APPENDIX P: SURFACE WATER STUDY

SURFACE WATER STUDY UPDATE

Mokala Mine

Prepared for: Mokala Manganese (Pty) Ltd

SLR Project No.: 710.09012.00010
Report No.:
Revision No.: B
February 2022

DOCUMENT INFORMATION

Title	Surface Water Study Update
Project Manager	Pfarelo Siebani
Project Manager Email	psiebani@slrconsulting.com
Author	Pfarelo Siebani
Reviewer	Paul Klimczak
Keywords	Keywords; Keywords
Status	Final
DEA Reference	Not Applicable
DMR Reference	Not Applicable
DWS Reference	Not Applicable
Report No.	1
SLR Company	SLR Consulting (South Africa) (Pty)Ltd

DOCUMENT REVISION RECORD

Rev No.	Issue Date	Description	Issued By
B	February 2022	First Report	PS

BASIS OF REPORT

EXECUTIVE SUMMARY

Introduction

SLR Consulting has been commissioned by Mokala Manganese (Pty) Ltd (Mokala) to undertake an amendment of a surface water study undertaken by SLR Consulting in 2015. The surface water update includes activity / infrastructure changes that have already taken place and proposed changes. These changes are required optimize their mining operations. The Mokala Mine is currently in the construction and operational phase of the project. In this regard, temporary infrastructure in support of the construction phase is currently on site. Construction facilities will either be removed at the end of the construction phase or incorporated into the layout of the operational mine. The mine has also begun with their open cast strip mining activities.

Baseline Hydrology

The Mokala Mine is located within the Quaternary Catchment (QC) D41K with a gross area of 4216 km^2 and a net MAR of 1.92 Mm^3. QC D41K falls within the Lower Vaal Water management area (WMA). The Molopo River, Harts River and the Vaal River are the major rivers draining the WMA. All the runoff of the WMA eventually drains westwards into the Orange River.

The average monthly rainfall data for the site is based on the nearest rainfall station managed by the South African Weather Services (SAWS). Rainfall record Wilton rain gauge (0392148 W) were obtained from SAWS. The mean annual precipitation (MAP) from the observed records (unpatched) is 334 mm. The daily rainfall record was used in the steady state and dynamic water balance models to demonstrate rainfall inflows in various process units of the mine on a monthly basis.

Evaporation data is based on Symonds Pan (S-Pan) data taken from the WR2012 database (WRC, 2012) for the quaternary catchment D41K, specifically Evaporation Zone 8A. S-Pan evaporation was converted to open water evaporation using evaporation coefficients.

Stormwater Management Plan

A review of the proposed surface infrastructure has been undertaken, and a series of design principles for stormwater management have been developed to ensure compliance with the requirements of Government Notice (GN) Regulation 704.

In order to meet the design principles detailed above, conceptual design details for the proposed stormwater management measures are recommended for each of the proposed opencast mine pit and infrastructure complexes, along with the specific hydraulic design standards, methodologies, assumptions, and input parameters for each management measure proposed.

The channels were sized to accommodate the maximum flow calculated for the downstream end of the contributing catchment and the channel sizing is uniform along the entire length. Some cut and fill may be required along the length of the channels to achieve the required gradient to ensure that water flows freely within these channels. The clean water will be kept out of the dirty water channels by construction of linear berms parallel to the dirty water channel with material excavated from the channel.

Site Wide Water Balance

The dry and wet water balances have been calculated for the mine. The water balance indicates that the Vaal Ga-Mogara Water Supply Scheme will be required to supply potable water to the site, in the order of 1 985 m^3/month, during dry periods. There will be no need to import plant makeup water due to the availability of pit ground water inflows and the recycling of the waste water treatment plant (WWTP) effluent.

Dynamic Daily Water Balance

Daily time step storm water modelling is undertaken using the software package GoldSim. The SCS method is used to calculate the portion of the rainfall that contributes to runoff for each of the catchment surface types. A soil water budgeting procedure is used to vary the SCS CN(II) value in accordance with the antecedent catchment moisture conditions. The storm water reports to the Recycle Water Pond (RWP) where a daily balance is calculated for water in storage, evaporation, abstractions, and spills. The model is run over the 74-year rainfall time series and the frequency of spills from the RWPs is analysed.

Recommendations

The following recommendations were made:

- Stormwater Management Plan
    - SWMP has been developed to ensure compliance with the requirements of GN 704. As part of the detailed design process, a geotechnical investigation is necessary to assess the structural integrity of the existing embankment as well as to determine the dam footprint for the lining, compaction, berm and storage estimates. Confirm all the levels (base of dam, full capacity, spillway and freeboard).
    - Management of silt by ensuring that the disturbance of soil is minimised, sediment source and erosion control, phasing of earthworks activities, diversion of upslope runoff from entering the earthworks areas and downstream treatment of any collected sediment runoff i.e., use of silt traps.
    - It is recommended that the hydraulic gradients and channel sizes are confirmed during the detailed design of the stormwater channels. The requirement for, and design of, in-channel velocity control measures should be confirmed during the detailed design of the channels. The specification for lining of the channels and the PCDs should also be confirmed during the detailed design of these features.
- Water Balance
    - A collection and water management strategy were also defined where the reuse of process water must be prioritised, thereby ideally reducing the impacts from the project on the surface water resources.
    - Any spills from the RWPs must be directed to the open pit for temporary storage and reuse / disposal. When the RWPs are operated in this way the resulting spills will cause minimal disruption to the mining operation as they are infrequent and of relatively small volumes.
    - In order to reduce the impacts from the project on the surface water resources, excess mine water can be used for dust suppression.

CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

Acronym / Abbreviation	Definition
DDF	Depth-Duration-Frequency
DEM	Digital Elevation Model
DWS	Department of Water and Sanitation
ETo	Evapotranspiration
GN704	General Notice 704
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
mamsl	meters above mean sea level
MRA	Mining Right Area
NWA	National Water Act
PFD	Process Flow Diagram
RM3	Rational Method Alternative 3
ROM	Run of Mine
RWP	Recycle Water Pond

1. INTRODUCTION

SLR Consulting has been commissioned by Mokala Manganese (Pty) Ltd (Mokala) to undertake an amendment of a surface water study undertaken by SLR Consulting in 2015. The surface water study update, presented herewith, includes activity / infrastructure changes that have already taken place and proposed changes. These changes are required to optimize their mining operations and are further discussed in the subsections below.

1.1 PROJECT BACKGROUND

The Mokala Mine is currently in the construction and operational phase of the project. In this regard, temporary infrastructure in support of the construction phase is currently on site. Construction facilities will either be removed at the end of the construction phase or incorporated into the layout of the operational mine. The mine has also begun with their open cast strip mining activities.

These changes are required to optimize their mining operations.

