CONCEPTUAL STORMWATER MANAGEMENT PLAN FOR THE MAMATWAN MINE

Mamatwan Mine

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ACRONYMS AND ABBREVIATIONS

Acronym / Abbreviation	**Definition**
BPG	Best Practice Guidelines
CN	Curve Number
DDF	Depth Duration Frequency
DHSWS	Department of Human Settlements, Water and Sanitation.
DRU	Daily Rainfall Utility Program
GN 704	Government Notice 704
ICFR	Institute for Commercial Forestry Research
MMT Mine	Mamatwan Mine
PCD	Pollution Control Dam
SANRAL	South African National Road Agency
SAWS	South African Weather Service
SCS	Soil Conservation Service
WRC	Water Research Commission

Conceptual Stormwater Management Plan for the Mamatwan Mine

1. INTRODUCTION

South32 operates the Mamatwan Mine (MMT) which is an opencast manganese operation (which forms part of the legal entity Hotazel Manganese Mines (Pty) Ltd) located approximately 25km to the south of Hotazel in the John Taolo Gaetsewe District Municipality and Joe Morolong Local Municipality of the Northern Cape Province of South Africa.

SLR Consulting (South Africa) (Pty) Ltd (SLR), an independent firm of engineering and environmental consultants, was appointed by South 32 to develop conceptual designs for the management of stormwater around the MMT. It is understood that numerous changes have taken place to the MMT infrastructure layout, and a Water Use Licence Application (WULA) is being prepared to authorise these changes. To support the WULA, a Stormwater Management Plan as well as the detailed design of stormwater infrastructure is required and must comply with the national regulations.

The Stormwater Management Plan (SWMP) must ensure compliance with The National Water Act (Act No. 36 of 1998), Government Notice 704 (Government Gazette 20119 of June 1999) (hereafter referred to as GN704).

1.1 SCOPE OF WORK

The scope of work for this study is:

- Undertake a site investigation to describe the current stormwater management system.
- A review of the baseline hydrology of the site and surroundings.
- Delineation of clean water and dirty water catchments based on site operations that will ensure compliance with GN 704; and
- Recommend infrastructure and practices that will further aid to compliance with GN 704.

Costing for the conceptual stormwater management is not covered under this scope of work. The high-level concepts proposed in this report will require refinement under the preliminary and detailed design phases.

2. APPLICABLE REGULATIONS AND GUIDELINES

Government Notice 704 (GN704) outlines the regulations for the use of water for mining and related activities and is aimed at protecting water resources. Although GN 704 was developed to regulate water use in mining applications, it is widely applied as the standard across all industries that have the potential to generate dirty water.

Regulations 5, 6, and 7 of GN704 are applicable to this study and are summarised below:

- **Regulation 5:** restricts the use of residues or substances which cause or are likely to cause pollution of a water resource from use in the construction of any dams, impoundments or embankments or any other infrastructure;
- **Regulation 6:** describes the capacity requirements of clean and dirty water systems. Clean and dirty water systems must be kept separate and must be designed, constructed, maintained and operated to ensure conveyance of flows for a 1:50 year recurrence event (i.e. clean and dirty water systems should not spill into each other more frequently than once in every 50 years). Any dirty water dams should have a minimum freeboard of 0.8m above full supply level; and
- **Regulation 7:** indicates that all dirty water or substances that may cause pollution should be prevented from entering a water resource (e.g. by spillage, seepage, erosion, etc.) and ensure that water used in any mining, industrial, etc. process is recycled as far as practicable.

Further requirements are outlined in the Department of Human Settlements, Water and Sanitation (DHSWS) ‘Best Practice Guidelines (BPGs) for Water Resource protection in the South African Mining Industry’ are highlighted below:

- **BPG A4 Pollution Control Dams, Section 6.4.3**. BPG4 defines the allowable RWD or PCD spillage frequency as being one spill every 50 years on average. To achieve this requirement, a RWD or PCD should be designed with an annual spillage probability of 1:50 (2%) or less. Further, BPG A4 recommends that the final design criteria should be determined through the use of a long-term continuous simulation water balance model, run at an appropriate time step (preferably daily), where:
    - The definition of an event is defined as a sequence of spill days occurring during a 30-day window.
    - The spillage frequency depends on the size of the dam (capacity) and the abstraction and re-use rate.
    - Confirmation of the dam sizing (based on spillage frequency), by means of continuous modelling.
    - It is important to consider the loss of storage due to sediment build up in the PCD when sizing the dam.
    - The PCD water balance will be used to specify a minimum storage level. This ensures that adequate freeboard is maintained so that the stormwater inflow can be accommodated, and the spillage frequency met. The management of the PCD should be according to this minimum level. The dam volume should be reduced to this minimum level as soon as possible after storm events.
    - It is important to consider that, in general, it is not the single events that result in spillage, but rather prolonged wet conditions.”
- **BPG G1 Stormwater Management, Section 4.2** defines a methodology of planning, designing and implementing stormwater management measures to ensure separation of clean and dirty water and provides guidelines to ensure sustainability over the mine’s life cycle. It also offers guidelines for the following:
    - Classification of clean and dirty areas;

  - Conceptual designs and review taking into account that at this stage, "The designer has to balance the need to obtain preliminary sizes so that water conveyance systems and retention structures can be provisionally sized, without undertaking a detailed design that may have to be discarded due to inadequacies in the stormwater management plan, or changes in the conceptual design.";
  - Assess the suitability of the existing infrastructure and define the changes to the stormwater infrastructure that may be required; and
  - Design of the required infrastructure informed by all prior steps.

As discussed in Section 3.1, GN 704 requires the following:

- Capacity: dirty water systems are to be designed, constructed, maintained and operated so that they are not likely to spill into any clean water system or the environment more frequently than once in 50 years.
- Conveyance: all water systems are to be designed, constructed, maintained and operated so that they convey a 1:50 year flood event.
- Freeboard: as a minimum, any dirty water dams are to be designed, constructed, maintained and operated to have a minimum of a 0.8m freeboard above full supply level.
- Collect and Re-Use: it is required that dirty water be collected and re-used as far as is practicable.
- Diversion: the flow of any surface water or floodwater into operational areas must be minimised.

3. PROJECT SITE AND EXISTING INFRASTRUCTURE

The MMT consists of a central product ore area, several waste rock dump (WRD) areas, plant area and access roads as can be seen in Figure 3-1.

