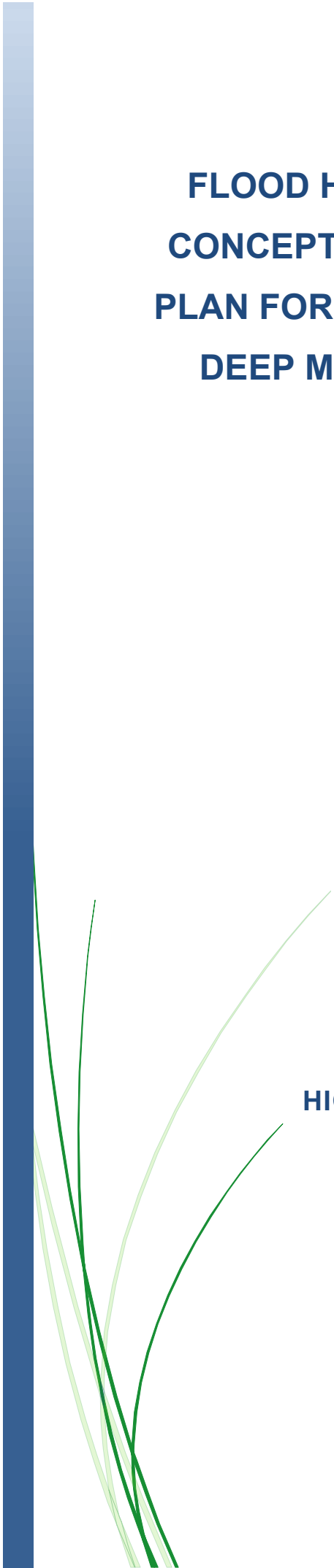


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FLOOD HYDROLOGICAL ASSESSMENT AND CONCEPTUAL STORM WATER MANAGEMENT PLAN FOR THE EXISTING GOLD FIELDS SOUTH DEEP MINING OPERATION, WESTONARIA, GAUTENG PROVINCE

Version 1

April 2026

HIGHLANDS HYDROLOGY (PTY) LTD

**FLOOD HYDROLOGICAL ASSESSMENT AND CONCEPTUAL
STORM WATER MANAGEMENT PLAN FOR THE EXISTING GOLD
FIELDS SOUTH DEEP MINING OPERATION, WESTONARIA,
GAUTENG PROVINCE**

Prepared For

Gold Fields South Deep

Prepared By

Highlands Hydrology (Pty) Ltd, in association with

Water Hunters

Version 1

April 2026

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FLOOD HYDROLOGICAL ASSESSMENT AND CONCEPTUAL STORM WATER MANAGEMENT PLAN FOR THE EXISTING GOLD FIELDS SOUTH DEEP MINING OPERATION, WESTONARIA, GAUTENG PROVINCE

1 INTRODUCTION

1.1 BACKGROUND

Highlands Hydrology (Pty) Ltd in association with Water Hunters has been appointed by Gold Fields South Deep to undertake a flood hydrological assessment and develop a conceptual Storm Water Management Plan (SWMP) for the existing South Deep Mining Operation (hereafter referred to as the site) which is located in Westonaria in the Gauteng Province of South Africa. The focus of the flood assessment is to determine flood-lines, flood depths and flood velocities for selected streams of interest located within the existing operational area. The conceptual SWMP was developed based a combination of existing infrastructure at the site as well as previous SWMPs as supplied.

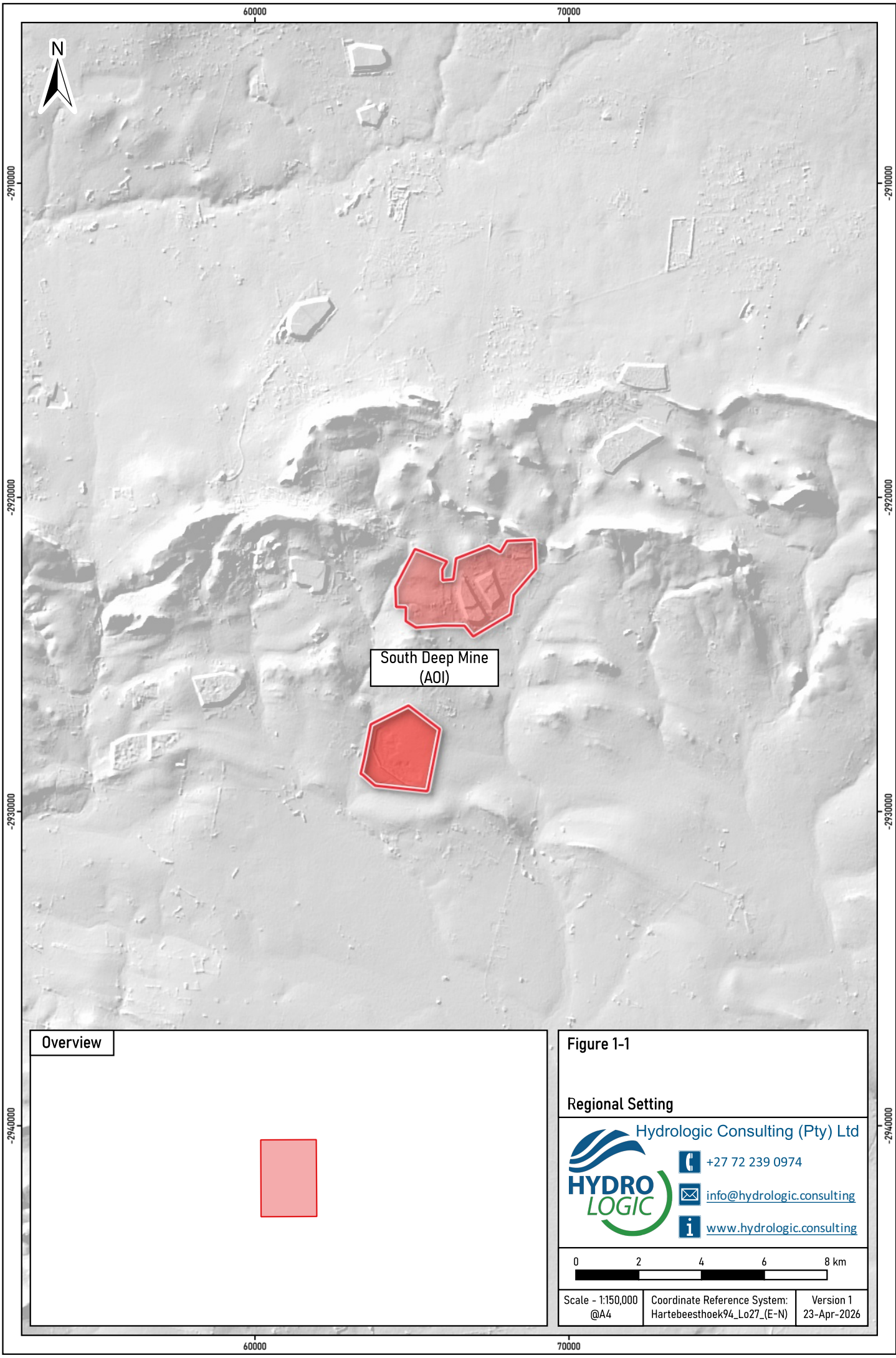
1.2 SCOPE OF WORK

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

- *Site Examination* – the site was visited by Luke Wiles (Hydrologist, PrSciNat), on 03 September 2025. This was to enable a better understanding of the dominant hydrological flow regimes as well as 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 2D fluvial flood model for the considered area in order to determine flooding for the specific streams of interest;
- *Conceptual SWMP* – the development of a conceptual SWMP for the effective management of clean and dirty water generating areas in line with Government Notice (GN) 704; and
- A technical report detailing the achieved scope of work.

1.3 REGIONAL SETTING AND LAYOUT

The site is located at 26° 24' 51" S and 27° 40' 36" E. The regional setting is illustrated in Figure 1-1, while the site layout is presented in Figure 1-2.



Overview



Figure 1-1

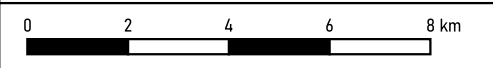
Regional Setting

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Scale - 1:150,000 @A4	Coordinate Reference System: Hartebeesthoek94_Lo27_(E-N)	Version 1 23-Apr-2026
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Legend

- Area of Interest
- Parent Farm
- Farm Portion
- Arterial Road (50K Topo)
- Footpath (50K Topo)
- Other Road (50K Topo)
- Secondary Road (50K Topo)
- Street (50K Topo)
- Furrow (50K Topo)
- Non-Perennial River (50K Topo)
- Perennial River (50K Topo)
- Dam (50K Topo)
- Open Reservoir (50K Topo)
- Vlei (50K Topo)
- 5m Contour (NGI)

Figure 1-2

Layout

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2 BASELINE INFORMATION

Baseline information in this section includes rainfall, evaporation, design event rainfall, soils, vegetation and land-cover, terrain, as well regional and local 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 site is station 475174 W (Kloof, GM) located approximately 8km west of the site. This SAWS station has a record length in excess of 33 years with a Mean Annual Precipitation (MAP) of 695mm. There are no DWS rainfall stations within close proximity to the site.

The potential for rainfall distributions to change over distance can be significant. Figure 2-1 presents the variation in MAP in the greater area. As such, an alternative and site-specific source of rainfall data was used to provide average monthly rainfall values for the actual site 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 621mm, comparing well to the distribution of rainfall as illustrated in Figure 2-1, as well as SAWS stations located in close proximity to the site. Table 2-1 presents the average monthly rainfall estimates from Pegram *et al* (2016) for the site.

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

Month	Rainfall (Pegram)
Jan	114
Feb	92
Mar	80
Apr	43
May	18
Jun	7
Jul	7
Aug	9
Sep	22
Oct	62
Nov	98
Dec	108
Total	660

* Estimates were sourced for the area of hydrological relevance.

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 rainfall estimates for various recurrence intervals and durations were sourced from the Design Rainfall Estimation Software for South Africa (DRESSA), developed by the University of Natal in 2002 as part of Water Research Commission (WRC) project K5/1060 (WRC, 2002). This method uses a regional I-moment algorithm 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 (2002) provides more detail on this method of design rainfall estimation. Table 2-2 presents the average DRESSA design rainfall estimates for the site.

TABLE 2-2: DRESSA 24-HOUR RAINFALL DEPTH

Recurrence Interval (Years)	Rainfall Depth (24 hour) (mm)
2	57.2
5	79.0
10	95.5
20	113.0
50	138.6
100	160.0
200	183.6

* Estimates were sourced for the area of hydrological relevance.

It is important to note, that no allowances for climate change were included 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 an increase in rainfall intensities.

2.3 EVAPORATION

Evaporation data was sourced from the South African Atlas of Climatology and Agrohydrology (Schulze and Lynch, 2006) in the form of A-Pan equivalent potential evaporation. The average monthly evaporation distribution is presented in Table 2-3 and shows an annual potential evaporation of 2170 mm for the centre of the site.

TABLE 2-3: MONTHLY A-PAN EQUIVALENT POTENTIAL EVAPORATION

Month	Schulze & Lynch (2006)
Jan	228
Feb	185
Mar	181
Apr	145
May	129
Jun	101
Jul	113
Aug	157
Sep	211
Oct	244
Nov	235
Dec	241
Total	2,170

2.4 AVERAGE CLIMATE

The average climate for the site is presented in Figure 2-2. While evaporation is shown to exceed rainfall greatly, this is representative of the maximum A-Pan equivalent potential evaporation that could occur, assuming no limitations are placed on evaporative demand. The combination of rainfall, evaporation, and temperature results in a temperate climate characterised by warm, wet summers and cool, dry winters.