Activity/infrastructure changes to the approved infrastructure that have already taken place include:

- The reconfiguration of plant area, ROM and high-grade product stockpiles to accommodate the expansion of the open pit.
- The relocation of the low-grade product stockpile.
- The relocation of support infrastructure (water storage facilities (potable and process water), workshops and washbay, change houses, sewage treatment plant, water treatment plant, fuel storage, administrative block (offices, kitchen, canteen, training centre, mustering centre, clinic), stores and waste storage).
- Relocation of transportation related facilities/infrastructure (internal haul road, weighbridges, parking areas, truck loading and staging facility).
- The relocation of the approved WRD to accommodate the expansion of the open pit.
- The relocation of the approved topsoil stockpiles.

Proposed activity/infrastructure changes to the approved surface layout include:

- The proposed expansion of the open pit.
- The proposed increase in the capacity of the approved WRD and the establishment of an additional WRD.
- The proposed establishment of addition topsoil stockpiles.
- The proposed relocation of stormwater management infrastructure.
- The proposed increase in the capacity of product stockpiles (ROM and Low Grade, High Grade).
- The proposed mining of the barrier pillar between the Kgalagadi Mine and Mokala Mine.
- No changes are anticipated to the realignment of the R380, the realignment of the Ga-Mogara drainage channel and the intersection to the entrance of the mine.

1.2 LEGISLATION

The following legislation was taken into account during this assessment:

1.2.1 The National Water Act (Act 36 of 1998)

Water resources management in South Africa is governed by the National Water Act (NWA). The Department of Water and Sanitation (DWS) must, as custodians of water, ensure that resources are used, conserved, protected, developed, managed and controlled in a sustainable manner for the benefit of all persons and the environment.

1.2.2 Regulations on the use of Water for Mining and Related Activities

Government Notice 704 (Government Gazette 20119 of June 1999) (hereafter referred to as GN 704), was established to provide regulations on the use of water for mining and related activities aimed at the protection of water resources. The three main conditions of GN 704 applicable to this project are:

- Condition 5 - indicates that no residue or substance which causes or is likely to cause pollution of a water resource may be used in the construction of any dams, impoundments or embankments or any other infrastructure which may cause pollution of a water resource.
- Condition 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 for the flows of a 1:50 year recurrence event. Clean and dirty water systems should not spill into each other more frequently than once in 50 years. Any dirty water dams should have a minimum freeboard of 0.8m above full supply level.
- Condition 7 - describes the measures which must be taken to protect water resources. All dirty water or substances which may cause pollution should be prevented from entering a water resource (by spillage, seepage, erosion etc.) and ensure that water used in any process is recycled as far as practicable.

1.2.3 Best Practice Guidelines

In addition to GN 704, Department of Water and Sanitation (then Department of Water and Forestry), has developed several Best Practice Guidelines (BPGs) for the mining industry including:

- BPG A4 Pollution Control Dams (PCDs), Section 3.5 In this document it defines the allowable PCD spillage frequency as being one spill every 50 years on average. This is equivalent to stating that a PCD should be designed with an annual spillage probability of 1:50 (2%) or less. In addition to this, 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 3.2 which 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, "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 infrastructure changes required.
    - Design of required infrastructure informed by all prior steps.
- BPG G2: Water and Salt Balances.

1.3 SCOPE OF WORK AND REPORTING

The scope of work for this study included the following:

- Baseline Hydrology – Section 2 presents a review and analysis of various sources of rainfall and evaporation data. The section also presents the characterisation of the baseline hydrology of the site and surroundings including topography, watercourse network and catchment delineation.
- Conceptual Stormwater Management – Section 3 presents the recommended stormwater management measures including a review of the layout, peak flow estimation (Rational method only), hydraulic sizing of the drainage infrastructure (protection berms and channels), and the location RWPs.
- Steady State Water Balance – Section 4 presents the steady state water balance model for the major water components of the mine. This chapter also presents an opportunity to optimize the water management at the mine site as well as determine the amount of make-up water required for the mine.
- Dynamic Water Balance – Section 5 of this study that present the sizing of the Recycle Water Ponds (RWPs) using daily time step water balance model.
- Conclusions and Recommendations – Section 6 presents a summary of the main conclusions of this report and a summary of the recommendations made based on this study.

1.4 DETAILS OF THE SPECIALISTS WHO PREPARED THE REPORT

Pfarelo Siebani (Cert.Sci.Nat) **-** Pfarelo is a Hydrologist with over 7 years' work experience specialising in mining/development hydrology, water resources management planning, hydrological modelling, hydraulic modelling, floodlines delineation studies, storm water management planning, soil, land use and land capability assessments. She has been primarily involved in the surface hydrology, soils science fields and water availability assessment projects for mines, municipalities, and agricultural enterprises.

I, Pfarelo Siebani, declare that I:

Act as an independent specialist for the Mokala Surface Water Study update.

- Do not have and will not have any financial interest in the undertaking of the activity, other than remuneration for work performed.
- Have no and will not have any vested interest in the proposed activity proceeding.
- Have no and will not engage in conflicting interests in the undertaking of the activity.
- Undertake to disclose, to the competent authority, any material information that has or may have the potential to influence the decision of the competent authority or the objectivity of any report, plan or document required in terms of the Environmental Authorisations.
- Will ensure that information containing all relevant facts in respect of the application are distributed or made available to interested and affected parties and the public.

Paul Klimczak (PR.Sci.Nat) **-** is a Principal Hydrologist with over 12 years' work experience specialising in hydrology and water resources management planning, hydrological modelling, hydraulic modelling, floodlines delineation studies, storm water management planning, soil, land use and land capability assessments.

I, Paul Klimczak, declare that I:

Act as an independent specialist for the Mokala Surface Water Study update.

- Do not have and will not have any financial interest in the undertaking of the activity, other than remuneration for work performed.
- Have no and will not have any vested interest in the proposed activity proceeding.
- Have no and will not engage in conflicting interests in the undertaking of the activity.
- Undertake to disclose, to the competent authority, any material information that has or may have the potential to influence the decision of the competent authority or the objectivity of any report, plan or document required in terms of the Environmental Authorisations.
- Will ensure that information containing all relevant facts in respect of the application are distributed or made available to interested and affected parties and the public

2. BASELINE HYDROLOGY

In order to inform the design of storm water management measures and water balances, an understanding of site-specific climatic conditions, topography, ground conditions, and existing storm water infrastructure is required. This section presents a review of the relevant information and the related sources.

2.1 CLIMATE

2.1.1 Rainfall

The average monthly rainfall data for the site is based on the nearest rainfall station managed by the South African Weather Services (SAWS). Rainfall record Wilton rain gauge (0392148 W) were obtained from SAWS. Monthly rainfall is presented Table 2-1.

The mean annual precipitation (MAP) from the observed records (unpatched) is 334 mm. The daily rainfall record was used in the steady state and dynamic water balance models to demonstrate rainfall inflows in various process units of the mine on a monthly basis.