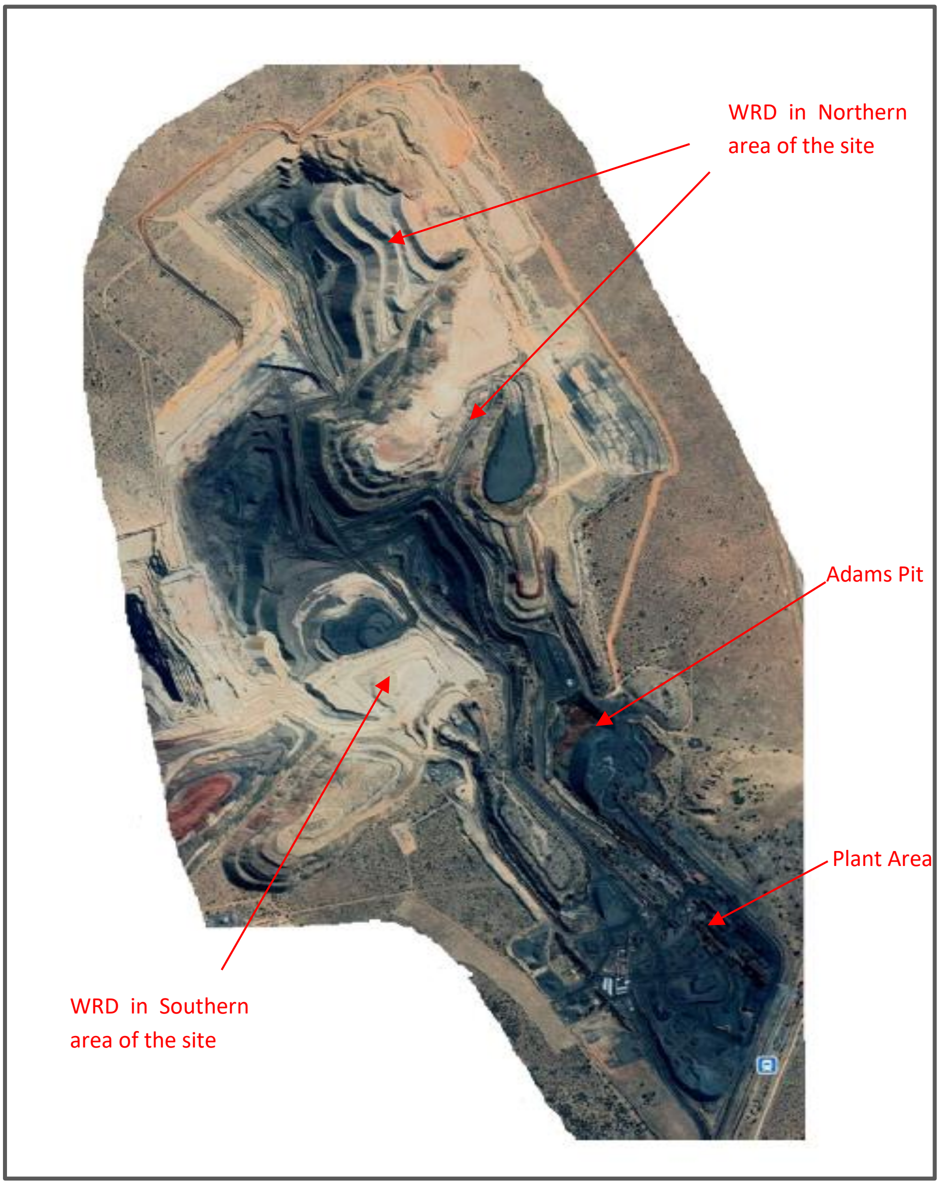

Figure 3-1 MAMATWAN MINE LAYOUT

All runoff within the mine area is considered "dirty" due to the potential contamination through contact with the processed materials.

Formal stormwater infrastructure exists in the southern-central portion of the site (plant area) and this area is shown in Figure 3-2. Currently the dirty runoff generated from this portion of the site is conveyed via concrete channels, concrete pipe culverts and an unlined earthen channel to discharge into Adams Pit. Adams Pit is an unlined and informal facility.

The existing conveyance infrastructure was observed, during a site visit by SLR, to be blocked and/or damaged and photographs illustrating this are provided in Annexure A.

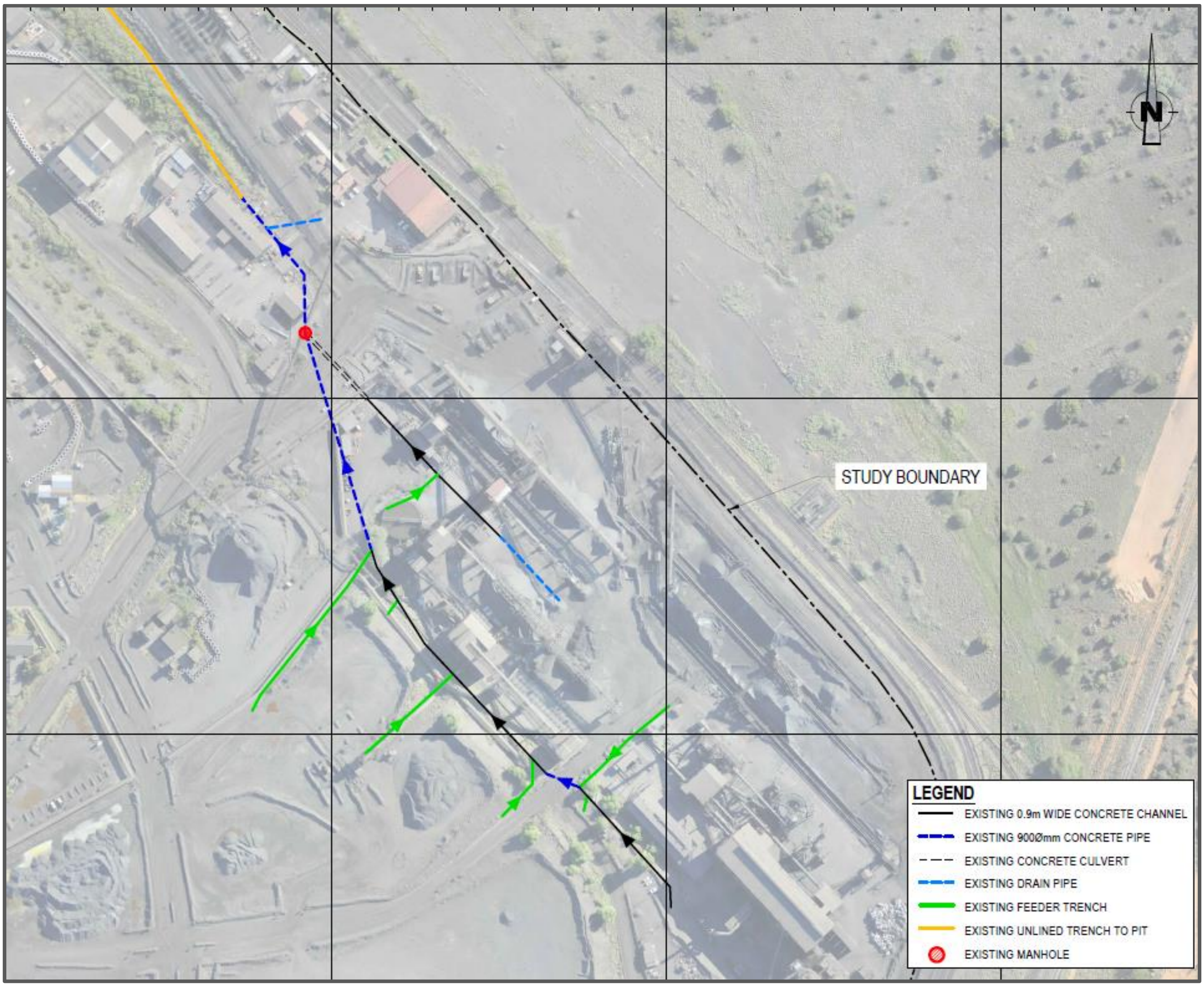

Figure 3-2 EXISTING INFRASTRUCTURE IN THE SOUTH-CENTRAL PORTION OF THE SITE

4. CONCEPT FOR THE STORMWATER MANAGEMENT PLAN

4.1 CONCERNS AND OBJECTIVES

The clean and dirty water catchment areas were delineated and the following noted:

- The runoff from the dirty water catchments, which all fall within the mine area, flow or are directed towards Adams Pit. There is risk of seepage from Adams Pit and the subsequent contamination of groundwater and so Adams Pit must be replaced by a formal and appropriately designed storage facility.
- The existing infrastructure may be undersized or in disrepair and therefore functionally inadequate. It is recommended that details on upgrades and repair to the existing infrastructure should be considered during the preliminary or detailed design stages.
- The south-western area of the site falls away from the existing infrastructure and mitigation measures are required to contain the dirty runoff within the site.
- Clean water catchments exist to the east of the site and mitigation measures are needed to minimise the volume of clean runoff entering the site.

4.2 STORMWATER MANAGEMENT CONCEPT

The concept of the proposed stormwater management plan is to allow the dirty runoff, within the mine area, to flow across the site as surface flow before discharging into lined storage facilities. It is recommended that a waste classification, as well as a groundwater study be undertaken in order to inform the lining details.

There is a risk of ponding in low lying areas, but these may be acceptable if mining operations are not impacted as a result. The existing conveyance infrastructure in the plant area is expected to have been designed to mitigate this ponding and will be assessed for functionality accordingly.

Further, earthen cut off channels and berms are proposed for construction towards the toe of the upstream catchment to contain and direct clean runoff away from the site.

The concept design to implement the stormwater management plan outlined, is discussed in the following sections.

A new topcut stockpile and product stockpile are planned towards the northern and central portion of the site. The proposed stormwater management infrastructure will include for directing dirty water runoff from these stockpiles towards containment facilities.

A rail loop has been designed by others and it is assumed that the rail loop design will include for stormwater considerations.

5. SITE HYDROLOGY

5.1 BASELINE INFORMATION

In order to inform the design of stormwater management infrastructure, an understanding of site-specific climatic conditions, topography, geotechnical and ground conditions is required.