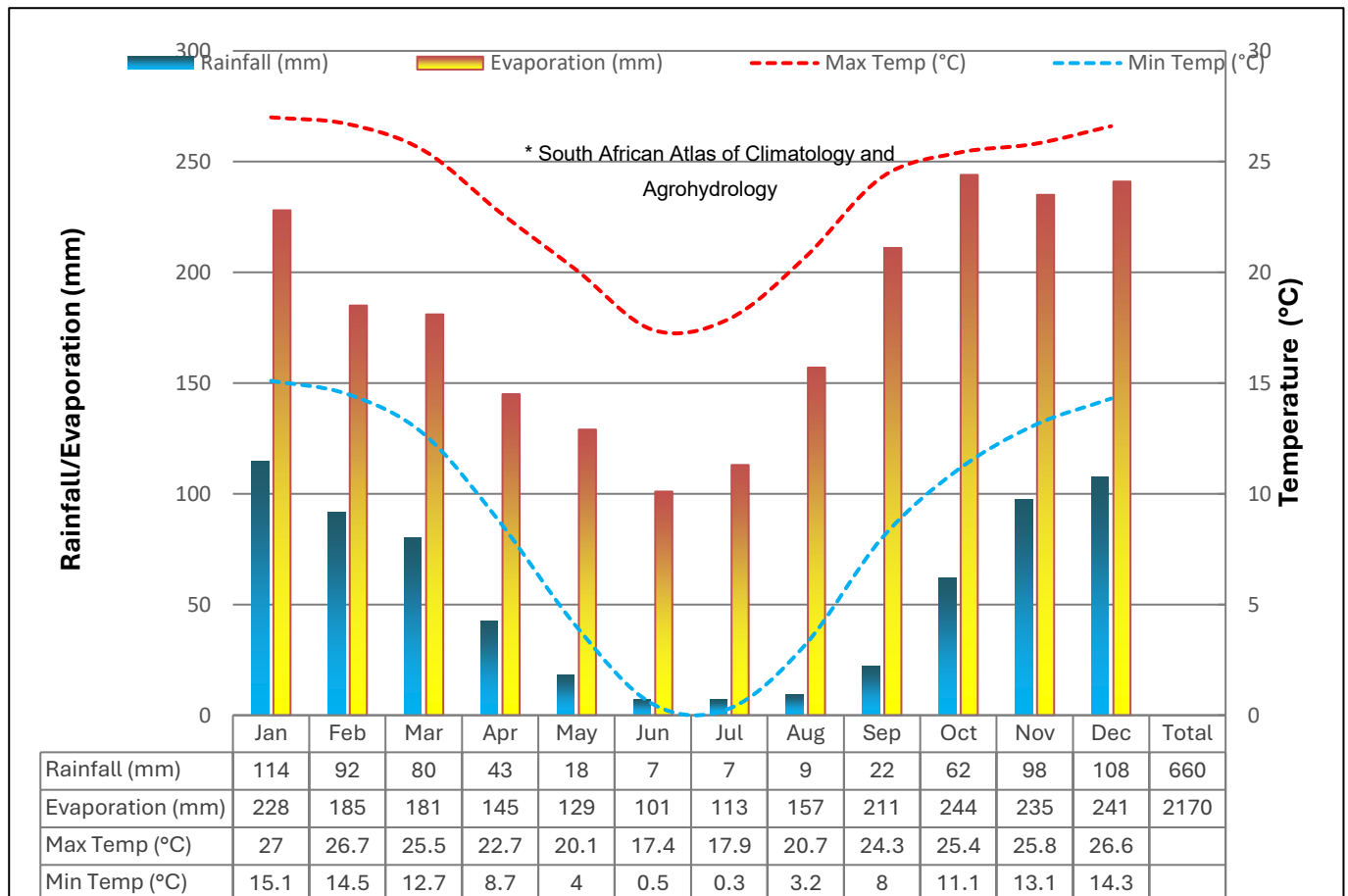


FIGURE 2-2: AVERAGE MONTHLY CLIMATE FOR THE SITE

2.5 TERRAIN

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

1. 0.2 m Digital Terrain Model (DTM) derived from two client-provided¹ Light Detection and Ranging (LiDAR) dataset; hereafter referred to as the 0.2m DTM;
2. 2 m DTM hereafter referred to as the 2 m DTM, purchased from Geosmart;
3. 30 m Digital Surface Model (DSM) COP30² data, hereafter referred to as the 30 m DSM; and
4. The National Geospatial Institute (NGI)³ 1:50,000 topographical map 5m contours.

¹ South Deep Doornpoort Wg27 Lidar 2025-04-08 Points.XYZ and South Deep TSF Wg27 Lidar 2025-04-12 Points.XYZ

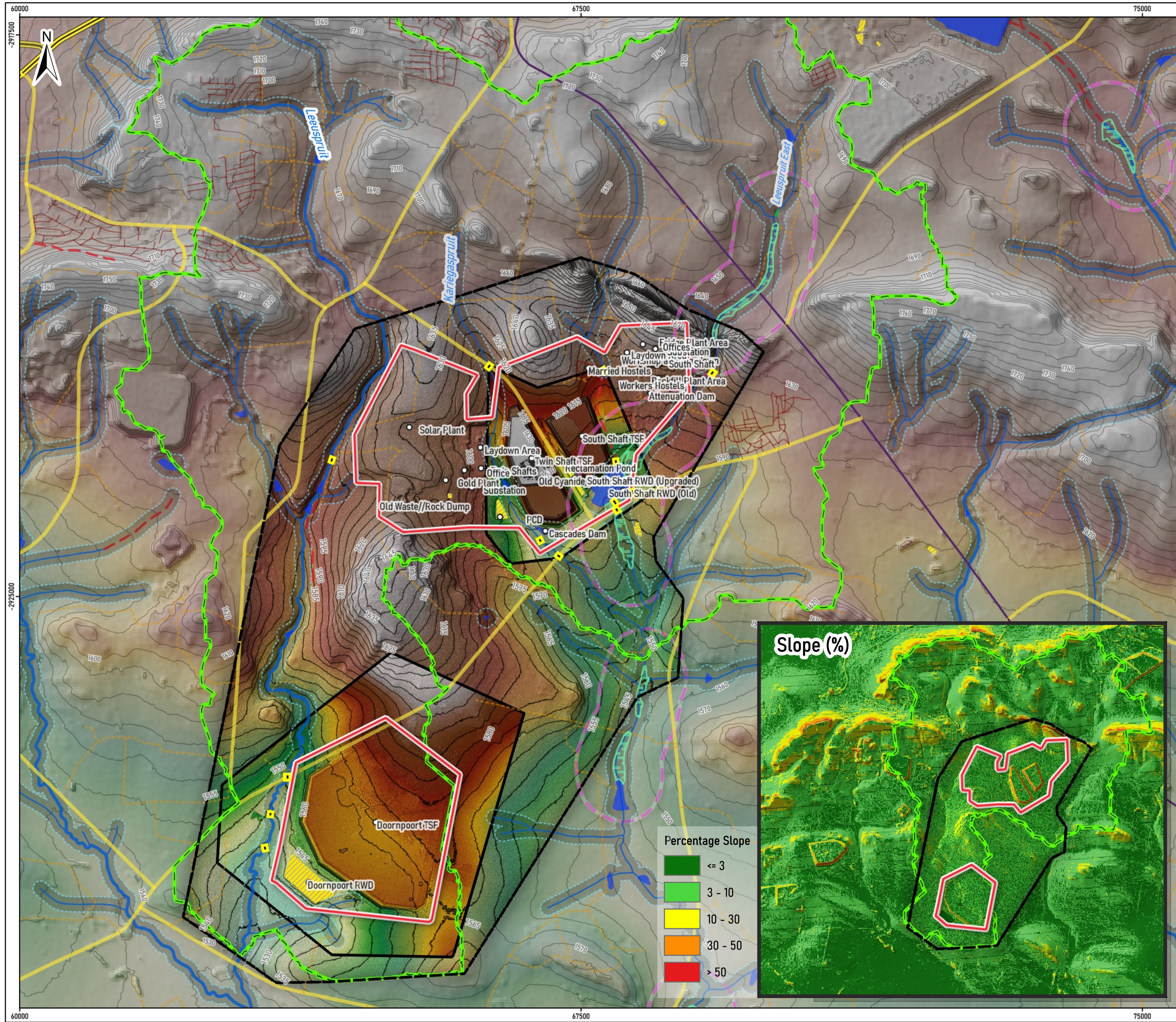
² [Copernicus Digital Elevation Model - Copernicus Contributing Missions Online](#)

The 0.2 m DTM provides a bare-earth representation of the terrain by removing surface features such as vegetation and built structures, thereby offering a more suitable elevation surface for flood modelling than a DSM, which retains these obstructions. Filtering of surface features to achieve a bare-earth model, does result in some areas in which the point density and resulting terrain representation is poorer (given a high incidence of vegetation which obscures terrain).

To supplement the areas of missing 0.2 m DTM data, a 2 m DSM purchased from Geosmart was incorporated. With reported vertical and horizontal accuracies of 0.5 m and 1 m, respectively, the 2 m DTM offered the more comprehensive coverage. The coverage of the 0.2 m DTM and 2m DTM was sufficient with regard to the river reaches for which flood modelling was undertaken.

Additionally, a 30 m DSM was employed for mapping and hydrological modelling in locations where neither the 0.2 m DTM nor the 2 m DTM provided sufficient coverage.

Ground elevations on the site are approximately 1,725 m Above Mean Sea Level (AMSL), whilst elevations over the non-perennial river reaches of interest range between approximately 1,615 m and 1,565 m AMSL. Slopes within the Area Of Interest (AOI) vary from gentle to mild, with slopes typically below 10%. Higher slopes are observed at the Tailings Storage Facilities (TSFs). The river channels within the modelled reaches exhibit low gradients, with channel slopes typically remaining below 3%.



- Legend**
- Area of Hydrological Relevance
 - Area of Interest
 - Survey Extent (2m DTM)
 - Survey Extent (0.2m DTM)
 - Survey Extent (0.5m Contours)
 - Furrow (50K Topo)
 - Non-Perennial River (50K Topo)
 - Perennial River (50K Topo)
 - Dam (50K Topo)
 - Open Reservoir (50K Topo)
 - Perennial Pan (50K Topo)
 - Vlei (50K Topo)
 - 100m Watercourse Buffer (DWS)
 - 500m Pan/Vlei Buffer (DWS)
 - Arterial Road (50K Topo)
 - Footpath (50K Topo)
 - Main Road (50K Topo)
 - National Road (50K Topo)
 - Secondary Road (50K Topo)
 - Street (50K Topo)
- Elevation (m AMSL)**
- 1 706
 - 1 447
 - 10m Contour (30m DSM Derived)
 - 2m Contour (DTM Derived)

Figure 2-3

Terrain and Hydrology

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0 500 1,000 1,500 2,000 m

Scale - 1:47,500 @A3

Coordinate Reference System: Hartebeesthoek94_Lo27_(E-N)

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2.6 HYDROLOGY

Figure 2-3 illustrates the hydrological setting of the site, while Figure 2-1 presents the river network of the greater region. This site is positioned in the quaternary catchment C22J, which is drained by the Rietspruit River. The site is bounded by two primary rivers, according to the 1:500,000 topographical map dataset: the perennial Leeuspruit River to the west and a non-perennial Leeuspruit East River to the east.

In Figure 2-3, the Area of Hydrological Relevance (AHR) captures the rivers relevant to this study and has an area of 84.8 km². Apart from the river to the west, which comes close to the Doornpoort TSF, all rivers are non-perennial (per the NGI's 1:50,000 topographical map data). Four rivers are relevant to the flood study, given their intersection with the AOI and are from west to east:

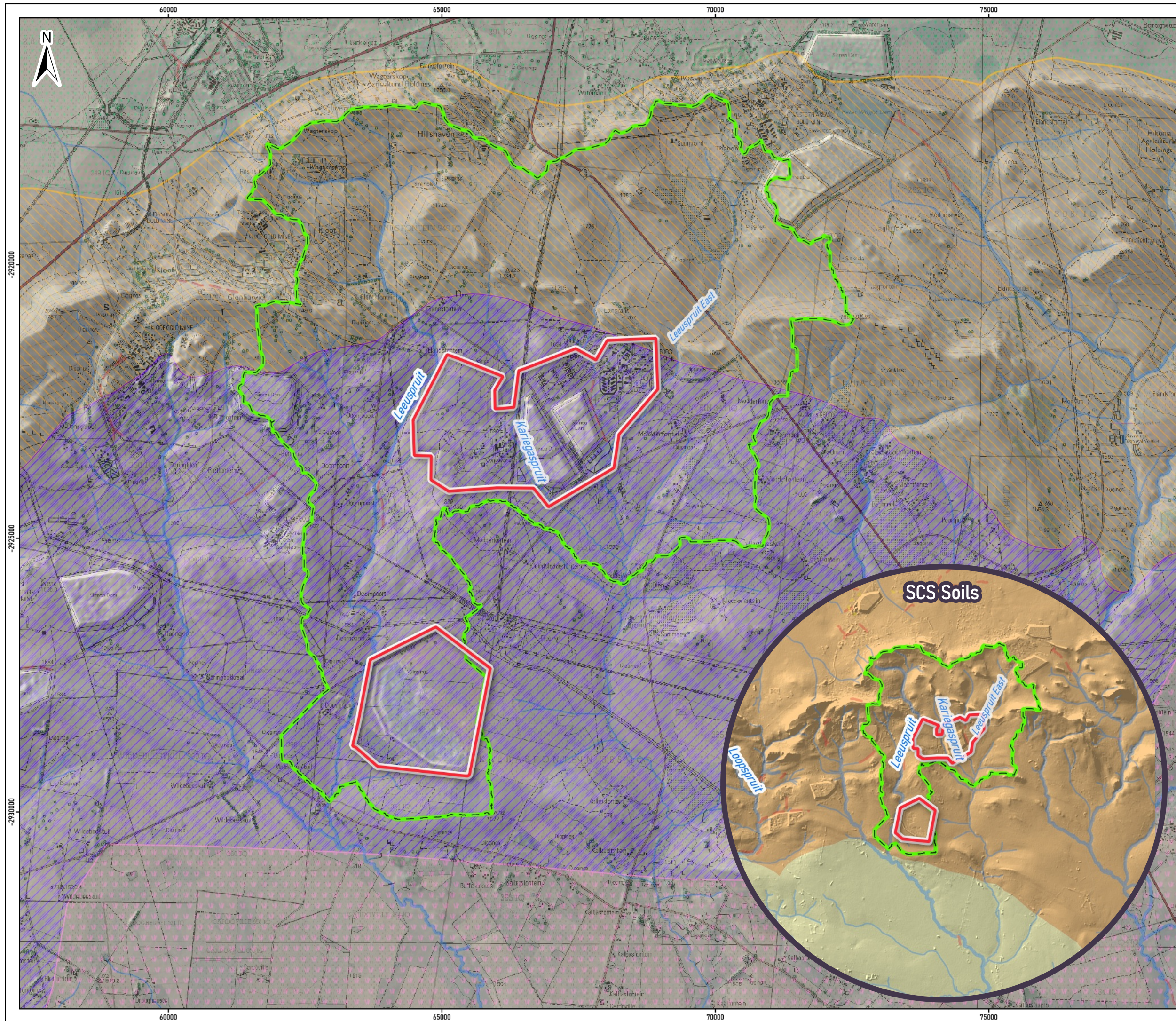
- The Leeuspruit River (1:50,000 topographical map name);
- Kariegaspruit (client provided report⁴);
- Unnamed non-perennial; and
- Leeuspruit East River⁵.

