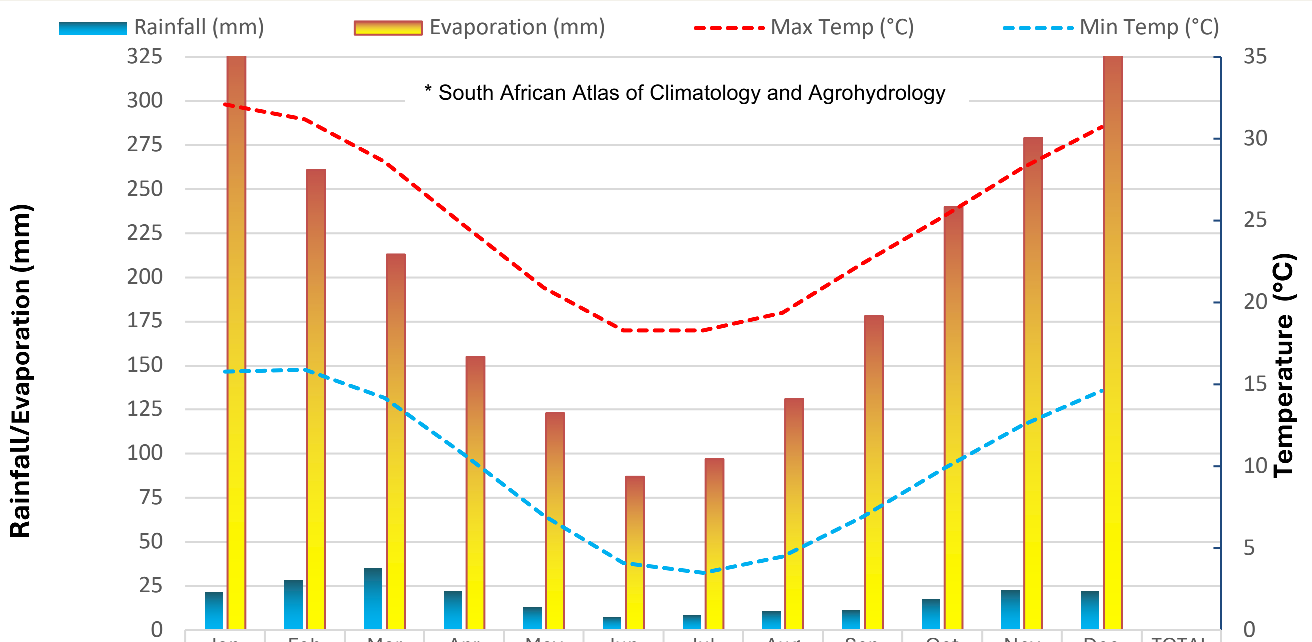
* Estimates were sourced at East and represent average values (not upper or lower limits).

2.3 AVERAGE CLIMATE

The average climate for the site is presented in Figures 2-1 and 2-2, for the West and East respectively using the outcome of the investigation into rainfall and evaporation for the site. 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 combination of rainfall (Pegram, 2016) and evaporation and temperature (Schulze and Lynch, 2006) results in a warm semi-desert hot arid, steppe climate according to the Köppen-Geiger climate classification . The West and East fall under the same Köppen-Geiger climate classification, there is negligible variation in the evaporation and rainfall as depicted in Tables 2-1 and 2-2.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
Rainfall (mm)	20	26	32	21	13	8	8	10	10	16	21	19	205
Evaporation (mm)	343	263	218	155	122	86	97	130	178	238	280	340	2450
Max Temp (°C)	32	31	28.5	24.5	20.7	18.3	18.3	19.4	22.4	25.1	28.1	30.6	
Min Temp (°C)	15.8	15.8	14.2	10.7	7	4.2	3.6	4.5	6.9	9.8	12.5	14.5	



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
Rainfall (mm)	22	29	35	22	13	7	9	11	11	18	23	22	222
Evaporation (mm)	342	261	213	155	123	87	97	131	178	240	279	338	2444
Max Temp (°C)	32.1	31.2	28.6	24.7	20.9	18.3	18.3	19.4	22.4	25.2	28.2	30.7	
Min Temp (°C)	15.8	15.9	14.2	10.7	7	4.1	3.5	4.5	6.9	9.8	12.5	14.6	

FIGURE 2-2: AVERAGE MONTHLY CLIMATE FOR THE EAST

2.4 TERRAIN

The following terrain (elevation) datasets were used in this study:

- 1m Digital Terrain Model (DTM) data, hereafter referred to as the 1m DTM;
- 30m digital surface model (DSM) COP30[1] data, hereafter referred to as the 30m DSM; and

The 1m DTM was derived from a lidar dataset (767 .xyz files) which provides a point cloud of the site. The lidar was interpolated to an elevation dataset with a resolution of 1m and presents a 'bare earth' model of the site and its surroundings, which is of value in hydrological modelling given the preference for a terrain without surface features such as buildings or vegetation.

However, it is important to note that the 1m DTM contains artefacts – specifically, scan line errors – which are anomalies or errors in the elevation data along a strip of the survey extent. Due to these artefacts, the 1m DTM has been superseded by the underlying terrain Copernicus 30-meter DSM in the affected area (Hannekuil). The extent of the artefact region in the 1m DTM is illustrated in Figure 2-3, with the exclusion of this artefact region delineated by the survey extent.

The 30m DSM represents the surface, inclusive of features such as vegetation and buildings (if captured by the coarse cell size). The natural setting of the upslope area (not covered by 1m DTM) limits the influence of vegetation for the 30m DSM.

Figure 2-3 illustrates the terrain of the site and includes a calculation of slope (for both the site and the area of hydrological relevance) most slopes within the area of hydrological relevance are below 3% with many slopes below 1%. This reveals the particularly flat nature of the site and surroundings. The elevations over the area of hydrological relevance and site range from approximately 950 - 824 m AMSL and 882 – 826 m AMSL respectively.

2.5 HYDROLOGY

Figure 2-3 illustrates the hydrological setting of the site, while Figure 2-1 presents the river network of the greater region. The site lies within the quaternary catchments L11G, L12A, and L12B. Figure 2-3 presents a more detailed illustration of the site's hydrological setting. The area of hydrological relevance to the site is illustrated in both figures and covers approximately 361.1 km^2 as defined by geoprocessing of the 30m DSM.

The 1:50,000 topographical map indicates the presence of several non-perennial rivers within the site and its surrounding area, dry watercourses that traverse the site, and several small dams. These non-perennial rivers are characteristic of the region's relatively low rainfall and flat terrain, which limits runoff generation and the formation of clearly defined flow paths. These poorly defined channels promote lateral diffuse flow between catchments.

[1] Copernicus Digital Elevation Model - Copernicus Contributing Missions Online

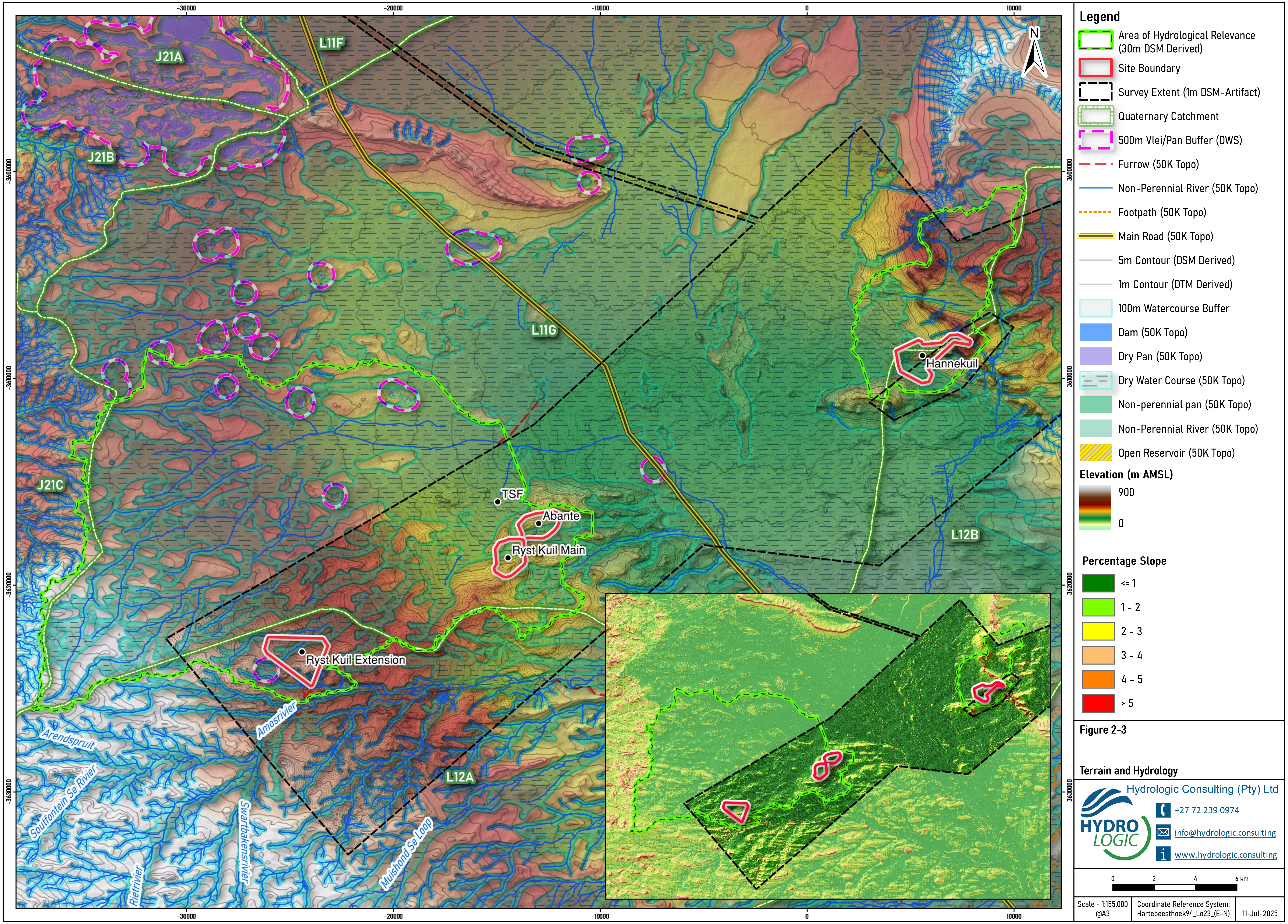


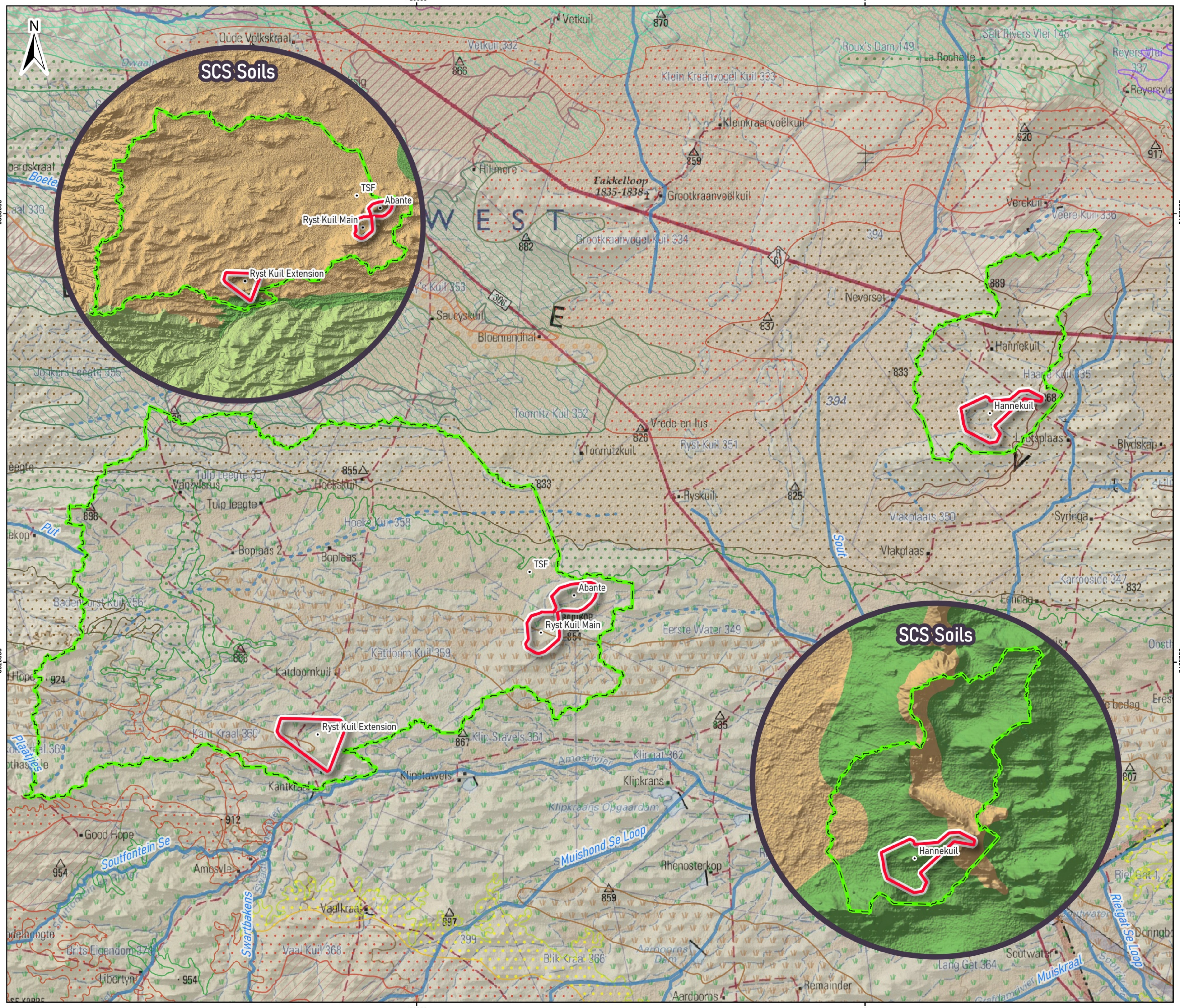
Figure 2-3

Terrain and Hydrology

2.6 SOILS, VEGETATION AND LAND-COVER

In considering the detailed Soil Conservation Service for South Africa (SCS-SA) dataset of the site, the western portion of the site is predominantly classified as hydrological soil group C, indicating moderately high runoff potential. The natural vegetation is Kouga Grassy Sandstone Fynbos, Sundays Arid Thicket, Saviaans Valley Thicket, and Willowmore Gwarrieveld (SANBI, 2018). A small portion of the upper catchment falls under group B, indicating moderately low runoff potential. In contrast, the eastern portion of the site is mainly classified as groups A/B, reflecting low to moderately low runoff potential, with a small central section classified as group C. The natural vegetation in the East is predominantly classified as Sundays Arid Thicket and Albany Alluvial Vegetation (according to SANBI, 2018). The variation in runoff potential influences the generation and movement of surface runoff across the site. Land-cover on the site is mostly classified as 'shrubland' according to the Department of Environmental Affairs (DEA) 2020 dataset.

Figure 2-4 presents the distribution of the SCS soil types (runoff potential) and natural vegetation while Figure 2-5 illustrates the land-cover in the region around the site. The site's semi-arid desert climate is characterised as having highly seasonal low rainfall, hot-dry summers, and cold winters. The climate is well-suited for the presence of Karoo shrubland, which thrives in warm, dry conditions typical of plains and lower slopes as detailed by the DEA, 2022 dataset presented in Figure 2-5.



Legend

- Area of Hydrological Relevance (30m DSM Derived)
- Site Boundary

SANBI Vegetation Atlas (2018)

- Willowmore Gwarrieveld
- Vanstadens Forest Thicket
- Suurberg Quartzite Fynbos
- Sundays Valley Thicket
- Sundays Arid Thicket
- Steytlerville Karoo
- Southern Karoo Riviere
- Southern Afrotemperate Forest
- Kouga Sandstone Fynbos
- Kouga Grassy Sandstone Fynbos
- Grootrivier Quartzite Fynbos
- Eastern Gwarrieveld
- Baviaans Valley Thicket
- Albany Alluvial Vegetation

SCS Soils Runoff Potential

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

Figure 2-4

Vegetation and Soil Runoff Potential

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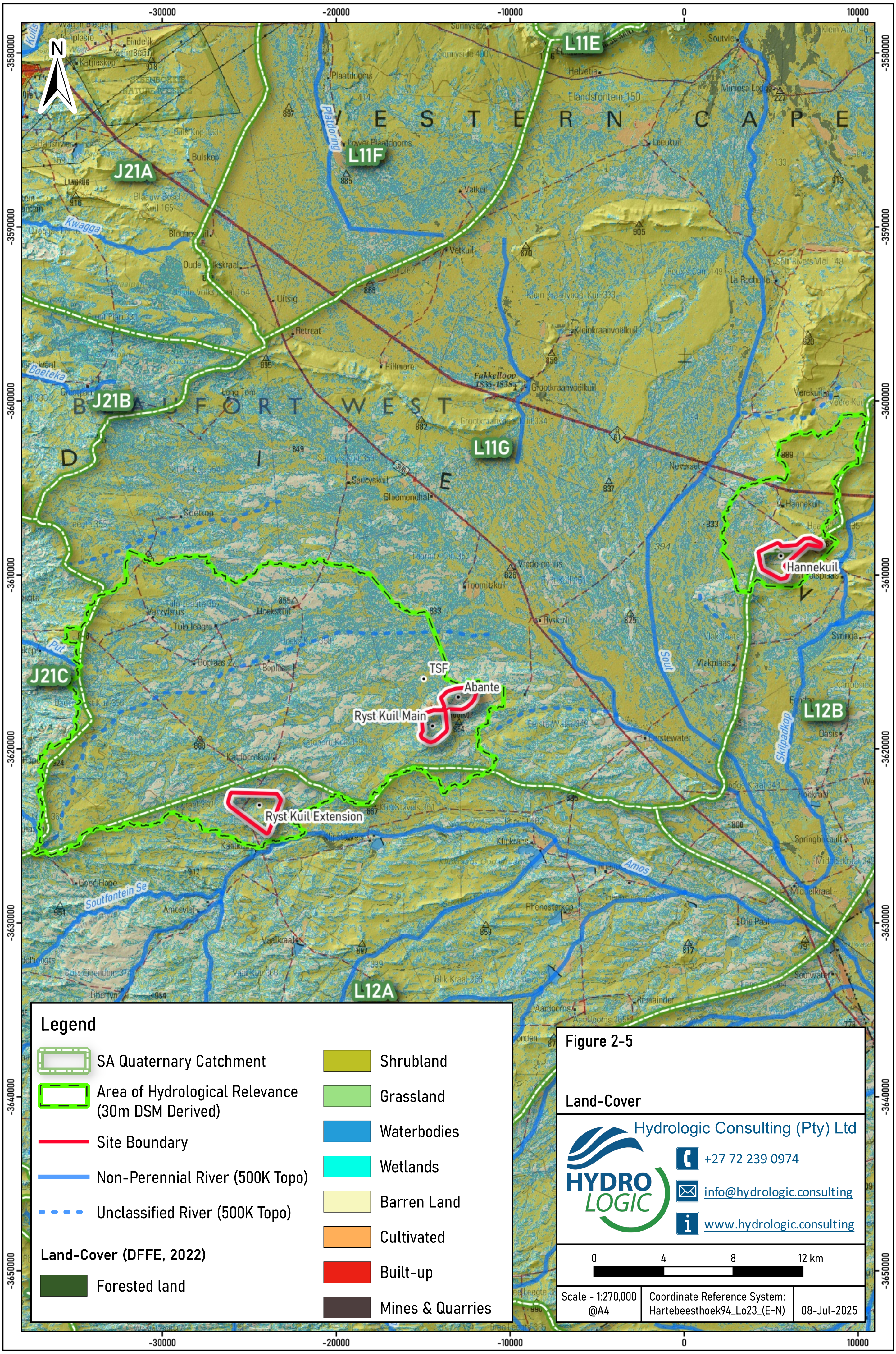


Figure 2-5

Land-Cover

3 APPLICABLE GUIDANCE

The guidance that informs the hydrological assessment outlined in this report includes the following:

- National Water Act (Act No. 36 of 1998) includes Section 21 water uses which require authorisation from the Department of Water and Sanitation (DWS).
- Government Notice 704 (Government Gazette 20118 of June 1999) which provides regulations on the use of water for mining and related activities aimed at the protection of water resources;

3.1.1 NATIONAL WATER ACT

Definitions applicable to the identification of Section 21 water uses as defined by the National Water Act (Act No 36 of 1998) consist of:

- *"Watercourse"* including:
  - a river or spring;
  - a natural channel in which water flows regularly or intermittently; or
  - a wetland, lake or dam into which, or from which, water flows.
- *"Water resource"* – which includes a watercourse, surface water, estuary, or aquifer;

3.2 GN 704

The Department of Water Affairs and Forestry (now the Department of Water and Sanitation), established GN 704 under the National Water Act (Act No. 36 of 1998) to provide regulations on the use of water for mining and related activities aimed at the protection of water resources.

3.2.1 IMPORTANT DEFINITIONS IN GN 704

- **Activity**: (a) any mining related process on the mine including the operation of washing plants, mineral processing facilities, mineral refineries and extraction plants, and (b) the operation and the use of mineral loading and off-loading zones, transport facilities and mineral storage yards, whether situated at the mine or not,
  - (i) in which any substance is stockpiled, stored, accumulated or transported for use in such process; or
  - (ii) out of which process any residue is derived, stored, stockpiled, accumulated, dumped, disposed of or transported;

- **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).

3.2.2 APPLICABLE CONDITIONS IN GN 704

The principal conditions of GN 704 applicable to 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 the DWS may in writing, authorise an exemption to instances of GN 704 non-compliance

4 FLOODING ASSESSMENT

The flood assessment involved the development and simulation of two separate models: a surface water flood model and a fluvial flood model. These models were used to assess flood risk for two recurrence intervals: 1:50-year and 1:100-year.