5.2 RAINFALL

Modelling of the stormwater inflows has been undertaken using daily rainfall from the South African Weather Service gauge, station 0393083_W (Milner), and a summary of the data is presented in Table 5-1. Rainfall data for the gauge was extracted using the Daily Rainfall Utility Program (DRU) - Institute for Commercial Forestry Research (ICFR). The programme uses a database of observed and patched daily rainfall data developed under the Water Resources Commission (WRC) project (K5/1156). The monthly averages for the record are presented in Table 5-2. The Milner rainfall record was chosen due to the long rainfall record (shown in the below Table), has a reliable rainfall record (55.9 %), low ratio of patched (32.3 %) and missing data (11.7 %) as well as the proximal location to the site (shown in the below Table). The station also has a higher rainfall amount, within the record, than the 1:50 year return period rainfall amount (143.4 mm).

The mean annual precipitation (MAP) from the observed records (unpatched) is 369 mm and was checked against the average MAP (334 mm) derived for the project site (27°23´S;22°59´E) as per Design Rainfall Estimation of South Africa database, discussed further in Section 2.3. The MAP defined by WR 2012 is shown to be 344 mm.

Table 5-1: RAINGAUGE 0393083_W (MILNER) – SUMMARY OF DAILY RAINFALL RECORD

Parameter	Value
Latitude	-27.22
Longitude	23.02
Record start (year)	1887
Record end date (DRU record limit) (year)	2000
Years of usable rainfall record	March 1932 to June 2019 (~88 years)
Additional rainfall data sourced	Sept 2000 – June 2019
Distance to site and direction (km)	7 km S
MAP (mm)	369
Max recorded daily rainfall (mm)	161.5
Altitude metres above mean sea level (mamsl)	1118

The rainfall record runs from March 1931 to June 2019. The data before March 1931 was discarded as it was mostly incomplete. The rainfall record from March 1931 to 2000 was lengthened to June 2019 by sourcing additional daily rainfall data from the South African Weather Service (SAWS). The daily rainfall record is shown in
Figure 5-1.

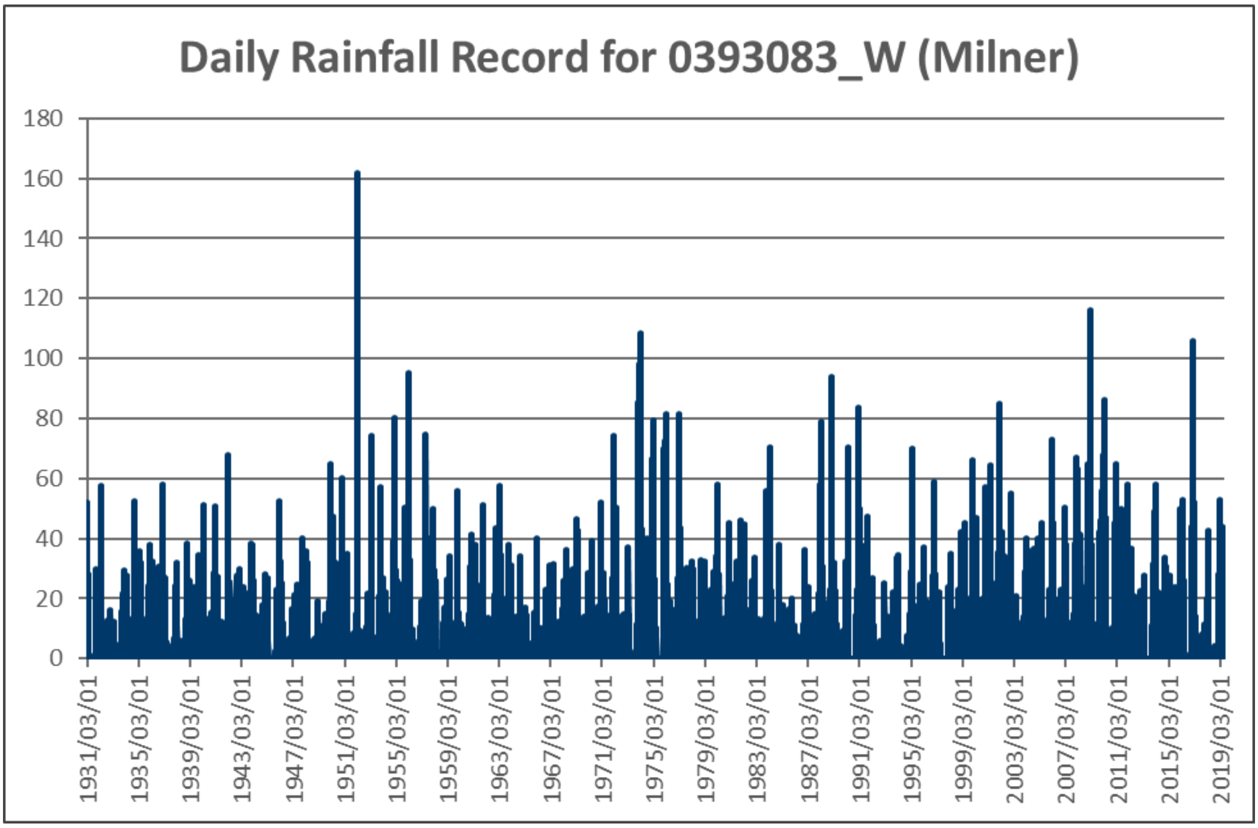

Figure 5-1: DAILY RAINFALL RECORD FOR 0393083_W (MILNER)

Table 5-2: RAIN GAUGE 0393083_W (MILNER) - MONTHLY AVERAGE RAINFALL DATA

Month	Average	Min	Max
Jan	71.3	0.00	311.7
Feb	63.2	0.00	241
Mar	65.5	0.00	276
Apr	37.5	0.00	197.9
May	15.2	0.00	108.5
Jun	6.7	0.00	86.5
Jul	1.8	0.00	47.2
Aug	3.6	0.00	44.5
Sep	6.1	0.00	77.8
Oct	18.6	0.00	108.8
Nov	32.2	0.00	137
Dec	47.1	0.00	261
Annual Total	**369**	-	-

5.3 EVAPORATION

Evaporation data is based on Symonds Pan (S-Pan) data taken from the WR2012 Database (WRC, 2012) for the quaternary catchment D41K (where the project site is located). S-Pan evaporation was converted to open water evaporation using evaporation coefficients from WR90 (WRC, 1990), as presented in Table 5-3 below. The evaporation zone is 8A and the Mean Annual Evaporation (MAE) is 2351 mm (WRC, 2012).

Table 5-3: MONTHLY AVERAGE EVAPORATION (WRC, 2012)

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
S Pan Evaporation (mm)	269.5	283.9	294.5	276.8	209.9	193.2	144.1	114.7	90.9	106.0	153.7	212.9
Pan Coefficient WR90	0.81	0.82	0.83	0.84	0.88	0.88	0.88	0.87	0.83	0.85	0.81	0.81
Lake Evaporation (mm)	218.3	232.8	244.4	232.5	184.7	170.0	126.8	99.8	77.3	88.0	124.5	172.5

5.4 DESIGN STORM DEPTHS

Design storm depth estimates for various return periods and storm durations were sourced from the Design Rainfall Estimation Software for South Africa, developed by the University of Kwazulu-Natal in 2002 as part of a WRC project K5/1060 (Smithers and Schulze, 2002).

Table 5-4 presents Depth Duration Frequency (DDF) rainfall estimates for the site that were derived from the Smithers and Schulze method based on analysis of the six nearest rainfall stations.