Table 2-1: Average Monthly Rainfall for Milner Station

Month	Average
Jan	56.3
Feb	63.5
Mar	62.7
Apr	34.2
May	16.4
Jun	5.1
Jul	3.4
Aug	5.5
Sep	6.2
Oct	14.7
Nov	24.5
Dec	42.3
Annual	**334.8**

2.1.2 Evaporation

Evaporation data is based on Symonds Pan (S-Pan) data taken from the WR2012 database (WRC, 2012)[1] for the quaternary catchment D41K, specifically Evaporation Zone 8A. S-Pan evaporation was converted to open water evaporation using evaporation coefficients from WR90 (WRC, 1990)[2] as presented Table 2-2.

[1] Water Resources of South Africa, 2012 Study (WR2012). http://waterresourceswr2012.co.za/
[2] Water Resources of South Africa 1990 - Volume 1 Appendices. WRC Report 298/1.1/94

Table 2-2: Monthly Average Evaporation

Months	Symons Pan Evaporation (mm)	Lake Evaporation Factor	Lake Evaporation (mm)
January	276.9	0.84	232.6
February	209.9	0.88	184.8
March	193.3	0.88	170.1
April	144.1	0.88	126.8
May	114.7	0.87	99.8
June	91.0	0.85	77.3
July	106.0	0.83	88.0
August	153.8	0.81	124.5
September	213.0	0.81	172.5
October	269.7	0.81	218.4
November	248.0	0.82	232.9
December	294.6	0.83	244.5
Annual	**2351**	**N/A**	**1972**

2.1.3 Design Rainfall

The design rainfall depths for the centroid of the site were extracted using the Design Rainfall Estimation software for South Africa (Smithers and Schulze, 2002)[3]. Depth Duration Frequency (DDF) rainfall estimates for the site were derived from the Smithers and Schulze method based on analysis of the six nearest rainfall stations (gridded rainfall) (Table 2-3). Design storm rainfall depths in millimetres for various return periods were determined as indicated in

Table 2-4**.**

Table 2-3: Summary of six closest SAWS stations

Station Name	SAWS Number	Distance (km)	Record Length (Years)	MAP (mm)	Altitude (mamsl)
Mukulu	0392640 W	10.2	28	289	1056
Wilton	0392148 W	40.0	105	335	1059
Heuningdraai	0392680 W	11.4	28	349	1060
Smuts	0392592 W	13.7	26	333	1073
Milner	0393083 W	19.1	67	369	1118
Kareepan	0393225 W	20.1	36	352	1130

[3] Smithers, J.C. and Schulze, R.E., 2002. Design rainfall and flood estimation in South Africa. WRC Project No. K5/1060. Draft final report (Project K5/1060) to Water Research Commission, Pretoria, RSA. 155 pp

Table 2-4: Adopted Storm rainfall depths for the project site (Smithers and Schulze, 2002).

Duration	Rainfall Depth (mm)						
(minutes/hours)	1:2-year	1:5-year	1:10-year	1:20-year	1:50-year	1:100-year	1:200-year
5 minutes	7.9	11.3	13.6	16.0	19.2	21.8	24.5
10 minutes	11.8	16.8	20.4	23.9	28.7	32.5	36.5
15 minutes	14.9	21.3	25.7	30.2	36.3	41.1	46.1
30 minutes	19.7	28.1	34.0	39.9	48.0	54.3	61.0
45 minutes	23.2	33.1	40.0	47.0	56.5	64.0	71.8
1 hour	26.1	37.1	44.9	52.7	63.4	71.8	80.6
1.5 hours	30.7	43.7	52.9	62.1	74.6	84.6	94.9
2 hours	34.5	49.1	59.4	69.7	83.8	94.9	106.5
4 hours	39.9	56.7	68.6	80.6	96.8	109.7	123.1
6 hours	43.4	61.7	74.7	87.7	105.4	119.4	134.0
8 hours	46.1	65.6	79.3	93.1	111.9	126.8	142.2
10 hours	48.3	68.7	83.1	97.5	117.2	132.8	149.0
12 hours	50.1	71.4	86.3	101.3	121.8	138.0	154.8
16 hours	53.2	75.8	91.6	107.6	129.3	146.5	164.4
20 hours	55.8	79.4	96.0	112.7	135.5	153.5	172.2
24 hours	57.9	82.5	99.7	117.1	140.7	159.5	178.9

2.2 LOCAL AND REGIONAL HYDROLOGY

The Mokala Mine is located within the Quaternary Catchment (QC) D41K with a gross area of 4216 km^2 and a net MAR of 1.92 Mm^3. QC D41K falls within the Lower Vaal Water management area (WMA). The Molopo River, Harts River and the Vaal River are the major rivers draining the WMA. All the runoff of the WMA eventually drains westwards into the Orange River.

QC D41K is mainly drained by the Ga-Mogara River flowing north to join the Kuruman River flowing in a western direction to join the Molopo River. Ga-Mmatshephe, Dooimansholte, Vermuisleegte, and Wilteegte rivers are tributaries of the Ga-Mogara River. The local and Regional Hydrological settings are presented in Figure 2-1.

2.2.1 Mean Annual Runoff

The Ga-Mogara River catchment falls both within quaternary catchment D41J and D41K, therefore the mean annual runoff (MAR) will be based on the percentage of the catchment area falling within each of the quaternary catchments. The total estimated MAR for the delineated catchments is shown in Table 2-5 and equates to approximately 0.13 % of the total MAP depth for the project site (368.8 mm) when applied to the catchment area (SLR, 2015).

It is noted that the MAR is derived from a monthly rainfall runoff model applied to the drainage region. The MAR figure is also a long-term average of the catchment annual runoff and so does not necessarily imply there is a constant base flow in the river (SLR, 2015).

Table 2-5: Summary of MAR for catchments (SLR, 2015)

Catchment Name	Area (km^2)	Total MAR (Mm^3)
Ga-Mogara River Catchment 1 (R380 road crossing)	8053	3.48
Ga-Mogara River Catchment 2 (Railway Bridge)	8054	3.49
D41J	3878	1.75
D41K	4216	1.92

2.3 TOPOGRAPHY

Average elevations at the eastern and western quaternary catchment boundary of D41K range from approximately 1200 mamsl to 1650 mamsl. The elevation drops gradually to 1000 mamsl at the confluence of the Ga-Mogara River and the Kuruman River at the outlet of D41K. The highest elevation is recorded within the eastern and western boundary of D41J, where elevations exceed 1800 mamsl (SLR, 2015).

Based on a review of the 20 m contours of the 1:50 000 Topographical Maps of South Africa, the Ga-Mogara catchment is bounded to the west, south and east by a sharp outcrop of hills, with elevations of 1200 mamsl at the foot of these hills up to and exceeding 1700 mamsl in the highest points within these hills. With the exception of these hills, which form a minor part of the catchment, the gradients are gentle <1% and slope from the foot of the hills which is between 1200 – 1300 mamsl to the outlet of the Ga-Mogara catchment at between 1000 and 1020 mamsl. It is also important to note that within the watercourse, there are areas which form natural depressions, which may encourage ponding during storm events (SLR, 2015).