Within the AHR, there are a few small dams, including a larger dam south of the South Shaft TSF, which is in fact the South Shaft Return Water Dam (RWD). This RWD is comprised of two components; an upgraded operational RWD and an old (historical) RWD which is now the recipient of clean water inflows from the river system to the north. The old RWD is planned to be rehabilitated. Open reservoirs are also present in the AHR and are typically either RWDs or Pollution Control Dams (PCDs). A 100m watercourse buffer is presented in Figure 2-3 (relevant to the interpretation of GN 704, discussed in Section 3.1).

2.7 SOILS, VEGETATION AND LAND COVER

According to the Soil Conservation Service for South Africa (SCS-SA) dataset, soils over the AHR are classified as being in the C hydrological soil group with moderately high runoff potential. According to South African National Biodiversity Institute (SANBI) (2018), the natural vegetation coverage of the rivers of relevance and the AHR is Rand Highveld Grassland (to the south) and Gauteng Shale Mountain Bushveld (to the north). As per the Department of Forestry, Fisheries and the Environment (DFFE) 2022 dataset, the most dominant land cover is grassland and cultivated land. Other land cover classifications within the AHR include mines & quarries, waterbodies, forested land, as well as some built-up areas. Figure 2-4 illustrates the natural vegetation and runoff potential while Figure 2-5 illustrates the land cover.

⁴ SLR, 2025, "Gold Fields Flood Risk Study South Deep Gold Mine", SLR Project No.: 710.070138.00001, 28 February 2025



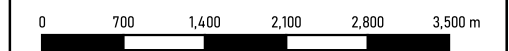
Legend

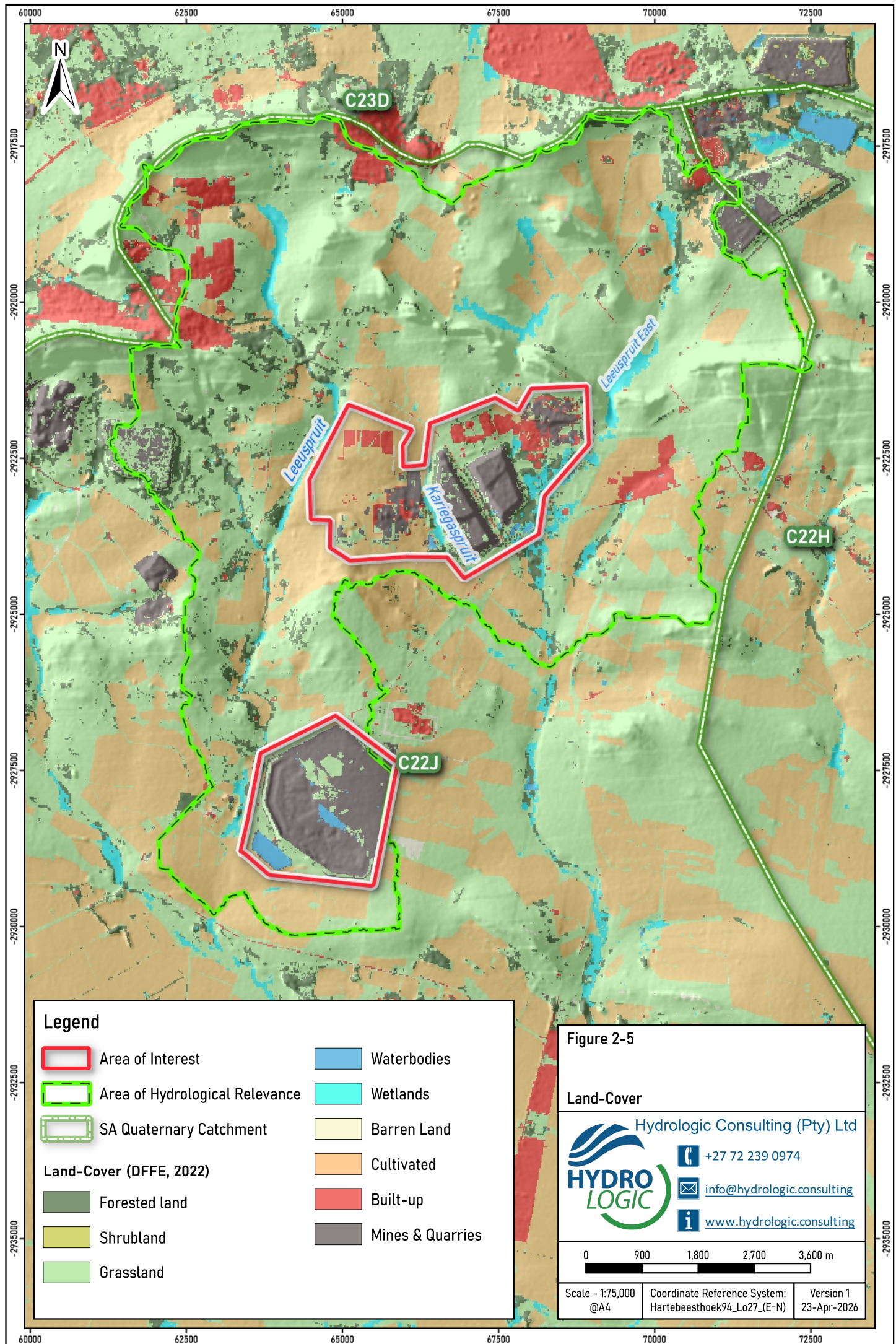
- Area of Interest
- Area of Hydrological Relevance
- Furrow (50K Topo)
- Non-Perennial River (50K Topo)
- Perennial River (50K Topo)
- SANBI Vegetation Atlas (2018)**
 - Rand Highveld Grassland
 - Soweto Highveld Grassland
 - Carletonville Dolomite Grassland
 - Gauteng Shale Mountain Bushveld
- SCS Soils Runoff Potential**
 - B/C - Moderately Low to Moderately High Runoff Potential
 - C - Moderately High Runoff Potential

Figure 2-4

Vegetation and Soil Runoff Potential

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3 APPLICABLE GUIDANCE

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

- National Water Act, 1998 (Act No. 36 of 1998) includes Section 21 water uses which require authorisation from the DWS.
- GN 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, 1998 (ACT NO. 36 OF 1998)

Definitions applicable to the identification of Section 21 water uses as defined by the National Water Act, 1998 (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 DWS), established GN 704 under the National Water Act, 1998 (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 detail of the flood modelling for the site is 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 HYDRAULIC MODEL CHOICE

HEC-RAS 6.7 was selected to model flood hydrology and hydraulics using a 2D model approach. 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 has been thoroughly tested (USACE, 2016, 2018).

4.2 MODEL APPROACH

4.2.1 FLOOD HYDROLOGY MODEL

A site-specific PCSWMM model was subsequently developed (as outlined in Appendix A) to determine the design hydrographs generated by the one perennial river and three non-perennial rivers of interest.

The first aspect of the flood modelling considered was the development of two suitable design hyetographs for the 1:50 RI and 1:100 RI flood events. These were calculated using a symmetric distribution of the DRESSA rainfall depths referred to in Section 2.1.1.

The flood hydrology model was developed using 11 locations at which design hydrographs would be generated for each of the two flood events of interest (i.e. 1:50 RI and 1:100 RI), thereby dividing the river of interest into smaller river reaches (with regard to modelling). The river reaches modelled only include those affecting the AOI (the mining operation). Of relevance in design hydrograph estimation is the assumption that the TSFs and RWDs do not contribute to the generation of streamflow.

Obtaining the design hydrographs for the river reaches of interest required the development of a hydrological (PCSWMM) model. This model used an approximate 50 ha division for subcatchments feeding the river reaches of interest, derived from the 0.2 m DTM, 2m DTM and 30m DSM (in this order of priority). After combining and splitting the subcatchments, where necessary, a total of 153 subcatchments were obtained.

Each subcatchment had its hydrological parameters informed by site-specific datasets. These subcatchments were connected by representative river channels (sized according to the 2m DTM and 30m DSM data), thereby simulating the routing of floodwaters along channel sections.

4.2.2 HYDRAULIC (FLOOD) MODEL

The output of the PCSWMM model was 22 24-hour design hydrographs – 11 for the 1:50 RI and 11 for the 1:100 RI flood events (for subsequent application in the flood 'hydraulic' model – HEC-RAS).

The availability of a continuous 0.2 m DTM and 2m DTM 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 terrain (as is the

case with cross-sections). Terrain limitations are present in both the 0.2 m DTM and 2m DTM as outlined in Section 2.3. Appendix A presents additional details on the development of the flood model.

4.3 FLOOD MODELLING RESULTS

The overall results of the flood modelling are presented in Figure 4-1, which illustrates both the 1:50 and 1:100 RI flood-line. A 100m watercourse buffer (defined according to the NGI's 1:50,000 topographical map dataset) is also presented in Figure 4-1. Figure 4-2 illustrates the maximum depth associated with the 1:100 RI flood event, while Figure 4-3 illustrates the maximum flood velocity associated with the 1:100 RI flood event.

While the 1:50 and 1:100-year recurrence interval (RI) flood lines in Figure 4-1 show a strong correlation to each other, the 1:100 RI flood line, as expected, extends slightly further due to the larger flood surge.

Figure 4-2 presents the maximum flood depth, with depths exceeding 2.0 m found along the perennial Leeuspruit River and at the entrance to culverts which throttle flows and cause the backup (deepening) of flood waters.

Figure 4-3 illustrates that larger maximum flood velocities are noticeable along the perennial Leeuspruit River and in the channel to the East of South Shaft TSF.

In reviewing the greater event (the 1:100 RI), flooding results demonstrate that the perennial Leeuspruit River to the west does not affect the mining operation, with flooding contained by a well-defined river channel.

A similar situation is present with the Kariega River between the Twin Shaft Main Shaft and the Twin Shaft TSF; however, floodwaters do come in close proximity to operational areas, specifically the Twin Shaft TSF toe paddocks and the Cascades Ponds

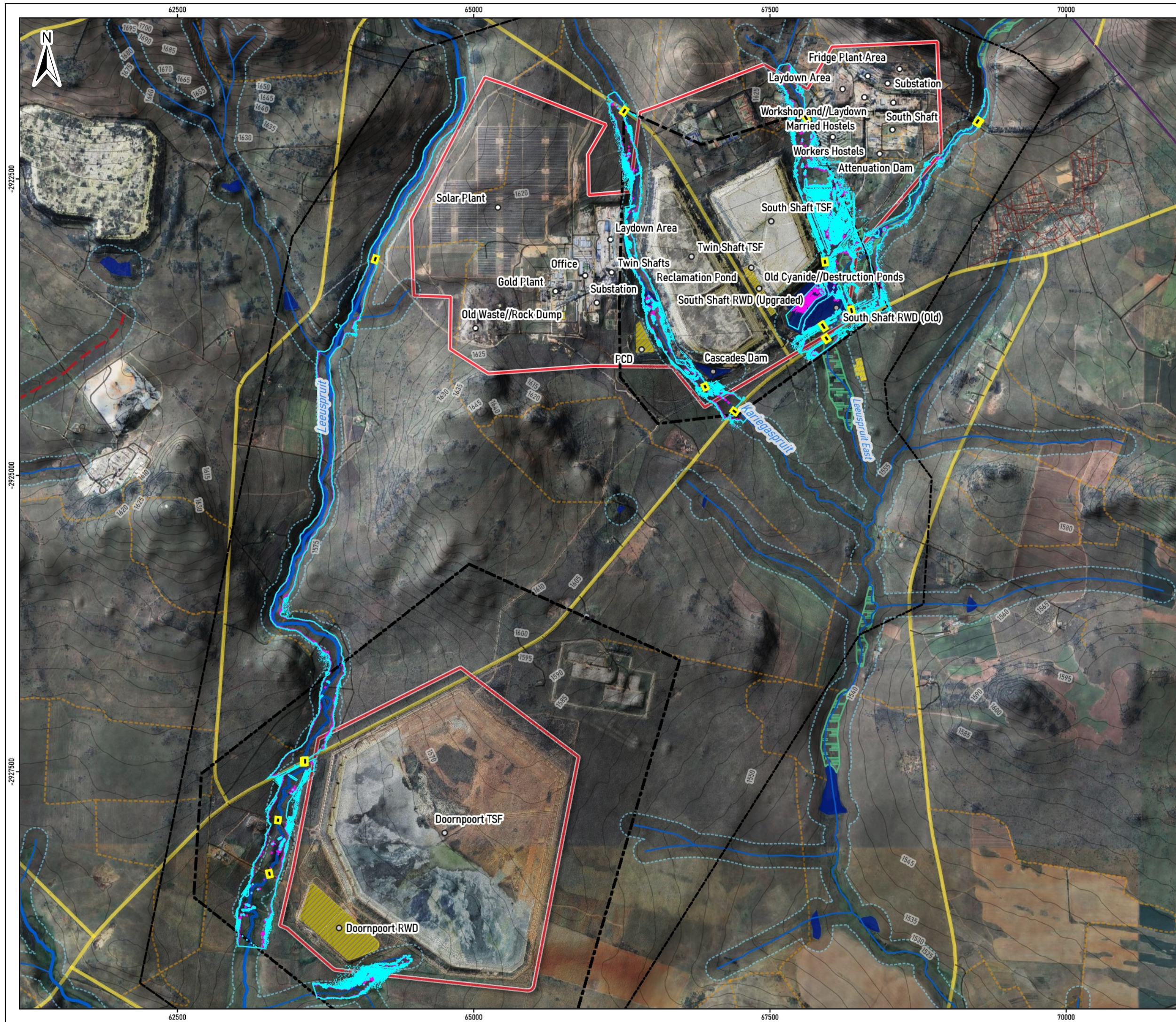
Further to the east, the unnamed non-perennial river between the South Shaft TSF and South Shaft, is characterised by a poorly defined river channel (per the available Lidar data). This results in a spread of flooding which affects residences before joining flows from the Leeuspruit East River.