Table 5-4: DEPTH DURATION FREQUENCY (DDF) ESTIMATES FOR THE SITE

Storm Duration (m/h/d)	Return Period (years)						
	2	5	10	20	50	100	200
15 min	15.0	21.3	25.7	30.2	36.3	41.2	46.2
30 min	19.8	28.1	34.0	40.0	48.0	54.4	61.1
45 min	23.3	33.1	40.1	47.1	56.6	64.1	71.9
1 hr	26.1	37.2	45.0	52.8	63.5	72.0	80.7
1.5 hr	30.8	43.8	53.0	62.2	74.8	84.7	95.1
2 hr	34.6	49.2	59.5	69.9	84.0	95.2	106.8
4 hr	40.0	56.9	68.8	80.7	97.0	110.0	123.4
6 hr	43.5	61.9	74.9	87.9	105.6	119.7	134.3
8 hr	46.2	65.7	79.5	93.3	112.1	127.1	142.6

Storm Duration (m/h/d)	Return Period (years)						
	2	5	10	20	50	100	200
10 hr	48.4	68.8	83.3	97.8	117.5	133.1	149.4
12 hr	50.3	71.5	86.5	101.5	122.0	138.3	155.2
16 hr	53.4	75.9	91.9	107.8	129.6	146.9	164.8
20 hr	55.9	79.6	96.2	113.0	135.8	153.9	172.6
24 hr	58.1	82.6	100.0	117.3	141.0	159.8	179.3
1 day	46.7	66.5	80.5	94.5	113.5	128.6	144.3
2 day	56.8	80.8	97.7	114.7	137.9	156.2	175.3
3 day	63.6	90.5	109.5	128.5	154.4	175.0	196.3
4 day	68.2	97.1	117.4	137.8	165.7	187.7	210.6
5 day	72.0	102.5	124.0	145.5	174.9	198.2	222.4
6 day	75.3	107.2	129.6	152.1	182.9	207.2	232.5
7 day	78.2	111.3	134.6	158.0	189.9	215.1	241.4

5.5 ADDITIONAL CONSIDERATIONS

The rainfall record that is available ranges from 1931 to 2019, providing an 87-year long record of daily rainfall. Figure 5-2 is a plot of the calculated storm depth of 141mm and the rainfall record. In the 87-year long record, the storm depth of 141mm was exceeded only once. We therefore postulate that this one occurrence (in March 1952 of 161mm) is representative of a storm depth equivalent to a 1 in 100 recurrence interval (RI).

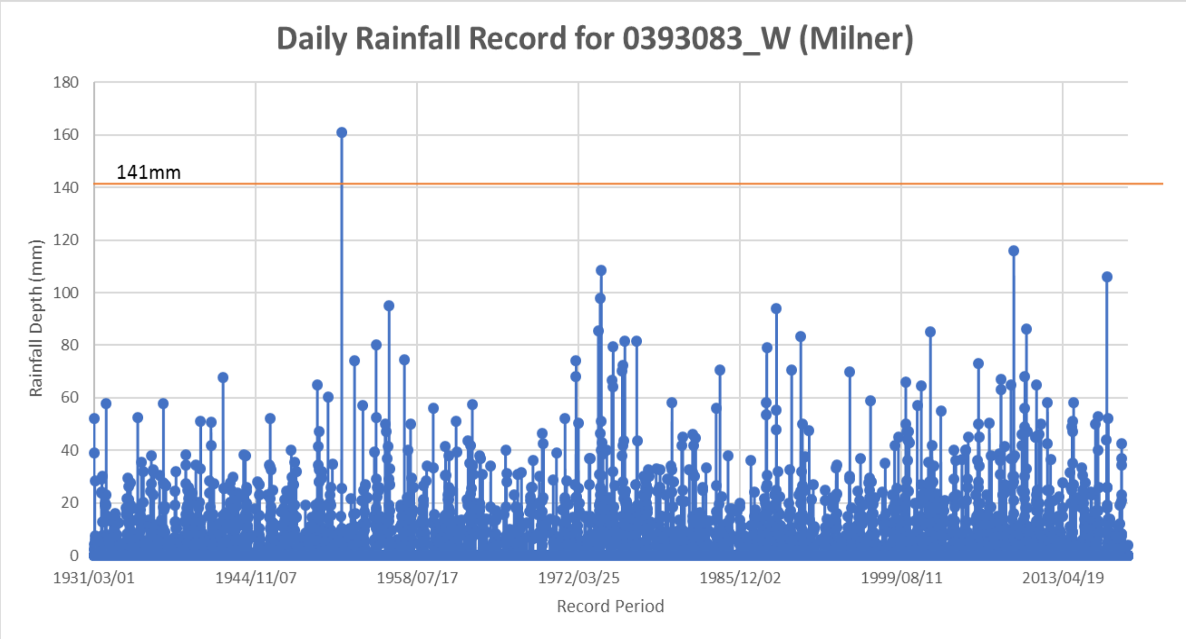

Figure 5-2: PLOT OF CALCULATED 1 IN 50 YEAR (24 HOUR) STORM DEPTH AND RAINFALL RECORD

Removing this outlier and replotting the rainfall record (refer to Figure 5-3) results in a more consistent rainfall pattern. Three noticeable storm events in the 87-year long record are observed, and all in the last 50 years. These three storm events (ranging from storm depths of 106mm to 116mm) are believed to be more representative of a storm depth with a 1 in 50 RI and it is proposed that the average of these three storm depths (110mm) be used to determine the design flood needed to design the proposed PCD. A design based on the storm depth of 110mm would only have overtopped once in the past 50 years as required by GN 704.

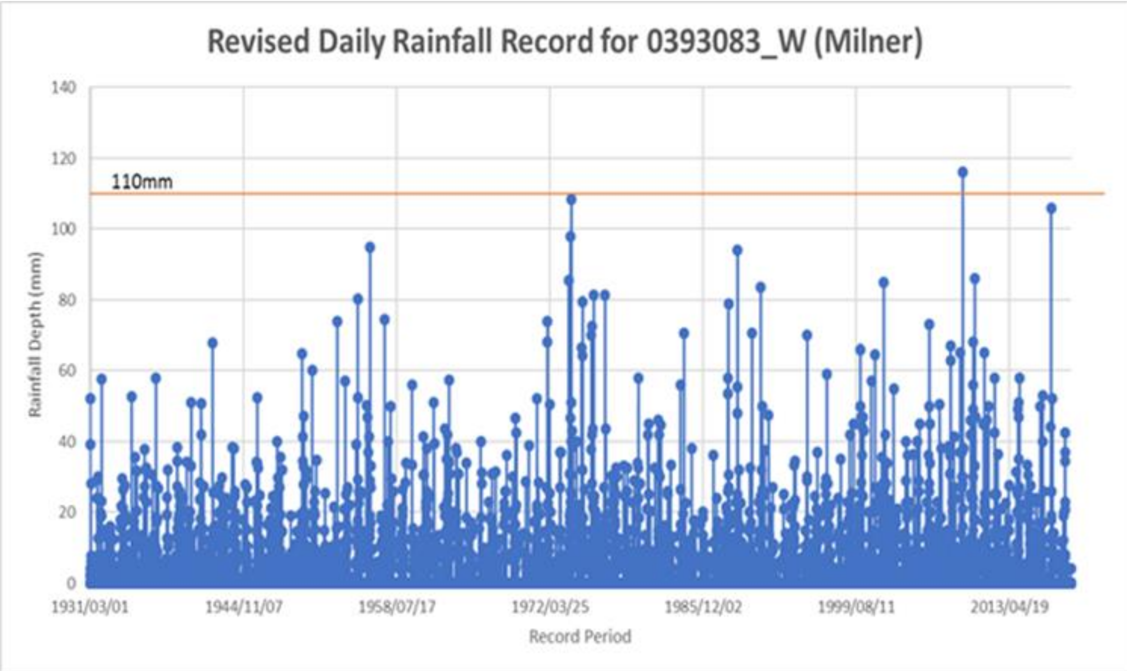

Figure 5-3: ADJUSTED RAINFALL RECORD AND CALCULATED 1 IN 50 YEAR (24 HOUR) STORM DEPTH

6. CONCEPT DESIGN

6.1 STORAGE INFRASTRUCTURE

A Pollution Control Dam (PCD) is proposed as the alternative storage facility to Adams Pit. As the topography currently facilitates flow of dirty runoff from the site towards Adams Pit, the proposed position of the PCD is in the same area.