2.4 FLOODLINES

Floodlines for the diverted stream were undertaken by SLR in 2015 and were plotted against the recent mine layout to evaluate the possibility of encroachment. All infrastructure is located outside for floodlines. The floodlines together with the 100m buffer are presented in Figure 2-2 .

Figure 2-1: Local and Regional Hydrology

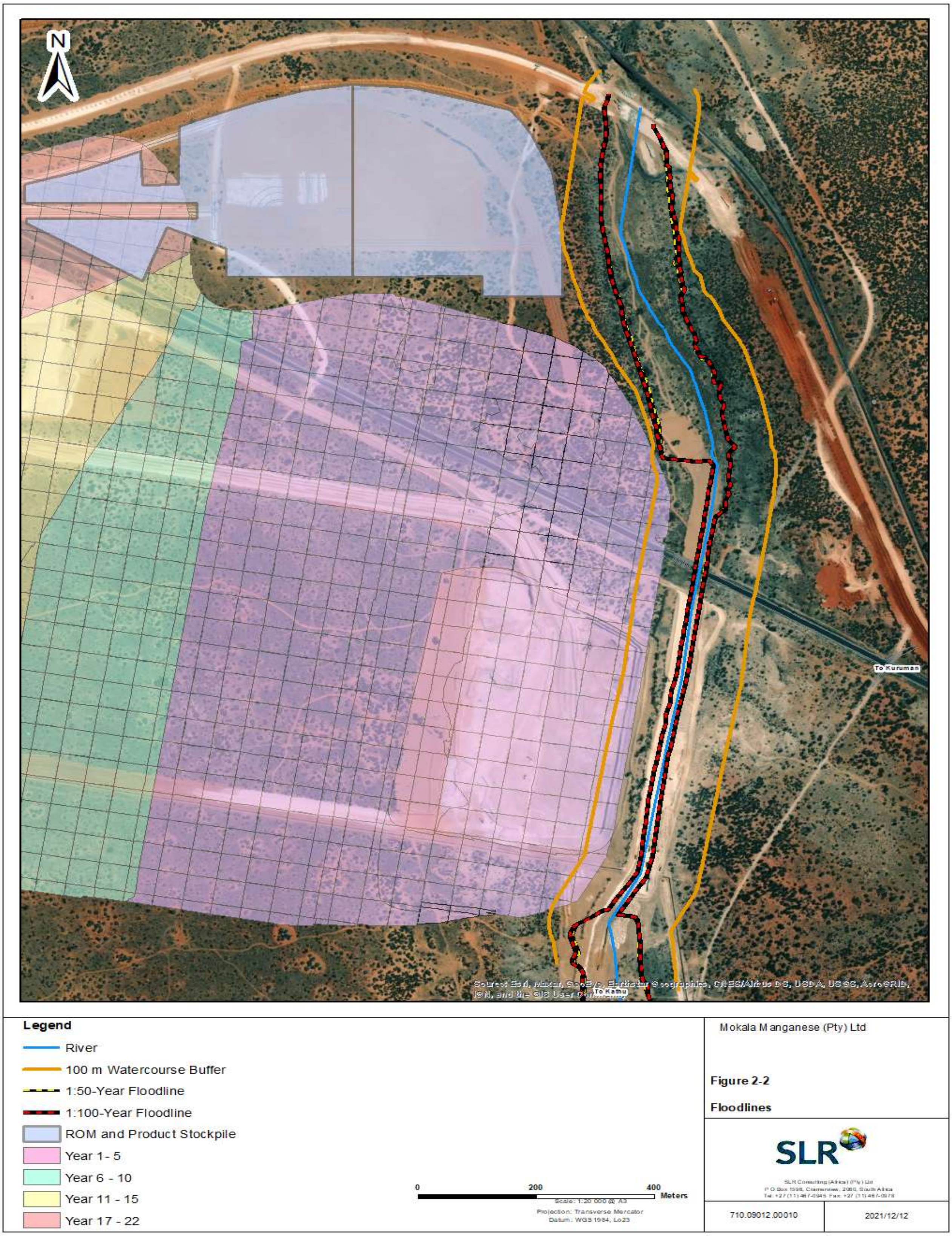


Figure 2-2: 1:50- and 1:100-Year Floodlines and 100 m Watercourse Buffer

3. STORMWATER MANAGEMENT PLAN

Informed by the situation appraisal of the site and its surroundings (as presented in Section 2), previous surface water study undertaken by SLR Consulting, (SLR, 2015), stormwater management plan study undertaken by AECOM (Pty) Ltd (AECOM, 2015), and the current proposed site layout, a series of design principles for storm water management have been developed to ensure compliance with the requirements of GN 704 and the BPGs.

3.1 DESIGN STANDARDS

As discussed in Section 1.3, GN 704 requires the following:

- Clean Stormwater
    - Undisturbed areas around the site that are not impacted by mining operations and as a result the stormwater runoff from these areas will not be conveyed to the recycle ponds. The uncontaminated stormwater runoff generated from these areas will be intercepted by a series of appropriately sized channels and earth berms (refer to appendix B for detailed specifications of berms). This runoff will discharge at ground level onto natural open areas through 5m v-drain chutes.
    - In between the contaminated stormwater areas, there exist areas where clean stormwater will be allowed to infiltrate naturally. These areas are classified as infiltration paddocks. These infiltration areas reduce the volume of clean stormwater unnecessarily reporting to the recycled water ponds and being contaminated, in turn reducing the size of the recycle water ponds required.
    - It must be noted that the climate is extremely arid and as a result any stormwater runoff which ponds in the small natural depressions or clean water accumulation areas will be permitted to infiltrate naturally.
- Dirty Stormwater
    - The stormwater runoff generated within areas that are disturbed by the mining operations will be dealt with as contaminated stormwater and will typically be of a turbid nature with suspended solids. The contaminated stormwater will be controlled on site via a series of trapezoidal drains and earth berms and contained within lined recycle water ponds 13, 14, and 16 (refer to Figure 3-1).
    - The respective elements of the contaminated stormwater drainage system are designed such that the contamination of the clean stormwater system is limited to a 1:50-year chance in any given year.
- 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 0.8m freeboard above full supply level.
- Clean storm water will be prevented from entering dirty water catchments by creating perimeter berms around the dirty water infrastructure.
- Collected storm water in the channels is passed through one silt trap before being conveyed into the RWPs. The sediment being transported in the storm water can then be recovered from the silt traps.
- Some ‘speed bump’ size berms may need to be created to direct water towards the correct channel.

- Ground levels may need to be raised in certain areas, to achieve drainage gradients and remove low spots although this will need to be confirmed through more detailed survey and design work.

In order to meet the design principles detailed above, conceptual designs for the proposed storm water management measures have been calculated and are presented below, along with the specific hydraulic design standards, methodologies, assumptions and input parameters for each measure proposed.

3.2 DIRTY WATER CATCHMENTS

Dirty catchments were delineated based on available site layout, land-use and topography. The sub-catchment layout and characteristics are shown in Figure 3-1 and Error! Reference source not found.. The dirty water containment facilities are designed, constructed and maintained to accommodate a 1:50-year/24-hour storm event.