The Leeuspruit East River is notable for not affecting the operational area of the mine until it joins with the unnamed non-perennial river, whereupon the combination of flows results in the South Shaft Old RWD (now functionally a wetland), becoming submerged.

More significantly, however, is the upgraded South Shaft RWD, which also receives flood waters – an occurrence which is no doubt undesirable (the pathway of flooding into the RWD occurring from a low point on the eastern crest of the RWD). The flooding into the old RWD and into the upgraded RWD occurs due to the route of the original river, which passes through this area, and the absence of a well-defined river diversion to route floodwaters towards the large (double) culvert passing beneath the secondary road.

When comparing the flood results to the 100m river buffer, the modelled flooding is mostly contained within the 100m buffer, with some exceptions particularly in the case of the unnamed non-perennial river and the Leeuspruit East River (near the old and upgraded RWDs).

The limitations in the terrain data outlined in Section 2.3 affect the accuracy of the flood model, particularly with regard to the coarser 2m DTM data.



- Legend**
- Area of Interest
 - Survey Extent (2m DTM)
 - Survey Extent (0.2m DTM)
 - Culverts (Modelled)
 - Furrow (50K Topo)
 - Non-Perennial River (50K Topo)
 - Perennial River (50K Topo)
 - 100m Watercourse Buffer (DWS)
 - Arterial Road (50K Topo)
 - Footpath (50K Topo)
 - Other Road (50K Topo)
 - Secondary Road (50K Topo)
 - Street (50K Topo)
 - Dam (50K Topo)
 - Open Reservoir (50K Topo)
 - Vlei (50K Topo)
 - Maximum Flood-Line (1:100 RI)
 - Maximum Flood-Line (1:50 RI)
 - 5m Contour (NGI)

Figure 4-1

Maximum Flood-Lines (1:100 RI & 1:50 RI)

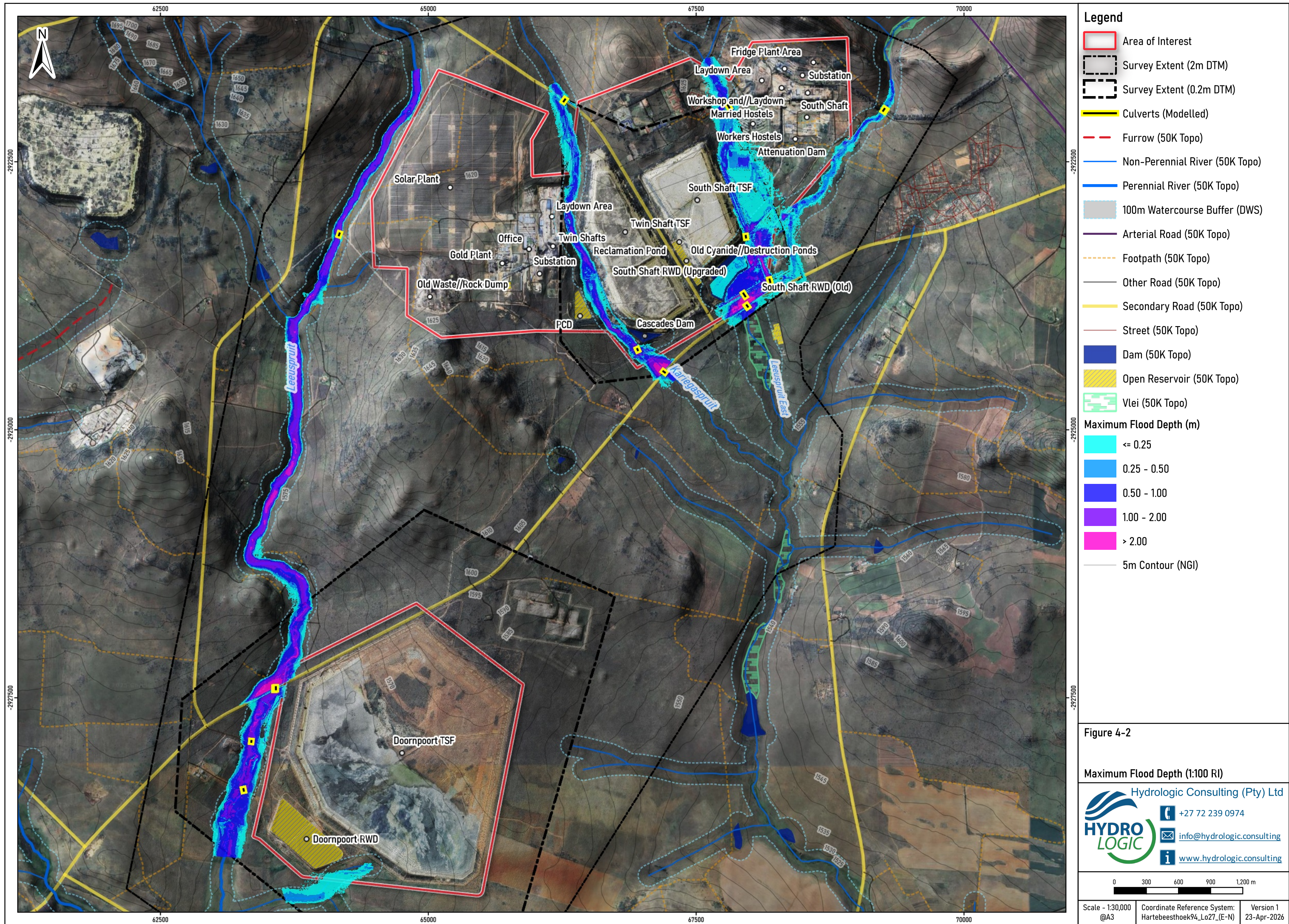
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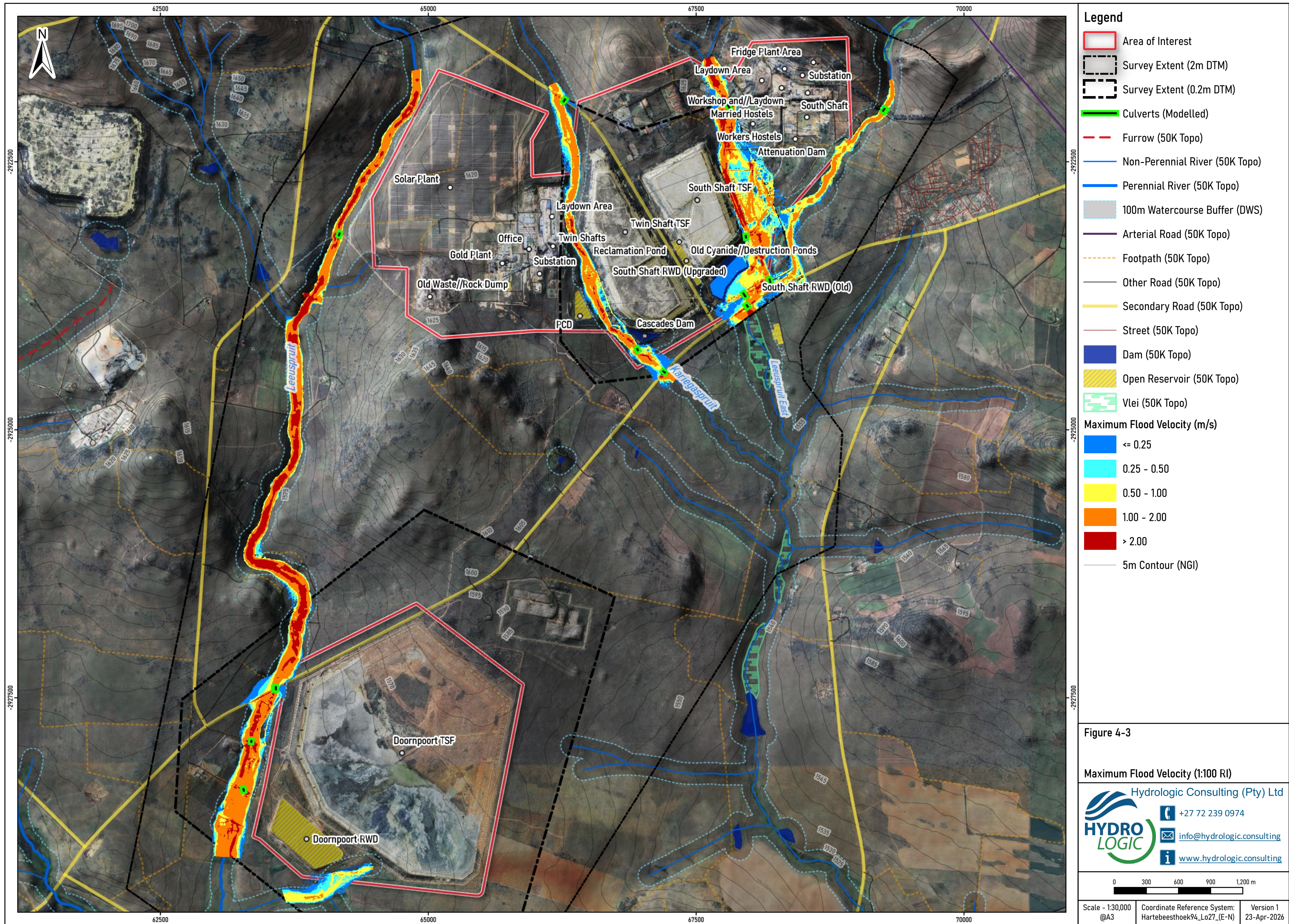
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5 CONCEPTUAL STORM WATER MANAGEMENT PLAN

The current mining operation has altered the natural environment, thereby affecting stormwater generation. Volumes of storm water generated over areas disturbed by mining operations are generally expected to increase due to reduced natural vegetation, while the quality of the storm water is expected to decrease due to the nature of mining operations. The purpose of this section is therefore to produce an updated conceptual-level SWMP that identifies and manages clean and dirty water-generating areas appropriately.

It should be noted that identification of clean and dirty areas has primarily relied on the South Deep Surface Plan and Google Imagery (from April 2023), which served as the basis for most delineations.

5.1 MANAGEMENT APPROACH

In Figure 5-1, areas requiring pollution control (i.e. dirty areas) have been delineated based upon aerial imagery. They include the shaft areas, plant areas, TSFs, RWDs and PCDs.

Due to the mine's historic operations, the majority of the required stormwater management infrastructure is already in place, and, where suitable, this SWMP update has retained it. This includes the channels and pollution control dam (PCD) managing the Twinshaft (North from PCD2) and South Shaft Areas. However, in the case of the South Shaft, the PCD is functionally an attenuation dam, receiving dirty water inflows and directing them to the South Shaft RWD (upgraded).

The routing of dirty water from the attenuation dam to the South Shaft RWD (upgraded) is one of the more significant changes within the SWMP update. At present, routing is via an open channel; however, this is poorly suited given its placement through a clean area (as it will intercept clean water). A culvert is consequently proposed to route the dirty water to the RWD.

North of the South Shaft, the previously dirty area has been divided into clean and dirty areas, with the fridge plant retained as a dirty area.

To the west of the South Shaft, the workshop and laydown area has been added to with a PCD to manage dirty water generated by this disconnected area (the disconnection appears to be present based on the available terrain data, which would make routing water from the laydown area challenging).

At the Twin Shafts, the primary change has been the addition of clean-water diversions to the west to prevent run-off from entering dirty areas. This includes runoff generated over a portion of the solar plant. Dirty management at the Twin Shaft includes the Gold Plant PCD, oil separator and Twin Shaft PCD (the primary storage of relevance to the Twin Shafts area).