The surface water flood model employed a rain-on-mesh approach to simulate flooding over the proposed development for both 1:100-year and 1:50-year recurrence interval (RI) flood events. The fluvial flooding was simulated along the Amos non-perennial river, that lie to the South of Ryst Kuil Extension.

In addition to these models, a high-level Regional Maximum Flood (RMF) flooding assessment was also conducted to provide an understanding of the flood risk to the two sites from the primary watercourse diving them (the Sout River).

Modelling results are described in this section, while the details of the flood modelling are presented in Appendix A. Since the modelling of flooding is (as undertaken) an approximation of reality, various assumptions and limitations are relevant (when considering the model results). These have been highlighted at various places in this report and are also outlined in Appendix A.

4.1 APPLICABLE GUIDANCE

GN 704 Condition 4 (Restrictions on locality) indicates that no person in control of a mine or activity may:

- 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;

As noted by Figure 2-3, the majority of the site is within a 100m of a watercourse and flood modelling is consequently highly relevant to understanding potential flood risk.

4.2 REGIONAL MAXIMUM FLOOD APPROACH

The expanse of the site on either side of a central basin near the upper middle catchment necessitated the need for a broader regional approach, namely the Regional Maximum Flood (RMF) method. This empirical method was adopted as it can be used to produce a regional flood frequency curve based upon homogenous catchments (du Plessis & Masule, 2023). In Section 2.4., it was mentioned that poorly defined channels promote lateral diffuse flow between catchments, due to the very low slopes in the region about the site. Accordingly, the application of the RMF was undertaken to determine the extent of this diffuse flow. Further information on the RMF method is provided in Appendix A. Figure 4-1 presents the outcome of the RMF investigation and illustrates that the Sout River does not affect the site.

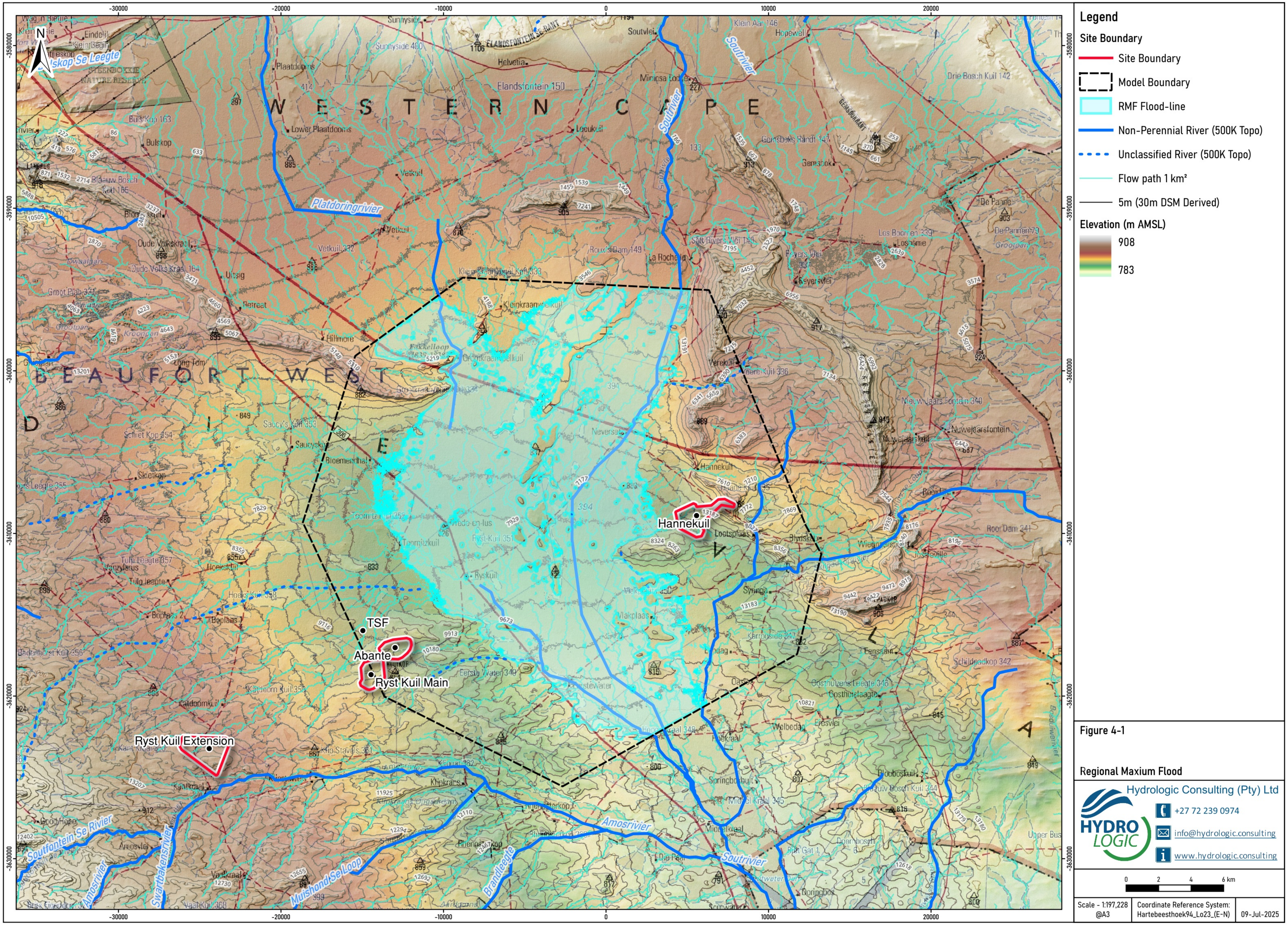


Figure 4-1

Regional Maxium Flood

4.3 SURFACE WATER FLOODING ASSESSMENT (RAIN-ON-MESH)

A rain-on-mesh approach was adopted for the West and East Area of Hydrological Relevance (approximately 315 km^2 and 46 km^2; see Figure 2-1), which also acted as the 2D flood model boundary. The area of hydrological relevance, or rather the 2D model boundary, was intentionally chosen to be larger than the site-specific catchment (118.22 km^2) to include neighbouring areas. The 1m DTM was the dominant terrain dataset utilised, although the 30m DSM was used as a supplementary dataset, including its use in the 'artefact region' which affected the modelling of flooding at Hannekuil. There are potentially additional areas of the flood model that used the 1m DSM that may also have terrain artefacts (scan lines).

The topographic conditions discussed in Section 2.4 facilitate the lateral spreading of runoff and enhance connectivity between adjacent catchments. Consequently, water flow is not confined to discrete channels but instead disperses across the landscape, increasing the potential for inter-catchment exchange. By extending the model boundary beyond the site-specific catchment, the model effectively captures these complex hydrological processes. This approach ensures that cross-boundary hydrological interactions (or just interplay among bordering catchments)—particularly during high-flow or flood events—are represented within the model.

The rain-on-mesh approach enables a distributed assessment of runoff generation (the rainfall-infiltration-runoff process), the attenuating influence of any depressions in the detailed terrain, the accumulation of flow, and any interaction between flow paths (where neighbouring catchments may spill at a certain depth of flow and become relevant to the site)

The first aspect of the flood modelling considered was the development of a suitable design hyetograph for each of the multiple design events of interest. These were calculated using a symmetric distribution of the DRESSA rainfall depths referred to in Section 2.1.1.

The rain-on-mesh model simulates rainfall falling over the surface, some of which infiltrates, with the remainder becoming runoff that is routed by the model mesh (as informed by the available terrain data). The simulation of infiltration adopted the SCS Curve number infiltration method, which was parameterised (in part) according to the SCS-SA soil type (group C/D and C) mentioned in Section 2.5.

4.4 FLUVIAL FLOODING ASSESSMENT

The 1m DTM covered the relevant reach of the Amos River selected for modelling. To simulate the flooding for the river, the standard design flooding (SDF) method was used to estimate 1:50-year and 1:100-year RI hydrographs. These hydrographs were applied to the upstream end of the river reach.

The availability of continuous DTM data allowed for the adoption of a 2D flood model approach using HEC-RAS. Unlike a 1D approach (using cross-sections), which samples the DTM at set cross-section locations, a 2D model approach uses a continuous model grid. The advantage of a 2D model is consequently its ability to account for more variation in the topographic data since no gaps are present in the model geometry (as is the case with cross sections).

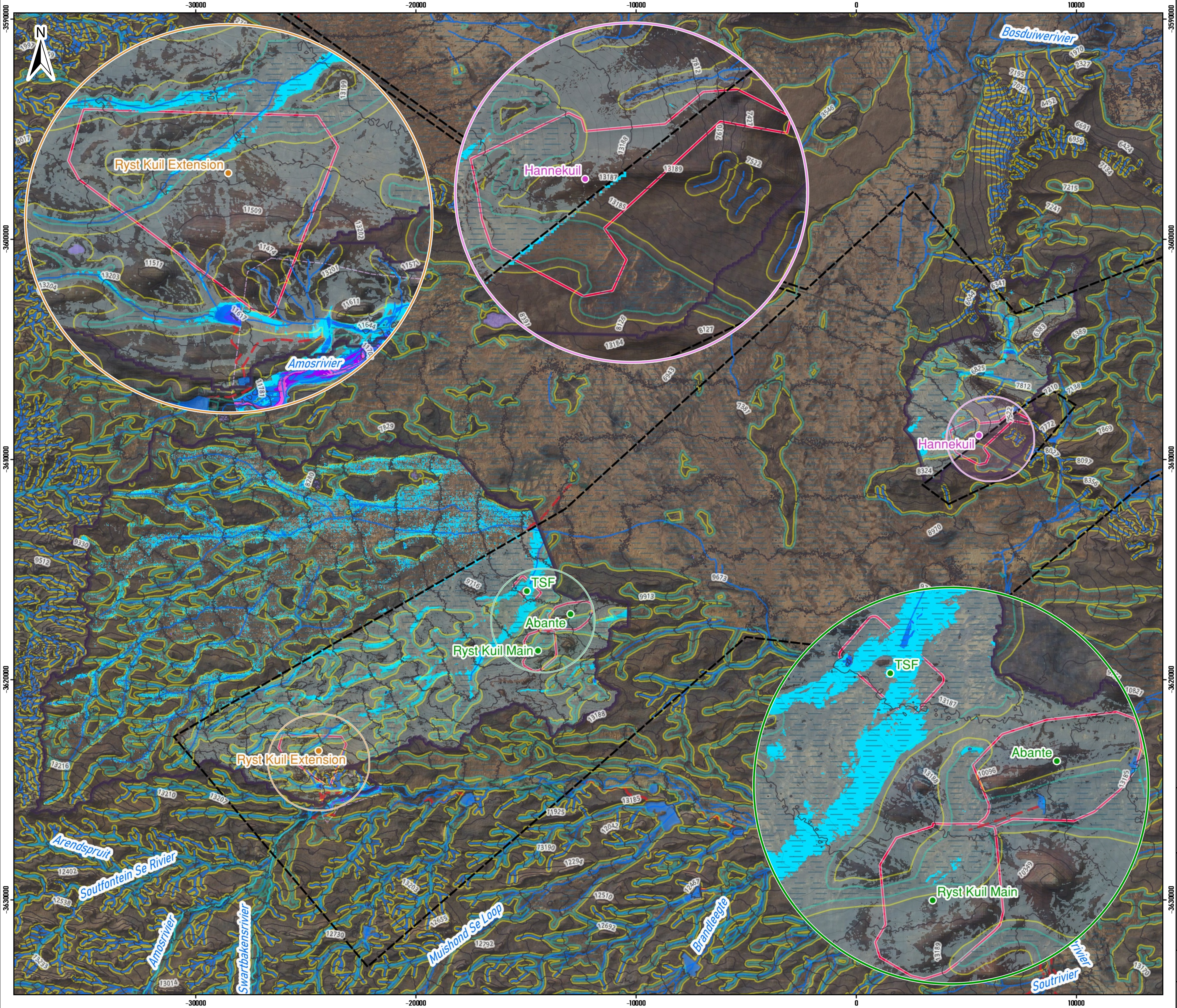
4.5 OVERALL FLOOD MODELLING RESULTS – STATUS QUO

Unlike fluvial flood modelling, flood lines for surface water flooding cannot be defined due to the absence of simulated flooding along clearly defined river channels (rain-on-mesh simulations produce flooding in all locations, even if shallow). To compensate for this (flooding shown everywhere), the maximum depth of flooding illustrated is for depths greater than 0.2m (depths below 0.2m use a faded colour in the Figures).

The maximum flood depths for the 1:50-year and 1:100-year return period events are presented in Figures 4-2 and 4-3, along with a 100m watercourse buffer defined according to the 1:50,000 topographical map data. For the 1:100-year event, the surface water flooding predominantly indicates flood depths that do not exceed 0.5m. These relatively low depths are due to the very low slopes of the site and surrounds and the absence of defined river channels, which means flood waters can spread out, limiting areas of appreciable depth. The proposed location of the TSF is an exception where flooding exceeds 0.5m. This is an indication of the concentration of flow at this location, which should be considered with regards to flooding protection of both the TSF and surrounds (including the CPP and ROM)

Figure 4-2 and 4-3 illustrate significant flood depths exceeding 2.5m along the south of Ryst Kuil Extension (Amos River) but these depths do not affect the site.

The velocity results for the flood modelling are presented in Figures 4-4 and 4-5, showing medium velocities (predominantly < 0.4 m/s) across the proposed development area with small spots of higher velocities (<0.8m/s).



Legend

- Site Boundary
- Survey Extent (1m DTM-Artifact)
- 2D Fluvial Model Boundary
- 2D ROM Model Boundary
- 100m Watercourse Buffer
- Dam (50K Topo)
- Dry Pan (50K Topo)
- Dry Water Course (50K Topo)
- Non-perennial pan (50K Topo)
- Non-Perennial River (50K Topo)
- Furrow (50K Topo)
- Non-Perennial River (50K Topo)
- 1m Contour (DTM Derived)
- 5m Contour (DSM Derived)

1:50 - Max. Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- > 1.5

Figure 4-2

Maximum Flood Depth (1:50 RI)

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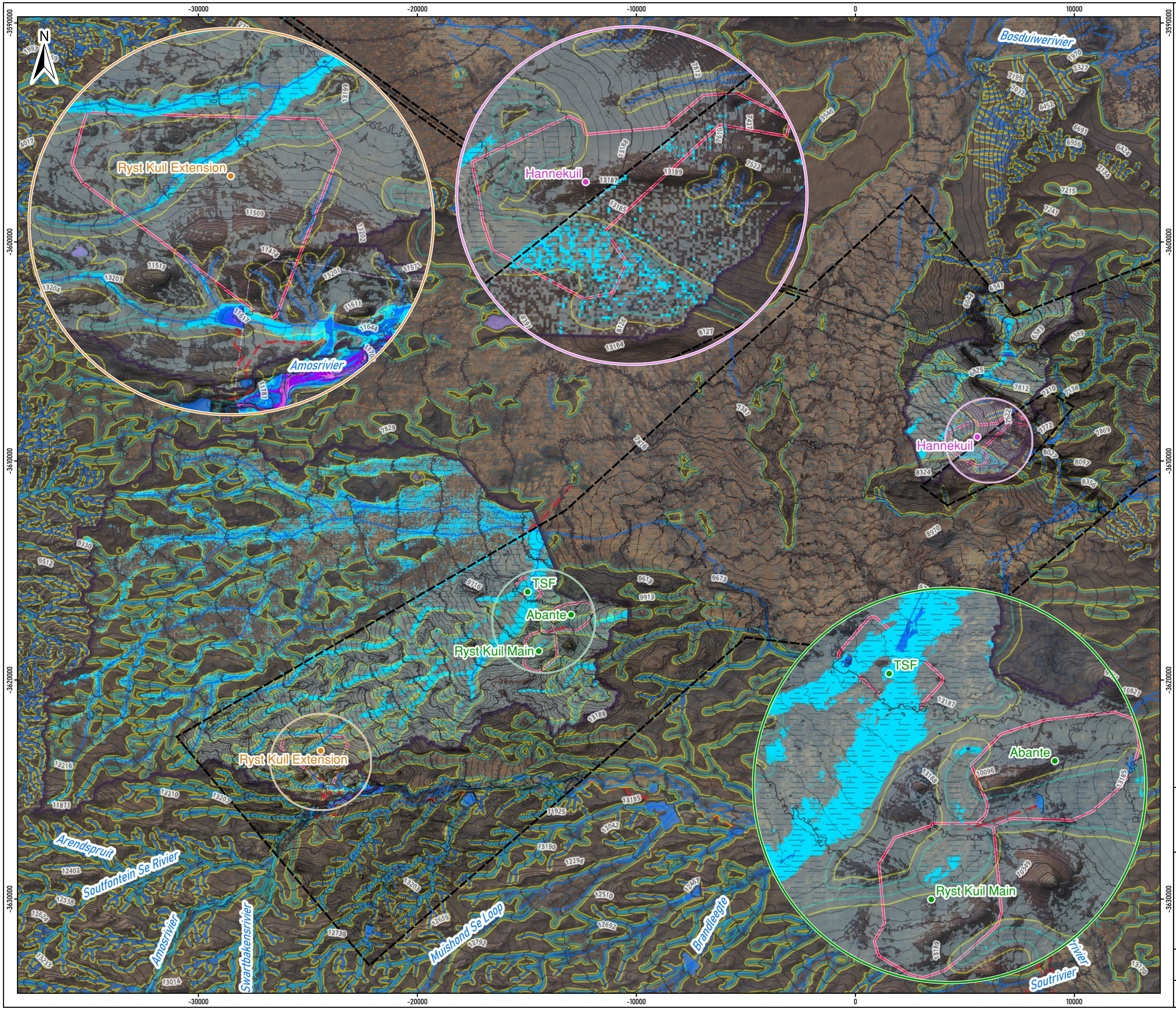
0 2 4 6 km

Scale - 1:160,000 @A3	Coordinate Reference System: Hartebeesthoek94_Lo23_(E-N)	16-Jul-2025



Legend

- Site Boundary
- Survey Extent (1m DTM-Artifact)
- 2D Fluvial Model Boundary
- 2D ROM Model Boundary
- 100m Watercourse Buffer
- Dam (50K Topo)
- Dry Pan (50K Topo)
- Dry Water Course (50K Topo)
- Non-perennial pan (50K Topo)
- Non-Perennial River (50K Topo)
- Furrow (50K Topo)
- Non-Perennial River (50K Topo)
- 1m Contour (DTM Derived)
- 5m Contour (DSM Derived)

1:100 - Max. Depth (m)

- <= 0.2
- 0.2 - 0.5
- 0.5 - 1.0
- 1.0 - 1.5
- > 1.5

Figure 4-3

Maximum Flood Depth (1:100 RI)

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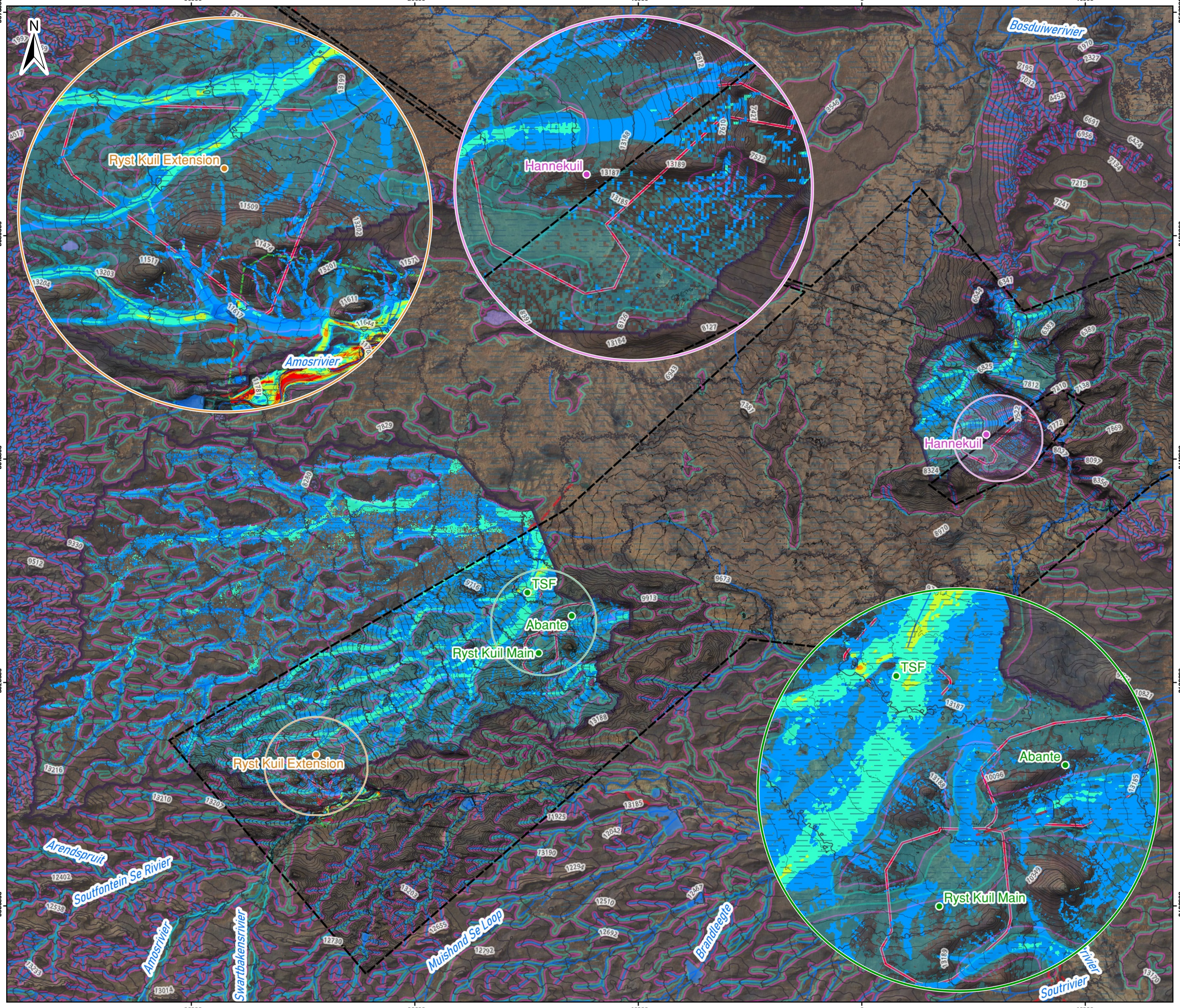
0 2 4 6 km