Areas contributing to stormwater runoff include:

- The plant area.
- Proposed expansion of approved waste rock dump.
- Proposed new waste rock dump.
- Low grade stockpile.
- Contractor’s workshop and hardpark area.
- Mine open pit area and the barrier pillar.
- Internal access roads to stockpiles and waste rock dumps.

Stormwater generated from the above-mentioned areas will be channelled via trapezoidal drains and berms to the previously sized Recycle Water Ponds (RWP). RWP 13, 14, and 16 were sized in a stormwater management plan study undertaken by AECOM (AECOM, 2015). The contractors workshop will be located within the footprint of the open pit as mining progresses (after year 10 of mining), therefore they will have to be demolished and relocated from their current location.

Stormwater around the pit will be allowed to flow into the pit. The pit inflows will include rainfall on the pool, stormwater around the pit as well as groundwater ingress. Pit dewatering will be undertaken where water will be pumped into RWP 14 located near the plant yard adjacent to the haul road. The volume of water to be pumped into the pond are provided in Section 4 of this study.

Table 3-1: Delineated Stormwater Subcatchments

Stormwater Name	Mine Infrastructure	Area (km^2)	Runoff Coefficient	Time of Concentration (hours)	Rainfall Intensity (mm/hr)	Flow (m^3/s)
Dirty Catchments						
S1	Proposed WRD	0.860	0.354	1.664	44.82	3.79
S2	Extended WRD	0.437	0.370	1.048	60.50	2.72
S3	Low Grade Stockpile	0.213	0.463	0.829	68.16	1.87
S4	Contractors Workshop	0.138	0.803	1.074	69.48	1.80
S5	Plant area, ROM, Product Stockpile	0.264	0.805	0.609	78.79	4.66

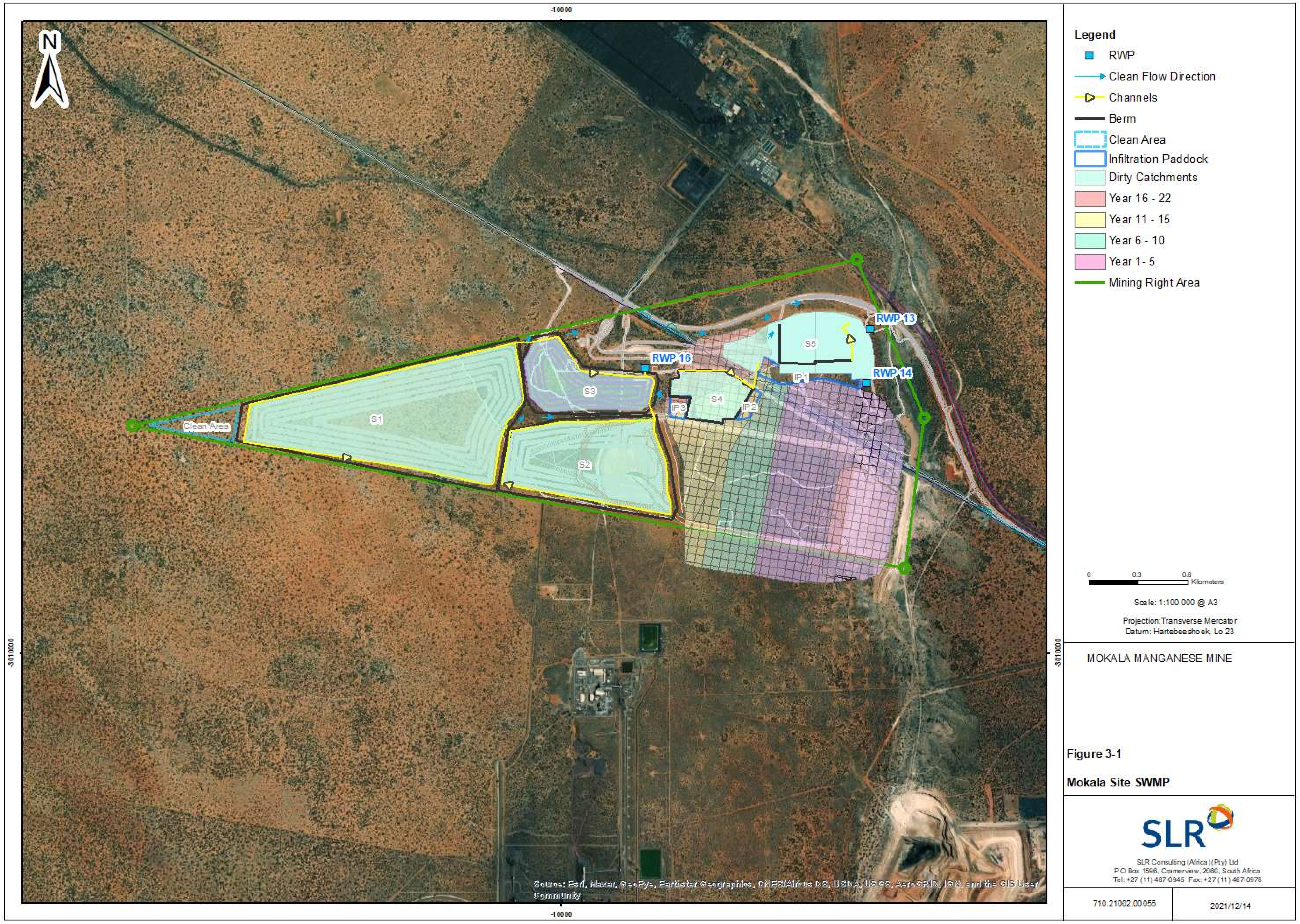


Figure 3-1: Conceptual SWMP

3.3 DRAINAGE CHANNEL AND BERMS

3.3.1 Design Standards

In compliance with conditions of the GN 704, for mining the permanent drainage installations are designed for a 50-year critical duration event if using Rational method. Peak flows for conveyance infrastructure were estimated using the Manning's Equation to ensure that the flow capacity of the channel is sufficient to convey the peak flows resulting from acritical storm. The manning's equation is presented below.

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

Where:

A = Area of Channel (m^2)

R = Hydraulic Radius (area / wetted perimeter) (m)

S = Longitudinal Slope of Channel; and (m/m)

n = Mannings Roughness Coefficient (unitless)

The channels were sized to take the maximum flow calculated for the downstream end of the contributing catchment and the channel sizing will be uniform along their entire length. Some cut and fill maybe required along the length of the channels to achieve the required gradient to ensure that water flows freely within these channels. Where practical the dirty channel should be lined with low permeability material e.g., compacted clay to prevent dirty water from infiltrating through the base of the channels which otherwise might impact upon the quality of underlying groundwater.

Typical cross section of recommended dirty water diversion channel in order to accommodate the design flows, the recommended channel sizes together with the reference channel cross section is shown in

Figure 3-2.