At the reclamation pond (per Figure 1-2), the dirty area has been tied into the toe drain of the South Shaft TSF to prevent the addition of a new PCD at this location.

The recommended diversions (channels) have been conceptually positioned and sized in this report.



Legend

- Area of Interest
- Survey Extent (2m DTM)
- 100m Watercourse Buffer (DWS)
- 5m Contour (NGI)

Clean and Dirty Areas

- Clean Area
- Dirty Area
- PCD (Dirty)
- Self-Contained (Dirty)
- Assumed to be rehabilitated (Clean)
- Substation (Clean - Local Hydrocarbon Management Required)
- RWD (Dirty)

Rivers

- Furrow (50K Topo)
- Non-Perennial River (50K Topo)
- Perennial River (50K Topo)

Roads

- Arterial Road (50K Topo)
- Footpath (50K Topo)
- Other Road (50K Topo)
- Secondary Road (50K Topo)
- Street (50K Topo)

Figure 5-1

Dirty and Clean Areas

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0 500 1,000 1,500 2,000 m

Scale - 1:33,370 @A3

Coordinate Reference System: Hartebeesthoek94_Lo27_(E-N)

Version 1 23-Apr-2026

The Old Waste Rock Dump (WRD) area appears partially rehabilitated based on aerial imagery. This WRD has consequently been considered as rehabilitation is progress in the SWMP. It is recommended that the operation prioritise this process in order to avoid the construction of lined channels and an additional PCD.

A non-perennial river passes between the married hostels and the workers' hostels. This watercourse has (as simulated) the potential to produce significant flooding, which current stormwater management does not adequately manage. As such, proposed channels have been put in place to route the 1:50 year design event downstream without flooding the hostels.

At Doornpoort TSF, clean area management alone is proposed. This is the same for all three TSFs over the mine, since while TSFs (including toe drains) and RWDs are illustrated, no sizing of TSF/RWD infrastructure is included in this SWMP (stormwater management of the TSFs/RWDs requires a holistic appreciation of their operation, which is beyond the scope of this SWMP).

Various clean areas have been defined. Where no definition of clean or dirty areas is present, the implication is that the area is irrelevant to the management of dirty areas on the mine.

Overall, this SWMP aims to minimise dirty water areas to limit the containment of dirty runoff. This benefits the mining operation by reducing the size of the dirty water diversions and any PCDs required to store dirty water generated on-site, as well as minimising the impact on the receiving water environment due to the reduction in natural runoff.

5.1.1 FUELS, LUBRICANTS AND CHEMICALS

The storage/handling of fuel, lubricants and chemicals requires special attention due to their hazardous nature as is the case with the diesel and oil bay. These areas must be managed on impermeable floors with appropriate bunding, sumps, and roofing. This is regarded as localised management and does not form part of this conceptual SWMP.

5.2 STORM WATER MANAGEMENT INFRASTRUCTURE

There is a significant amount of stormwater management-related infrastructure already designed and constructed on site, including numerous concrete-lined channels and PCDs. The approach of this report is to incorporate (as suitable) existing infrastructure, such as channels and PCDs, and to undertake an assessment of what the conceptual stormwater management at the operation should encompass. There may, therefore, be overlap and/or gaps when comparing what is recommended in this report with what already exists at the site, particularly for the more specific design requirements of, for example, concrete-lined channels.

It is recommended that, following this report, the differences between what exists on site and what is recommended in this conceptual report are highlighted, and gaps closed; however, in doing so, some activities may trigger specific water use activities and the operation should not go ahead and build new structures before identifying possible additional water uses. Stormwater management infrastructure has been conceptually designed in this report in accordance with the requirements of GN704 and BPG1, using the 1:50-year RI event; however, it reflects actual conditions as far as possible. No account has been taken of climate change and any potential future increases in rainfall depth or intensity.

Figures 5-2 and 5-3 illustrate the conceptual SWMP, while Appendix B presents details relating to the development of the SWMP using PCSWMM, which is based on the Storm Water Management Model (Rossman, 2008).

5.2.1 AVAILABLE INFORMATION

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

- Climate Data: Particularly monthly rainfall, design rainfall depths and monthly evaporation data;
- Elevation Data: The 0.2m DTM, 2m DTM and 30m COP30 as outlined in Section 2.3 were used to define flow routes and subcatchment divisions; and
- Catchment characteristics: Soil characteristics, land-cover and slopes were used to define catchment characteristics.
- Existing stormwater management: The general arrangement⁵ of the operation and the 2025 SLR report⁶ informed existing channel positions.

5.2.2 PERMISSIBLE VELOCITIES

The conceptual SWMP review has not expressly taken account of velocities in the diversions as this was assumed to have been accounted for during the detailed design phase, prior to construction (EPOCH, 2016). In general, velocities over 2 m/s are high enough to potentially 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) provides guidance on maximum permissible velocities.

5.2.3 CLEAN WATER SYSTEM - DIVERSIONS

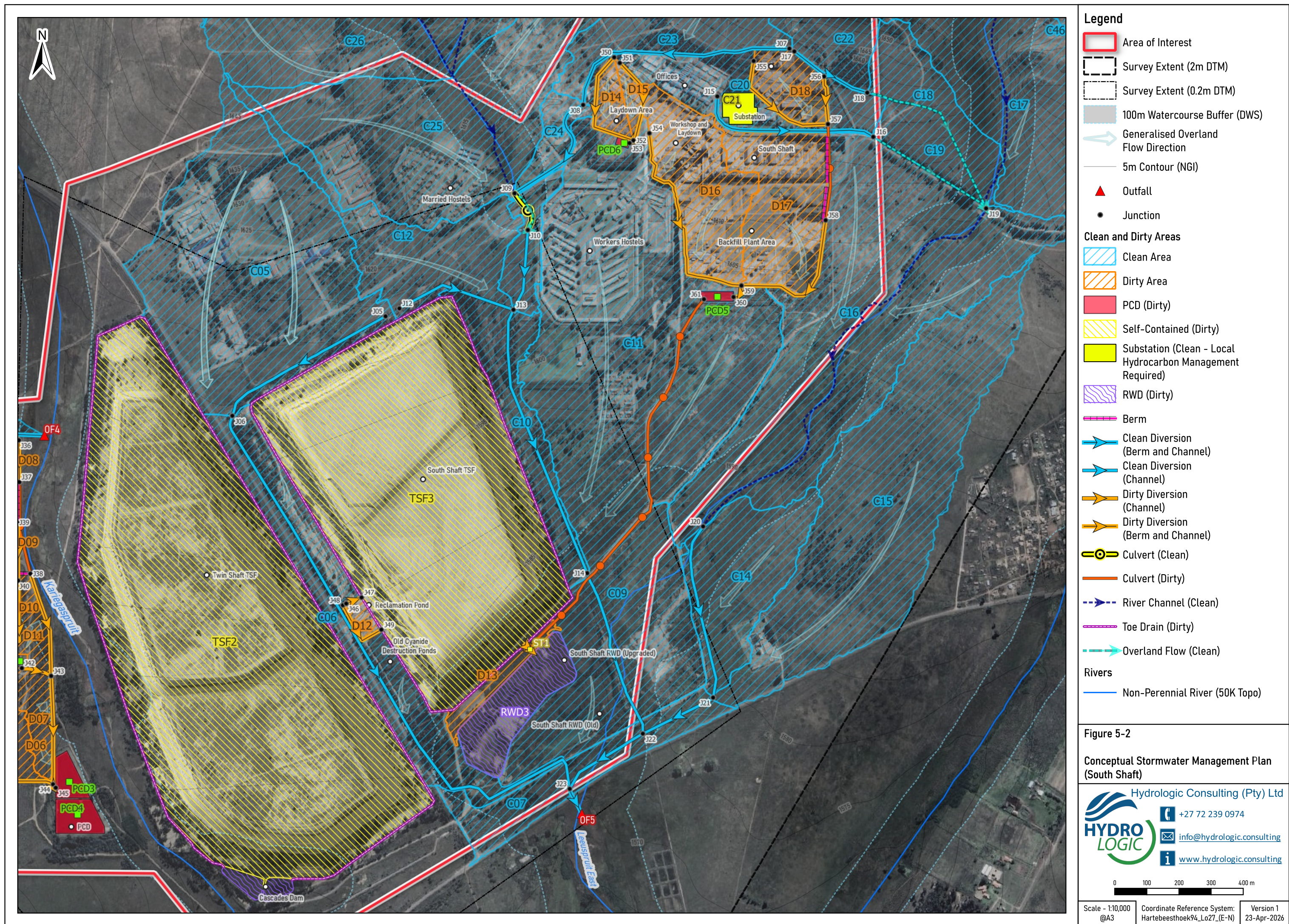
Figures 5-4, represents a typical clean area diversion consisting of a containment berm and channel. The purpose of the channel section is to divert upstream/upslope clean water that would otherwise flow into the dirty area, while the berm section ensures containment of dirty water within the dirty areas. The SWMP does, however, differentiate between diversions which consist of a berm and channel component (as per Figures 5-2 and 5-3), and a channel-only diversion (to enable inflow from both sides, and a piped diversion (culvert) to route storm water underneath existing infrastructure. For modelling purposes, the side slopes for all berms and channels have nevertheless 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.

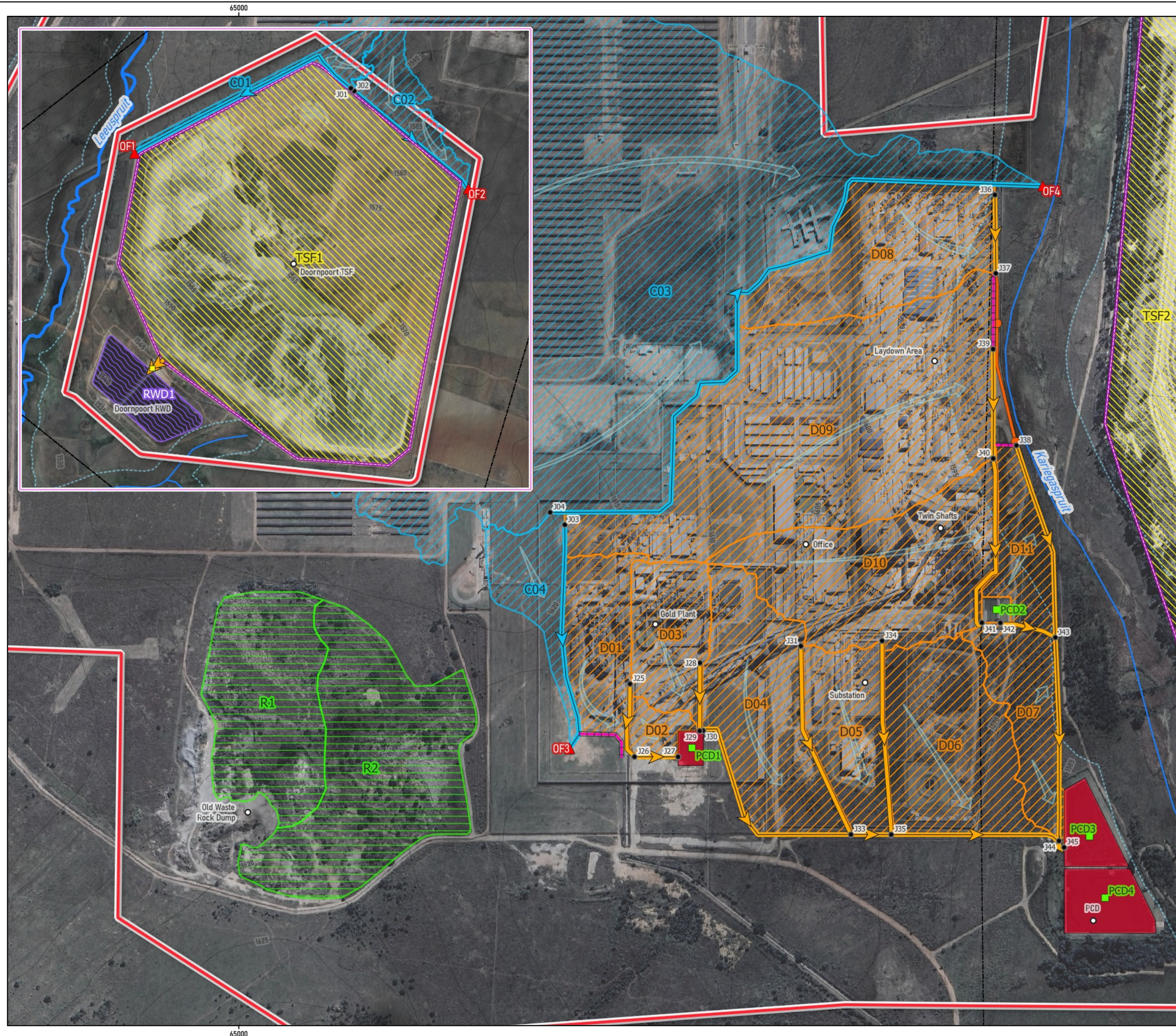
The channel component has been sized using PCSWMM storm water modelling software to meet the requirement of accommodating the 1:50 year RI event. A Manning's 'n' roughness coefficient of 0.035 (grass) was used in sizing of the diversions channels as presented in Figure 5-4, where:

- a = Channel Depth
- b = Channel Base Breadth

⁵ South Deep Surface Plan.dxf

⁶ SLR, 2025, "Gold Fields Flood Risk Study", SLR Project No.: 710.070138.00001, 28 February 2025





- Legend**
- Area of Interest
 - Survey Extent (2m DTM)
 - Survey Extent (0.2m DTM)
 - 100m Watercourse Buffer (DWS)
 - Generalised Overland Flow Direction
 - 5m Contour (NGI)
 - ▲ Outfall
 - Junction
- Clean and Dirty Areas**
- Clean Area
 - Dirty Area
 - PCD (Dirty)
 - Self-Contained (Dirty)
 - Assumed to be rehabilitated (Clean)
 - Berm
 - Clean Diversion (Berm and Channel)
 - Dirty Diversion (Channel)
 - Dirty Diversion (Berm and Channel)
 - Culvert (Dirty)
 - Toe Drain (Dirty)
- Rivers**
- Non-Perennial River (50K Topo)

Figure 5-3
Conceptual Stormwater Management Plan
(Twin Shafts and Doornpoort)

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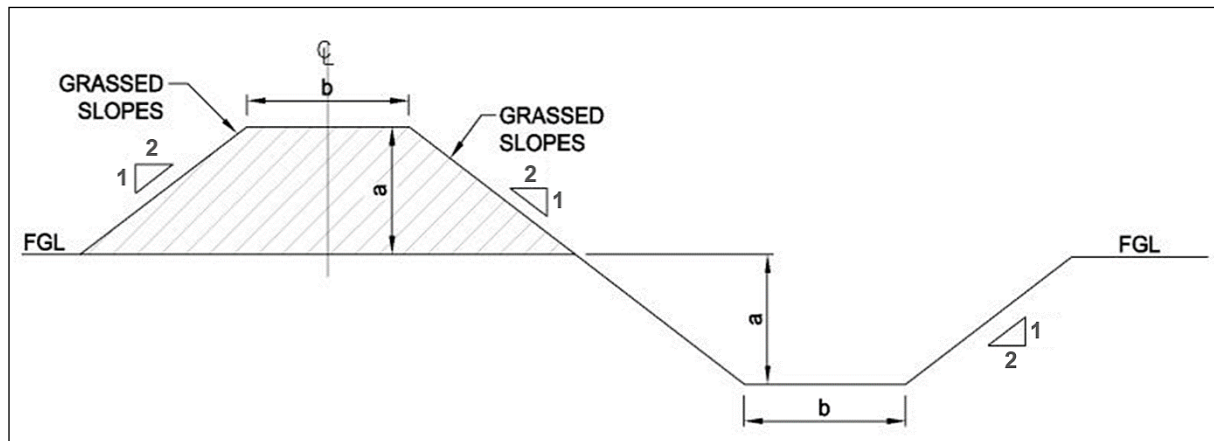


FIGURE 5-4: TYPICAL BERM AND CHANNEL FOR STORMWATER DIVERSION SYSTEM

The indicated dimensions as used in the model are presented in Table 5-1. presents the dimensions of the dirty-area diversions, including the average longitudinal dimension. Average longitudinal slopes were used in the modelling of each channel segment, since the detail required to determine variations in channel slope would have required a more accurate DEM than was available. The indicated construction dimensions and flows may differ from the final design, depending on the construction method, the location of diversions, and the additional details included in the detailed design. The diversion dimensions should consequently be reviewed during the detailed design phase. Only major culverts (two for the clean diversions) have been included in the conceptual SWMP.

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

Diversion	a (m)	b (m)	Average Longitudinal Slope (%)	Peak Flow (m³/s)*	Comment
J01 to OF1	0.50	1.00	2.4	3.1	Berm & Channel
J02 to OF2	0.75	1.00	1.3	3.8	Berm & Channel
J03 to OF3	0.50	1.00	2.0	0.6	Berm & Channel
J04 to OF4	1.00	2.00	1.9	9.2	Berm & Channel
J05 to J06	1.00	2.00	1.4	5.6	Channel Only
J06 to J23	1.00	2.00	1.8	8.6	Channel Only
J07 to J08	0.75	1.00	3.4	2.9	Berm & Channel
J08 to J09	1.00	1.00	2.0	3.4	Berm & Channel
J09 to J10	1.80	1.80	0.8	11.2	Channel Only
J09 to J10	1.00	12.00	0.8	66.1	Excess Overland Flow
	1.8 x 1.8m Culvert			11.2	Culvert
J10 to J13	2.00	10.00	2.0	77.5	Channel Only
J12 to J13	0.75	1.00	2.7	3.0	Channel Only
J13 to J14	2.00	10.00	2.3	78.9	Channel Only
J14 to J22	2.00	10.00	1.3	84.1	Channel Only
J15 to J16	1.00	1.00	0.5	2.6	Berm & Channel
J17 to J18	0.50	1.00	2.8	1.6	Berm & Channel
J20 to J21	2.00	2.00	1.0	83.6	Channel Only
J21 to J22	2.00	60.00	1.8	85.7	Channel Only
J22 to J23	2.00	60.00	1.4	168.2	Channel Only
J23 to OF5	1.00	10.00	1.0	22.7	Excess Overland Flow
	2x 2.0 x 5.0m Culvert			149.3	Culvert

* peak flows have been rounded up to a single decimal point.

Overland flow occurs at 'J09 to J10' and 'J23 to OF5' (i.e. the present culvert does not convey the 1:50 year RI event). In the case of 'J23 to OF5', the excess flows do not affect the operation but rather the secondary road.

As noted in the flood results (see Figure 4-1), the 1:50 RI flood event floods parts of the workers' hostels and the married hostels. While the SWMP is not focused on mitigating flooding, the routing of clean water through the site required a high-level intervention (a simple 1m x 12m rectangular channel) used to contain the stormwater in this section. The 1m x 12m channel design has not been optimised.

5.2.4 DIRTY WATER SYSTEM – DIVERSIONS

In this conceptual model, 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 towards the appropriate dirty water containment facility.

Figure 5-4 represents a typical dirty water containment berm and channel. At this conceptual stage, (as with the clean area diversions), it is also uncertain as to whether deep, narrow channels or shallow, wide channels are preferred, given the potential construction issues regarding soil depth. The side slopes for all berms and channels have nevertheless 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.

Table 5-2 presents the dimensions of the dirty area diversions, including the average longitudinal slope. 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 channel dimensions should consequently be reviewed during the detailed design phase and should take cognisance of available 'downstream' depression storage. All diversions include the accumulation of flow from upslope subcatchments where applicable. Only major culverts (three for the dirty diversions) have been included in the conceptual SWMP.

TABLE 5-2: DIMENSIONS FOR DIRTY AREA DIVERSIONS (1:50 RI EVENT)

Diversion	a (m)	b (m)	Average Longitudinal Slope (%)	Peak Flow (m ³ /s)*	Comment
J25 to J26	0.50	1.00	0.6	1.5	Channel Only
J26 to J27	0.50	1.00	3.9	1.9	Berm & Channel
J28 to J29	0.50	1.00	1.3	1.6	Channel Only
J30 to J33	0.50	1.00	3.0	2.0	Berm & Channel
J31 to J33	0.50	1.00	2.3	2.3	Channel Only
J33 to J35	0.50	1.00	5.4	3.8	Berm & Channel
J34 to J35	0.50	1.00	1.6	1.5	Channel Only
J35 to J44	0.75	1.00	3.1	6.4	Berm & Channel
J36 to J37	0.75	1.00	0.2	2.3	Berm & Channel
J37 to J38	1x 1.0m Culvert		1.1	2.1	Culvert
J38 to J43	0.50	1.00	1.6	2.8	Berm & Channel
J39 to J40	1.00	1.00	0.1	6.8	Berm & Channel
J40 to J41	1.00	1.00	1.1	10.5	Channel Only

J42 to J43	1.00	1.00	4.5	8.9	Channel Only
J43 to J44	1.00	2.00	0.8	12.1	Berm & Channel
J44 to J45	1.00	1.00	3.5	18.2	Berm & Channel
J46 to J47	0.50	1.00	4.5	0.0	Berm & Channel
J48 to J49	0.50	1.00	1.5	0.0	Berm & Channel
J50 to J52	0.50	1.00	0.7	0.8	Berm & Channel
J51 to J52	0.50	1.00	1.1	0.5	Berm & Channel
J52 to J53	0.50	1.00	0.2	1.3	Berm & Channel
J54 to J59	0.75	1.00	2.6	5.2	Berm & Channel
J55 to J57	0.50	1.00	3.4	1.8	Berm & Channel
J56 to J57	0.50	1.00	7.2	0.0	Berm & Channel
J57 to J58	1x 0.75m Culvert		4.6	1.6	Culvert
J58 to J59	0.75	1.00	1.9	5.4	Berm & Channel
J59 to J60	0.75	2.00	2.3	10.4	Berm & Channel
J61 to ST1	1x 1.2m Culvert		1.9	3.9	Culvert

* peak flows have been rounded up to a single decimal point.

5.2.5 ENERGY DISSIPATION AT DIVERSION OUTLETS AND OUTFALLS

The velocities at the outlets and outfalls of the clean and dirty water diversion channels have not been explicitly evaluated in this conceptual SWMP, as permissible flow speeds are a critical consideration reserved for the final designs. Velocities exceeding 2 m/s risk eroding grass-lined channels, while those surpassing 2.5 m/s can compromise concrete-lined channels at joints or cracks. Given the identified peak flows, outlet velocities may exceed these safety thresholds, necessitating potential energy dissipation structures such as rock aprons, gabion mattresses, or stilling basins. During detailed design, accurate hydraulic calculations and geotechnical considerations (construction feasibility and structural stability) based on confirmed dimensions and as-built conditions will determine the necessity and specific type of energy dissipater required at each outfall. This should be guided by the SANRAL Drainage Manual (2013) and other applicable standards to ensure that outlet scour and downstream erosion risks are effectively mitigated.

5.2.6 DIRTY WATER SYSTEM – POLLUTION CONTROL DAMS

Condition 6 of GN704 states that clean and dirty water systems must be kept separate and designed, constructed, maintained, and operated so that they do not spill into each other as a result of storm events below and including the 1:50-year event. A minimum freeboard of 0.8 m above the full supply level (FSL) must also be maintained, as required by GN704.

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

Figures 5-2 and 5-3 illustrate the position of the South Shaft's attenuation pond (PCD) plus its overflow to the upgraded RWD (via a culvert) plus the workshop and laydown area PCD (new). The Twin Shaft, the PCDs remain as current.

Table 5-3 presents the volume requirements for the PCDs, including a minimum volume to contain the 1:50 RI rainfall event and a recommended volume that accounts for the addition of the highest monthly rainfall (January). The volume indicated does not account for additions of process water, dewatering, wash water or abstractions of water. Table 5-3 should be evaluated and revised (if necessary) to include additional process water requirements.

TABLE 5-3: VOLUME REQUIREMENTS (1:50 RI EVENT)

	Surface Area (m ²)	Max Depth (m)*	Minimum (1:50) Volume (m ³)	Recommended Volume (m ³)
PCD1	2,407	2.6	5,426	6,359
PCD3	10,084	4.3	34,775	43,089
PCD4	14,354	3.9	33,805	56,328
PCD5	3,133	3.5	10,900**	10,900**
PCD6	951	4.9	3,421	4,647
ST1	-	-	29,600	-

* Vertical walls and a linear volume-to-depth relationship are assumed for the storage facilities. Maximum depth is based on the recommended volume.

** attenuation basin which discharges water to RWD3.

PCD5 is an attenuation basin and has been assumed to have a 1m dead storage given the appearance of water in the basin when looking at aerial imagery. Above this dead storage, a 1.2m culvert routes excess flow to the South Shaft RWD (RWD3). The 1.2m culvert was sized according to the existing open channel (which should be replaced by the culvert due to unsuitable clean water interaction).

The volume of dirty water received by the RWD3 is reported by the silt trap before the RWD (ST1), with a volume of 29,600m³ discharged from the attenuation basin. The RWD3 volume is not reported, as it will depend on the performance of the South Shaft TSF.

5.2.7 1:50 YEAR RI TSF VOLUMES

The TSFs have intentionally be left out of the SWMP given the holistic consideration of their operation. 1:50 year RI stormwater volumes have, however, been included for consideration in the management of the TSF and associated RWDs (presented in Table 5-4).

TABLE 5-4: VOLUME REQUIREMENTS (1:50 RI EVENT)

	1:50 Volume (m ³)
TSF1	397,610
TSF2	114,500
TSF3	78,990

Volumes are representative of the TSF as a whole, inclusive of the basin, side slopes and toe paddocks.

6 CONCLUSIONS

Baseline Assessment

Baseline information including monthly rainfall, monthly evaporation, design event rainfall, soil runoff potential, vegetation and land cover, terrain, as well as regional and local catchment hydrology have been assessed for the existing Gold Fields South Deep Mining Operation which operates in Westonaria, Gauteng Province of South Africa. This baseline assessment confirmed a MAP of approximately 660mm and mean annual evaporation of approximately 2170mm resulting in a temperate climate characterised by warm, wet summers and cool, dry winters. Design rainfall depths associated with extreme events are still significant at 95.5, 113mm, 138.6mm, and 160mm for the 24-hour, 1:10, 1:20, 1:50 and 1:100 RI respectively.