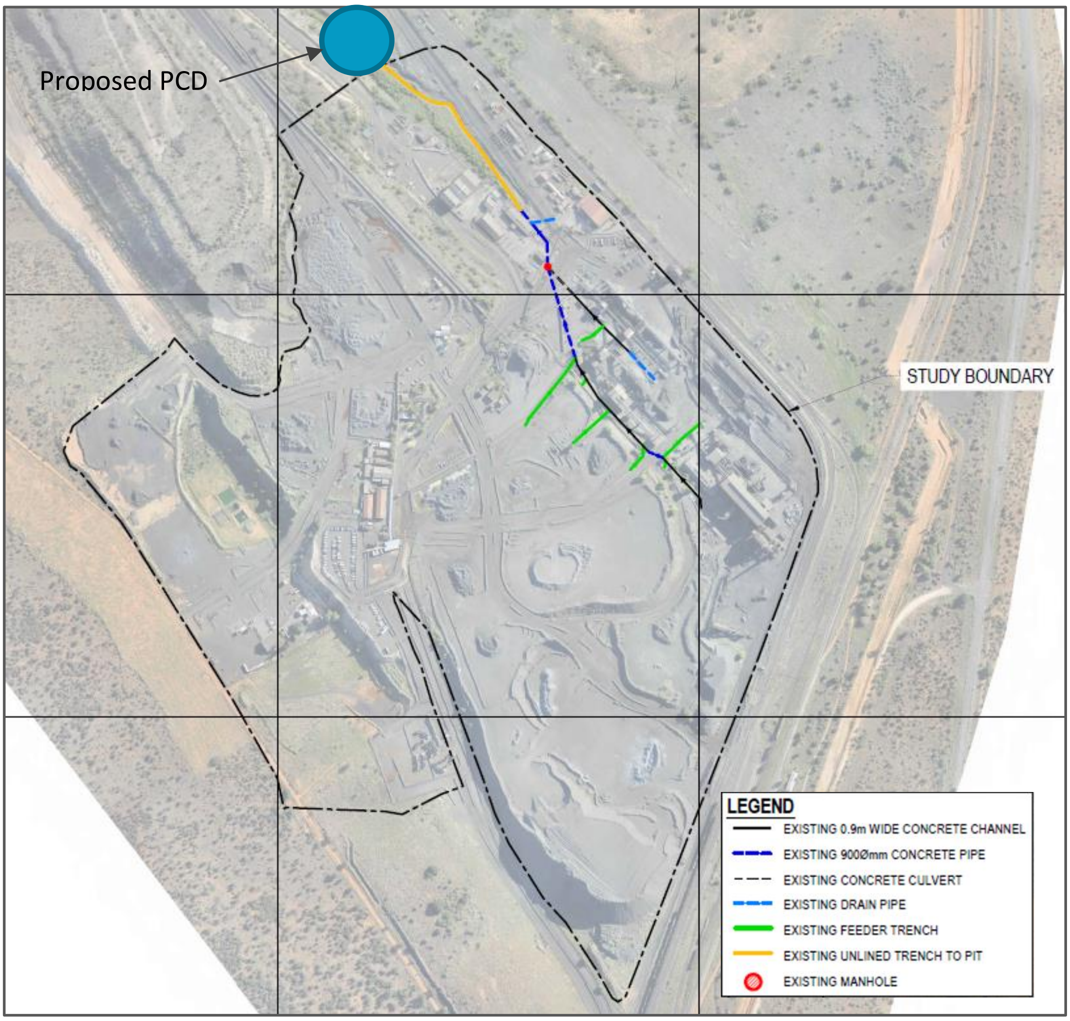

FIGURE 6-1: ESTIMATED POSITION OF PROPOSED PCD

6.1.1 Methodology for sizing the PCD

A daily time step rainfall-runoff model for the dirty stormwater catchments was coupled with a daily time step water balance model for the PCD. The rainfall-runoff model is based on the Soil Conservation Service (SCS) method and is used to estimate the portion of the rainfall which infiltrates or runs off from each catchment, for each day of the simulation. The PCD water balance model considers stormwater inflows, the direct rainfall reaching the dam, the evaporation losses and the return water pumping policy and calculates the volume of water in the PCD for each day of the simulation.

The key variables and assumptions used in the modelling are as follows:

- The model is run on a daily time step using the almost 88 years of daily rainfall data available as described in Section 5.2.
- Fixed monthly evaporation values were used as defined in Section 5.3;
- Stormwater runoff from two catchment types were considered:
  - Impermeable surfaces; and
  - Permeable (soil) surfaces
- The return water pumping system will be set up to pump water out of the PCD whenever water is available. The mine currently prioritises using clean water in the Plant, except for in the DMS Plant where it is mostly a closed loop cycle. Dirty water that is pumped from the North and South Pit can be potentially used at the Primary Crusher and in the Plant, but this is not the situation currently being adopted. The only current water use for dirty water around the mine is for dust suppression. There are many opportunities available for use of dirty water around the mine, such as:
  - Dust suppression (as mentioned);
  - Use within the Plant (the Plant currently only uses potable water from the Vaal-Gamagara Pipeline (VGP), which is managed by the Sedibeng Water. This would be beneficial as the cost of potable water is increasing and the MMT would not be completely reliant on Sedibeng Water;
  - Another option that could be explored is the selling of this dirty water to neighbouring mines in the water scarce Northern Cape Province;
  - Dirty water treatment and reuse.
- The PCD have been modelled assuming vertical sides for simplicity;
- The runoff from the infrastructure related areas was calculated using the SCS stormflow equation (Schulze et al., 1992) using a curve number (CN) of 84 for the plant areas (area weighted). The CN describes the runoff factor for sub-catchments. The simulated runoff was then entered into the daily time step water balance model to calculate the size of the PCD and the associated spillage frequency;
- The volume of water in the dams, the evaporation, and the amount abstracted through pumping and the spill volumes were calculated for each day over the full simulation record available. The simulation calculates the required capacity of the dams and the number of spills during the ~88-year simulation period which is directly related to the abstraction rate. Table 6-1 indicates the dimensions of the PCD, the annual spill frequency and the associated abstraction rates.

6.1.2 PCD modelling results

The results of the PCD simulations show three potential dam sizes and related daily abstraction volumes. Three options were considered to allow the mine to choose whether a smaller dam, with a higher abstraction rate suited them or conversely whether a larger dam with a lower abstraction rate suited the MMT Mine more. A 70 000 m^3 dam size is recommended for the PCD. Table 6-1 shows the three potential dam volumes and the required daily abstraction amounts. The option that has been recommended is based on the current dirty water reuse practice. Should the mine adopt a practice of utilising (reusing) more dirty water moving forward, then the three options give the mine the flexibility to suit a range of future water management possibilities. The mine will have to abstract and reuse the amount of water that is shown Table 6-1.

The abstraction rate provided is needed to ensure the risk of spill in any one year, as detailed in Table 6-1. Also, that the alternatives provided should be investigated as these have not been evaluated as part of this study.

Table 6-1: SIZING OPTIONS FOR THE PCD - VOLUMES AND REQUIRED DAILY ABSTRACTION RATES

PCD (5 m deep)					
Option A – 50 000 m^3 Dam		Option B – 60 000 m^3 Dam		Option C – 70 000 m^3 Dam	
Abstraction (m^3/day)	% Annual Spill	Abstraction (m^3/day)	% Annual Spill	Abstraction (m^3/day)	% Annual Spill
620	4.52	350	4.52	210	4.52
720	3.39	460	3.39	260	3.39
1070	2.26	590	2.26	350	2.26
2240	1.13	1320	1.13	470	1.13

The daily volume, the spill volume, the rainfall as well as the maximum dam volume for the chosen PCD size are shown below in Figure 6-2.