Scale - 1:160,000 @A3	Coordinate Reference System: Hartebeesthoek94_Lo23_(E-N)	11-Jul-2025



Legend

- Site Boundary
- Survey Extent (1m DTM-Artifact)
- 2D Fluvial Model Boundary
- 2D ROM Model Boundary
- 100m Watercourse Buffer
- Dam (50K Topo)
- Dry Pan (50K Topo)
- Dry Water Course (50K Topo)
- Non-perennial pan (50K Topo)
- Non-Perennial River (50K Topo)
- Furrow (50K Topo)
- Non-Perennial River (50K Topo)
- 1m Contour (DTM Derived)
- 5m Contour (DSM Derived)

Maximum Flood Velocity (1:50 RI)

- <= 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1.0
- 1.0 - 2.0
- > 2.0

Figure 4-4

Maximum Flood Velocity (1:50 RI)

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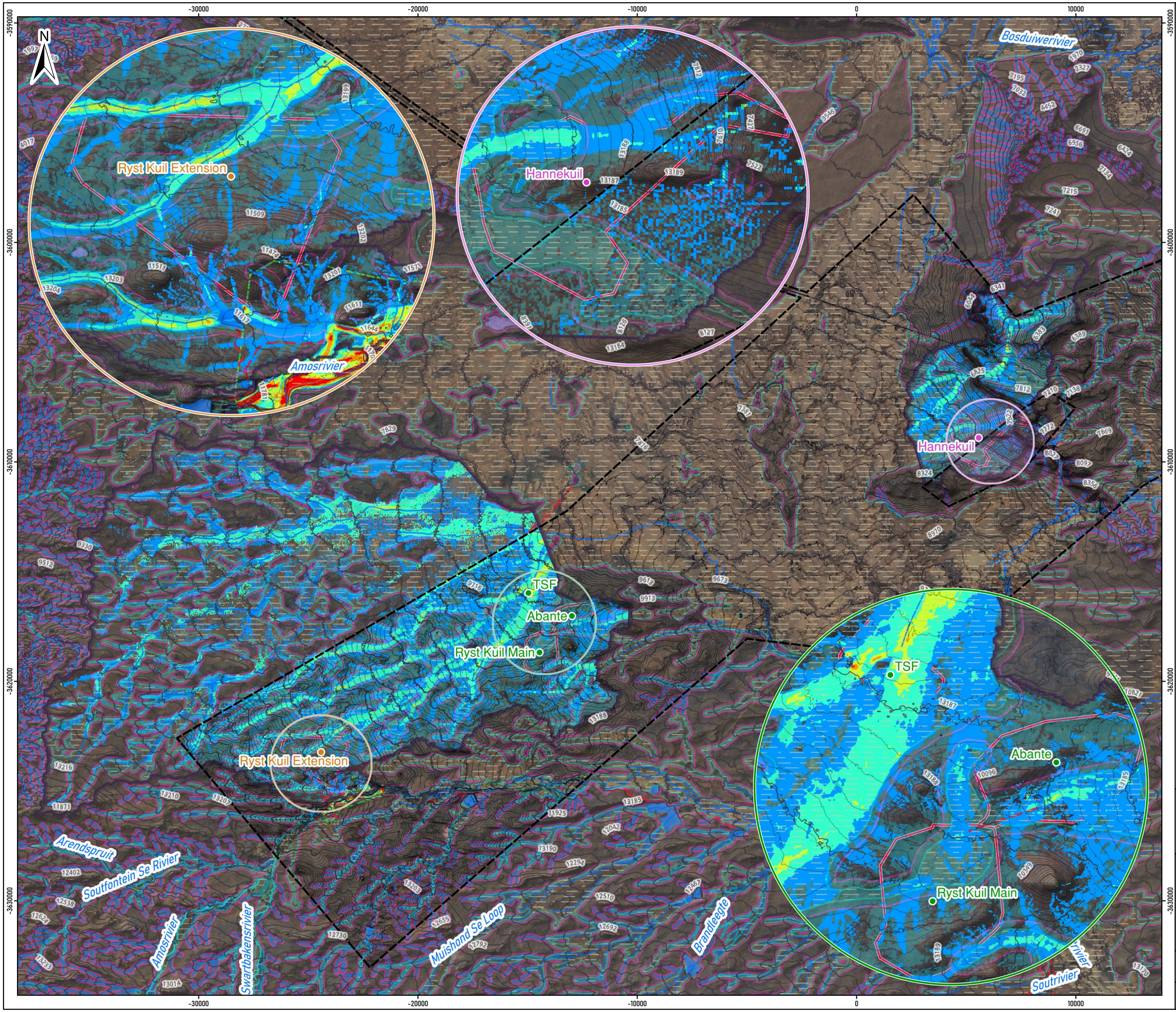
0 2 4 6 km

Scale - 1:160,000 @A3	Coordinate Reference System: Hartebeesthoek94_Lo23_(E-N)	16-Jul-2025



Legend

- Site Boundary
- Survey Extent (1m DTM-Artifact)
- 2D Fluvial Model Boundary
- 2D ROM Model Boundary
- 100m Watercourse Buffer
- Dam (50K Topo)
- Dry Pan (50K Topo)
- Dry Water Course (50K Topo)
- Non-perennial pan (50K Topo)
- Non-Perennial River (50K Topo)
- Furrow (50K Topo)
- Non-Perennial River (50K Topo)
- 1m Contour (DTM Derived)
- 5m Contour (DSM Derived)

Maximum Flood Velocity (1:100 RI)

- <= 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1.0
- 1.0 - 2.0
- > 2.0

Figure 4-5

Maximum Flood Velocity (1:100 RI)

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0 2 4 6 km

Scale - 1:160,000 @A3	Coordinate Reference System: Hartebeesthoek94_Lo23_(E-N)	11-Jul-2025

5 CONCEPTUAL STORMWATER MANAGEMENT PLAN

The proposed mining operation will alter the natural environmental state, thereby affecting the generation of stormwater. Volumes of stormwater generated over areas disturbed by mining operations are generally expected to increase because of the reduction in natural vegetation and removal/compaction of soils, while the quality of the stormwater generated is expected to decrease due to the nature of mining operations. Therefore, the purpose of this section is to produce a conceptual level SWMP by which clean and dirty water-generating areas are first identified and then managed appropriately. This stormwater management plan is based upon the principles presented in the DWS Best Practice Guideline G1 for Stormwater Management (BPG1).

5.1 AREAS REQUIRING MANAGEMENT

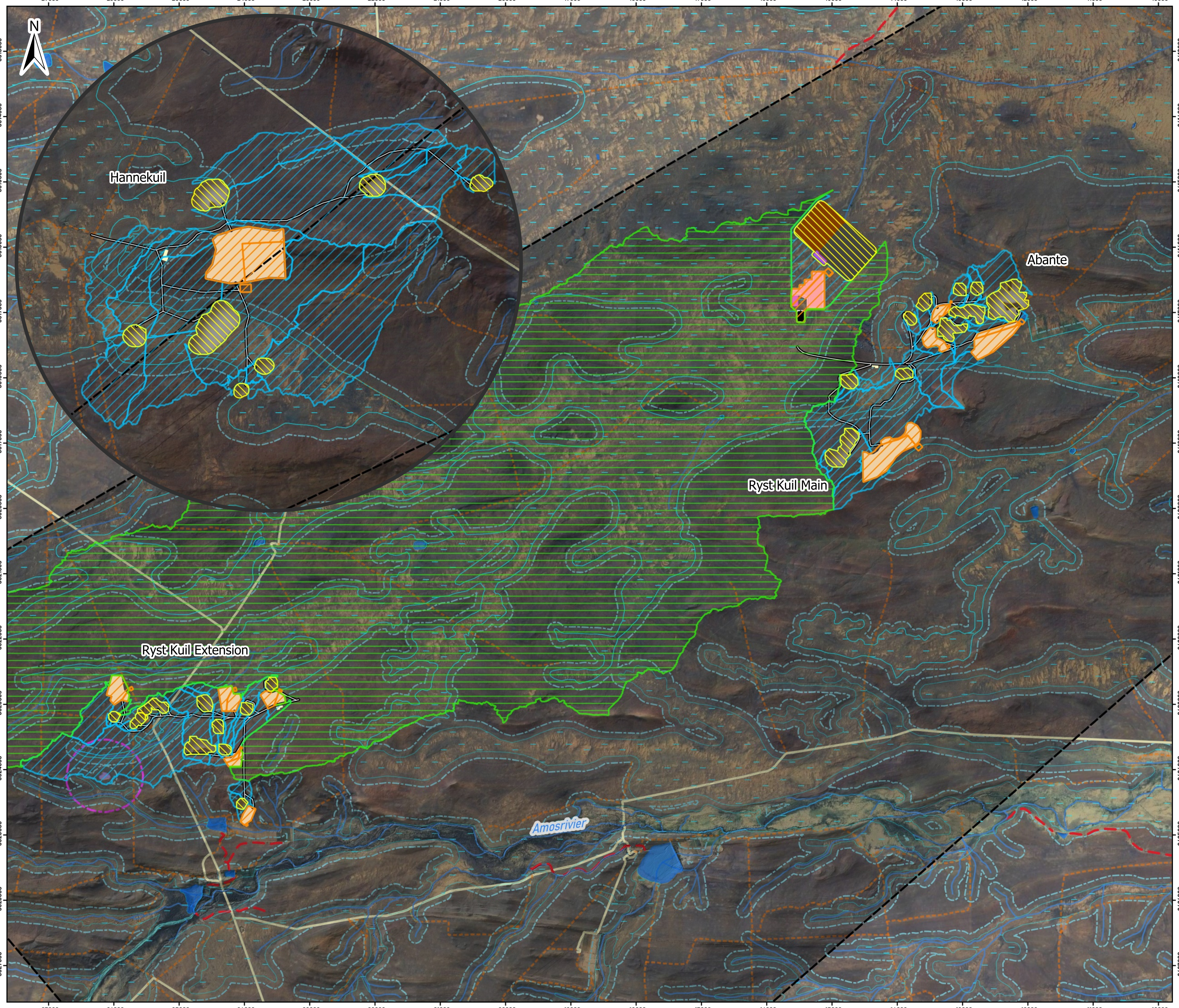
In Figure 5-1, areas requiring pollution control (i.e. dirty areas) have been delineated based upon the layout, originally presented in Figure 1-2. The SWMP has been based upon the mine in its fully developed state, inclusive of both TSF Phases 1 and 2.

A constraint in the development of the SWMP was the position of infrastructure within defined watercourses, which means that the stormwater management necessary to achieve GN 704 compliance is unavoidably placed within areas which will require a GN 704 exemption with regard to flood risk. It should also be noted that the stormwater infrastructure has been designed (conceptualised) around stormwater management and not flood protection. Additional flood protection may be necessary, particularly in the case of pollution control dams (PCDs), where the consequence of failure is considerable.

Clean areas are identifiable as both defined clean areas and areas without a clean or dirty classification (i.e. where there is only aerial imagery in Figure 5-1). These additional clean areas have not been formally recognised since they either do not flow into the operation (therefore do not require diversion around the operation) or are located on the operation but do not require diversions to route them away from dirty areas. Clean areas may, however, have occasional spills of dirty material requiring periodic cleaning of this material.

Dirty areas are also delineated; however, there is a differentiation depending on the type of dirty area, with typical dirty areas and 'self-contained' dirty areas (specific to the pits and TSF) illustrated. The self-containment of the pits has been reinforced through the use of proposed berms (where no diversion and berm is present). The TSF has been delineated as a dirty (self-contained) area; however, no management beyond the diversion of clean areas has been proposed since the design of the TSF will require specific engineering beyond this report's detail.

The remaining dirty areas and defined clean water areas are consequently the focus of this section since they require management (diversion) and containment (within suitability-sized PCDs). Dirty diversions are used to divert water towards PCDs, while berms act as partitions to define dirty areas more clearly, as well as creating a partition between clean areas. In most instances, clean and diversions include a berm element (to create a partition between clean and dirty areas); however, there are locations at Hannekuil where the clean diversion excludes a berm (to allow inflow from both sides).



Legend

Survey Extent (1m DTM-Artifact)	
Clean and Dirty Areas	
Clean	
Dirty	
Self-Contained (Dirty)	
Clean (Flood model Outputs)	
Layout	
TSF - Phase 1	
TSF - Phase 2	
CPP	
Ancillary (CPP)	
Open Pit	
ROM	
RWD	
Site Office, Stores & Changehouse	
Waste Rock Dump	
Site Road	
Dam (50K Topo)	
Dry Pan	
Dry Water Course (50K Topo)	
Non-Perennial River	
Furrow (50K Topo)	
Non-Perennial River (50K Topo)	
Footpath (50K Topo)	
Other Road (50K Topo)	
500m Pan/Vlei Buffer	
100m Watercourse Buffer	

Figure 5-1

Dirty and Clean Areas

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0 700 1,400 2,100 m

Scale - 1:54,729 @A3	Coordinate Reference System: Hartebeesthoek94_Lo23_(E-N)	11-Jul-2025

It should also be noted that due to the very low slopes of the surrounding areas, clean diversions have utilised the natural landscape to enhance conveyance. This has been done by keeping one side slope at 1:2 (for the berm) and the other side slope at 1:50 or 1:100 (depending on terrain and model needs; see slope in Figure 2-3).

Site roads have not been specifically assessed with regard to this SWMP, given their linear nature and the uncertainty as to which sections of internal roads will experience possible spillage of excavated material (thereby being deemed dirty areas). This SWMP should be revised based on the final expected section of haul roads that are likely to experience regular spillage of excavated material. Haul roads not within a dirty area routing to a PCD, should have regular clean-up of spilt material undertaken as part of their management.

5.1.1 FUELS, LUBRICANTS AND CHEMICALS

The storage/handling of fuel, lubricants and chemicals will require special attention due to their hazardous nature as is the case with the diesel and oil bay. 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 from part of this conceptual SWMP.

5.2 STORMWATER MANAGEMENT INFRASTRUCTURE

Stormwater management infrastructure has been conceptually designed in this report as per the requirements of GN 704 and BPG1 using the 1:50 year RI event. No account has been taken of climate change and any potential future increases in rainfall depth or intensity. These will need to be considered depending on the expected life of the structure.

Figures 5-2 to 5-6 illustrates the conceptual SWMP for the site, while Appendix B presents details relating to the development of the SWMP using PCSWMM, which is based on the Stormwater Management Model (Rossman, 2008). Sizing of diversions has been based upon a review of the layout, land-cover, soils and terrain of the relevant area.

Legend

- Site Boundary
- Survey Extent (1m DTM-Artifact)
- 100m Watercourse Buffer
- Dry Water Course (50K Topo)
- Non-Perennial River (50K Topo)
- Footpath (50K Topo)
- Other Road (50K Topo)
- 1m Contour (DTM Derivived)
- Outfall
- Junction
- Storage
- Berm
- Clean Diversion (Berm and Channel)
- Clean Diversion (Channel)
- Dirty Diversion (Berm and Channel)
- overland
- Routing

Clean and Dirty Areas

- Clean
- Dirty
- PCD (Dirty)
- Self-Contained (Dirty)

Layout

- Open Pit
- Site Office, Stores & Changehouse
- Waste Rock Dump
- Site Road

Figure 5-2

Conceptual Stormwater Management Plan Hannekuil

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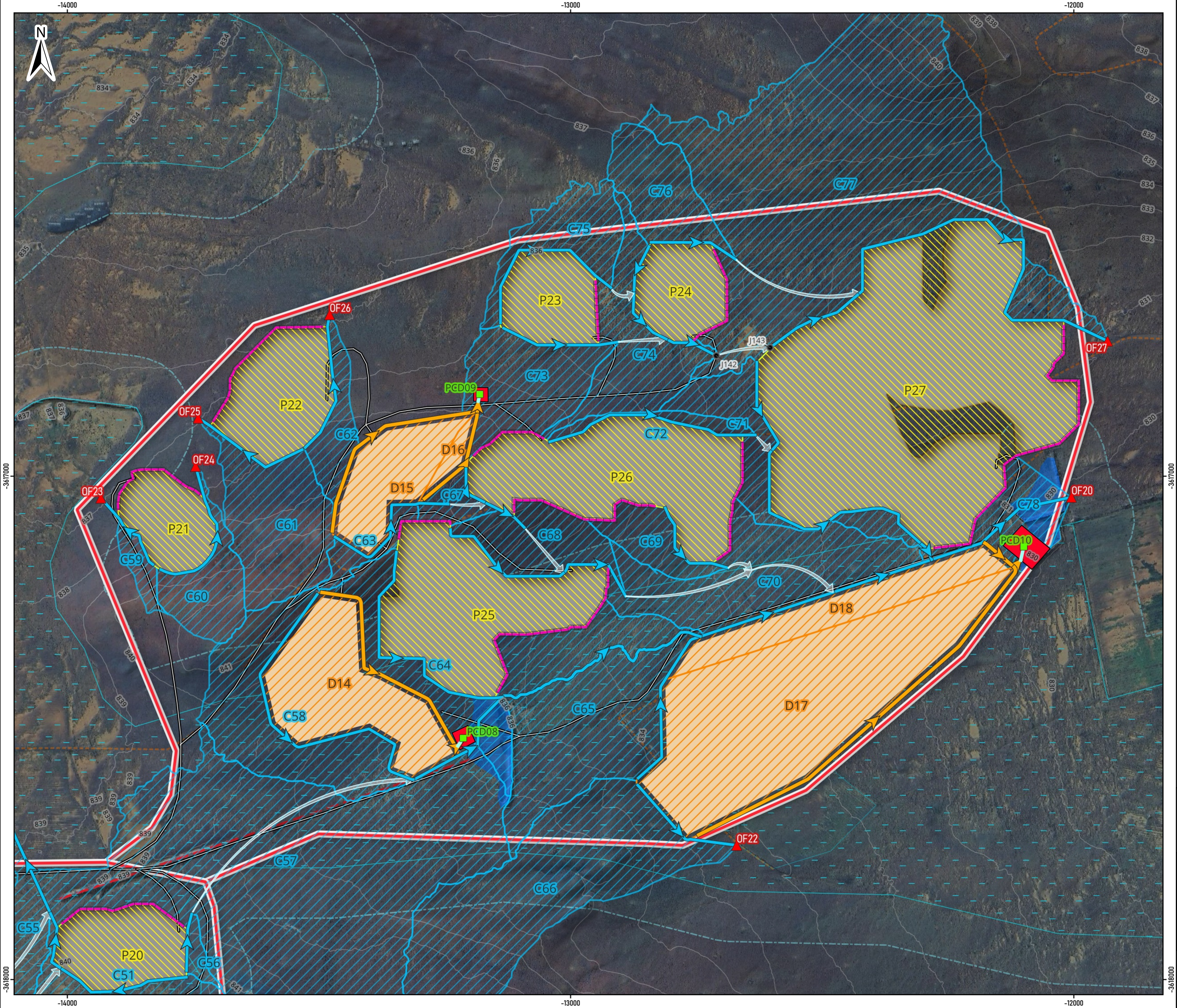
0 100 200 300 m

Scale - 1:12,000 @A3	Coordinate Reference System: Hartebeesthoek94_Lo23_(E-N)	11-Jul-2025



Legend

- Site Boundary
- Survey Extent (1m DTM-Artifact)
- 100m Watercourse Buffer
- Dam (50K Topo)
- Dry Water Course (50K Topo)
- Furrow (50K Topo)
- Footpath (50K Topo)
- 1m Contour (DTM Derivived)
- Outfall
- Junction
- Storage
- Berm
- Clean Diversion (Berm and Channel)
- Dirty Diversion (Berm and Channel)
- overland
- Routing

Clean and Dirty Areas

- Clean
- Dirty
- PCD (Dirty)
- Self-Contained (Dirty)