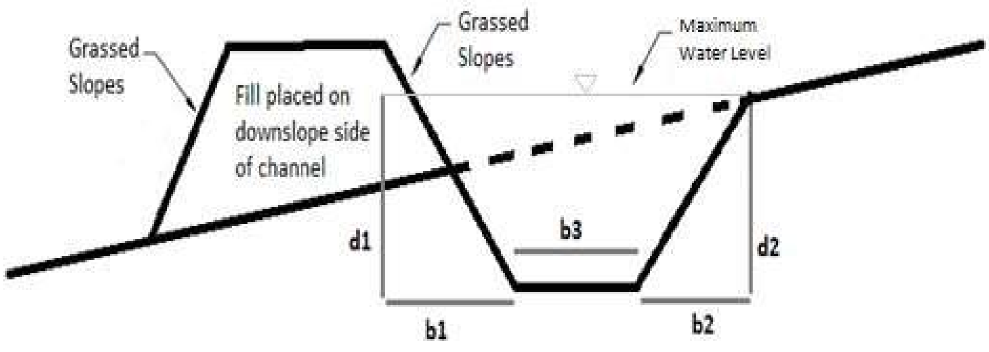


Figure 3-2: Stormwater Diversion Channel Cross section

3.3.2 Peak Flow Estimates

The plant catchment characteristics used to derive the peak flow for the design of stormwater diversion channel from the catchment parameters presented in Table 3-2. The estimated design flows and recommended conveyance infrastructure (berms and channels) are presented below.

Table 3-2: Stormwater Channel Dimensions

Catchment	Design Flow	Channel Dimensions											
		b1	d1	b2	d2	b3	S	n	A	P	R	V	Design Flow (Q)
	m^3/s	m	m	m	m	m	m/m	-	m^2	m	m	m/s	m^3/s
S1	3.79	0.8	0.9	0.8	0.9	1.0	0.010	0.025	1.6	3.4	0.5	2.4	3.94
S2	2.72	0.8	0.8	0.8	0.8	0.8	0.010	0.025	1.3	3.1	0.4	2.2	2.85
S3	8.38	0.7	0.7	0.7	0.7	0.7	0.010	0.025	1.0	2.7	0.4	2.0	2.00
S4	2.14	0.8	0.8	0.8	0.8	0.6	0.010	0.025	1.1	2.9	0.4	2.1	2.39
S5	4.66	1.0	1.0	1.0	1.0	0.9	0.010	0.025	1.9	3.7	0.5	2.5	4.84

3.4 RECYCLE STORMWATER PONDS

A study undertaken by AECOM (AECOM, 2015) sized four RWP 13, 14 and 16. These stormwater storage containments were adopted in this current study with the assumption that they have the capacity to attenuate the stormwater to be generated from operational areas. The RWPs are briefly described below.

- RWP 13 is designed to accommodate surface water, from rainfall and runoff, from all elements within the plant area. In the event of the pond being overtopped, overflow will be pumped to RWP 14.
- RWP 14 is designed to accommodate surface water, from rainfall and runoff, from the stockpile access road (haul road), the contaminated lower plant area catchment, overflow from RWP and contaminated areas around the contractors workshop. Additionally, groundwater inflow from the mine pit will be pumped to the pond as well as all surface water, from rainfall and runoff, within the mine pit. The depth and capacity of the pond must be altered accordingly to accommodate the additional inflow from the mine pit if needed.
- RWP 16 is designed to accommodate rainfall and runoff from the Low-Grade Stockpile area, proposed WRD, and extended WRD. Surface water run-off generated from the roofing and LDV car park at the administration area, typically classified as uncontaminated stormwater, will be relatively marginal in volume and will not warrant the expenditure required to delineate the flows. This run-off too will be contained in RWP 16.

Detailed sizing of the RWPs is provided in Section 5 of this report.

4. SITE WATER BALANCE

4.1 INTRODUCTION

A steady state wet and dry monthly water balance has been developed for the Mokala Mine including the proposed additional and already relocated infrastructure. The approach, assumptions and majority of the input parameters for the water are adopted from the 2015 Surface Water Study undertaken by SLR, which is provided in Appendix A.

The water balance will focus predominantly on the interaction between rainfall, evaporation, mine water demands and make up water requirements with the aim of developing a water balance control philosophy for the management of water on the mine. The modelled water balance circuit includes water inflows, losses and transfers for the following aspects of the operation:

- Open Pit including the Barrier Pillar.
- Plant area.
- Recycle Water Ponds (RWP).
- Sewage Treatment Plant.
- Administration Blocks, Workshop and Stores.
- Waste rock dumps.
- Stockpile area.

4.2 WATER BALANCE INPUT

4.2.1 Hydro-Climate Input

Rainfall

The average monthly rainfall data for the Wilton rainfall station managed by the South African Weather Services (SAWS) was obtained and used in the calculations of the water balance. Monthly rainfall data is provided in Table 2-1.

Evaporation

Evaporation data was obtained from the WR2012. S-Pan evaporation was converted to open water evaporation using evaporation coefficients. Detailed evaporation description is provided in Table 2-2.

An average of the evaporation rates for June, July and August is used in the 'dry' water balance, while the monthly average evaporation rate for February is used for the 'wet' water balance.

An evaporation rate is applied to 50% of the pit area open at any one time to account for evaporation of ground water inflows at the seepage face.

4.2.2 Dirty Water Catchments Runoff

Average monthly runoff coefficients for the various land surface types on the mine were estimated using the Soil Conservation Services (SCS) rainfall runoff method applied to the daily rainfall time series from the Winton (392148 W) gauge.

4.2.3 Groundwater Ingress into Open Pit

To account for the level of confidence in the calibration of the steady state numerical groundwater model and to provide an uncertainty range in calculated mine pit inflow rates the calibrated hydraulic conductivities were increased and lowered by 20% in additional scenarios. The inflow rates range between 241 m^3/d (2.79 L/s) and 327 m^3/d (3.7 L/s). Calibrated model inflow rate was 285 m^3/d (3.30 L/s).

4.2.4 Mine Water Requirement

Mine water will be sourced from the Vaal Ga-Mogara Water Supply Scheme. It is believed that there will be no need to source make-up water due to the availability of pit water to supplement the water demand in the mine. A summary of water balance input is provided in Table 4-1.