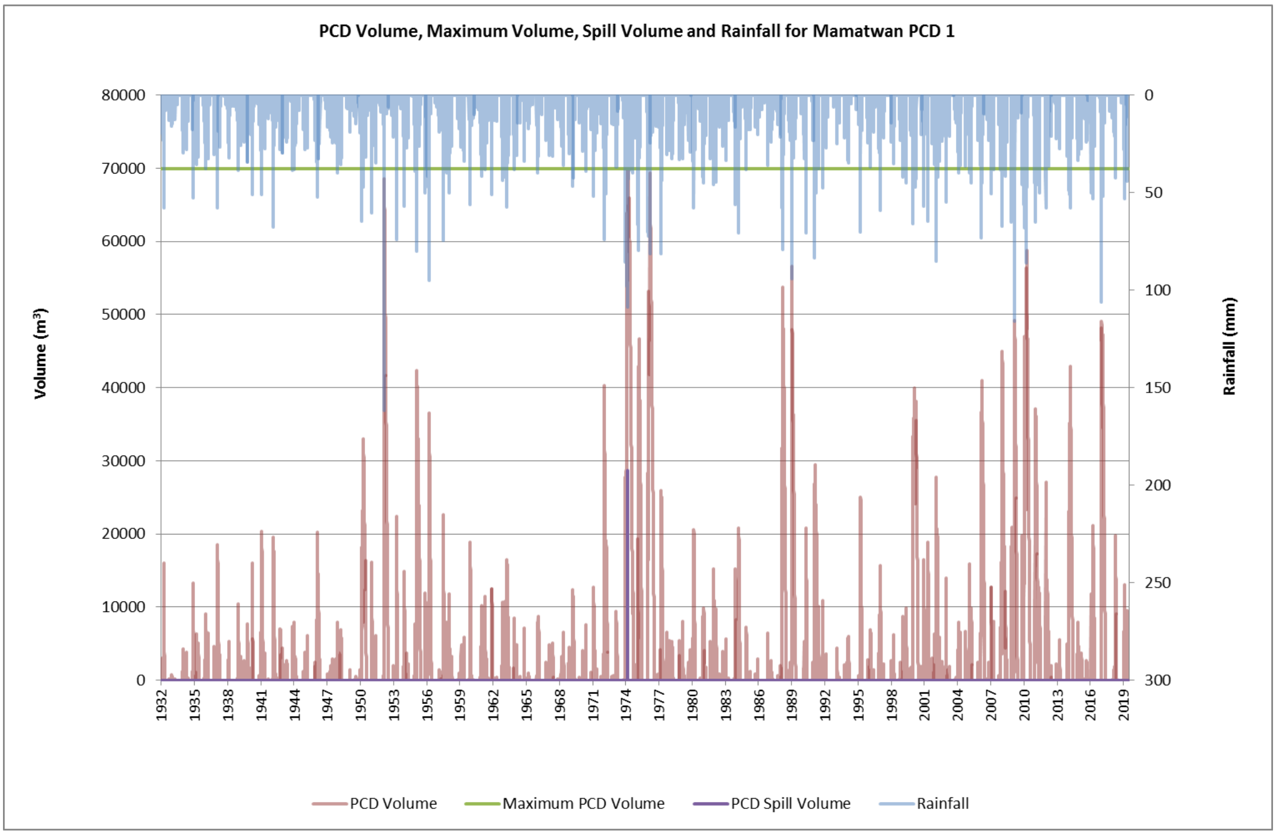

Figure 6-2: MMT PCD STORMWATER DAM DAILY VOLUME, SPILL VOLUME, RAINFALL AND MAXIMUM VOLUME (OPTION C)

6.1.3 Design considerations

A geotechnical site investigation will be required during detailed design to determine the construction materials available from the site for use in the construction of the PCD.

The regulations require that the PCD must be lined and the liner will comprise clay material/impermeable material, a geomembrane liner (double HDPE liner) or a composite liner, depending on availability of material from the site. The liner system including leakage detection and drainage will need to be designed during the detailed design phase and will be based on recent geochemical and waste classification analyses.

The channel inlet to the PCD will require the use of a silt trap. The silt trap will have to be concrete lined to allow for ease of removal of material. The silt trap will have two separate equally sized compartments, an operational and a standby compartment to allow one compartment to be cleaned whilst the other is in operation.

Should the PCD spill, it is recommended that the spill is conveyed to the area outside of the flood protection berm.

It is recommended that in detailed design, the adjusted rainfall record discussed in Section 5.5 should be considered in sizing the PCD.

6.2 CONVEYANCE INFRASTRUCTURE

The areas of concern are shown in FIGURE 6-3. The existing infrastructure was checked against the calculated 1:50 year (24 hour) peak flow event. It was found that the existing concrete infrastructure are adequately sized for such an event and only require cleaning and repairing to ensure that the pipe culverts/channels are fully operational. The channel that directs flow from Areas 1, 2 and 4 is unlined and will need to be lined and realigned to direct the dirty runoff into the proposed PCD.

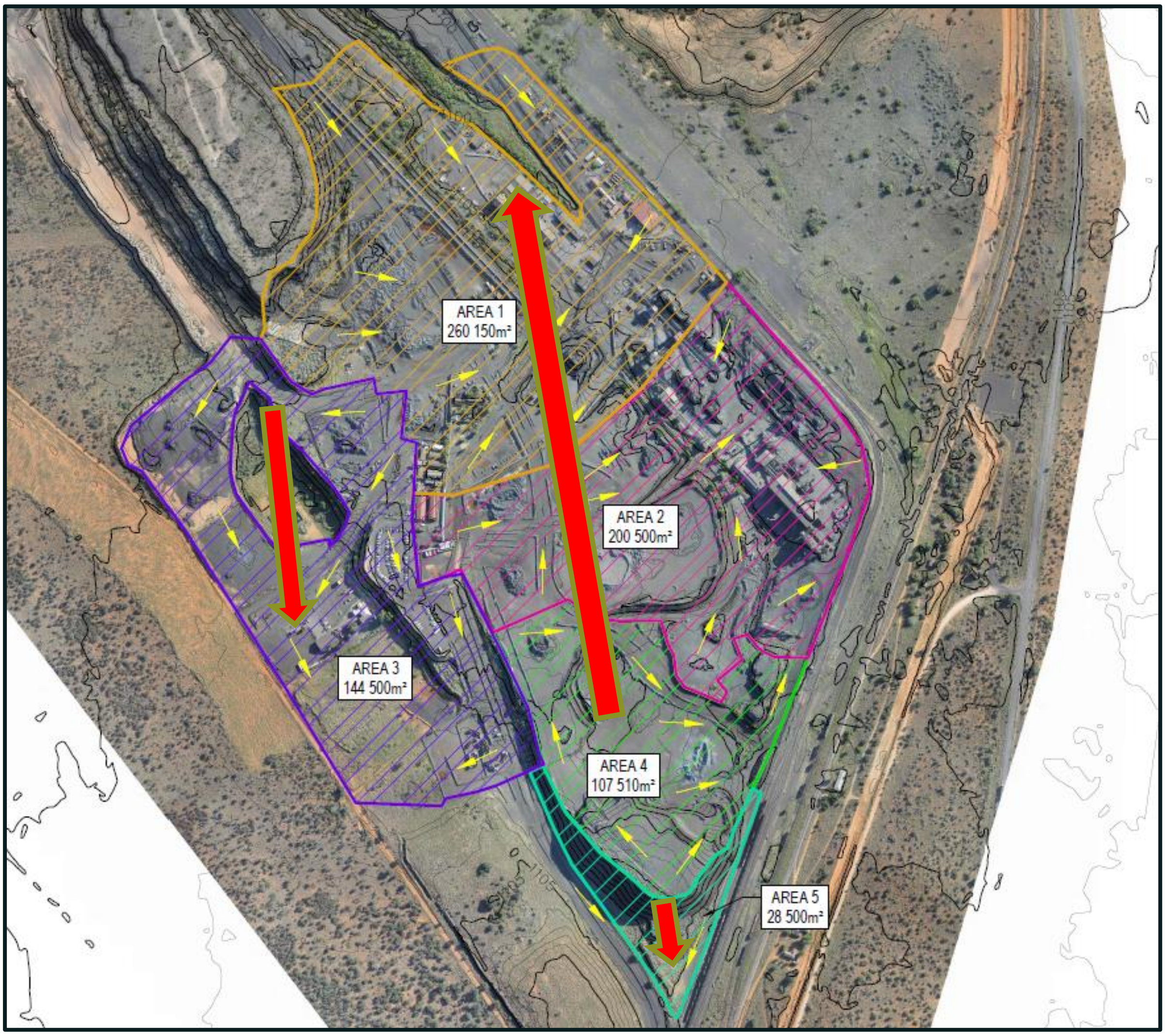

FIGURE 6-3 DIRTY CATCHMENT AREAS WITHIN THE PLANT AREA AND THE DIRECTION OF FLOW

New conveyance infrastructure will be required in Area 3 and 5 as there is no existing infrastructure to contain the dirty runoff from these areas. Lined channels are recommended for construction around the perimeter of Area 3 and 5 (refer to FIGURE 6-4). A wide channel/evaporation paddock structure that facilitates evaporation of this runoff, may be needed to attenuate flows from Area 3. As the expected runoff volume from Area 5 are comparatively small, dirty water that collects in the proposed lined channels are expected to evaporate.