Layout

- Open Pit
- Waste Rock Dump
- Site Road

Figure 5-3

Conceptual Stormwater Management Plan Abante

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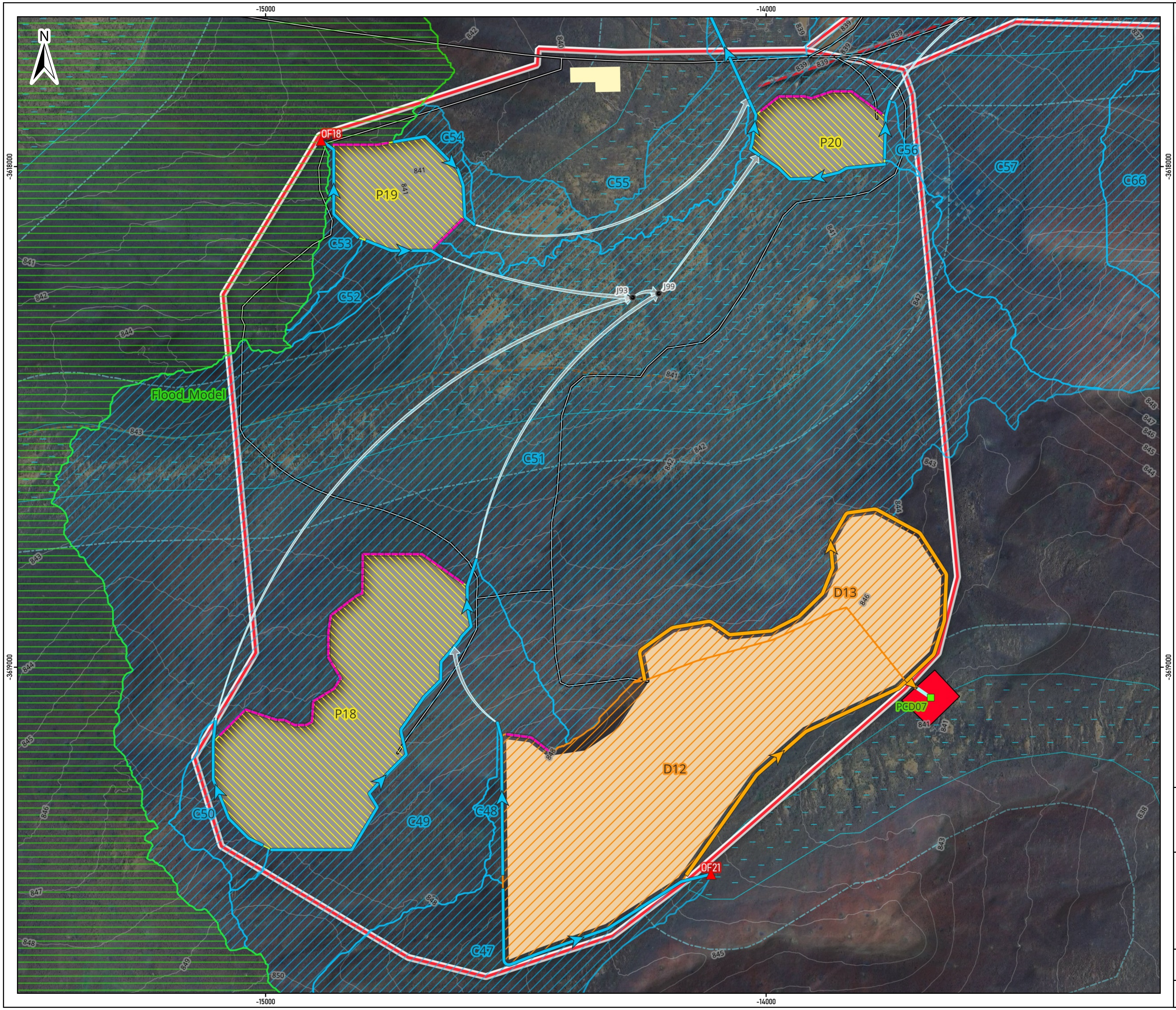
0 100 200 300 m

Scale - 1:7,000 @A3	Coordinate Reference System: Hartebeesthoek94_Lo23_(E-N)	11-Jul-2025



Legend

- Site Boundary
- Survey Extent (1m DTM-Artifact)
- 100m Watercourse Buffer
- Dry Water Course (50K Topo)
- Furrow (50K Topo)
- Footpath (50K Topo)
- 1m Contour (DTM Derivived)
- Outfall
- Junction
- Storage
- Berm
- Clean Diversion (Berm and Channel)
- Dirty Diversion (Berm and Channel)
- overland
- Routing

Clean and Dirty Areas

- Clean
- Dirty
- PCD (Dirty)
- Self-Contained (Dirty)
- Clean (Flood model Outputs)

Layout

- Open Pit
- Site Office, Stores & Changehouse
- Waste Rock Dump
- Site Road

Figure 5-4

Conceptual Stormwater Management Plan RK Main

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0 100 200 300 m

Scale - 1:7,000 @A3	Coordinate Reference System: Hartebeesthoek94_Lo23_(E-N)	11-Jul-2025

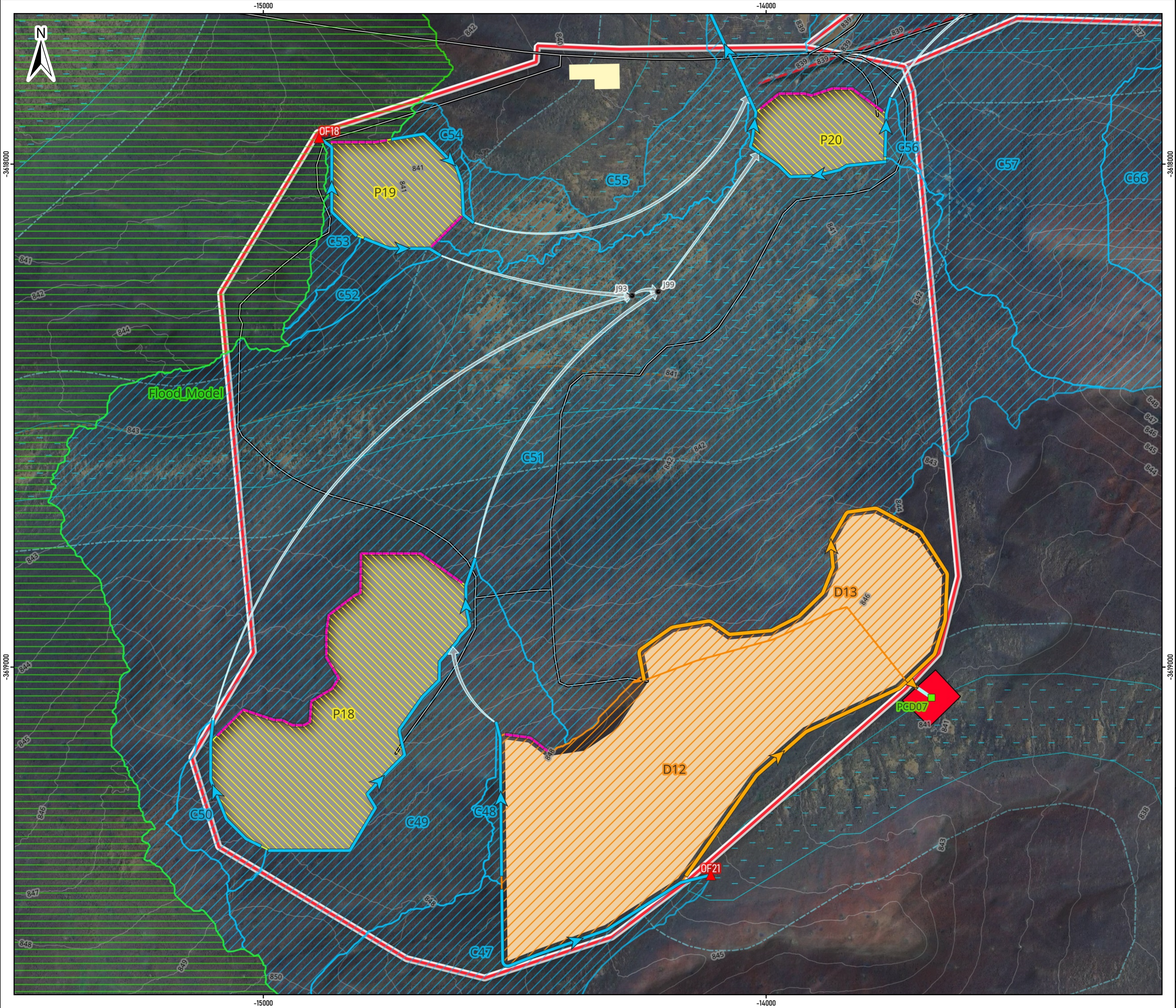

Figure 5-4

Conceptual Stormwater Management Plan RK Main

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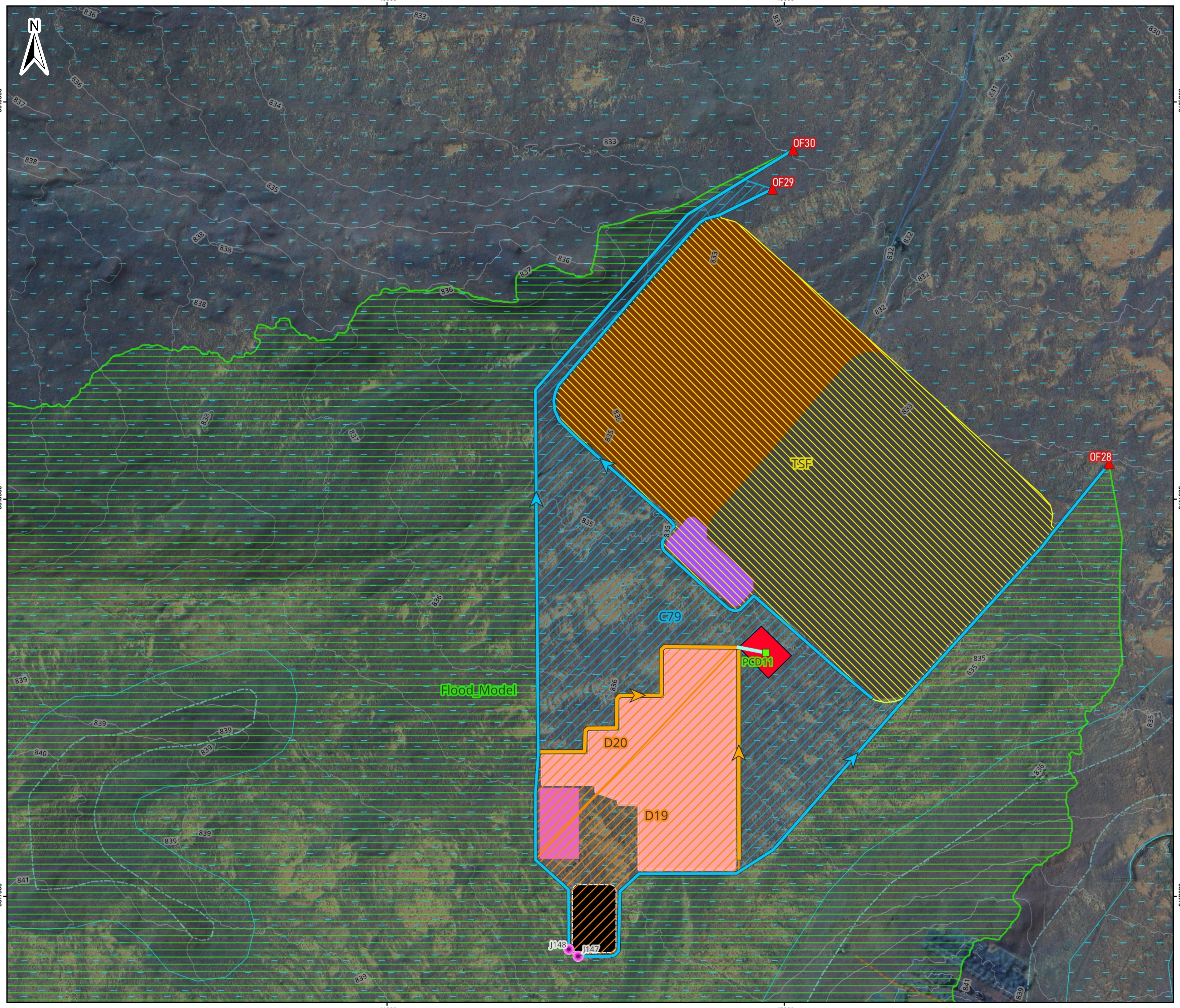
Scale - 1:7,000 @A3	Coordinate Reference System: Hartebeesthoek94_Lo23_(E-N)	11-Jul-2025



Legend

- 100m Watercourse Buffer
- Dam (50K Topo)
- Dry Water Course (50K Topo)
- Non-Perennial River (50K Topo)
- Footpath (50K Topo)
- 1m Contour (DTM Derivived)
- Outfall
- Junction (Flood Model Input)
- Storage
- Clean Diversion (Berm and Channel)
- Dirty Diversion (Berm and Channel)
- Routing

Clean and Dirty Areas

- Clean
- Dirty
- PCD (Dirty)
- Self-Contained (Dirty)
- Clean (Flood model Outputs)

Layout

- TSF - Phase 1
- TSF - Phase 2
- CPP
- Ancillary (CPP)
- ROM
- RWD

Figure 5-5

Conceptual Stormwater Management Plan
TSF+CPP

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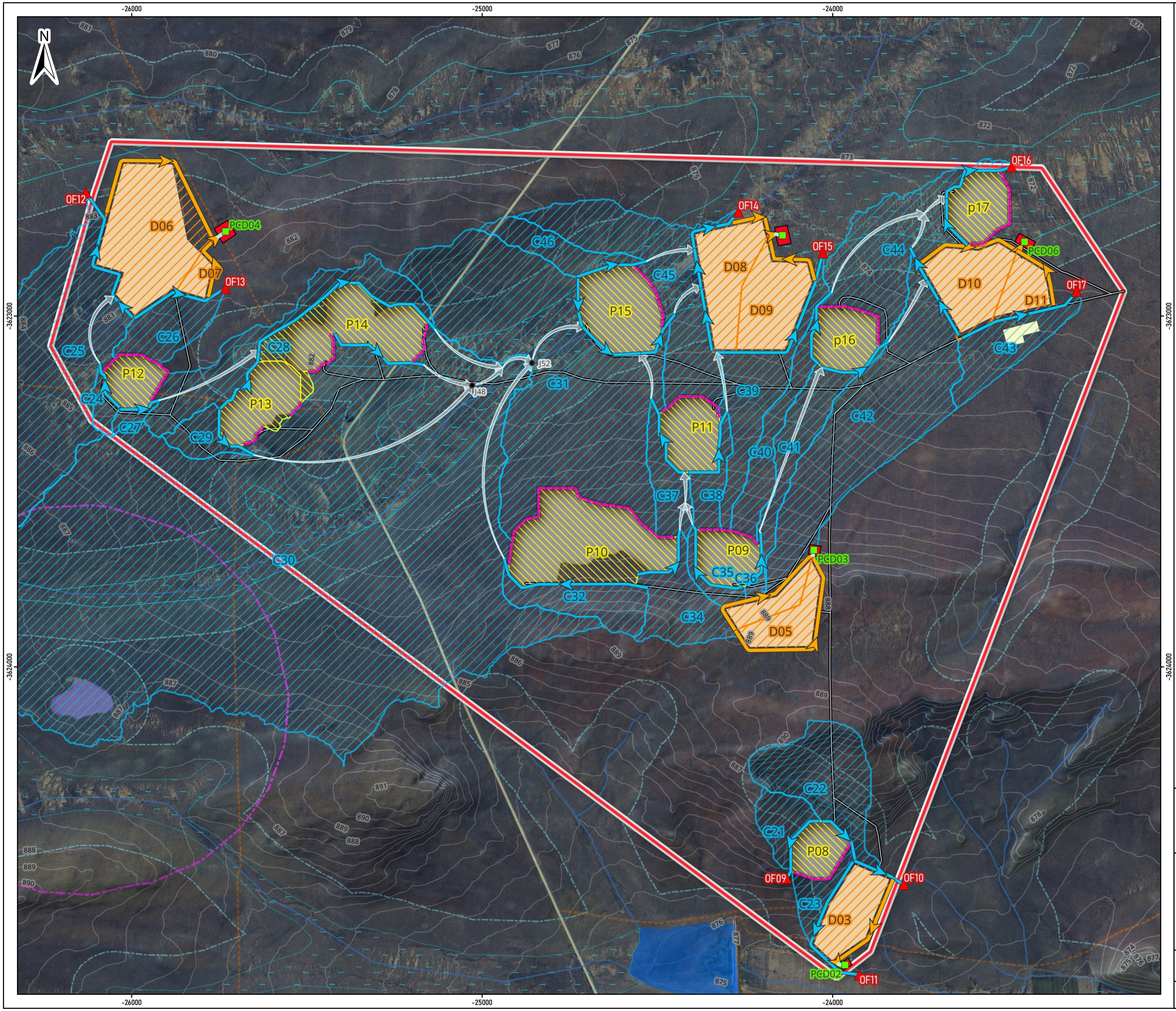
0 100 200 300 m

Scale - 1:9,000 @A3	Coordinate Reference System: Hartebeesthoek94_Lo23_(E-N)	11-Jul-2025



Legend

- Site Boundary
- Survey Extent (1m DTM-Artifact)
- 500m Pan/Vlei Buffer
- 100m Watercourse Buffer
- Dam (50K Topo)
- Dry Pan (50K Topo)
- Dry Water Course (50K Topo)
- Non-Perennial River (50K Topo)
- Footpath (50K Topo)
- Other Road (50K Topo)
- 1m Contour (DTM Derivived)
- Outfall
- Junction
- Storage
- Berm
- Clean Diversion (Berm and Channel)
- Dirty Diversion (Berm and Channel)
- overland
- Routing

Layout

- Open Pit
- Site Office, Stores & Changehouse
- Waste Rock Dump
- Site Road

Figure 5-6

Conceptual Stormwater Management Plan RK Extension

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0 100 200 300 m

Scale - 1:10,000 @A3	Coordinate Reference System: Hartebeesthoek94_Lo23_(E-N)	11-Jul-2025

5.2.1 AVAILABLE INFORMATION

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

- Climate Data: Particularly design rainfall depths;
- Elevation Data: The 1 DTM and 30m DSM as outlined in Section 2.3 wer used to define flow routes and subcatchment divisions; and
- Catchment characteristics: Soil characteristics, land-cover and slopes were used to define catchment characteristics.

5.2.2 PERMISSIBLE VELOCITIES

The conceptual SWMP has not taken account of velocities in the diversions since this is expected to be considered during details design. In general, velocities over 2 m/s are high enough to cause erosion of grass-lined channels, while velocities over 2.5 m/s can erode concrete linings with joints or cracks, with an upper limit of 8 m/s in the case of reinforced concrete. The South African National Roads Agency Limited (SANRAL) drainage manual (SANRAL, 2013) guides maximum permissible velocities and should be consulted during the detailed design phase. Deposition of sediment due to velocities that are too low may also need to be accounted for.

In noting the results of the flood modelling, flood velocities are typically below 1m/s (for natural channels).

5.2.3 CLEAN WATER SYSTEM - DIVERSIONS

Figure 3-3 represents a typical clean area diversion consisting of a containment berm and channel component. The purpose of the channel section is to divert upstream/upslope clean water which would otherwise flow towards a dirty area, while the berm section will ensure containment of dirty water within dirty areas. The side slopes for all berms have been kept constant at 1 vertical: 2 horizontal. Channels have otherwise adopted the natural landscape with side slopes of either 1:50 or 1:100. A minimum channel dimension of 1m (berm height) and 1.0m channel base breadth has been used to simplify the design. The 1m high berm has been used as a minimum to provide additional freeboard in an region known for diffuse flooding.

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 0.03 (bare earth with limited vegetation) was used in the sizing of the diversions channels. Figure 5-7 illustrates a typical berm and channel where:

- a = Channel Depth
- b = Channel Base Breadth

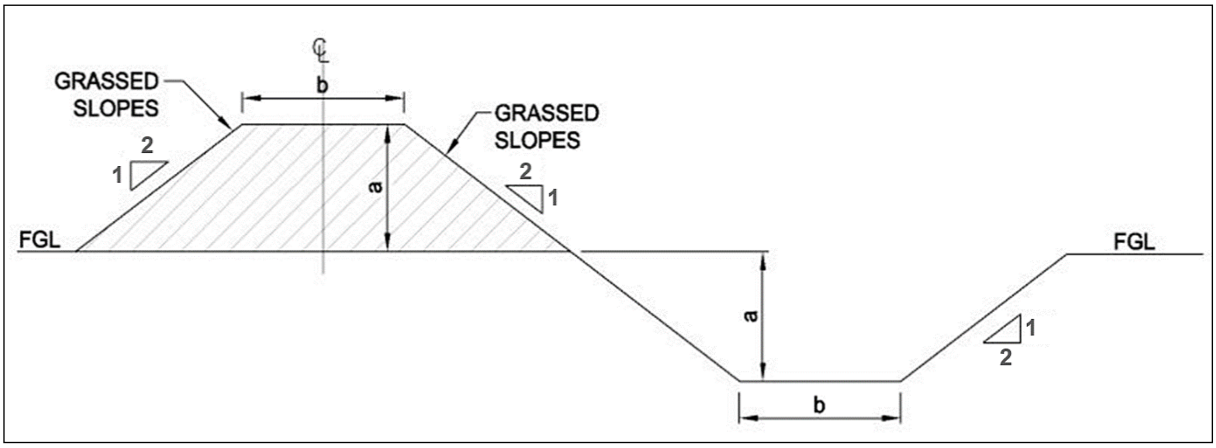

FIGURE 5-7: TYPICAL BERM AND CHANNEL FOR STORMWATER DIVERSION SYSTEM

Tables 5-1 to 5-5 presents the dimensions of the dirty area diversions, including the average longitudinal. Average longitudinal slopes were used in the modelling of each channel segment since the detail to determine variations in channel slope requires a more accurate DEM than was available. The indicated construction dimensions and flows may differ from the final, depending on the construction method, the location of diversions and the additional detail included in the detailed design. The diversion dimensions should consequently be reviewed during the detailed design phase.