4.2.5 Assumptions

The approach, assumptions, parameters adopted from the 2015 study and limitations, and any further work identified in 2015 (SLR Consulting, 2015), remains relevant. The water balance assumes the following:

- The open pit is not fully developed; however, the water balance accommodates runoff contribution from an area of 87 ha (mining extent from year 1 to 5). Towards year 6 of mining, the pit will extend over the contractors workshop and other stormwater infrastructures. The extension of the pit area is not considered in the water balance.
    - Other infrastructures such as WRDs and low-grade stockpile are also not fully developed but are included in the water balance.
- Pit ground water inflows a minimum and maximum estimate were adopted from the Groundwater Report (SLR Consulting, 2021), being 2.79 l/s and 3.7 l/s respectively.
    - The lower estimate is applied to the 'dry' water balance while the upper estimate is applied to the 'wet' water balance to give a conservative range of flows.
- An evaporation rate is applied to 50% of the pit area open at any one time to account for evaporation of ground water inflows at the seepage face.
- No rainfall is applied for the 'dry' water balance while the average monthly value of 63.5 mm (February) is used for the 'wet' water balance.
- An average of the evaporation rates for June, July and August is used in the 'dry' water balance, being 97 mm, while the monthly average evaporation rate for February is used for the 'wet' water balance, being 185 mm.
- No consideration is given to storage in the water balance, i.e., flow in = flow out.
- It is assumed that borehole water will have to be treated to potable standards with reverse osmosis (RO).
- Ground water inflows to the pit will not be suitable for RO treatment due to the high suspended solids content.
- External water requirements will be supplied from the Vaal Ga-Mogara Water Supply Scheme when required.

Table 4-1: Summary of Water Balance Input

Parameter	Description	Source
Mine water requirements	• Potable Water Requirement – 62 350 l/d • Mining Water Consumption – 40 000 l/d	Flow Process Diagram, drawing number FE-004-403-110-100-001-P-

Parameter	Description	Source
	• Plant and Roads Dust Suppression – 49 396 l/d • Plant Wash Down – 961 l/d	01 (AECOM, 2015) (Appendix B)

Dirty water catchment areas	• RWP 13
	  ○ Plant area / roads - 26.4 ha
	  ○ Natural ground – 1 ha
	• RWP 14
	  ○ Contractors Workshop and Tar Road – 13.8 ha
	  ○ Gravel haul road – 4.0 ha
	  ○ Open pit – 87 ha (Year 1 – 5)
	• RWP 16
	  ○ Low Grade Stockpile – 21.3 ha
	  ○ Waste Rock Dumps – 129.7 ha
		Catchment areas measured from the Storm Water Management Plan. Chapter 3 of this study.

Recycle Water Pond surface areas	• RWP 13 – 3 632.4 m^2 • RWP 14 – 13 052.6 m^2 • RWP 16 – 16 522.7 m^2	Sized using Goldsim
Open pit groundwater inflows	• Lower estimate 2.79 l/s • Upper estimate 3.7 l/s • Calibrated Model Inflow 3.3 l/s	SLR Groundwater Assessment Study, 2021
Average monthly runoff coefficients (W - denotes Wet Month, D - denotes Dry Month)	Plant area, gravel roads, open pit and WRDs, Stockpile– W (0.13)/D (0.06) Tar roads and mine offices – W (0.73)/D (0.64) Natural ground (Deep sand with grass cover) – W (0.0)/D (0.0)	SLR Consulting (2015) (Appendix A)

4.3 WATER BALANCE RESULTS

The dry and wet water balances have been calculated for the mine and are presented in Figure 4-1 and Figure 4-2. The water balance indicates that the Vaal Ga-Mogara Water Supply Scheme will be required to supply potable water to the site, in the order of 1 985 m^3/month, during dry periods. There will be no need to import plant makeup water due to the availability of pit ground water inflows and the recycling of the waste water treatment plant (WWTP) effluent.

The water balance therefore shows that during both wet and dry periods the mine will rely on the Vaal Ga-Mogara Water Supply Scheme for the supply of potable water. It is recommended that further investigation is undertaken to give more certainty to the yield of any water supply boreholes drilled on the site such that the extent to which the mine will rely on external water sources can be more accurately quantified. Further work could also be undertaken to look at collecting and treating pit ground water inflows to a potable standard.

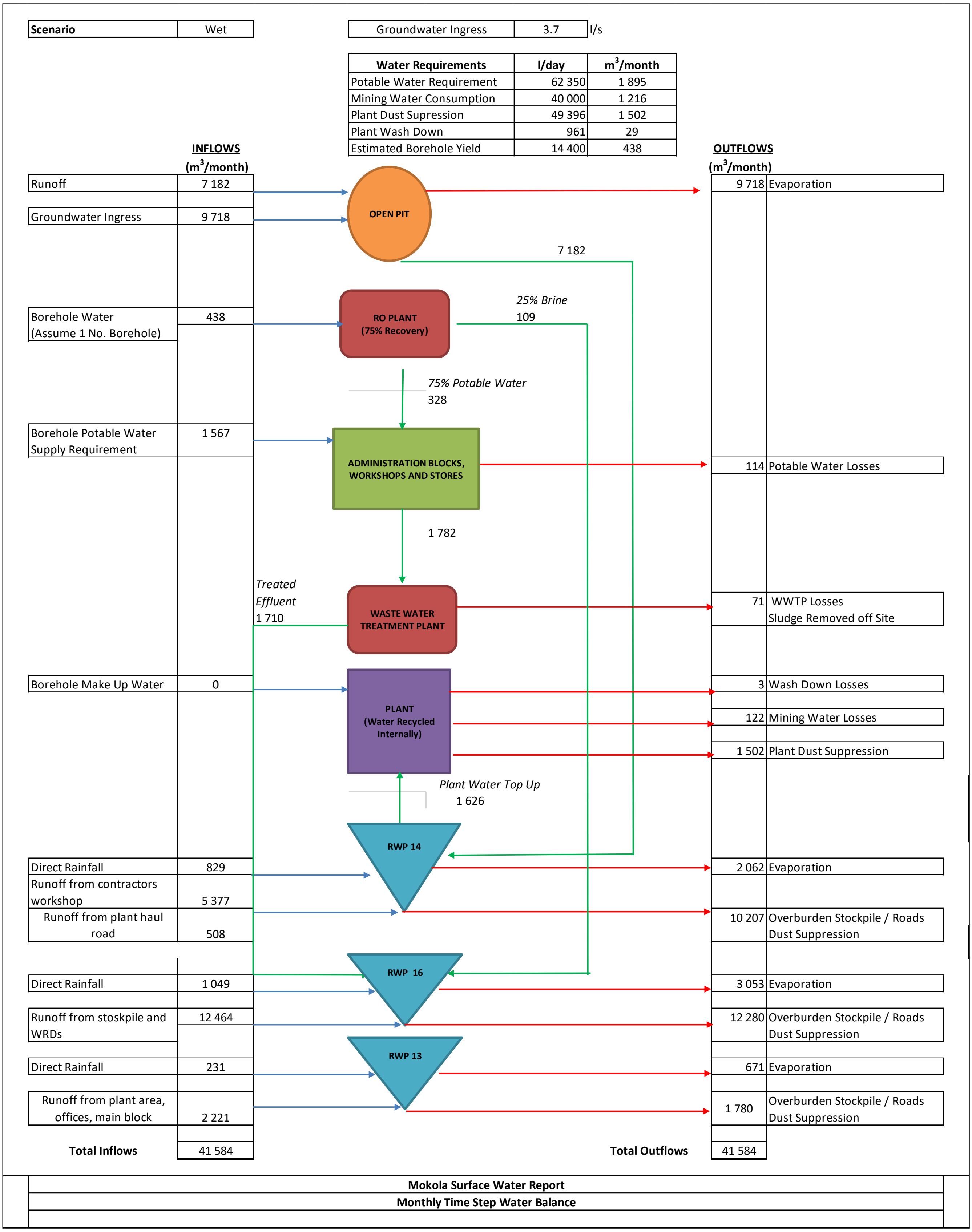


Figure 4-1: Wet Water Balance

Scenario	Dry

Groundwater Ingress	2.79	l/s

Water Requirements	l/day	m^3/month
Potable Water Requirement	62 350	1 895
Mining Water Consumption	40 000	1 216
Plant Dust Supression	49 396	1 502
Plant Wash Down	961	29
Estimated Borehole Yield	14 400	438