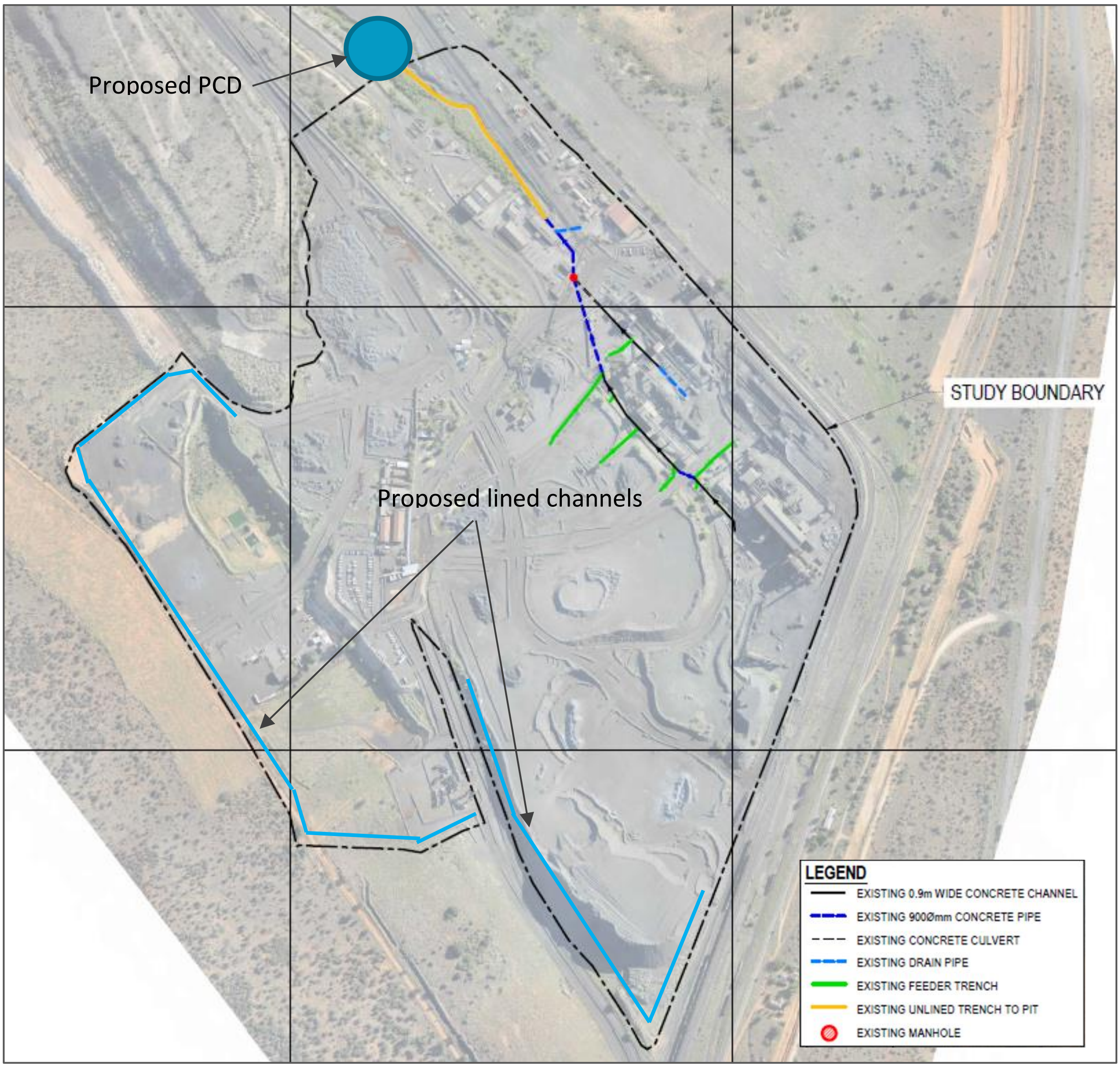

FIGURE 6-4: PROPOSED LINED CHANNELS

The design and construction of earthen cut-off channels and berms are proposed to prevent dirty water from leaving the northern portion of the site (refer to FIGURE 6-5). A low volume of water is expected to collect in these channels and so will be allowed to evaporate. No storage facilities deemed necessary for areas north of the plant.

These channels can be constructed using a simple cut to fill operation and can be maintained regularly.

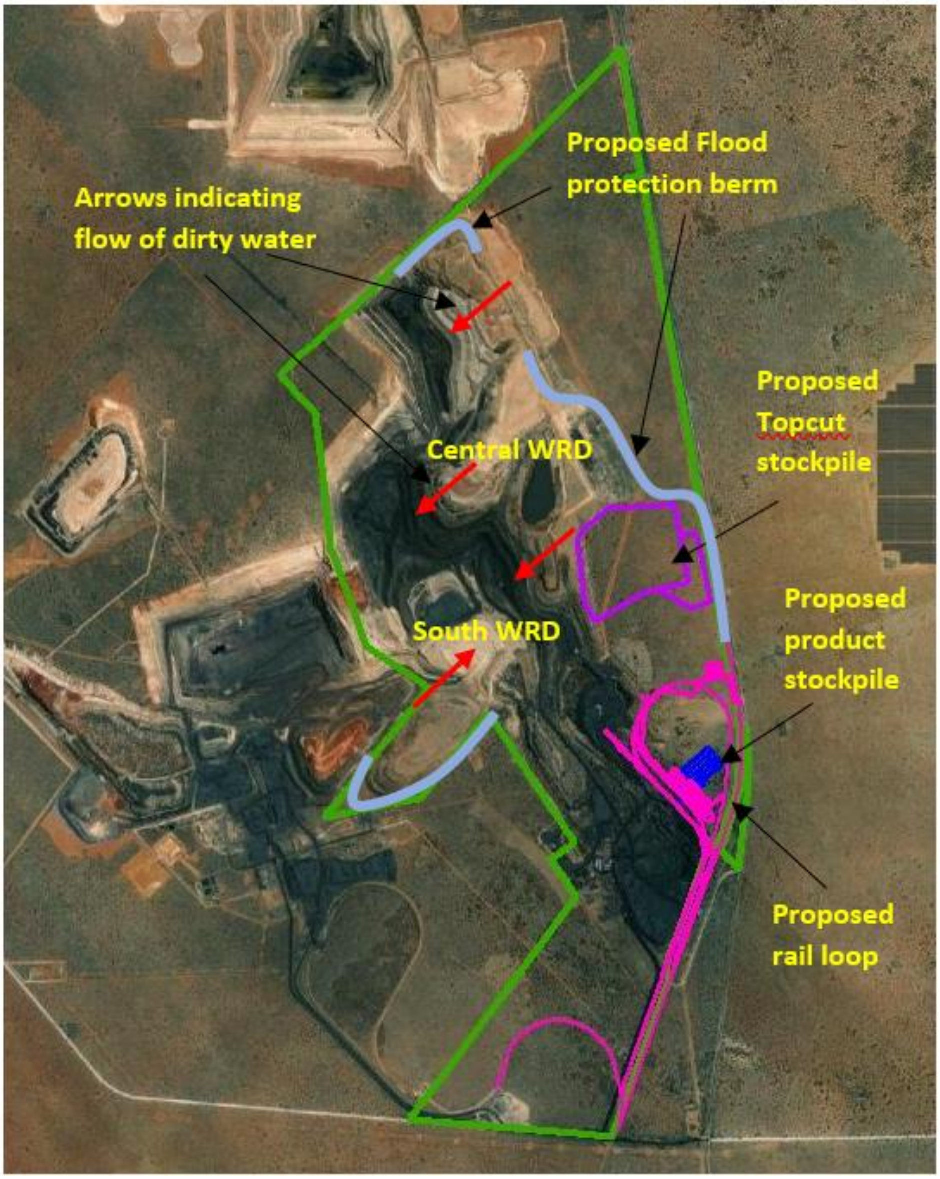

FIGURE 6-5: EXPECTED DIRECTION OF FLOW OF DIRTY WATER IN THE NORTHERN PORTION OF THE SITE

The clean water will be kept out of the dirty water catchments through the construction of berms and cut-off channels, constructed at the toe of the upstream clean catchments (refer to FIGURE 6-6). The dirty water collection channels will have a 0.8 m freeboard height, in line with the GN704 regulation. These channels and berms can be constructed using a simple cut to fill operation and can be maintained regularly.