TABLE 5-1: DIMENSIONS FOR CLEAN AREA DIVERSIONS (1:50 RI EVENT) - HANNEKUIL

Diversion	a (m)	b (m)	Side Slope	Average Longitudinal Slope (%)	Peak Flow (m^3/s)
J01 to OF01	1	1	1:2 (berm); 1:50 (channel)	2.8	1.0
J02 to OF02	1	1	1:2 (berm); 1:50 (channel)	1.7	0.1
J03 to J04	1	1	1:2 (berm); 1:50 (channel)	1.1	2.3
J05 to J06	1	1	1:2 (berm); 1:50 (channel)	1.2	0.5
J08 to J09	1	1	1:2 (berm); 1:50 (channel)	0.1	3.2
J09 to OF03	1	1	1:2 (berm); 1:50 (channel)	0.5	2.7
J10 to OF04	1	1	1:2 (berm); 1:50 (channel)	0.5	2.0
J11 to J12	1	1	1:2 (berm); 1:50 (channel)	0.1	3.0
J12 to J14	1	1	1:2 (berm); 1:50 (channel)	0.0	2.3
J14 to OF05	1	1	1:2 (berm); 1:50 (channel)	0.2	2.4
J15 to OF06	1	1	1:2 (berm); 1:50 (channel)	0.1	0.2
J16 to OF07	1	1	1:2 (berm); 1:50 (channel)	0.7	0.2
J17 to J18	1	1	1:2 (berm); 1:50 (channel)	2.5	0.1
J19 to J20	1	1	1:2 (berm); 1:50 (channel)	0.6	3.5
J20 to J21	1	1	1:2 (berm); 1:50 (channel)	0.0	1.3
J21 to J22	1	1	1:2 (berm); 1:50 (channel)	0.0	1.8
J22 to J23	1	1	1:2 (berm); 1:50 (channel)	0.0	2.1
J23 to J28	1	1	1:2 (berm); 1:50 (channel)	0.0	2.2
J24 to J25	1	1	1:2 (berm); 1:50 (channel)	0.3	1.6
J25 to J26	1	1	1:2 (berm); 1:50 (channel)	0.0	1.0
J26 to J27	1	1	1:2 (berm); 1:50 (channel)	0.0	1.3
J27 to J28	1	1	1:2 (berm); 1:50 (channel)	0.0	1.7
J28 to OF08	1	1	1:2 (berm); 1:50 (channel)	0.0	3.7

TABLE 5-2: DIMENSIONS FOR CLEAN AREA DIVERSIONS (1:50 RI EVENT) – RK EXTENSION

Diversion	a (m)	b (m)	Side Slope	Average Longitudinal Slope (%)	Peak Flow (m^3/s)
J30 to OF09	1	1	1:2 (berm); 1:50 (channel)	0.4	0.3
J31 to J32	1	1	1:2 (berm); 1:50 (channel)	1.5	0.9
J32 to OF10	1	1	1:2 (berm); 1:50 (channel)	1.4	0.8
J33 to OF11	1	1	1:2 (berm); 1:50 (channel)	1.0	0.2
J34 to J35	1	1	1:2 (berm); 1:50 (channel)	0.4	0.1
J36 to J37	1	1	1:2 (berm); 1:50 (channel)	1.4	2.1
J37 to OF12	1	1	1:2 (berm); 1:50 (channel)	0.1	1.4
J38 to OF13	1	1	1:2 (berm); 1:50 (channel)	0.6	0.3
J39 to J40	1	1	1:2 (berm); 1:50 (channel)	0.7	0.1
J41 to J42	1	1	1:2 (berm); 1:50 (channel)	0.6	0.9
J42 to J43	1	1	1:2 (berm); 1:50 (channel)	0.3	0.5
J44 to J45	1	1	1:2 (berm); 1:50 (channel)	0.5	0.0
J46 to J47	1	1	1:2 (berm); 1:50 (channel)	0.3	0.2
J49 to J50	1	1	1:2 (berm); 1:50 (channel)	0.8	0.6
J53 to J54	1	1	1:2 (berm); 1:50 (channel)	0.1	2.8
J54 to J62	1	1	1:2 (berm); 1:50 (channel)	0.0	7.9
J55 to J56	1	1	1:2 (berm); 1:50 (channel)	1.0	0.6
J57 to J58	1	1	1:2 (berm); 1:50 (channel)	1.4	0.2
J60 to J61	1	1	1:2 (berm); 1:50 (channel)	1.1	0.9
J62 to J63	1	1	1:2 (berm); 1:50 (channel)	0.7	8.5
J64 to J65	1	1	1:2 (berm); 1:50 (channel)	0.7	0.3
J66 to J67	1	1	1:2 (berm); 1:50 (channel)	0.9	1.1
J67 to J68	1	1	1:2 (berm); 1:50 (channel)	0.2	9.1
J68 to OF14	1	1	1:2 (berm); 1:50 (channel)	0.4	9.2
J69 to J70	1	1	1:2 (berm); 1:50 (channel)	0.9	0.3
J71 to OF15	1	1	1:2 (berm); 1:50 (channel)	0.6	0.6
J72 to J73	1	1	1:2 (berm); 1:50 (channel)	2.5	0.1
J74 to J75	1	1	1:2 (berm); 1:50 (channel)	0.7	0.3
J76 to J77	1	1	1:2 (berm); 1:50 (channel)	0.4	1.4
J77 to J78	1	1	1:2 (berm); 1:50 (channel)	0.3	1.3
J79 to J80	1	1	1:2 (berm); 1:50 (channel)	0.8	0.3
J82 to J83	1	1	1:2 (berm); 1:50 (channel)	0.1	0.8
J83 to OF16	1	1	1:2 (berm); 1:50 (channel)	0.3	1.8
J84 to OF17	1	1	1:2 (berm); 1:50 (channel)	0.4	0.4

TABLE 5-3: DIMENSIONS FOR CLEAN AREA DIVERSIONS (1:50 RI EVENT) – RK MAIN

Diversion	a (m)	b (m)	Side Slope	Average Longitudinal Slope (%)	Peak Flow (m^3/s)
J86 to OF18	1	1	1:2 (berm); 1:50 (channel)	0.3	0.2
J87 to J88	1	1	1:2 (berm); 1:50 (channel)	0.2	0.1
J89 to J90	1	1	1:2 (berm); 1:50 (channel)	0.2	0.3
J91 to J92	1	1	1:2 (berm); 1:50 (channel)	1.0	0.3
J94 to J97	1	1	1:2 (berm); 1:50 (channel)	0.6	1.7
J95 to J96	1	1	1:2 (berm); 1:50 (channel)	0.4	0.1
J97 to J98	1	1	1:2 (berm); 1:50 (channel)	0.7	1.6
J100 to J101	1	1	1:2 (berm); 1:50 (channel)	0.2	8.5
J101 to J102	1	1	1:2 (berm); 1:50 (channel)	0.5	8.0

J102 to OF19	1	1	1:2 (berm); 1:50 (channel)	0.2	7.2
J103 to J104	1	1	1:2 (berm); 1:50 (channel)	0.9	0.1
J129 to OF21	1	1	1:2 (berm); 1:50 (channel)	0.7	1.4

TABLE 5-4: DIMENSIONS FOR CLEAN AREA DIVERSIONS (1:50 RI EVENT) – RK ABANTE

Diversion	a (m)	b (m)	Side Slope	Average Longitudinal Slope (%)	Peak Flow (m^3/s)
J105 to J106	1	1	1:2 (berm); 1:50 (channel)	0.6	0.7
J106 to J108	1	1	1:2 (berm); 1:50 (channel)	0.5	2.9
J107 to J108	1	1	1:2 (berm); 1:50 (channel)	0.9	0.6
J108 to J110	1	1	1:2 (berm); 1:50 (channel)	0.5	2.8
J109 to J110	1	1	1:2 (berm); 1:50 (channel)	0.3	1.3
J110 to J122	1	1	1:2 (berm); 1:50 (channel)	0.5	3.7
J111 to J112	1	1	1:2 (berm); 1:50 (channel)	0.5	0.1
J113 to J114	1	1	1:2 (berm); 1:50 (channel)	0.5	0.2
J114 to J115	1	1	1:2 (berm); 1:50 (channel)	1.4	0.2
J116 to J117	1	1	1:2 (berm); 1:50 (channel)	1.4	0.6
J117 to J118	1	1	1:2 (berm); 1:50 (channel)	0.7	0.6
J119 to J120	1	1	1:2 (berm); 1:50 (channel)	0.7	0.4
J122 to J128	1	1	1:2 (berm); 1:50 (channel)	0.4	4.2
J123 to J124	1	1	1:2 (berm); 1:50 (channel)	0.8	0.0
J125 to J126	1	1	1:2 (berm); 1:50 (channel)	0.6	0.6
J126 to J127	1	1	1:2 (berm); 1:50 (channel)	0.5	0.5
J127 to J128	1	1	1:2 (berm); 1:50 (channel)	0.2	0.2
J128 to OF20	1	1	1:2 (berm); 1:50 (channel)	0.4	4.4
J130 to OF22	1	1	1:2 (berm); 1:50 (channel)	0.5	1.4
J131 to OF23	1	1	1:2 (berm); 1:50 (channel)	1.3	0.1
J132 to OF24	1	1	1:2 (berm); 1:50 (channel)	0.7	0.4
J133 to OF25	1	1	1:2 (berm); 1:50 (channel)	0.6	0.6
J134 to OF26	1	1	1:2 (berm); 1:50 (channel)	0.9	0.3
J135 to J136	1	1	1:2 (berm); 1:50 (channel)	0.4	0.4
J137 to J138	1	1	1:2 (berm); 1:50 (channel)	0.6	0.6
J139 to J140	1	1	1:2 (berm); 1:50 (channel)	0.5	0.8
J140 to J141	1	1	1:2 (berm); 1:50 (channel)	0.1	0.7
J141 to J142	1	1	1:2 (berm); 1:50 (channel)	0.4	1.1
J143 to J146	1	1	1:2 (berm); 1:50 (channel)	0.5	2.8
J144 to J145	1	1	1:2 (berm); 1:50 (channel)	0.4	0.5
J146 to OF27	1	1	1:2 (berm); 1:50 (channel)	0.3	2.6

TABLE 5-5: DIMENSIONS FOR CLEAN AREA DIVERSIONS (1:50 RI EVENT) – TSF AND CPP

Diversion	a (m)	b (m)	Side Slope	Average Longitudinal Slope (%)	Peak Flow (m^3/s)
J147 to OF28	2	1	1:2 (berm); 1:50 (channel)	0.2	69.8
J148 to OF30	2	1	1:2 (berm); 1:50 (channel)	0.2	52.9
J149 to OF29	1	1	1:2 (berm); 1:50 (channel)	0.1	1.9

5.2.4 DIRTY WATER SYSTEM - DIVERSIONS

Dirty area diversions have been designed to ensure dirty water generated on the operation is contained. These systems will typically consist of a berm and channel component routing to a PCD. The berm and channel component have been designed to accommodate the 1:50 year RI storm event 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 it towards the appropriate dirty water containment facility.

Figure 5-7 represents a typical dirty water containment berm and channel. The side slopes for all berms and channels have been kept constant at 1 vertical: 2 horizontal. A minimum channel dimension of 0.5m channel depth and 1.0m channel base breadth has been used to simplify the design. The channel component has been sized using PCSWMM to meet the requirement of accommodating the 1:50 year RI event. A Manning's 'n of 0.015 (concrete) was used in the calculations, associated with a concrete-lined channel.

Tables 5-6 to 5-10 present the dimensions of the dirty area diversions, including the average longitudinal. Average longitudinal slopes were used in the modelling of each channel segment since the detail to determine variations in channel slope requires a more accurate DEM than was available. The indicated construction dimensions and flows may differ from the final, depending on the construction method, the location of diversions and the additional detail included in the detailed design. The diversion dimensions should consequently be reviewed during the detailed design phase.

TABLE 5-6: DIMENSIONS FOR DIRTY AREA DIVERSIONS (1:50 RI EVENT) – HANNEKUIL

Diversion	a (m)	b (m)	Side Slope	Average Longitudinal Slope (%)	Peak Flow (m^3/s)
J150 to J152	0.5	1	1:2 (berm and channel)	0.6	0.7
J151 to J152	0.5	1	1:2 (berm and channel)	0.4	0.6
J152 to J153	0.5	1	1:2 (berm and channel)	2.6	1.3

TABLE 5-7: DIMENSIONS FOR DIRTY AREA DIVERSIONS (1:50 RI EVENT) – RK EXTENSION

Diversion	a (m)	b (m)	Side Slope	Average Longitudinal Slope (%)	Peak Flow (m^3/s)
J154 to J155	0.5	1	1:2 (berm and channel)	0.8	0.2
J155 to J156	0.5	1	1:2 (berm and channel)	1.2	0.2
J157 to J159	0.5	1	1:2 (berm and channel)	0.9	0.1
J158 to J159	0.5	1	1:2 (berm and channel)	1.2	0.1
J160 to J163	0.5	1	1:2 (berm and channel)	0.8	0.1
J161 to J163	0.5	1	1:2 (berm and channel)	0.4	0.3
J163 to J164	0.5	1	1:2 (berm and channel)	0.5	0.3
J165 to J167	0.5	1	1:2 (berm and channel)	0.2	0.1
J166 to J167	0.5	1	1:2 (berm and channel)	0.1	0.1
J167 to J168	0.5	1	1:2 (berm and channel)	0.5	0.3
J169 to J171	0.5	1	1:2 (berm and channel)	0.3	0.2
J170 to J171	0.5	1	1:2 (berm and channel)	0.4	0.1
J171 to J172	0.5	1	1:2 (berm and channel)	0.3	0.3

TABLE 5-8: DIMENSIONS FOR DIRTY AREA DIVERSIONS (1:50 RI EVENT) – RK MAIN

Diversion	a (m)	b (m)	Side Slope	Average Longitudinal Slope (%)	Peak Flow (m^3/s)
J173 to J175	0.5	1	1:2 (berm and channel)	0.4	0.3
J174 to J175	0.5	1	1:2 (berm and channel)	0.4	0.6
J175 to J176	0.5	1	1:2 (berm and channel)	0.8	0.8

TABLE 5-9: DIMENSIONS FOR DIRTY AREA DIVERSIONS (1:50 RI EVENT) – RK ABANTE

Diversion	a (m)	b (m)	Side Slope	Average Longitudinal Slope (%)	Peak Flow (m^3/s)
J178 to J179	0.5	1	1:2 (berm and channel)	1.1	0.2
J179 to J180	0.5	1	1:2 (berm and channel)	0.3	0.2
J190 to J192	0.5	1	1:2 (berm and channel)	0.5	0.2
J191 to J192	0.5	1	1:2 (berm and channel)	0.6	0.0
J192 to J193	0.5	1	1:2 (berm and channel)	1.4	0.2
J194 to J197	0.5	1	1:2 (berm and channel)	0.4	0.3
J195 to J197	0.5	1	1:2 (berm and channel)	0.4	0.1
J197 to J198	0.5	1	1:2 (berm and channel)	0.4	0.3

TABLE 5-10: DIMENSIONS FOR DIRTY AREA DIVERSIONS (1:50 RI EVENT) – TSF AND CPP

Diversion	a (m)	b (m)	Side Slope	Average Longitudinal Slope (%)	Peak Flow (m^3/s)
J199 to J201	0.75	1	1:2 (berm and channel)	0.2	1.5
J200 to J201	1	1	1:2 (berm and channel)	0.2	3.3

5.2.5 DIRTY WATER SYSTEM – CONTAINMENT

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 RI event. A minimum freeboard of 0.8m above full supply level must also be maintained as per the requirements of GN 704.

The capacity of eleven PCDs was calculated based on the summation of the 1:50 year RI 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. 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 PCSWMM. The addition of other sources of water such as process water or dewatering from the opencast pit has not been accounted for and should be added to the volumes indicated. A freeboard allowance is also necessary to comply with GN 704.

Table 5-11 presents the volume requirement of the various PCDs that should be evaluated and revised as part of the detailed design phase of the project to include additional process or wash water requirements. PCDs have been conceptualised as vertically walled (constant volume/area relationship). It is noted in Table 5-11 that the recommended volume is only a little higher than the 1:50 year RI volume (for PCD 01 to PCD10 which manage waste rock dumps). This is due to the limited wet season runoff (March) and the high potential evaporation.

TABLE 5-11: PCD CONTAINMENT VOLUME REQUIREMENTS

Containment	Area	Area (m^2)	Maximum Depth (m; exc. freeboard)	1:50 RI Volume (m^3)	Recommended Volume
PCD01	Hannekuil	6,664	1.63	10,642	10,845
PCD02	RK Extension	710	1.51	1,032	1,075
PCD03	RK Extension	959	1.36	1,267	1,305
PCD04	RK Extension	2,129	1.45	2,968	3,078
PCD05	RK Extension	1,942	1.40	2,628	2,728
PCD06	RK Extension	1,461	1.35	1,907	1,966
PCD07	RK Main	6,490	1.41	8,829	9,178
PCD08	RK Abante	1,286	1.59	1,950	2,039
PCD09	RK Abante	829	1.55	1,231	1,282
PCD10	RK Abante	4,063	1.36	5,332	5,538
PCD11	CPP	8,550	2.64	19,184	22,605

In addition to the formal containment listed above, there remains some informal containment in the form of the inflow volume into various self-contained (or separately managed) areas presented in Table 5-12 below. The opencast pits are large and their potential 1:50 RI event inflow volumes are consequently equally large (assuming full pit development).

TABLE 5-12: ADDITIONAL VOLUMES

	Area	1:50 RI Volume (m^3)		Area	1:50 RI Volume (m^3)
P01	Hannekuil	2,150	P15	RK Extension	4,120
P02	Hannekuil	3,520	p16	RK Extension	2,520
P03	Hannekuil	6,770	p17	RK Extension	2,500
P04	Hannekuil	1,910	P18	RK Main	12,640
P05	Hannekuil	1,330	P19	RK Main	3,980
P06	Hannekuil	12,670	P20	RK Main	3,040
P07	Hannekuil	3,120	P21	RK Abante	2,360
P08	RK Extension	1,740	P22	RK Abante	3,830
P09	RK Extension	2,190	P23	RK Abante	2,630
P10	RK Extension	7,510	P24	RK Abante	2,530
P11	RK Extension	2,640	P25	RK Abante	7,380
P12	RK Extension	1,740	P26	RK Abante	7,860
P13	RK Extension	3,060	P27	RK Abante	22,390
P14	RK Extension	5,730	TSF	CPP and TSF	56,680

6 HYDROLOGICAL IMPACT ASSESSMENT

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. Impacts include changes in the physical-chemical, biological, cultural and/or socio-economic environmental system that can be attributed to human activities. Informed by the site layout, baseline hydrology, floodline results, the stormwater management plan and the sensitivity of surface water resources, this section evaluates the potential impact of the proposed mining activities on adjacent watercourses. Watercourse is a term used in the National Water Act (Act No. 36 of 1998) (NWA) that includes various water resources, such as different types of wetlands (both natural and artificial), rivers, riparian habitat, dams and drainage lines (e.g. natural channels in which water flows regularly or intermittently). Expected watercourse impacts associated with the proposed mine are assessed in detail for the construction, operational and decommissioning phases of the project, using the approach provided in the Impact Assessment Methodology (Section 6.1 below). In addition, a summary of recommended mitigation measures and monitoring requirements have been provided.

6.1 HYDROLOGICAL IMPACT ASSESSMENT METHODOLOGY

In order to be compliant with statutory requirements, a hydrological impact assessment was undertaken as per Regulation 31(2) (l) of the National Environmental Management Act (Act 107 of 1998) (NEMA). Regulation 31 (2) (l) states "(2) An environmental impact assessment report must contain all information that is necessary for the competent authority to consider the application and to reach a decision …", and must comprise (l) an assessment of each identified potentially significant impact, including:

- Cumulative impacts;
- The nature of the impact;
- The extent and duration of the impact;
- The probability of the impact occurring;
- The degree to which the impact can be reversed;
- The degree to which the impact may cause irreplaceable loss of resources; and
- The degree to which the impact can be mitigated.

Assessment of predicted significance of impacts for a proposed development is by its nature, inherently uncertain. To deal with such uncertainty in a comparable manner, standardized and internationally recognized methodology have been developed. The potential impacts of the proposed 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 NEMA.

Based on the above, the significance of potential impacts was determined through a synthesis of impact characteristics which include context and intensity of an impact. Context refers to the geographical scale (i.e. site, local, national or global), whereas intensity is defined by the severity of the impact e.g. the magnitude of deviation from background conditions, the size of the area affected, the duration of the impact and the overall probability of occurrence. Significance is calculated as shown in Tables 6-1 and 6-2.

Significance is an indication of the importance of the impact in terms of both physical extent and time scale, and therefore indicates the level of mitigation required. The total number of points scored for each impact indicates the level of significance of the impact.

6.1.1 RATING SCALES APPLIED DURING THE IMPACT ASSESSMENT

In order to determine the significance of each identified potential impact, a numerical value has been linked to the respective factor (EXTENT; PROBABILITY; REVERSIBILITY; IRREPLACEABLE LOSS OF RESOURCES; DURATION; and INTENSITY/MAGNITUDE). Table 6-1 provides the rating assessment scales used in this study.

TABLE 6-1: RATING ASSESSMENT CLASSIFICATION

EXTENT (E)		
This is defined as the area over which the impact will be expressed. Typically, the severity and significance of an impact has different scales and as such bracketing ranges are often required. This is often useful during the detailed assessment of a project in terms of further defining the determined.		
Rating	**Extent aspect**	**Scale**
1	Site	The impact will only affect the site
2	Local/district	Will affect the local area or district
3	Province/Region	Will affect the entire province or region
4	International and National	Will affect the entire country
PROBABILITY (P)		
This describes the chance of occurrence of an impact		
Rating	**Probability aspect**	**% Chance of occurring**
1	Unlikely	The chance of the impact occurring is extremely low (Less than a 25% chance of occurrence).
2	Possible	The impact may occur (Between a 25% to 50% chance of occurrence).
3	Probable	The impact will likely occur (Between a 50% to 75% chance of occurrence).
4	Definite	Impact will certainly occur (Greater than a 75% chance of occurrence).
REVERSIBILITY (R)		
This describes the degree to which an impact on an environmental parameter can be successfully reversed upon completion of the proposed activity.		
Rating	**Reversibility aspect**	**Degree**
1	Completely reversible	The impact is reversible with implementation of minor mitigation measures
2	Partly reversible	The impact is partly reversible but more intense mitigation measures are required.
3	Barely reversible	The impact is unlikely to be reversed even with intense mitigation measures.
4	Irreversible	The impact is irreversible and no mitigation measures exist.
IRREPLACEABLE LOSS OF RESOURCES (L)		
This describes the degree to which resources will be irreplaceably lost as a result of a proposed activity.		
Rating	**Loss of Resources aspect**	**Degree**
1	No loss of resource.	The impact will not result in the loss of any resources.
2	Marginal loss of resource	The impact will result in marginal loss of resources.
3	Significant loss of resources	The impact will result in significant loss of resources.
4	Complete loss of resources	The impact is result in a complete loss of all resources.