The following terrain datasets were used in this study:

- 0.2 m DTM derived from two client-provided LiDAR datasets;
- 2 m DTM as purchased from Geosmart;
- 30 m DSM COP30 data; and
- The NGI 1:50,000 topographical map 5m contours

The 0.2 m DTM provides a bare-earth representation of the terrain by removing surface features such as vegetation and built structures, thereby offering a more suitable elevation surface for flood modelling than a DSM, which retains these obstructions. To supplement the areas of missing 0.2 m DTM data, a 2 m DTM purchased from Geosmart was incorporated. With reported vertical and horizontal accuracies of 0.5 m and 1 m, respectively, the 2 m DTM offered the more comprehensive coverage. The coverage of the 0.2 m DTM and 2m DTM was sufficient with regard to the river reaches for which flood modelling was undertaken. Additionally, a 30 m DSM was employed for mapping and hydrological modelling in locations where neither the 0.2 m DTM nor the 2 m DTM provided sufficient coverage. Ground elevations on the site are approximately 1,725 m AMSL, whilst elevations over the non-perennial river reaches of interest range between approximately 1,615 m and 1,565 m AMSL. Slopes within the AOI vary from gentle to mild, with slopes typically below 10%. Higher slopes are observed at the Tailings Storage Facilities (TSFs). The river channels within the modelled reaches exhibit low gradients, with channel slopes typically remaining below 3%.

This site is positioned in the quaternary catchment C22J, which is drained by the Rietspruit River. The site is bounded by two primary rivers, according to the 1:500,000 topographical map dataset: the perennial Leeuspruit River to the west and a non-perennial Leeuspruit East River to the east. The AHR relevant to this study has an area of 84.8 km². Apart from the river to the west, which comes close to the Doornpoort TSF, all rivers are non-perennial (per the NGI's 1:50,000 topographical map data). Four rivers are relevant to the flood study, given their intersection with the AOI and are from west to east:

- The Leeuspruit River;
- Kariëga River;
- An unnamed non-perennial; and
- Leeuspruit East River

Soils over the AHR are classified as being in the C hydrological soil group with moderately high runoff potential. The natural vegetation coverage of the rivers of relevance and the AHR is Rand Highveld Grassland (to the south) and Gauteng Shale Mountain Bushveld (to the north). The most dominant land cover is grassland and cultivated

land. Other land cover classifications within the AHR include mines & quarries, waterbodies, forested land, as well as some built-up areas.

Flood Assessment

HEC-RAS 6.7 was selected to model flood hydrology and hydraulics using a 2D model approach. HEC-RAS is designed to perform one-dimensional and two-dimensional calculations for a full network of natural and constructed channels. A site-specific PCSWMM model was developed to determine the design hydrographs generated by the one perennial river and three non-perennial rivers of interest.

The first aspect of the flood modelling considered was the development of two suitable design hydrographs for the 1:50 RI and 1:100 RI flood events. These were calculated using a symmetric distribution of the DRESSA rainfall depths. The flood hydrology model was developed using 11 locations at which design hydrographs were generated for each of the two flood events of interest, thereby dividing the selected rivers of interest into smaller river reaches (with regard to modelling). Obtaining the design hydrographs for the river reaches of interest required the development of a hydrological (PCSWMM) model. This model used an approximate 50 ha division for subcatchments feeding the river reaches of interest, derived from the 0.2 m DTM, 2m DTM and 30m DSM (in this order of priority). After combining and splitting the subcatchments, where necessary, a total of 153 subcatchments were obtained. Each subcatchment had its hydrological parameters informed by site-specific datasets. These subcatchments were connected by representative river channels (sized according to the 2m DTM and 30m DSM data), thereby simulating the routing of floodwaters along channel sections.

The output of the PCSWMM model was 22 24-hour design hydrographs – 11 for the 1:50 RI and 11 for the 1:100 RI flood events. The availability of a continuous 0.2 m DTM and 2m DTM allowed for the adoption of a 2D flood model approach using HEC-RAS.

The overall results of the flood modelling illustrate both the 1:50 and 1:100 RI flood-lines. In addition to this, a 100m watercourse buffer (defined according to the NGI's 1:50,000 topographical map dataset) was also presented. Maximum flood depths and maximum flood velocities associated with the 1:100 RI flood event were also presented.

While the 1:50 and 1:100-year recurrence interval (RI) flood-lines show a strong correlation to each other, the 1:100 RI flood line, as expected, extends slightly further due to the larger flood surge. Maximum flood depths were noted to exceed 2.0 m along the perennial Leeuspruit River and at the entrance to culverts which throttle flows and cause the backup (deepening) of flood waters. The larger maximum flood velocities were noticeable along the perennial Leeuspruit River and in the channel to the East of South Shaft TSF.

In reviewing the greater event (the 1:100 RI), flooding results demonstrate that the perennial Leeuspruit River to the west does not affect the mining operation, with flooding contained by a well-defined river channel. A similar situation is present with the Kariega River between the Twin Shaft Main Shaft and the Twin Shaft TSF; however, floodwaters do come in close proximity to operational areas, specifically the Twin Shaft TSF toe paddocks and the Cascades Dam (RWD). Further to the east, the unnamed non-perennial river between the South Shaft TSF and South Shaft, is characterised by a poorly defined river channel (per the available Lidar data). This results in a spread of flooding which affects residences before joining flows from the Leeuspruit East River. The Leeuspruit East River is notable for not affecting the operational area of the mine until it joins with the unnamed non-perennial river, whereupon the combination of flows results in the South Shaft Old RWD becoming submerged.

More significantly, however, is the Upgraded South Shaft RWD, which also receives flood waters – an occurrence which is no doubt undesirable (the pathway of flooding into the RWD occurring from a low point on the eastern crest of the RWD). The flooding into the Old RWD and into the Upgraded RWD occurs due to the route of the original river, which passes through this area, and the absence of a well-defined river diversion to route floodwaters towards the large (double) culvert passing beneath the secondary road. When comparing the flood results to the 100m river buffer, the modelled flooding is mostly contained within the 100m buffer, with some exceptions particularly in the case of the unnamed non-perennial river and the Leeuspruit East River (near the old and upgraded RWDs). It is noted that the limitations in the terrain data affect the accuracy of the flood model, particularly with regard to the coarser 2m DTM data.

Conceptual Storm Water Management Plan Assessment

A conceptual Storm Water Management Plan (SWMP) has been developed for the existing South Deep operation using PCSWMM modelling software. Cognisance was taken of previous work related to the management of storm water; in particular the 2025 SLR Gold fields Flood Risk Study. The combination of the infrastructure layout, site examination as well as aerial imagery allowed for the delineation of clean and dirty water generating areas. Dirty water producing areas were subsequently isolated by diverting upstream clean water around them via clean water diversions. Dirty water produced within dirty areas has been routed to PCDs. All berms and channels (clean and dirty) have been sized to effectively route the 1:50 year rainfall event. Dirty water runoff volumes for both the minimum and recommended storage volumes have been calculated for all PCDs. This approach was taken to meet the requirements of GN704 and best practice guidance. The Old WRD area appears partially rehabilitated. This WRD has consequently been considered as rehabilitation in progress in the SWMP. It is recommended that the operation prioritise this process in order to avoid the construction of lined channels and an additional PCD. It is recommended that where relevant, the conceptual designs presented in this report be assessed and confirmed during the detailed design phase prior to construction.



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APPENDIX A: FLOOD MODELLING

A.1 HYDROLOGICAL MODEL

A hydrological model (PCSWMM) was required to model the three non-perennial rivers and one perennial river of interest. As a comparison, the Standard Design Flood (SDF) method was considered.

A.1.1 HYDROLOGICAL MODEL - PCSWMM

PCSWMM is a model package that makes use of the USEPA Storm Water 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 suited application to this study since it could account for:

- Time-varying rainfall;
- Rainfall interception in depression storage;
- Infiltration of rainfall into unsaturated soil layers;
- Routing of overland flow;
- Dynamic wave flow routing of flood waters; and
- Capture and retention of rainfall/runoff.

The hydrological modelling as it pertains to the development of stormwater management plans and flooding assessments using SWMM has been undertaken for many thousands of studies throughout the world (Rossman, 2008), including South Africa and was well suited to deriving the upstream inflows and effective rainfall as input into the hydraulic component of this study.

Hydrological Model Domain

The 2m DTM and 30m DSM formed the basis of the hydrological model domain, informing the partitioning of subcatchments, the accumulation of flow, and some parameterisation of the model (e.g. subcatchment slope). Subcatchments of interest were derived through geoprocessing of the available elevation data. Sequential computations of flow direction, flow accumulation, and stream definition, based upon a contributing area of 100ha, were then used to delineate subcatchments with a total subcatchment area of approximately 18 km² being modelled.

Subcatchment Parameterisation

Land-cover parameters were estimated according to the SCS-SA soil for the AOI, DFFE 2022 land-cover, the 2m DTM, 30m DSM, and satellite imagery, for each of the 153 subcatchments. These were used to populate model attributes relating to depression storage, surface roughness, infiltration loss, slope, and impervious areas.

Design rainfall

In assessing flooding, 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 2.1.1). This hypothetical storm is the design rainfall depth that will produce the highest degree of flooding 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, DRESSA 1:50 and 1:100 year RI rainfall depths of various durations (e.g. 5 minutes, 30 minutes and 2 hours) were transformed into a synthetic rainfall distribution or design hyetograph.

When considering the catchment area upstream, it was not necessary to use an areal reduction factor (ARF). ARFs consider the difference between the design rainfall estimate for a point versus the same estimate over a large catchment (since larger catchments are less likely to experience high-intensity storms over the full catchment area). The ARF for the AHR was calculated as 97%. Absence of an ARF consequently results in a slightly conservative model approach, where more rainfall is conservative.

A.1.2 HYDROLOGICAL MODEL - SDF

For comparative purposes, the SDF method was also considered. The SDF method is a regional methodology that applies set parameters per 29 areas defined for South Africa. The methodology consequently assumes hydrological homogeneity between the catchment area and region of relevance (one of 29).

Per SANRAL (2013), 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 this project, both the western and eastern non-perennial rivers were assessed using the SDF method for comparative purposes, with the AHR covering region 7 (of the SDF).

A.1.3 DESIGN HYDROGRAPHS

The 1:50-year and 1:100-year RI design hydrographs were extracted from the PCSWMM model for 11 locations along the four rivers of interest. A comparison of the modelled hydrographs estimated (for the 1:100 RI flood event) using PCSWMM to the Standard Design Flood (SDF) method was subsequently made at the most downstream points (the locations with the most significant contributing catchments, more likely to tend towards the regional SDF approach).

Flood peak flow estimates generated using a regional approach (such as the SDF) can sometimes serve as a high-level validation of modelled stormflows.

A 1:100 RI PCSWMM peak flow of 244 m³/s (versus an SDF estimate of 278 m³/s) was noted for the Leeuspruit River to the west, while the Leeuspruit East River had a peak flow of 351 m³/s (versus an SDF estimate of 396 m³/s). This indicates that the PCSWMM estimates are approximately 13% higher than the SDF estimates. Figure A-1 illustrates this difference.