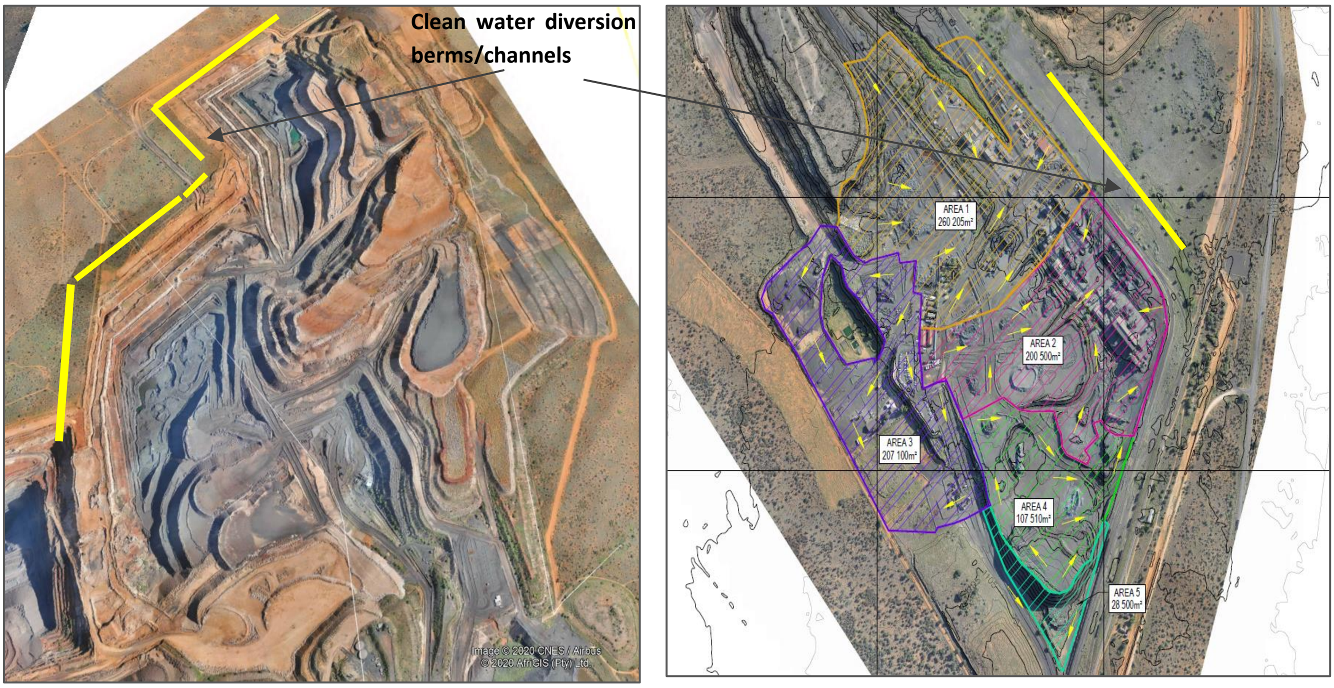

FIGURE 6-6: PROPOSED POSITIONS OF CLEAN WATER DIVERSION BERMS/CHANNELS

Peak flows for design of the stormwater conveyance infrastructure were estimated using the SCS Method as applied within the PCSWMM stormwater design software package. A Curve Number (CN) of 72 was applied to all catchments and the extent of the impermeable area was adjusted to distinguish between unaffected soil and a hard-impervious catchment, such as concrete paving. A Type III storm profile was applied to the 1:50 year, 24-hour rainfall depth (143.4 mm) to estimate peak flows from each catchment.

New channels were sized to take the maximum flow calculated for the downstream end of the contributing catchment and the channel sizing was taken as uniform along the entire length. Some cut and fill may be required along the length of the channels to achieve the required gradient and to ensure that water flows freely along the channels. The dirty water channels have been sized to accommodate the expected 1:50 year peak flow event.

Following confirmation of the design flows for each diversion channel, the channels have been sized using the Manning's Equation to ensure that the flow capacity of the channel is sufficient to convey the 1:50 year rainfall event.

The Manning's equation is:

$$Q = A\frac{1}{n}R^{2/3}S^{1/2}$$

Where:

A = Area of Channel

R = Hydraulic Radius (area / wetted perimeter);

S = Longitudinal Slope of Channel; and

n = Manning's Roughness Coefficient

A Manning's 'n' coefficient of 0.014 was used, as recommended for concrete lined channels. Preliminary sizing of the channels is contained in Appendix B.

7. CONCLUSIONS AND RECOMMENDATIONS

A stormwater management plan has been conceptualized to meet the applicable regulations and to minimise capital costs by South32.

The following is a summary of the concept SWMP:

- Design and construct a lined PCD in the vicinity of Adams Pit to store the runoff from the mine site. It is recommended that a waste classification, as well as a groundwater study be undertaken in order to inform the lining details.
- Allow the dirty runoff, within the mine area, to flow across the site as surface flow before discharging into the PCD.
- Design and construct earthen cut-off channels and berms in the northern area of the site to contain dirty water from WRDs and proposed stockpiles.
- Where existing infrastructure is available, clean and repair as required for continued use.
- Design and construct a lined channel to convey dirty runoff from the existing infrastructure in the plant area to the proposed PCD.
- Design and construct new lined channels along the perimeter of the western area of the plant site (Area 3 and 5), increasing the width in suitable areas to facilitate evaporation.
- Design and construct earthen cut off channels and berms towards the toe of the upstream clean catchments to contain and direct clean runoff away from the site.
- It is recommended that a preliminary and detailed engineering design be initiated for the proposed storm water management infrastructure. This would entail further development and optimisation of the concepts proposed including: a waste classification to determine liner requirements; a geotechnical investigation on the canal alignments and at PCD locations and a cost estimate for the proposed works.
- A rail loop has been designed by others and it is assumed that the rail loop design will include for stormwater considerations. Nonetheless, the design of the rail loop will be incorporated into the detailed design of the stormwater management infrastructure to ensure completeness.

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Meeressa Pillay	**Natasha Smyth**	**Fred Sutherland**
(Report Author)		(Reviewer)

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APPENDIX A: PHOTOGRAPHS OF EXISTING INFRASTRUCTURE

Chanel Section 1: Rectangular open channel

Chanel Section 1: Rectangular open channel

Channel section 2: Circular concrete Pipe (900ID)

Channel Section 3: Rectangular open channel

Channel Section 3: Rectangular open channel

Channel section 4: Circular concrete Pipe (900ID)

Section 5: Discharge to unlined Adams pit trench

Section 6: Portal culvert

Section 7: Rectangular open channel

Section 7: Culvert under buildings

APPENDIX B: PROPOSED CHANNEL SIZING

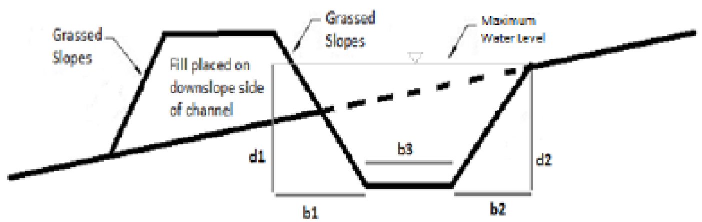
Project Number:	720.19136.00002	**Date created:**	26/05/2021
Project Name:	Mamatwan SWMP	**Created by:**	MN
Name:	Mamatwan conveyance preliminary sizing	**Reviewed by:**	MP
		Date reviewed:	06/08/2021

Assumptions

* A flood depth of **143.4 mm** for 24 hours of a 1:50 year recurrence interval is used throughout the design of the lined channels
* The side slopes for all berms and channels will be kept constant at 1 vertical: 2 horizontal
* A Manning's 'n' coefficient of 0.014 was used, as recommended for concrete lined channels
* Manning's equation (as shown below) is used to determine channel geometry

$$Q = A\frac{1}{n}R^{2/3}S^{1/2}$$

* Typical cross sections of the berms and channels are shown below



Preliminary sizing for the catchments

Catchment Area	Area	Rainfall	Run-off	Run-off	b1	d1	b2	d2	b3	S	n	A	R	V	Design Flow (Q)
	m^2	m^3/d	m^3/d	m^3/s	m	m	m	m	m	m/m		m^2	m	m/s	m^3/s
Area 1	260150	0.143	37201.450	**0.431**	0.3	0.5	0.3	0.5	0.5	0.01	0.014	0.4	0.2	2.7	**1.10**
Area 2	200500	0.143	28671.500	**0.332**	0.3	0.5	0.3	0.5	0.5	0.01	0.014	0.4	0.2	2.7	**1.10**
Area 3	144500	0.143	20663.500	**0.239**	0.3	0.5	0.3	0.5	0.5	0.01	0.014	0.4	0.2	2.7	**1.10**
Area 4	107510	0.143	15373.930	**0.178**	0.3	0.5	0.3	0.5	0.5	0.01	0.014	0.4	0.2	2.7	**1.10**
Area 5	28500	0.143	4075.500	**0.047**	0.3	0.5	0.3	0.5	0.5	0.01	0.014	0.4	0.2	2.7	**1.10**

** Design flow to be greater than run-off values*

RECORD OF REPORT DISTRIBUTION

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