DURATION (D)		
This describes the duration of the impacts on the environmental parameter. Duration indicates the lifetime of the impact as a result of the proposed activity.		
Rating	**Duration aspect**	**Timeframe**
1	Short term	The impact and its effects will either disappear with mitigation or will be mitigated through natural process in a span shorter than the construction phase (0 – 1 years), or the impact and its effects will last for the period of a relatively short construction period and a limited recovery time after construction, thereafter it will be entirely negated (0 – 2 years).
2	Medium term	The impact and its effects will continue or last for some time after the construction phase but will be mitigated by direct human action or by natural processes thereafter (2 – 10 years).
3	Long term	The impact and its effects will continue or last for the entire operational life of the development, but will be mitigated by direct human action or by natural processes thereafter (10 – 50 years).
4	Permanent	The only class of impact that will be non-transitory. Mitigation either by man or natural process will not occur in such a way or such a time span that the impact can be considered transient (Indefinite).
INTENSITY / MAGNITUDE (I / M)		
Describes the severity of an impact (i.e. whether the impact has the ability to alter the functionality or quality of a system permanently or temporarily).		
Rating	**Intensity/Magnitude aspect**	**Intensity/Magnitude description**
1	Low	Impact affects the quality, use and integrity of the system/component in a way that is barely perceptible.
2	Medium	Impact alters the quality, use and integrity of the system/component but system/ component still continues to function in a moderately modified way and maintains general integrity (some impact on integrity).
3	High	Impact affects the continued viability of the system/component and the quality, use, integrity and functionality of the system or component is severely impaired and may temporarily cease. High costs of rehabilitation and remediation.
4	Very High	Impact affects the continued viability of the system/component and the quality, use, integrity and functionality of the system or component permanently ceases and is irreversibly impaired (system collapse). Rehabilitation and remediation often impossible. If possible rehabilitation and remediation often unfeasible due to extremely high costs of rehabilitation and remediation.

6.1.2 METHODOLOGY USED IN DETERMINING THE SIGNIFICANCE OF IMPACTS

A quantitative approach was taken in determining environmental significance since this enables a cross disciplinary assessment of impacts and a consistent interpretation of impact significance.

Based on the information contained in the above rating assessment classification (Table 6-1), the potential impacts are assigned a significance rating (S). Significance is determined through a synthesis of impact characteristics. Significance is an indication of the importance of the impact in terms of both physical extent and time scale, and therefore indicates the level of mitigation required. This describes the significance of the impact on the environmental parameter. The calculation of the significance of an impact uses the following formula:

Significance = Extent (E) + Probability (P) + Reversibility (R) + Irreplaceable Loss (L) + Duration (D) x Intensity/Magnitude (I / M).

The summation of the different criteria will produce a non-weighted value. By multiplying this value with the magnitude/intensity, the resultant value acquires a weighted characteristic which can be measured and assigned a significance rating.

The significance of any identified potential impact is rated as either very high, high, medium, and low, as illustrated in Table 6-2.

TABLE 6-2: SIGNIFICANCE RATINGS

POINTS	IMPACT SIGNIFICANCE RATING	DESCRIPTION
5 to 23	Negative Low impact	The anticipated impact will have negligible negative effects and will require little to no mitigation.
5 to 23	Positive Low impact	The anticipated impact will have minor positive effects.
24 to 42	Negative Medium impact	The anticipated impact will have moderate negative effects and will require moderate mitigation measures.
24 to 42	Positive Medium impact	The anticipated impact will have moderate positive effects.
43 to 61	Negative High impact	The anticipated impact will have significant effects and will require significant mitigation measures to achieve an acceptable level of impact.
43 to 61	Positive High impact	The anticipated impact will have significant positive effects.
62 to 80	Negative Very high impact	The anticipated impact will have highly significant effects and are unlikely to be able to be mitigated adequately. These impacts could be considered "fatal flaws".
62 to 80	Positive Very high impact	The anticipated impact will have highly significant positive effects.

In order to reduce the degree to which the identified potential impacts may affect catchment hydrology, a series of mitigation measures relating to the identified potential impacts have been proposed. These mitigation measures are presented in Section 6.3.

6.1.3 SOURCE – PATHWAY – RECEPTOR MODEL

This assessment was carried out to determine the impacts on surface water and groundwater. The potential impacts were assessed for the construction phase, operational phase, and decommissioning phase. The methodology for assessing and quantifying the significance of these impacts is detailed in this present Section 6.1. The impacts were assessed based on the indicators that are identified in the baseline study within Section 2.

The *Source – Pathway – Receptor* model was used for the identification and assessment of potential hydrological impacts. The three different items of this model are detailed below in Sections 6.1.3.1 – 6.1.3.3.

6.1.3.1 SOURCES

The Source is the proposed development as detailed in Section 1. The proposed Lukisa Uranium Mining Operation is located in the Western Cape Province of South Africa, between the towns of Beaufort West and Rietbron (Eastern Cape Province). Due to the site's geographical extent, it has been divided into two distinct sections, namely west and east. The sources from both these site sections differ during construction, operational, and decommissioning stages.

Construction Phase

The construction phase is the more important stage in relation to impacts. The following activities are anticipated during the construction/preparation phase of the project:

- Clearing vegetation on site
- Construction of access roads and pathways
- Storage and erection of temporary structures to facilitate construction phase
- Establishment of temporary site camps and laydown facilities
- Construction of site offices, stores and changehouse
- Construction of Central Processing Plant (CPP) and Ancillary CPP
- Stockpiling of materials
- Excavations based on construction designs
- Dust suppression on roads and construction areas
- Drainage during construction
- Drainage diversion channels and berms
- Hydrocarbons from vehicles/machinery
- Cement based products suspended in water
- Handling and transporting of waste and hazardous materials
- Sewerage from construction personnel
- Rehabilitation and re-vegetation

Operational Phase

The main activities during the operational stage that could cause impacts are as follows:

- Drainage from paved roads or hardened gravel areas that have access to vehicles
- Drainage from other compacted / hardened gravel areas

- Drainage over access pathways in clean areas on site
- Dirty areas (mine opencast pits, waste rock dumps, and mine waste disposal areas)
- Clean and dirty water system diversion berms, channels, and outfalls
- Overflow/runoff/leaching from dirty water system containment (pollution control dams)
- Overflow/runoff/leaching from mine tailings storage facilities
- Impermeable surfaces of mine plant, mine office infrastructure, parking areas, weighbridge, etc.
- Localised hydrocarbon management areas (machinery/equipment workshops and diesel/oil bays)
- Partial flooding of the site

Decommissioning Phase

- Cessation of mining operations and de-establishment of mine plant and associated infrastructure
- De-establishment of hydrocarbon management areas
- Backfill and closure of the mine opencast pits with waste rock dump material
- Earthworks and disturbances to pollution control dams
- Earthworks and soil disturbances required to re-shape mine tailings and material storage facilities
- Earthworks and soil disturbances to earth berms and diversion channels
- Rehabilitation and re-vegetation
- Partial flooding of the site

6.1.3.2 PATHWAYS

The pathways are surface, subsurface and through conduits in bedrock. The surface pathways are drains, natural flow paths and overland sheet flow. The subsurface pathways are vertical and horizontal. The vertical pathways are determined from topsoil and subsoil permeability and groundwater vulnerability.

Soils over the western portion of the site are expected to have moderately high runoff potential (SCS-SA soil group C). A small portion of the upper catchment falls under soil group B, indicating moderately low runoff potential. In contrast, the eastern portion of the site is mainly classified as groups A/B, reflecting low to moderately low runoff potential, with a small central section classified as group C. The variation in runoff potential influences the generation and movement of surface runoff across the site. The dominant occurrence of low-growing Karoo shrubland vegetation on site means that these areas would slow down surface runoff (and promote infiltration).

There are several non-perennial rivers within the site and its surrounding area, dry watercourses that traverse the site, and several small dams. These non-perennial rivers are characteristic of the region's relatively low rainfall and flat terrain, which limits runoff generation and the formation of clearly defined flow paths. These poorly defined channels promote lateral diffuse flow between catchments.

6.1.3.3 RECEPTORS

The relevant receptors are as follows:

- The Amosrivier that traverses the western site portions
- The Soutrivier and Skilpadkoprivier that traverse the central and eastern portions of the site
- Braided network of non-perennial streams / smaller tributaries
- Vleis and dry pans surrounding the non-perennial streams
- Several small farm dams located within and around the site
- The larger Beervlei Dam located further downstream, which receives drainage from the Soutrivier
- The area of hydrological relevance derived during the hydrological modelling process, outlining the catchment area contributing to flows at the site
- The site lies within quaternary catchments L11G, L12A, and L12B

6.2 ASSESSMENT OF THE IMPACTS FROM THE PROPOSED MINING OPERATION

This assessment is carried out as detailed in the Methodology, Section 6.1.3 for the Sources noted in Section 6.1.3.1. The sources were identified for the construction phase, operational phase and decommissioning phase. The same categorisation is continued in this Section. The proposed mining operation is considered in its entirety rather than the separate portions.

6.2.1 CONSTRUCTION PHASE

Clearing vegetation on site

Clearing of vegetation on site will result in change of biodiversity, degradation of the topsoil due to erosion and presence of suspended solids in surface runoff. Biodiversity is outside the scope of the present report and erosion could happen only during the period that the land is exposed after the vegetation is removed and construction work commences. A worst-case scenario is the site areas earmarked for construction are left for a long duration after the Karoo shrub vegetation is removed. The receptors are the surface water channels, the Amosrivier, Soutrivier and Skilpadkoprivier, their network of non-perennial streams, and adjacent dams.

Construction of access roads

This will also cause suspended solids in surface runoff. Compaction of soils could lead to increased runoff and possible erosion. The receptors are the surface water channels, the Amosrivier, Soutrivier and Skilpadkoprivier, their network of non-perennial streams, and adjacent dams. Certain constructed internal access roads will be in close proximity to these non-perennial drainage lines.

Storage and erection of temporary structures to facilitate construction phase

Hydrocarbons and cement are considered under a separate heading and are not considered here. This includes stockpiles, laydown, material storage areas, or temporary structures erected on site. Poorly managed construction material stockpiles could lead to sediment increases in runoff. The effects may be on diminished water quality or impeded water flow. The receptors are the surface water channels, the Amosrivier, Soutrivier and Skilpadkoprivier, their network of non-perennial streams, adjacent dams; and probably groundwater, depending on the material on storage.

General waste from construction personnel

This refers to the waste generated during the construction phase. Handling of waste and transportation of waste materials can cause various types of spills which can be washed off-site by runoff during rain events into the surrounding environment. The receptors are the surface water channels, the Amosrivier, Soutrivier and Skilpadkoprivier, their network of non-perennial streams, adjacent dams; and probably groundwater.

Excavations based on construction designs

Excavations are envisaged during the construction of the proposed mine operation based on the site layout. Clearing topsoil from footprint areas will influence the rate of infiltration of water into the underlying soils and shallow groundwater systems and/or baseflow components to shallow streams. The receptors are the surface water channels, the Amosrivier, Soutrivier and Skilpadkoprivier, their network of non-perennial streams, and adjacent dams. The effects are similar to those noted in headings above: degradation of the topsoil due to erosion and the presence of suspended solids in surface runoff.

Drainage during construction

The drainage considered here refers to those provided during the construction stages: diversion of water flow away from construction areas; construction of storm water management infrastructure channels; and road crossings with culverts over existing drainage lines. The receptors are the surface water channels, the Amosrivier, Soutrivier and Skilpadkoprivier, and their network of non-perennial streams. The main effect is erosion based on velocities and quantity.

Hydrocarbons from machinery and vehicles

These constitute storage, leaks and accidental spills of fuels and lubricants. They are all petroleum-based products. The main receptors are the surface water channels, the Amosrivier, Soutrivier and Skilpadkoprivier, their network of non-perennial streams, adjacent dams; and groundwater.

Cement based products suspended in water

Cement will be used in concreting throughout the site and may result in wash aways and other spillages from use and transport. The main receptors are the surface water channels, the Amosrivier, Soutrivier and Skilpadkoprivier, their network of non-perennial streams, adjacent dams; and groundwater.

Landscaping / Grassing

The effects from landscaping are similar to the effects from the headings above, in that it will disturb topsoil layers and increase suspended solids in surface runoff. An increase in lawn areas as opposed to woody shrubs will reduce the 'surface roughness' provided by natural vegetation, thus encouraging sheet flow and increased runoff velocities. The receptors are the surface water channels, the Amosrivier, Soutrivier and Skilpadkoprivier, and their network of non-perennial streams.

Partial Flooding of site

The slopes are typically low across the site. With the site's non-perennial streams, comprising a braided network of dry river beds extending over relatively flat terrain, extreme rainfall events may result in a less contained or channelled flood response, but rather a low-velocity 'ponding' across the site. The ponding of flood waters across the site will result in increased infiltration rather than high discharge fluvial flow. The flood model results confirmed certain areas of flood risk within the modelled flooding of the site's flatter areas. This terrain data, together with the rainfall characteristics of this region, indicate that the risk of flooding of the full site from the adjacent areas is extremely low.

6.2.2 OPERATIONAL PHASE

Drainage from paved areas that have access to vehicles

Drainage of surface water runoff from paved internal roads, gravel roads, parking areas, and other hardened/compacted surfaces. The increase of surface water runoff volumes and the time of concentration (travel time) could increase the flood peaks in the surface water channels, the Amosrivier, Soutrivier and Skilpadkoprivier, and their non-perennial streams. The surface runoff could have dissolved hydrocarbons and could affect groundwater.

An increase in the kinetic energy and splash erosion potential resulting from the 'hard' surfaces of mine plant, mine offices, central processing plant, storage areas, and other infrastructure

The kinetic energy of runoff falling from impermeable surfaces of mine infrastructure is a possible cause of erosion (adjacent to infrastructure). Possible increased erosivity of runoff falling from impermeable surfaces could increase the sediment loads reaching the surface water channels, the Amosrivier, Soutrivier and Skilpadkoprivier, their non-perennial streams, and adjacent dams.

Drainage from mine opencast pits, waste rock dumps, and tailing storage facilities

The development of the mine is expected to significantly alter the hydrological soil groups within the relevant catchment due to the excavation of the pits and the development of the waste rock dumps and tailings, resulting in higher infiltration potential. Opencast mining pits and stormwater measures will reduce the amount of runoff that would naturally return to the environment. Poor quality (or contaminated) runoff from the waste disposal areas could enter the surrounding environment if not properly managed. Seepage from the waste rock dumps or mine tailings into the vadose zone and subsequent groundwater table, could result in poor quality or contaminated baseflow. Surface and groundwater contamination from acid mine drainage (AMD) is a possibility, but given the limited data available for this site, it is considered to be less probable and of low risk at this stage. This should be further investigated once more information is available in this regard.

Spillages from pollution control dams

Spillages, leaks and runoff from pollution control dams (PCDs) if they overflow during high rainfall events. The receptors are nearby surface water channels, the Amosrivier, Soutrivier and Skilpadkoprivier, their non-perennial streams, adjacent dams, and groundwater. Spillages from the PCDs are considered a large risk and should be managed with the conceptual stormwater management plan as proposed in this document.

Hydrocarbons from machinery and vehicles

These constitute storage, leaks and accidental spills of fuels and lubricants. They are all petroleum-based products. The main receptors are the surface water channels, the Amosrivier, Soutrivier and Skilpadkoprivier, their non-perennial streams, adjacent dams, and groundwater.

Partial Flooding of site

The slopes are typically low across the site. With the site's non-perennial streams, comprising a braided network of dry river beds extending over relatively flat terrain, extreme rainfall events may result in a less contained or channelled flood response, but rather a low-velocity 'ponding' across the site. The ponding of flood waters across the site will result in increased infiltration rather than high discharge fluvial flow. The flood model results confirmed certain areas of flood risk within the modelled flooding of the site's flatter areas. This terrain data, together with the rainfall characteristics of this region, indicate that the risk of flooding of the full site from the adjacent areas is extremely low. The proposed mine infrastructure areas are positioned away from the main drainage lines. Therefore, the risk of flooding of the entire site from the Amosrivier, Soutrivier and Skilpadkoprivier, is low.

6.2.3 DECOMMISSIONING PHASE

Clearing or disturbance to vegetation on site

Clearing of any re-vegetated growth that established over the project's life-cycle will result in degradation of the topsoil due to erosion and presence of suspended solids in surface runoff. A worst-case scenario is the site is left for a long duration after the vegetation is disturbed. The receptors are the surface water channels, the Amosrivier, Soutrivier and Skilpadkoprivier, their non-perennial streams, and adjacent dams.

Storage, stockpiling and removal of existing structures to facilitate decommissioning phase

This includes stockpiles, material storage areas, or waste removed from site. The effects may be on diminished water quality or impeded water flow. The receptors are the surface water channels; the Amosrivier, Soutrivier and Skilpadkoprivier, their non-perennial streams; and probably groundwater, depending on the material on storage.

Hydrocarbons from machinery and vehicles

These constitute storage, leaks and accidental spills of fuels and lubricants. They are all petroleum-based products. The main receptors are surface water channels, the Amosrivier, Soutrivier and Skilpadkoprivier, their network of non-perennial streams, and groundwater.

Backfill and closure of the mine opencast pits

Backfilling and closure of the opencast pits with waste rock dump material is expected to significantly alter the hydrological soil groups within the site's area of hydrological relevance, due to size and porosity of backfill waste rock materials, with higher infiltration potential.

Rehabilitation and re-vegetation

Earthworks and soil disturbances are required to re-shape mine dumps and stockpile areas. This could result in temporary poor-quality runoff and temporary sedimentation during rehabilitation activities, until such time that vegetation has re-established.

Partial flooding of the site

Flooding of decommissioned mining works and resultant altering of the groundwater flow regime for the flooding period.

6.3 HYDROLOGICAL IMPACT SIGNIFICANCE AND MITIGATION MEASURES

This assessment is carried out as detailed in the Methodology, Section 6.1.1 and 6.1.2, where the significance of hydrological impacts are quantified as per the ratings criteria in Tables 6-1 and 6-2.

The following potential hydrological impacts were identified to be associated with the proposed mining operation and are included in this impact assessment:

- Changes in catchment water resources,
- Changes in catchment water quality, and
- Changes in flood hydrology.

Table 6-3 presents the results of the significance ratings attributed to each of the identified potential impacts for the construction, operational, and decommissioning phases.

TABLE 6-3: SIGNIFICANCE RATINGS OF POTENTIAL IMPACTS

ENVIRONMENTAL PARAMETER ISSUE / IMPACT / EFFECT	ENVIRONMENTAL SIGNIFICANCE BEFORE MITIGATION									COMMENTS / RECOMMENDED MITIGATION MEASURES	ENVIRONMENTAL SIGNIFICANCE AFTER MITIGATION								
	E	P	R	L	D	I / M	TOTAL	STATUS (+ OR -)	S		E	P	R	L	D	I / M	TOTAL	STATUS (+ OR -)	S
Construction Phase																			
Changes in Catchment Water Resources due to:																			
Impeding or diverting the flow of water in a watercourse	1	4	2	2	3	2	24	–	Medium	Storm water management infrastructure development such as diversion berms, channels and silt management	1	2	1	2	1	1	7	–	Low
Altering the characteristics of catchment areas	1	1	2	2	1	1	7	–	Low	The proposed mine operation is associated with the conversion of natural areas to mine areas. This is likely to alter the hydrological characteristics of the immediate areas associated with operation. This impact is largely limited to the project site and is therefore associated with a low significance level. Natural vegetation should be re-established to represent the previously undisturbed environment as closely as possible.	1	1	1	1	1	1	5	–	Low

Reduction in Catchment Water Quality due to:																			
Erosion from disturbed open ground areas during construction (Disturbed and unconsolidated soil and stockpiles)	2	4	2	2	2	2	24	–	Medium	Any rainfall falling onto open ground during the construction phase may result in erosion and sediment being transported into the nearby streams. Clearing of vegetation and associated excavation areas should be kept to a minimum, particularly in areas where soils are unstable. Mitigation measures include the implantation of flow control measures upstream of a construction site (through berms) and limiting sediment from being eroded from stockpiles (through silt fences)	1	2	1	1	1	1	6	–	Low
Contamination of the watercourses and adjacent dams by spills of cement and other construction-related hazardous chemicals	2	3	3	3	1	2	24	–	Medium	The storage/handling of fuel, lubricants and chemicals will require special attention due to their hazardous nature as is the case with the laydown areas. These areas are required to be secured and managed on impermeable floors with appropriate bunding, sumps and roofing.	1	1	1	1	1	1	5	–	Low
Contamination of the watercourses and adjacent dams by spills of hydrocarbons from construction vehicles and workshop areas	2	3	3	3	2	2	26	–	Medium	There is an inherent risk of spillage from machinery and hydrocarbon stores, particularly during the construction phase.	1	1	1	1	1	1	5	–	Low
Disturbance to vegetation cover thus reducing the site's natural ability to biofilter the surface runoff and groundwater reaching downstream drainage lines	1	4	2	2	2	2	22	–	Low	Clearing of vegetation on site will result in change of biodiversity, degradation of the topsoil due to erosion and presence of suspended solids in surface runoff. Retention or rehabilitation of the natural land-cover and drainage of the site (post construction or decommissioning) will also serve to limit potential increases in erosion.	1	3	2	2	1	1	9	–	Low