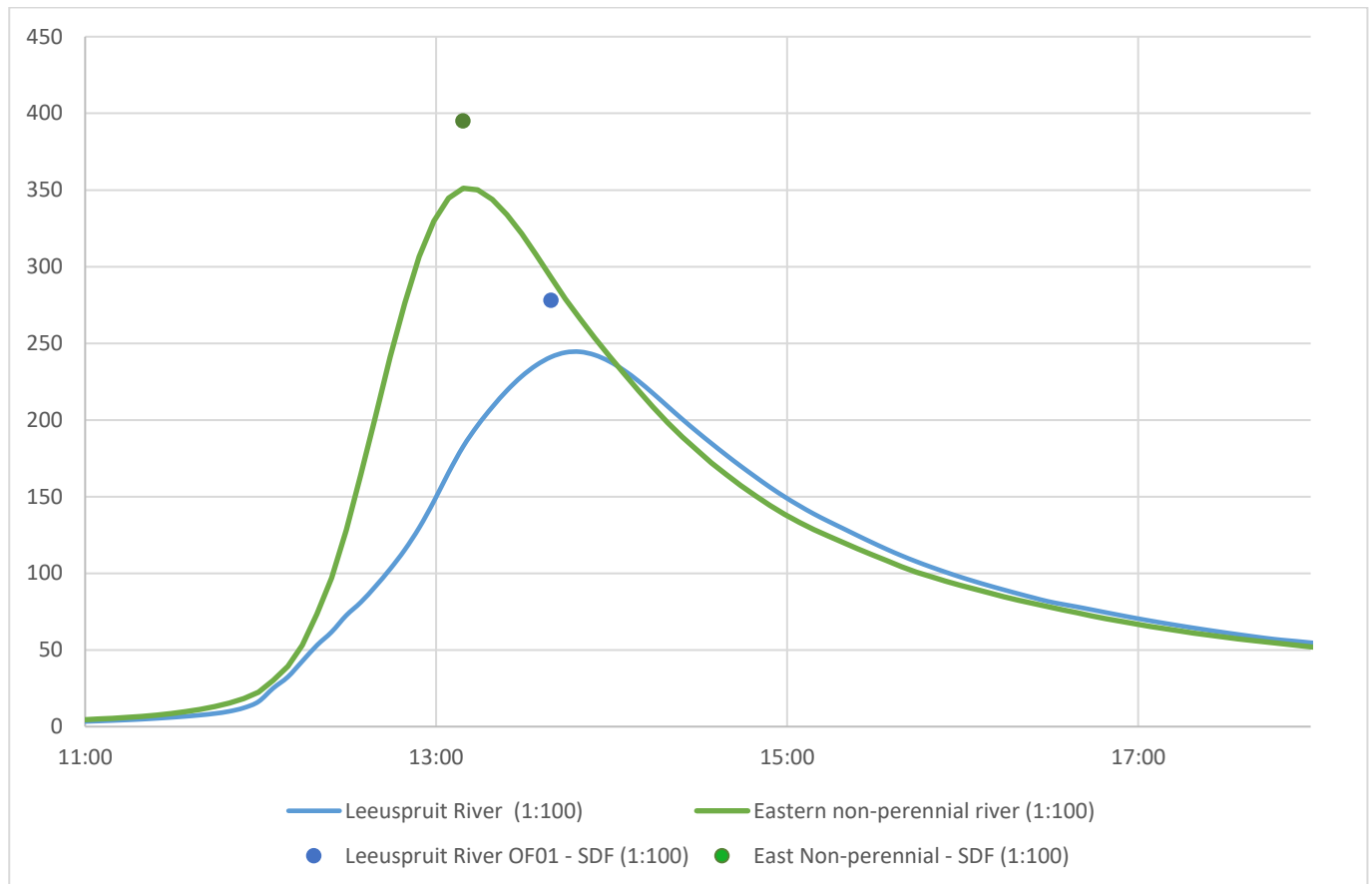


FIGURE A-1: 1:100-YEAR RI HYDROGRAPHS AND COMPARATIVE PEAK FLOWS

It is, however, also the specific hydrological characteristics of the AHR that lead to one of the largest uncertainties concerning the flood modelling undertaken. The parameterisation of the AHR's subcatchments has utilised site-specific datasets, however, some inaccuracy is expected with the potential for the peak flows and design hydrographs to vary in reality. Lack of calibration due to an absence of suitable observed flows means that the PCSWMM model results couldn't be verified.

A.2 HYDRAULIC (FLOOD) MODELLING

A.2.1 HYDRAULIC MODEL CHOICE

HEC-RAS 6.7 was selected to model the hydraulic flooding along the three non-perennial river reaches of interest. HEC-RAS is designed to perform one-dimensional and two-dimensional hydraulic 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 of the HEC-RAS model is a more recent addition, having been released in 2015, although robust benchmarking (USACE, 2016) and verification and validation tests (USACE, 2018) have been performed to prove that the 2D component of the model works as intended.

A.2.2 TOPOGRAPHIC DATA

Both the 0.2m DTM and 2m DTM data (detailed in Section 2.3) provided the available terrain data for the hydraulic model build. This terrain data was detailed and served as the base (terrain) for the flood model.

A.2.3 COMPUTATIONAL MODEL MESH

In developing a 2D HEC-RAS model, it was necessary first to delineate the model boundary. The model boundary was then used to define the model grid, with a 10m model mesh spacing selected to maximise spatial detail while limiting unnecessary model complexity. Additionally, a refinement region with a finer 5m mesh size was applied over areas where the higher-resolution 0.25 DTM coverage was available, allowing for improved representation of terrain features within that zone.

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

One of HEC-RAS's major advances in hydraulic modelling has been the addition of a subgrid. The subgrid extracts the detail available in the underlying terrain (e.g. the 0.2m x 0.2m DTM) 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.2.4 BOUNDARY CONDITIONS AND BREAKLINES

Upstream and downstream boundaries were defined for the model using a normal depth slope. This 'normal depth' is estimated according to the riverbed slope.

The 11 inflow hydrographs were applied to the upstream ends of the relevant portions of both non-perennial river reaches within the hydraulic model, despite being representative of the accumulated flows at the downstream end of the respective river portions. This is common practice, whereby the design hydrographs for a point at the end of a modelled river reach are applied to a point upstream and result in some conservatism (where more flooding is conservative).

Breaklines were used to represent linear or high-ground features that may otherwise have been missed by the application of a consistent model mesh.

A.2.5 ROUGHNESS VALUES

The assignment of suitable surface roughness in HEC-RAS's model mesh (defined according to 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 three river reaches of interest and their immediate surrounds based on a review of available aerial imagery. Values ranged from 0.02 (roads) to 1.0 (buildings). The most

predominant land covers were wetlands (assigned a Manning's value of 0.06) and grassland (assigned a Manning's value of 0.04). Manning's 'n' values are approximate only and assume uniformity in areas (where some localised variation is expected).

A.2.6 CULVERTS

17 culverts were included in the model with dimensions measured during the site visit.

A.2.7 MODEL RUN

More accurate full momentum equations were used in the running of the model. A stable model run was achieved.

A.2.8 ASSUMPTIONS AND LIMITATIONS

Various assumptions were required in the development of the hydraulic model with resultant limitations in the accuracy of the modelled flooding. They included the following:

- *Accuracy of terrain datasets* – the 0.2m DTM and 2m DTM are assumed accurate despite errors likely being present (more so in the 2m DTM). The flood model accuracy cannot improve on the accuracy of the parent data.
- *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 and the 1:50 RI storm produces the 1:50 RI flood).
- *PCSWMM parameterisation* – Design hydrographs estimated using PCSWMM are accurate, given the potential for deviations in their estimation to significantly influence resulting flooding.
- *Land-cover* – the land-cover per the 2022 DFFE and aerial imagery is assumed to apply to the AHR and the site (i.e. the site has been evaluated in its 2022 condition). Changes in the land-cover will alter the flood model results.
- *Potential error in the parameterisation of the model* – this included the soils and land-cover classification used which may not accurately represent the AHR and the site. Infiltration losses are significant to this study. These losses have only been considered using a generalised approach to infiltration and are not based on measured data.
- *Catchment delineation* – a primary catchment (AHR) has been used for hydrological modelling. This catchment has been defined using the 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 primary catchment extent.
- *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.
- *Climate change* – climate change was not 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.

- *Mesh detail* – the model utilised a 10m mesh size and a refinement region with a 5m mesh size over the 0.2m DTM. 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 will 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 these breaklines is assumed correct/sufficient.
- *Roughness values* – the selected Manning's 'n' values were representative of the areas they covered, including being representative regardless of the depth of flooding.
- *Model calibration* – no calibration of the model was undertaken as there is no suitable observed data for calibration purposes.
- *Software Performance* - the software and methods utilised are assumed accurate with regard to their utilisation of input data and the processes they simulate.

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% and 0.3% respectively, which is close to 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	14.9	138.6	46.5	0.65	13.5	3.4
C02	24.0	138.6	49.4	0.63	20.9	4.0
C03	80.4	138.6	49.2	0.63	69.8	10.4
C04	2.3	138.6	45.7	0.66	2.1	0.6
C05	45.8	138.6	50.4	0.62	39.2	6.2
C06	19.2	138.6	44.9	0.66	17.7	5.5
C07	5.0	138.6	44.3	0.67	4.6	1.1
C08	5.1	138.6	31.1	0.77	5.4	1.8
C09	25.9	138.6	37.0	0.72	25.8	6.5
C10	10.4	138.6	48.5	0.63	9.1	2.0
C11	64.8	138.6	37.7	0.71	63.8	11.3
C12	15.2	138.6	48.6	0.64	13.4	3.1
C13	4.2	138.6	34.7	0.74	4.3	1.5
C14	14.5	138.6	44.1	0.67	13.4	2.7
C15	44.2	138.6	50.9	0.61	37.3	3.9
C16	54.5	138.6	44.2	0.67	50.3	11.6
C17	35.0	138.6	45.7	0.66	31.9	8.7
C18	7.7	138.6	46.0	0.66	7.0	2.2
C19	4.6	138.6	56.3	0.58	3.8	1.2
C20	9.4	138.6	36.8	0.73	9.5	3.3
C21	0.9	138.6	12.7	0.90	1.2	0.5
C22	9.0	138.6	56.5	0.58	7.2	1.7
C23	19.3	138.6	54.0	0.60	15.9	3.2
C24	3.2	138.6	26.2	0.80	3.6	1.3
C25	61.6	138.6	50.8	0.62	52.7	9.1
C26	65.3	138.6	56.1	0.58	52.3	7.7
C27	45.6	138.6	57.1	0.57	35.9	4.1
C28	34.0	138.6	52.4	0.61	28.6	6.1
C29	76.7	138.6	46.3	0.65	69.3	15.2
C30	27.7	138.6	57.1	0.57	21.8	2.7
C31	60.8	138.6	44.6	0.66	55.7	13.0
C32	32.8	138.6	47.4	0.64	28.8	2.9
C33	36.6	138.6	47.8	0.64	32.4	6.3
C34	50.1	138.6	47.2	0.64	44.3	5.7
C35	42.8	138.6	47.7	0.63	37.5	4.3
C36	27.1	138.6	45.5	0.66	24.8	6.9
C37	22.7	138.6	48.5	0.63	19.9	2.9
C38	29.0	138.6	55.5	0.58	23.5	3.7
C39	38.4	138.6	48.4	0.63	33.5	4.5
C40	49.7	138.6	48.1	0.63	43.6	6.4
C41	31.0	138.6	42.0	0.68	29.2	5.0
C42	69.9	138.6	50.6	0.62	60.2	14.1
C43	45.4	138.6	52.9	0.60	38.1	8.0
C44	45.8	138.6	56.0	0.57	36.3	3.0
C45	34.6	138.6	57.0	0.57	27.3	3.2
C46	39.9	138.6	44.0	0.67	37.2	10.3
C47	78.3	138.6	56.7	0.57	62.1	7.6
C48	58.5	138.6	50.4	0.62	50.4	10.3
C49	50.6	138.6	54.8	0.59	41.0	4.7
C50	43.6	138.6	54.9	0.59	35.5	5.9
C51	31.1	138.6	56.6	0.58	25.0	5.8
C52	43.7	138.6	57.1	0.56	34.1	2.8
C53	58.9	138.6	56.0	0.58	47.4	9.6
C54	19.5	138.6	56.8	0.57	15.3	1.6
C55	44.2	138.6	57.1	0.57	34.8	3.6
C56	27.3	138.6	57.1	0.57	21.6	2.9
C57	48.0	138.6	56.0	0.58	38.2	4.0
C58	68.7	138.6	56.9	0.57	54.0	5.2
C59	45.8	138.6	54.1	0.59	37.7	7.7
C60	29.4	138.6	54.4	0.58	23.7	2.2
C61	47.0	138.6	53.5	0.59	38.6	5.3

C62	88.2	138.6	47.6	0.63	77.2	9.6
C63	47.8	138.6	54.6	0.58	38.4	2.9
C64	59.2	138.6	49.2	0.62	51.0	5.1
C65	63.3	138.6	52.3	0.60	52.6	4.9
C66	31.9	138.6	43.8	0.66	29.2	5.2
C67	54.6	138.6	44.7	0.65	49.5	6.1
C68	44.5	138.6	47.5	0.64	39.2	5.1
C69	36.9	138.6	56.6	0.57	29.1	3.2
D01	3.2	138.6	19.0	0.86	3.8	1.5
D02	0.7	138.6	26.2	0.81	0.8	0.4
D03	3.1	138.6	11.5	0.91	3.9	1.6
D04	6.5	138.6	39.5	0.71	6.4	2.3
D05	3.6	138.6	28.4	0.79	3.9	1.6
D06	6.4	138.6	46.9	0.64	5.7	1.3
D07	3.1	138.6	56.0	0.58	2.5	0.6
D08	6.6	138.6	28.2	0.79	7.2	2.5
D09	18.7	138.6	21.7	0.84	21.6	7.0
D10	8.4	138.6	16.5	0.88	10.2	4.0
D11	2.2	138.6	48.0	0.64	2.0	0.8
D12	0.8	138.6	28.5	0.79	0.9	0.4
D13	2.1	138.6	46.1	0.65	1.9	0.5
D14	1.8	138.6	21.3	0.84	2.1	0.9
D15	1.0	138.6	21.3	0.84	1.2	0.5
D16	12.1	138.6	20.6	0.84	14.1	5.5
D17	12.5	138.6	30.8	0.77	13.4	4.1
D18	4.2	138.6	27.1	0.80	4.7	1.9
RWD1	19.8	138.6	0.0	1.00	27.5	10.1
RWD2	1.2	138.6	0.0	1.00	1.7	0.7
RWD3	6.6	138.6	0.0	1.00	11.9	4.3
TSF1	352.5	138.6	24.6	0.81	397.6	88.5
TSF2	101.1	138.6	24.6	0.82	114.5	43.7
TSF3	69.7	138.6	24.6	0.82	79.0	32.3