Changes in Flood Hydrology due to:																			
An increase in impervious areas	1	4	2	2	2	2	22	–	Low	Due to the conversion of permeable surfaces to impermeable surfaces (i.e. internal roads, construction camps, laydown areas, storage areas, and mine infrastructure), the peak discharge rate of local streams will be increased. Due to the site's flatter terrain, the impact of this is associated with a low significance rating.	1	4	2	1	2	2	20	–	Low
Impeding flow	1	3	2	1	3	2	20	–	Low	Diversion channels and berms are proposed near the buildable area, and the construction camp/laydown area. These areas are unlikely to impede the natural flow of water across the site.	1	2	2	1	2	2	16	–	Low
Operational Phase																			
Changes in Catchment Water Resources due to:																			
Impeding or diverting the flow of water in a watercourse	2	4	2	2	3	2	26	–	Medium	Mitigation measures required through implementation of Storm water management plan, and proposed diversion berms / channels. Changes in catchment water resources and ecosystem functionality are expected as a result of the mining operation.	1	2	1	1	3	1	8	–	Low
Altering the characteristics of local catchment areas	2	4	2	2	3	2	26	–	Medium	Impacts on the local hydrology are unavoidable. These impacts are, however, limited to the local/district hydrology and are therefore associated with a lower significance rating.	1	1	2	1	2	1	7	–	Low

Natural vegetation disturbance/loss resulting in the emergence of invasive alien vegetation, placing further pressure on water resources	2	1	1	2	2	2	16	–	Low	Rehabilitation design should initially include those pioneer species for fast coverage and establishment. With the aim of later include a mix of locally indigenous Karoo shrubbery for biodiversity re-establishment and reinstatement to baseline site conditions. This will minimize the opportunity for invasives to establish on disturbed soils.	1	1	1	2	2	1	7	–	Low
Reduction in Catchment Water Quality due to:																			
Separation of clean and dirty water area: Clean water runoff from areas outside the dirty water footprint could flow into this area and potentially become polluted	2	3	3	2	3	2	26	–	Medium	Clean and dirty water systems have been formulated within the SWMP utilizing diversion berms, channels, and outfalls. With the implementation of designed mitigation measures, the significance rating is lowered.	1	1	2	1	2	1	7	–	Low
Contamination of the watercourses, adjacent dams and groundwater by spills of hydrocarbons from maintenance of mining vehicles and heavy machinery	2	3	3	2	3	2	26	–	Medium	The storage/handling of fuel, lubricants and chemicals will require special attention due to their hazardous nature. These areas are required to be secured and managed on impermeable floors with appropriate bunding, sumps and roofing. The movement of vehicles over the site will also introduce possible hydrocarbons. These constitute storage, leaks and accidental spills of fuels and lubricants.	1	1	1	1	1	1	5	–	Low
Discharge or overflow of water from PCDs and Runoff/drainage/leakage from waste rock sites and tailings storage facilities	2	4	3	3	3	3	45	-	High	Uranium and its decay products have the potential to leach from mine tailings / waste rock. Radioactive materials or contaminated water, if released into natural water systems, pose a significant risk. Dirty water drainage and storage systems have been formulated within the SWMP utilizing diversion berms, channels, and outfalls.	2	2	3	2	3	2	24	-	Medium

Disturbance to the 'surface roughness' of baseline vegetation cover, thus reducing the site's natural ability to biofilter the runoff and groundwater reaching downstream drainage lines	1	3	2	2	2	2	20	–	Low	Timeous and effective post-construction rehabilitation / re-vegetation adds protection to those disturbed topsoil layers and reduces the suspended solids in surface runoff. Rehabilitation design should aim to increase the 'surface roughness' provided by natural vegetation, thus reducing sheet flow and runoff velocities.	1	2	1	1	2	2	14	–	Low
Changes in Flood Hydrology due to:																			
An increase in impervious areas, in the form of internal access roads and service infrastructure	1	2	2	1	3	1	9	–	Low	The presence of paved or gravel roads and parking areas could increase the amount of surface runoff generated. The significance rating is low due to the site's flat terrain.	1	2	1	1	2	1	7	–	Low
An increase in the kinetic energy and splash erosion potential resulting from the mass introduction of 'hard' surfaces, in the form of mining infrastructure	1	3	3	1	3	1	11	–	Low	The kinetic energy of runoff falling from mining infrastructure and building facilities is a possible cause of erosion. The significance rating is low due to the site's flat terrain.	1	3	3	1	3	1	11	–	Low
Impeding / diverting natural flows	2	4	3	2	2	2	26	–	Medium	In order to mitigate against discharge rates impacting the proposed development areas, it is recommended that the proposed storm water management plan is implemented. This will ensure the attenuation of storm water runoff. It is also recommended that berms, channels, and sediment traps associated with the drainage lines are designed appropriately (in accordance with the best practice guidelines).	1	3	2	1	2	2	18	–	Low

Decommissioning Phase																				
Reduction in Catchment Water Quality due to:																				
Contamination of the watercourses and adjacent dams by spills of hydrocarbons from an increase in decommissioning machinery or loading / transport vehicles	2	3	3	3	2	2	26	–	Medium	There is an inherent risk of spillage from machinery and hydrocarbon stores, particularly when there is an increase in vehicular traffic during the decommissioning phase.	1	1	1	1	1	1	5	–	Low
Disturbance to the site's established vegetation cover, resulting in bare soil exposure, and thus increasing the risk of erosion and sediment reaching downstream drainage lines	2	4	2	2	2	2	24	–	Medium	Clearing of vegetation on site will result in change of biodiversity, degradation of the topsoil due to erosion and presence of suspended solids in surface runoff. Retention or rehabilitation of the natural land-cover and drainage of the site (post-decommissioning) will serve to limit potential increases in erosion.	1	2	1	1	2	2	14	–	Low
Cumulative																				
Reduction in Catchment Water Quality due to:																				
A series (or high frequency) of localised hydrocarbon / hazardous material spills or continued contaminated water runoff, leads to a 'larger-scale' impact on surrounding freshwater ecological systems, which may become irreversible.	3	3	3	3	3	3	45	–	High	Although the probability of this occurring on a frequent basis is low, the cumulative impacts of these events would be severely negative for downstream systems over the long term.	2	3	3	3	2	2	26	–	Medium
Changes in Flood Hydrology due to:																				
This mining operation, together with any other proposed and existing mining projects and activities in the area would have a cumulative impact on the surface runoff regime, due to a 'broad-scale' increase in vegetation removal and soil surface disturbance	3	4	2	3	2	3	42	–	Medium	With respect to soils, erosion potential, and from a surface run-off perspective, multiple projects would result in a large disturbance footprint, collectively causing a series of cumulative impacts.	2	4	2	2	2	2	24	–	Medium

As presented in Table 6-3, a number of the identified potential impacts are associated with a medium significance level. The following Sections 6.3.1 to 6.3.3 provide further details regarding the significance of the potential impacts as well as mitigation measures that should be implemented to reduce these potential negative impacts.

6.3.1 REDUCTION IN WATER QUALITY

A reduction in catchment water quality has implication to both the downstream ecology and downstream water users. Potential sources and types of surface water contamination include the following:

- Sediment entering the downstream environment during construction.
- General waste (including litter) entering the downstream environment.
- Heavy metals from cement mixing on site, building waste and rubble entering the downstream environment during construction.
- Hydrocarbon spillages from leaking plant and equipment entering the downstream environment.
- Radioactive and contaminated water associated with Uranium mining from either runoff or leaching of the PCDs, waste rock dumps or tailings storage facilities.

In order to mitigate against these identified potential sources of contaminated runoff, the following is proposed:

- All soil excavated during the construction process should be deposited outside of the drainage lines. This will limit the amount of fine sediments transported downstream (negatively affecting ecosystems).
- Berms upslope and downslope of areas likely to be a source of sediment contamination should be implemented. Upslope berms will ensure limited surface flows through areas associated with sediment loss. Downslope berms will ensure that sediments eroded from areas associated with sediment loss will be trapped, therefore reducing the impact to the downstream receiving environment. It is recommended that the berms are constructed out of a non-erodible material.
- All storm water runoff from areas likely to be a source of sediment contamination should be directed to a sediment trap, where sediment will be deposited rather than entering into the receiving environment.
- All waste should be regularly removed from the construction site on a regular basis and dumped in appropriate waste handling facilities.
- Berms or bunded areas should be implemented around the cement mixing area, as well as the building waste and rubble area to prevent storm water runoff to the downstream environment.
- Plant and equipment should be regularly checked (at least daily) for oil leaks and repaired timeously if required to prevent hydrocarbon contamination. During periods where the machinery is not in use, drip trays should be placed under the machinery to contain any spillages,
- Areas that may result in the contamination to groundwater should be sufficiently lined to meet with regulatory requirements, and
- Once the construction has been completed, rehabilitation of the affected areas should be undertaken. This should include planting indigenous pioneer Karoo shrub vegetation to ensure that erosion from the construction site is minimised.
- Construction should be scheduled to take place during the dry seasons when rainfall and associated erosion potential is at its least.

It is envisaged that if the above-mentioned mitigation measures are implemented, the risk of negatively impacting upon the water resources and ecosystem functionality downstream of the project site will be largely reduced.

6.3.2 DESIGNED MITIGATION MEASURES

Stormwater management:

- Separation of clean and dirty water through the development of stormwater structures as detailed in this report. It must be ensured that diverted runoff from disturbed areas is collected in dirty areas and clean water freely discharges to the surrounding clean catchment.
- Management of silt by ensuring that the disturbance of topsoil is minimised, sediment source and erosion control, phasing of earthworks activities, diversion of upslope runoff from entering the earthworks areas and downstream treatment of any collected sediment runoff i.e., use of silt traps;
- Regularly schedule inspection and maintenance of water management facilities, to include inspection of drainage structures and liners for any in channel erosion or cracks; de-silting of silt traps/sumps and PCDs; and any pumps and pipelines should be maintained according to manufacturer's specifications;
- Infrastructure design: the design of all onsite access roads, storage areas, central processing plant, stockpiles, etc. must include stormwater management and erosion control during both the construction and operational phases

6.3.3 ADDITIONAL MITIGATION MEASURES

In addition to the measures presented and discussed throughout this report, the following management measures should be implemented:

- Good housekeeping practices must be implemented and maintained by clean-up of accidental spillages, as well as ensuring all dislodged material like run-of-mine stockpile are kept within the confined storage footprints. In addition, clean-up material and materials safety data sheets for chemical and hazardous substances should be kept on site for immediate clean-up of accidental spillages of pollutants;
- Vehicles and plant equipment servicing must be undertaken within suitably equipped facilities, either within workshops, or within bunded areas, from which any stormwater is conveyed to a pollution control dam, after passing through an oil and silt interceptor.

All measures implemented for the mitigation of impacts, should be regularly reviewed as best practice and as compliance with various licences issued on site by authorities. The purpose of the mitigation measures is to ensure that the pre-mining / current water resource status is not deteriorated by the mining activities.

6.4 MONITORING AND REPORTING

A monitoring programme is an essential tool to identify any risks of potential impacts as they arise and to assist in impact management plans. Monitoring should be implemented throughout the life of the project.

Tables 6-4 to 6-6 below, provide a description of the key monitoring recommendations for the applicable mitigation measures identified for each phase of the project.

6.4.1 CONSTRUCTION PHASE

TABLE 6-4: KEY MONITORING RECOMMENDATIONS FOR THE CONSTRUCTION PHASE

Impact/Aspect	Mitigation/Management Actions	Responsibility	Methodology	Mitigation/Management Objectives and Outcomes	Frequency
Impeding or diverting the flow of water in a watercourse	Storm water management infrastructure development such as diversion berms / channels and silt management structures	Engineer / Contractor / ECO	Ensure berms, channels and silt traps are built in accordance with design specs, and their integrity is maintained	Diversion of surface/stream flow away from construction footprints, site camps, and laydown/storage areas	Initial construction / Monthly / After major rainfall event
Erosion from disturbed open ground areas, unconsolidated soil and stockpiles	All exposed soil, including stockpiles, must be protected for the duration of the construction phase with a suitable geotextile (e.g., Geojute or hessian sheeting)	Contractor / ECO	Inspect stockpiles and exposed ground areas, particularly during wind or rainy conditions	To prevent excessive erosion, and sedimentation of the receiving freshwater environment.	Weekly / After major rainfall event
Contamination of the watercourses and adjacent dams by spills of hydrocarbons from construction vehicles and workshop areas	Ensure adequate training of all machine operators, and conduct daily checks on vehicles/machinery. Breakdowns to be fixed off-site. Spill kits to be readily available. Ongoing sampling/monitoring of nearby water resources.	Contractor / ECO / Water Scientist	Do spot checks on vehicle checklists / operational compliance. Collect & analyse water quality parameters at specified monitoring points	Water monitoring points should be located both upstream and downstream of the proposed development site to ensure any impacts can be identified with appropriate responsive mitigation measures implemented.	Monthly / After major spill event
Disturbance to natural vegetation cover	All footprint areas must remain as small as possible and vegetation clearing to be limited to what is absolutely essential to ensure as much indigenous vegetation is retained. Adequate re-vegetation to those disturbed areas.	Contractor / ECO	Monitoring of grass germination and soil amelioration. Ensure that no natural vegetation on site is disturbed unnecessarily.	To ensure adequate and fast surface coverage, to minimise erosion potential.	Weekly
An increase in impervious areas	All excavated areas must be compacted to natural soil compaction levels to prevent the formation of preferential surface flow paths and subsequent erosion. Conversely, areas compacted as a result of construction must be loosened to natural soil compaction levels.	Contractor / ECO	Non-footprint areas to be assessed for adequate rehabilitation. Grass berms to be closely monitored.	To reduce the impact and erosive potential of water flowing off hardened surfaces.	Weekly

6.4.2 OPERATIONAL PHASE

TABLE 6-5: KEY MONITORING RECOMMENDATIONS FOR THE OPERATIONAL PHASE

Impact/Aspect	Mitigation/Management Actions	Responsibility	Methodology	Mitigation/Management Objectives and Outcomes	Frequency
Natural vegetation disturbance/loss resulting in the emergence of invasive alien vegetation	Alien and invasive plant species identified must be removed and disposed of as per an Alien and Invasive Species Control Plan and the area must be revegetated with suitable indigenous vegetation;	Contractor / ECO	Regular inspection of the area surrounding the surface infrastructure should occur to monitor the establishment of vegetation, prevent the establishment of alien and invasive vegetation species, and their potential spread into the surrounding freshwater ecosystem;	Reintroduce indigenous vegetation during rehabilitation, to outcompete in emerging aliens. Ensure that invasive species do not become established on site and further impact freshwater systems.	Monthly
Contamination of the watercourses and adjacent dams by spills from chemicals used to clean or maintain the facility's assets	Ensure adequate training of all cleaning staff. conduct daily checks on cleaning equipment. Spill kits to be readily available. Ongoing sampling/monitoring of nearby water resources	Contractor / ECO / Water Scientist	Do spot checks on cleaning equipment checklists / storage facilities. Collect & analyse water quality parameters at specified monitoring points	Water monitoring points should be located both upstream and downstream of the proposed development site to ensure any impacts can be identified with appropriate responsive mitigation measures implemented.	Monthly / After major spill event
An increase in impervious areas, in the form of internal access roads and service infrastructure	All footprint areas must remain as small as possible and vegetation clearing to be limited to what is absolutely essential to ensure as much indigenous vegetation is retained. Vegetated berms to be placed along the downslope of infrastructure, so slow the accelerated runoff from hardened surfaces.	Contractor / ECO	Assess and document vegetation growth around site infrastructure. Record areas of erosion, subsidence, or soil loss. Ensure surface runoff is adequately channelled.	To reduce the rates of increased surface flow velocity, thus decreasing the risk of erosion and sediment reaching the natural water resources	Weekly

6.4.3 DECOMMISSIONING PHASE

TABLE 6-6: KEY MONITORING RECOMMENDATIONS FOR THE DECOMMISSIONING PHASE

Impact/Aspect	Mitigation/Management Actions	Responsibility	Methodology	Mitigation/Management Objectives and Outcomes	Frequency
Contamination of the watercourses and adjacent dams by spills of hydrocarbons from an increase in decommissioning machinery or loading / transport vehicles	Ensure adequate training of all machine operators, and conduct daily checks on vehicles/machinery. Breakdowns to be fixed off-site. Spill kits to be readily available. Ongoing sampling/monitoring of nearby water resources.	Contractor / ECO / Water Scientist	Do spot checks on vehicle checklists / operational compliance. Collect & analyse water quality parameters at specified monitoring points	Water monitoring points should be located both upstream and downstream of the proposed development site to ensure any impacts can be identified with appropriate responsive mitigation measures implemented.	Monthly / After major spill event
Disturbance to the site's established vegetation cover, resulting in bare soil exposure, and thus increasing the risk of erosion and sediment reaching downstream drainage lines	All excavated areas must be compacted to natural soil compaction levels to prevent the formation of preferential surface flow paths and subsequent erosion. Conversely, areas compacted as a result of construction activities must be loosened to natural soil compaction levels. Adequate re-vegetation to those disturbed areas.	Contractor / ECO	Monitoring of grass germination and soil amelioration. Ensure that no natural vegetation on site is disturbed unnecessarily.	To ensure adequate and fast surface coverage, to minimise erosion potential.	Weekly

7 CONCLUSIONS

Baseline Assessment

Baseline information including monthly rainfall, monthly evaporation, design event rainfall, soils and associated runoff response, vegetation and land cover, as well as site topography and regional and local catchment hydrology were considered for the proposed Lusika Invest Uranium Mining project located near Beaufort West in the Western Cape Province of South Africa. This baseline assessment confirmed that potential evaporation greatly exceeds rainfall (2450mm versus 205mm respectively for the wester section). The combination of rainfall, evaporation and temperature result in a warm semi-desert hot arid, steppe climate. The design rainfall depths associated with extreme events are still significant at 107mm and 124mm for the 24-hour 1:50, and 1:100 year recurrence interval respectively for the eastern section of the proposed operation. The following terrain (elevation) datasets were used in this assessment:

- 1m Digital Terrain Model (DTM) data; and
- 30m digital surface model (DSM) COP30 data

The 1m DTM was derived from a lidar dataset (767 .xyz files) which provides a point cloud of the site. The lidar was interpolated to an elevation dataset with a resolution of 1m and presents a 'bare earth' model of the site and its surroundings, which is of value in hydrological modelling given the preference for a terrain without surface features such as buildings or vegetation. It is important to note that the 1m DTM contains artefacts – specifically, scan line errors – which are anomalies or errors in the elevation data along a strip of the survey extent. Due to these artefacts, the 1m DTM has been superseded by the underlying terrain 30-meter DSM in the affected areas.

The 30m DSM represents the surface, inclusive of features such as vegetation and buildings (if captured by the coarse cell size). The natural setting of the upslope area (not covered by 1m DTM) limits the influence of vegetation for the 30m DSM. Majority of the slopes within the area of hydrological relevance are below 3% with many slopes below 1%. This reveals the particularly flat nature of the site and surroundings. The elevations over the area of hydrological relevance and site range from approximately 950 - 824 m AMSL and 882 – 826 m AMSL respectively.

The site lies within the quaternary catchments L11G, L12A, and L12B. The area of hydrological relevance to the site is approximately 361.1 km^2 as defined by geoprocessing of the 30m DSM. The 1:50,000 topographical map indicates the presence of several non-perennial rivers within the site and its surrounding area, dry watercourses that traverse the site, and several small dams. These non-perennial rivers are characteristic of the region's relatively low rainfall and flat terrain, which limits runoff generation and the formation of clearly defined flow paths. These poorly defined channels promote lateral diffuse flow between catchments.

In considering the detailed Soil Conservation Service for South Africa (SCS-SA) dataset of the site, the western portion of the site is predominantly classified as hydrological soil group C, indicating moderately high runoff potential. The natural vegetation is Kouga Grassy Sandstone Fynbos, Sundays Arid Thicket, Saviaans Valley Thicket, and Willowmore Gwarrieveld. A small portion of the upper catchment falls under group B, indicating moderately low runoff potential. In contrast, the eastern portion of the site is mainly classified as groups A/B, reflecting low to moderately low runoff potential, with a small central section classified as group C. The natural vegetation in the East is predominantly classified as Sundays Arid Thicket and Albany Alluvial Vegetation. The variation in runoff potential influences the generation and movement of surface runoff across the site. Land-cover on the site is mostly classified as 'shrubland'.

Flood Assessment

The flood assessment involved the development and simulation of two separate models: a surface water flood model and a fluvial flood model. These models were used to assess flood risk for two recurrence intervals: 1:50-year and 1:100-year. The surface water flood model employed a rain-on-mesh approach to simulate flooding over the proposed development for both 1:100-year and 1:50-year recurrence interval (RI) flood events. The fluvial flooding was simulated along the Amos non-perennial river, that lies to the South of Ryst Kuil Extension. In addition to these models, a high-level Regional Maximum Flood (RMF) flooding assessment was also conducted to provide an understanding of the flood risk to the two sites from the primary watercourse diving them (the Sout River). The results of the RMF assessment indicate that the Sout River does not affect the site.

A rain-on-mesh approach was adopted for the West and East Area of Hydrological Relevance (approximately 315 km^2 and 46 km^2), which also acted as the 2D flood model boundary. The area of hydrological relevance, or rather the 2D model boundary, was intentionally chosen to be larger than the site-specific catchment (118.22 km^2) to include neighbouring areas. The 1m DTM was the dominant terrain dataset utilised, although the 30m DSM was used as a supplementary dataset, including its use in the 'artefact region' which affected the modelling of flooding, particularly at Hannekuil. The topographic conditions facilitate the lateral spreading of runoff and enhance connectivity between adjacent catchments. Consequently, water flow is not confined to discrete channels but instead disperses across the landscape, increasing the potential for inter-catchment exchange. By extending the model boundary beyond the site-specific catchment, the model effectively captures these complex hydrological processes. This approach ensures that cross-boundary hydrological interactions (or just interplay among bordering catchments) particularly during high-flow or flood events are represented within the model. The rain-on-mesh approach enables a distributed assessment of runoff generation (the rainfall-infiltration-runoff process), the attenuating influence of any depressions in the detailed terrain, the accumulation of flow, and any interaction between flow paths (where neighbouring catchments may spill at a certain depth of flow and become relevant to the site)

A fluvial approach was adopted for the relevant reach of the Amos River selected for modelling. To simulate the flooding for the river, the standard design flooding (SDF) method was used to estimate 1:50-year and 1:100-year RI hydrographs. These hydrographs were applied to the upstream end of the river reach. The availability of continuous DTM data allowed for the adoption of a 2D flood model approach using HEC-RAS. The advantage of a 2D model is consequently its ability to account for more variation in the topographic data since no gaps are present in the model geometry.

Unlike fluvial flood modelling, flood lines for surface water flooding cannot be defined due to the absence of simulated flooding along clearly defined river channels (rain-on-mesh simulations produce flooding in all locations, even if shallow). To compensate for this (flooding shown everywhere), the maximum depth of flooding illustrated is for depths greater than 0.2m. For the 1:100-year event, the surface water flooding predominantly indicates flood depths that do not exceed 0.5m. These relatively low depths are due to the very low slopes of the site and surrounds and the absence of defined river channels, which means flood waters can spread out, limiting areas of appreciable depth. The proposed location of the TSF is an exception where flooding exceeds 0.5m. This is an indication of the concentration of flow at this location, which should be considered with regards to flooding protection of both the TSF and surrounds (including the CPP and ROM). The model results indicate that more significant flood depths (exceeding 2.5m) are noted along the south of Ryst Kuil Extension (Amos River) but these depths do not affect proposed infrastructure at the site. The results for the flood modelling show stream velocities to be predominantly < 0.4 m/s across the proposed development area with small areas of higher velocities (<0.8m/s) noted.

Storm Water Management Assessment

The proposed mining operation will alter the natural environmental state, thereby affecting the generation of storm water. Volumes of storm water generated over areas disturbed by mining operations are generally expected to increase because of the reduction in natural vegetation and removal/compaction of soils, while the quality of the storm water generated is expected to decrease due to the nature of mining operations. The conceptual SWMP has been developed to ensure clean and dirty water-generating areas are firstly identified and then managed appropriately based upon GN704 as well as the principles presented in the DWS Best Practice Guideline G1 for Storm water Management (BPG1).

The infrastructure layout, aerial imagery and DTM were used in combination to identify and delineate clean and dirty water generating catchments with associated flood peaks estimated based upon the proposed development scenario. The aim of the SWMP is to ensure upstream clean water, which would otherwise flow into the identified dirty areas, can be effectively diverted around dirty water producing areas as well as to ensure dirty water can be effectively isolated and routed towards an appropriately sized dirty water containment facility.

In order to achieve this, infrastructure such as berms and channels have been indicatively placed to ensure effective routing of water, sized to accommodate the 1:50 year peak flow per GN704 requirements. 11 Pollution Control Dams (PCDs) have been recommended based on the delineation of dirty areas requiring containment. These have been conceptually sited and sized based on the anticipated 1:50 year flood generated at each of the dirty water generating areas. The anticipated volumes of storm water generated at the pits as well as the TSF have also been estimated based on their respective self-containing contributing catchment areas. The conceptual storm water management plan presented in this report will need to be verified during the detailed design phase prior to the construction of infrastructure.

Hydrological Impact Assessment

A hydrological impact assessment was undertaken to determine the significance of each identified potential impact according to impact probability, frequency, extent, duration, and intensity. Potential impacts considered in this assessment for the construction, operational, and decommissioning phases were changes in catchment water resources, changes in catchment water quality, and changes in flood hydrology. The assessment further considered appropriate mitigation techniques which should be adopted in order to reduce impact significance. Potential significance for the considered impacts ranged from high in the pre-mitigation scenarios to medium in the post-mitigation scenarios. A monitoring programme is an essential tool to identify any risks of potential impacts as they arise and to assist in impact management plans and as such, a monitoring program has been provided with a description of the key monitoring recommendations for the applicable mitigation measures identified for each phase of the project. In addition to this, it is recommended that a surface water monitoring plan be developed for the proposed operation. This should be developed prior to development to highlight any impacts on receiving water resources resulting from both the construction and subsequent operation of the proposed development. These monitoring points should be located both upstream and downstream of the proposed development site to ensure any impacts can be identified with appropriate responsive mitigation measures implemented.

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APPENDIX A: FLOOD MODELLING

A surface water flood model needed to be developed to model the 1:50 and 1:100 RI event over the proposed development and a fluvial flood model needed to be developed to model flooding along the river, furthermore a Regional Maximum Flood (RMF) model was conducted to assess flood risks in the central basin between the two areas of interest. This model utilised the available data in the form of 1m DTM and 30m DSM and was simulated within the HEC-RAS 6.7 BETA3 software.

A.1 REGIONAL MAXIUM FLOOD (HYDROLOGICAL MODELLING)

The Empirical flood estimation method is a conservative approach to generating flood frequency curves that is widely used in South Africa (du Plessis & Masule, 2023). The approach plots observed maximum flood flows against the catchment area (Kovacs, 1988). The RMF incorporates a deliberate 15% safety margin above the highest observed flood peaks to account for future climate variability and uncertainties, enhancing its reliability (Du Plessis & Masule, 2023). The implementation of safety parameters was implemented after critique and review of the method discussed by Kovacs (1988). The works of du Plessis and Masule (2023) discussed the initial works of Kovacs (1988), the critiques and proposed alternatives which aim to reduce systematic errors in the peak flow generation. The decision to use RMF was based largely on the characteristics of the catchment in which the site is located due to the flat downstream area with shallow channels and pans (du Plessis & Masule, 2023).

Furthermore, the Regional Maximum Flood (RMF) is a conservative upper-bound estimate commonly utilized in hydraulic structure design to ensure infrastructure resilience against extreme flood events, as endorsed by South African water authorities and engineering guidelines (Du Plessis & Masule, 2023; SANCOLD, 1990)

TABLE A-1: HYDROGRAPHS FOR SOUT AND PLATDORING (RMF METHOD)

Non-Perennial River	Maximum Regional Flow (m^3/s)
Sout	5554.1

A.2 STANDARD DESIGN FLOOD (HYDROLOGICAL MODELLING)

The Standard Design Flood (SDF) method was selected for modelling the catchments feeding the non-perennial river on the basis that a sufficiently large catchment area would suit the regional SDF approach. SANRAL (2013) points out that the SDF Method "*relieves one from having to evaluate the relative applicability of alternative methods for determining the design flood. It encourages one to use engineering factors of safety to accommodate uncertainties in the hydrological analyses, rather than investigate, evaluate, and apply alternative hydrological procedures*".

For the Amos non-perennial river, the SDF method was used to calculate the 1:50 and 1:100 year RI design hydrographs. Table A-1 illustrates the peak flow m^3/s calculated for each river.

TABLE A-2: HYDROGRAPHS FOR AMOS (SDF METHOD)

	1:100 year (m^3/s)	1:50 year (m^3/s)
Amos	344.5	269.3

A.3 HEC-RAS MODELLING

For the flood modelling, HEC-RAS 6.7 BETA3 was selected to model the surface water flooding. The rain-on-mesh approach was adopted for the surface water flood model. HEC-RAS is designed to perform one-dimensional and two-dimensional calculations for a full network of natural and constructed channels. The software is used worldwide and the 1D component of the model has been thoroughly tested through numerous case studies. The 2D component to the HEC-RAS model is a recent addition having been released in 2015 although robust benchmarking (USACE, 2016) and verification and validation tests (USACE, 2018) have been performed to prove the 2D component of the model works as intended.

A.4 FLOOD MODEL SETUP

A.4.1 DESIGN RAINFALL

In assessing flooding, it was necessary to define the associated rainfall that would be simulated as falling over the model boundary and subsequently causing flooding. A hypothetical storm consequently needed to be developed which utilised DRESSA results discussed in Section 2.1.1. This hypothetical storm is the design rainfall that will produce the highest peak flow at each location independent of catchment response time (which is the index of the rate at which stormflow moves through a catchment). To calculate the hypothetical storm, the DRESSA estimates were transformed into a synthetic rainfall distribution for up to the 24-hour event. An areal reduction factor accounting for the anticipated reduction in rainfall over a large model area was not applied.

A.4.2 MODEL MESH

The computational model mesh is the primary element that makes up the HEC-RAS 2D model. This mesh contains the data pertaining to the terrain of the underlying elevation data, the presence of linear features, surface roughness and infiltration parameters.

One of HEC-RAS's major advances to hydraulic modelling has been the addition of a subgrid. The subgrid extracts the detail available in the detail of the underlying terrain into a hydraulic properties table for each cell and cell face in the model mesh. This includes variables such as the elevation/volume relationship per cell and the cross-section, elevation/area, and wetted perimeter for each cell face. This results in HEC-RAS models being able to use a larger cell size while still representing much of the underlying terrain, thereby producing an improved model result. Aside from added hydraulic detail, the visual benefit from HEC-RAS using a subgrid, is that a more representative result of the expected flooding is possible since HEC-RAS will show only partial flooding for a mesh cell (where applicable).

A.4.3 MODEL BOUNDARY AND CELL SIZE

The boundary for the rain-on-mesh flood model was delineated using both the 1m DTM and 30m DSM. The model employed a mesh size of 300m for the 30m DSM area and 20m for the 1m DTM area. This enhanced resolution allows for better representation of terrain details, even in areas that are relatively flat and uniform.

A.4.4 BREAKLINES

Breaklines are used in hydraulic models to define areas of important and abrupt change in topography that may otherwise be missed by the application of a consistent cell size. This approach was largely unnecessary in this study, with few changes in topography.

A.4.5 SURFACE ROUGHNESS

The assignment of suitable surface roughness in HEC-RAS's model mesh (Manning's 'n' values) was necessary to account for the influence that different surfaces have on the movement of water. A Manning's 'n' value shapefile was developed for the site based on the land-cover illustrated in Figure 2-5. Values ranged between 0.02 ('water) to 0.175 (forest). Manning's 'n' values are approximate only and assume uniformity in areas (where some localised variation is expected).

A.4.6 BOUNDARY CONDITIONS

Boundary conditions that would route water in or out of the model were defined with a normal depth slope according to an estimate based on the available terrain data.

A.4.7 FLOW ROUTING EQUATION

HEC-RAS includes two types of 2D unsteady flow routing equations, namely; Diffusion Wave or Full Saint Venant (a.k.a. Full Momentum). The more accurate Full Momentum equations were used.

A.7 ASSUMPTIONS AND LIMITATIONS

There are various assumptions and limitations which affect the accuracy of the flood model. Some of these assumptions and limitations are presented below:

- *Terrain accuracy* – the development of a flood model has relied on the detail and accuracy of 1m DSM and 30m DSM. The flood model cannot improve on the accuracy of the parent data (i.e. the terrain data used).
- *Terrain representation* – The terrain can only be expected to represent the terrain at the time of data capture. Changes in terrain, including changes in the morphology of any flow paths or river channel morphology can alter the results of this assessment.
- *Equivalence in recurrence interval* – the design rainfall event applied to the flood model is assumed to result in the equivalent design flood event (i.e. the 1:100 RI storm, produces the 1:100 RI flood).
- *Potential error in the parameterisation of the model* – this included the soils and land-cover classification used which may not accurately represent the site and surrounding area. These losses have only been considered using a generalised approach to infiltration and are not based on measured data.
- *Catchment delineation* – a containing catchment has been used for modelling. This catchment has been defined using geoprocessing of the available terrain data. This geoprocessing is based upon an 8-point pour model with the lowest neighbouring cell assumed to receive all the flow from the cell upstream of it. As such, there is no consideration of the flow rate and the potential for an upstream cell to feed into more than one downstream cell. This has potential implications for the final containing catchment extent.
- *Rainfall distribution* – the rainfall distribution used is hypothetical, with a symmetrical S-curve approach adopted (centred at the 12-hour mark). Extreme rainfall may occur differently from this.

- *Rainfall depth* – DRESSA rainfall depths are assumed accurate, with normal DRESSA values applied to this study. DRESSA also includes upper values representative of upper confidence limits. In addition, rainfall duration up to the 24-hour event has been considered. Longer event rainfall could exacerbate flooding, however, this may be limited due to the balance of infiltration loss compared to longer-duration rainfall.
- *Mesh detail* – the default mesh utilised a 300m mesh size with a 20m refinement region. While one of HEC-RAS's major strengths is the use of a subgrid, the obstructing or routing influence of linear features that are smaller than the mesh resolution may not be well defined.
- *Breaklines* – To compensate for mesh detail, linear features (and ridges in particular) were digitised as breaklines and then applied to the model mesh. The application of breaklines is assumed adequate.
- *Roughness values* – the absence of depth-varying roughness in HEC-RAS as this time meant that a pseudo approach to surface roughness needed to be adopted. There are, consequently, limitations to this approach as depths of flooding do vary during flooding, with surface roughness likewise varying (according to depth).
- *Model calibration* – no calibration of the model was undertaken as there is no suitable observed data for calibration purposes.
- *Climate Change* – climate change for one recurrence interval (100 RI) was considered in this study. 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). Climate change is expected to exacerbate any flooding due to a likely increase in rainfall intensities.

APPENDIX B: STORMWATER CALCULATIONS

B.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.

B.2 DESIGN HYDROGRAPHS

B.2.1 DESIGN STORM

In assessing the stormwater management, it was necessary to define the associated rainfall that would cause this flooding. A hypothetical storm consequently needed to be developed which utilised the depth-duration-frequency (DDF) data provided by DRESSA (see Section 2.1). This hypothetical storm is the design rainfall that will produce the highest peak flow at each location independent of catchment response time (which is the index of the rate at which stormflow moves through a catchment). To calculate the hypothetical storm, the DRESSA 1:50 year RI rainfall depth for various durations (e.g. 5 minutes, 30 minutes and 2 hours) was transformed into a synthetic rainfall distribution or design hyetograph.

B.2.2 MODEL PARAMETERISATION

The 1m DTM was used to identify subcatchments. Land-cover parameters were estimated according to the surface infrastructure layout with the baseline land-cover and soil type being set according to Section 2.5.

B.2.2 MODEL RUN

Dynamic wave routing was set for the model run along with a variable time step. The resulting runoff and routing continuity errors of 0% are optimum. The peak flows and characteristics for the subcatchments of interest are presented in Table B-1.

TABLE B-1: SUBCATCHMENT CHARACTERISTICS FOR THE 1:50 YEAR EVENT

Name	Area (ha)	Precipitation (mm)	Infiltration (mm)	Runoff Coefficient	Runoff Volume (ML)	Peak Runoff (m^3/s)
C01	7.6	107	40.78	0.61	5.0	1.1
C02	0.7	107	40.43	0.61	0.5	0.2
C03	22.6	107	41.41	0.60	14.7	2.5
C04	4.5	107	44.99	0.57	2.8	0.5
C05	97.0	107	62.85	0.40	42.0	3.3
C06	55.9	107	58.3	0.45	26.8	2.5
C07	104.9	107	62.1	0.41	46.2	4.0
C08	1.8	107	63.93	0.39	0.8	0.2
C09	1.6	107	62.96	0.40	0.7	0.2
C10	2.0	107	60.25	0.43	0.9	0.3
C11	77.4	107	61.62	0.42	34.5	3.6
C12	1.5	107	62.9	0.40	0.7	0.1
C13	3.8	107	63.06	0.40	1.6	0.2
C14	37.0	107	60.09	0.43	17.1	1.9
C15	30.0	107	63.38	0.40	12.8	1.3
C16	27.7	107	61.02	0.42	12.5	1.5
C17	28.4	107	62.44	0.41	12.4	1.2
C18	29.4	107	62.24	0.41	12.9	1.2
C19	1.3	107	62.87	0.40	0.6	0.1
C21	2.2	93	51.87	0.43	0.9	0.3
C22	7.5	93	49.08	0.46	3.2	0.9
C23	1.7	93	54.87	0.39	0.6	0.2
C24	0.8	93	36.85	0.59	0.5	0.2
C25	29.3	93	36.34	0.59	16.1	2.1
C26	3.5	93	36.45	0.59	1.9	0.4
C27	0.5	93	34.6	0.61	0.3	0.1
C28	7.4	93	34.77	0.61	4.2	1.1
C29	1.8	93	36.55	0.59	1.0	0.3
C30	173.0	93	35.32	0.60	95.8	9.3
C31	32.1	93	36.18	0.60	17.7	3.2
C32	3.9	93	37.01	0.59	2.1	0.8
C34	4.4	93	36.37	0.59	2.4	0.7
C35	1.0	93	37.32	0.59	0.5	0.2
C36	0.4	93	37.16	0.59	0.2	0.1
C37	2.8	93	37.66	0.58	1.5	0.4
C38	1.9	93	37.9	0.58	1.0	0.3
C39	6.0	93	37.87	0.58	3.2	0.6
C40	3.8	93	38.74	0.57	2.0	0.3
C41	4.3	93	38.35	0.57	2.3	0.4
C42	17.6	93	38.57	0.57	9.3	1.2
C43	4.3	93	34.22	0.62	2.5	0.6
C44	9.7	93	36.82	0.59	5.3	1.0
C45	11.3	93	37.57	0.58	6.1	1.2
C46	2.9	93	34.57	0.61	1.6	0.4
C47	19.0	93	36.22	0.60	10.5	1.8
C48	0.7	93	32.21	0.64	0.4	0.2
C49	19.5	93	34.99	0.61	11.0	2.0
C50	2.4	93	35.87	0.60	1.4	0.4
C51	134.5	93	35.18	0.60	75.3	9.3
C52	2.0	93	29.95	0.66	1.2	0.3

C53	1.3	93	28.91	0.68	0.8	0.3
C54	1.0	93	33.6	0.63	0.6	0.2
C55	9.0	93	38.04	0.58	4.8	0.7
C56	0.4	93	28.07	0.69	0.3	0.1
C57	42.9	93	34.93	0.61	24.2	3.2
C58	6.4	93	30.99	0.65	3.9	1.0
C59	0.7	93	31.19	0.65	0.4	0.2
C60	2.6	93	33.33	0.63	1.5	0.5
C61	5.5	93	35.74	0.60	3.1	0.7
C62	1.7	93	30.23	0.66	1.0	0.4
C63	0.8	93	34.44	0.62	0.5	0.2
C64	3.3	93	32.7	0.64	2.0	0.9
C65	11.2	93	32.29	0.64	6.6	1.5
C66	16.2	93	35.1	0.61	9.1	1.6
Ç67	0.9	93	33.02	0.63	0.5	0.2
C68	3.2	93	28.6	0.68	2.0	0.7
C69	1.8	93	29.27	0.67	1.1	0.4
C70	7.6	93	32.55	0.64	4.5	0.9
C71	3.3	93	32.05	0.64	2.0	0.7
C72	0.7	93	29.51	0.67	0.5	0.2
C73	4.5	93	33.55	0.63	2.6	0.7
C74	4.5	93	33.52	0.63	2.6	0.9
C75	3.0	93	35.4	0.61	1.7	0.5
C76	3.4	93	31.82	0.64	2.0	0.5
C77	27.9	93	36.5	0.59	15.3	2.7
C78	2.2	93	37.47	0.58	1.2	0.3
C79	41.2	93	36.23	0.60	22.7	3.8
D01	17.5	107	72.63	0.31	5.9	0.8
D02	12.2	107	72.77	0.31	4.1	0.6
D03	3.8	93	65.09	0.28	1.0	0.2
D04	1.7	93	64.53	0.28	0.5	0.1
D05	2.8	93	64.64	0.28	0.7	0.2
D06	9.9	93	64.61	0.28	2.5	0.3
D07	0.9	93	64.37	0.29	0.2	0.1
D08	4.9	93	64.83	0.27	1.2	0.1
D09	4.9	93	64.84	0.27	1.2	0.1
D10	4.8	93	64.75	0.27	1.2	0.2
D11	2.1	93	64.51	0.28	0.6	0.1
D12	25.9	93	64.95	0.27	6.4	0.6
D13	7.3	93	64.72	0.28	1.9	0.3
D14	7.2	93	64.66	0.28	1.8	0.2
D15	3.9	93	64.66	0.28	1.0	0.2
D16	0.5	93	63.42	0.30	0.2	0.1
D17	16.1	93	65.05	0.26	3.9	0.3
D18	4.3	93	64.65	0.27	1.1	0.1
D19	18.5	93	20.11	0.77	13.1	3.6
D20	7.2	93	18.19	0.79	5.3	1.9
P01	2.2	107	11.21	0.90	2.2	1.0
P02	3.7	107	11.17	0.90	3.5	1.6
P03	7.1	107	12.13	0.89	6.8	2.9
P04	2.0	107	11.17	0.90	1.9	0.8
P05	1.4	107	11.17	0.90	1.3	0.6
P06	13.2	107	11.17	0.90	12.7	5.2

P07	3.2	107	11.17	0.90	3.1	1.4
P08	2.1	93	10.81	0.89	1.7	0.9
P09	2.7	93	10.81	0.89	2.2	1.2
P10	9.6	93	14.56	0.84	7.5	3.7
P11	3.2	93	10.81	0.89	2.6	1.3
P12	2.1	93	10.81	0.89	1.7	0.9
P13	3.8	93	11.28	0.88	3.1	1.6
P14	7.3	93	13.96	0.85	5.7	2.9
P15	5.0	93	10.81	0.89	4.1	2.1
p16	3.1	93	10.81	0.89	2.5	1.3
p17	3.1	93	10.81	0.89	2.5	1.3
P18	15.4	93	10.81	0.89	12.6	6.2
P19	4.9	93	10.81	0.89	4.0	2.0
P20	3.7	93	10.81	0.89	3.0	1.6
P21	2.9	93	10.84	0.89	2.4	1.2
P22	4.7	93	10.81	0.89	3.8	2.0
P23	3.2	93	10.81	0.89	2.6	1.4
P24	3.1	93	10.81	0.89	2.5	1.3
P25	9.0	93	10.94	0.88	7.4	3.7
P26	9.6	93	10.81	0.89	7.9	3.8
P27	27.8	93	12.1	0.87	22.4	10.5
TSF	80.7	93	21.16	0.76	56.7	16.6