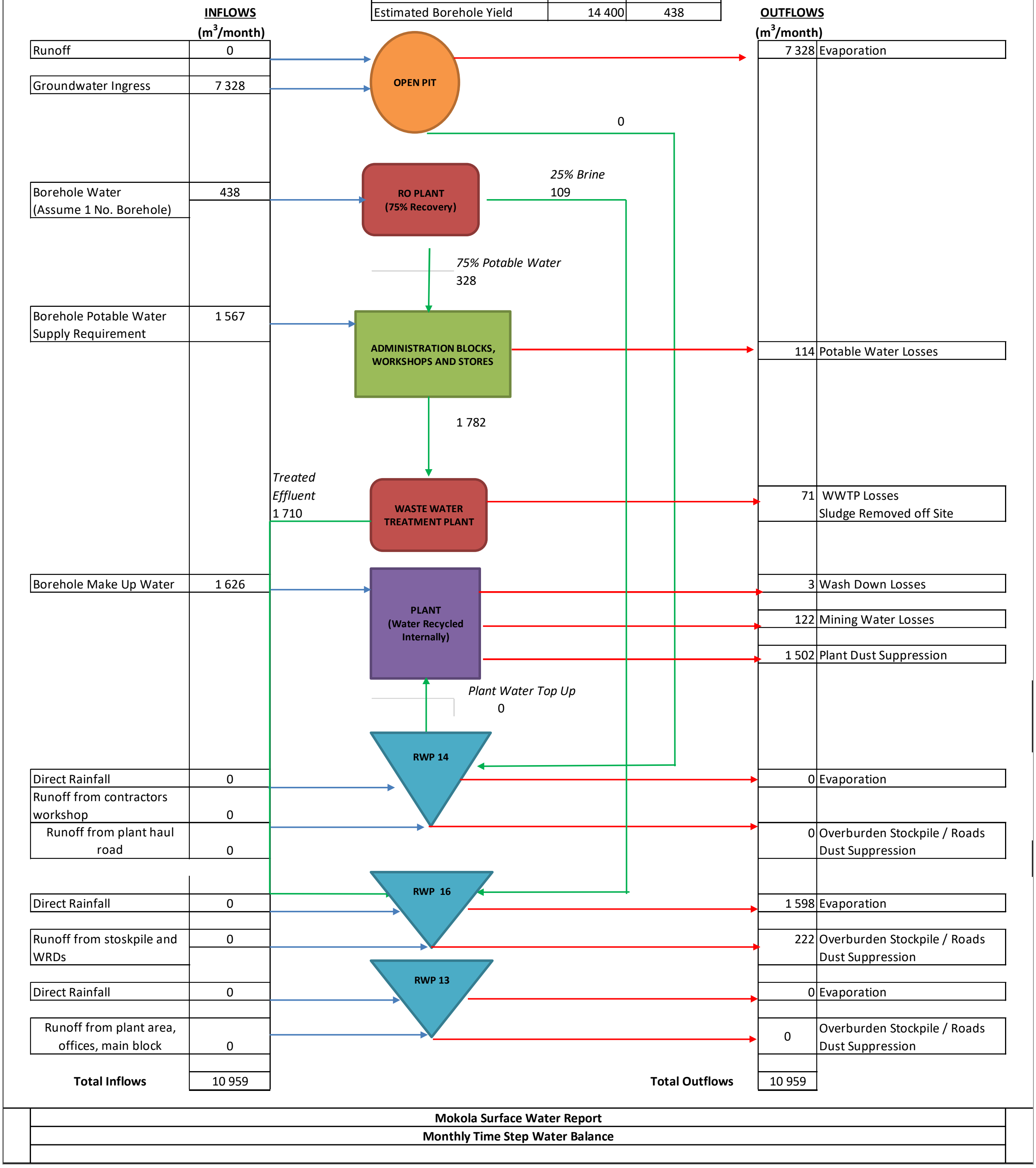


Figure 4-2: Dry Water Balance

5. DYNAMIC DAILY WATER BALANCE

5.1 INTRODUCTION

A conceptual stormwater management plan was undertaken and presented in Chapter 3. As part of this a number of recycle water ponds (RWP) have been included for capturing storm water runoff from catchments classified as 'dirty' to control the risk of dirty water mixing with clean water. The RWP therefore function as pollution control dams (PCD) in terms of the applicable legislation (see section 5.2).

The design and management of PCD is to be undertaken in accordance with the GN704 regulations issued by the DWS under the NWA. The clause (6(d)) in GN704 relates to the design of PCDs are provided in Section 1.2.3.

5.2 APPLICABLE LEGISLATION

The design and management of PCDs is to be undertaken in accordance with the GN704 regulations issued by the DWS under the NWA. The following clause (6(d)) in GN704 relates to the design of PCDs.

"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;"

Further guidance on this requirement can be gained from the DWS document 'Best Practice Guidance for Water Resource protection in the South African Mining Industry (BPG) – Pollution Control Dams, Section 6.4.3'. In this document it defines the allowable PCD spillage frequency as being a spill every 50 years on average. This is equivalent to stating that a PCD should be designed such that there is less than a 1 in 50 chance of a spill occurring in any given year. In addition to this, the document recommends the following:

- *"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 reuse 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 storm water inflow can be accommodated, and the spillage frequency met. The management of the PCD should be according to this*

5.3 METHODOLOGY

The approach and assumptions for the dynamic daily water balance model are adopted from the 2015 Surface Water Study undertaken by SLR, which is provided in Appendix A. The information presented below comprises a summary only.

Daily time step storm water modelling is undertaken using the software package GoldSim. The SCS method is used to calculate the portion of the rainfall that contributes to runoff for each of the catchment surface types. A soil water budgeting procedure is used to vary the SCS CN(II) value in accordance with the antecedent catchment moisture conditions. The storm water reports to the RWP where a daily balance is calculated for water in storage, evaporation, abstractions, and spills. The model is run over the 74-year rainfall time series and the frequency of spills from the RWPs is analysed.

The following assumptions were made on how the RWPs are operated.

- It is assumed that all dry weather flows entering the RWPs are abstracted at a rate matching the inflow rate. The RWP storage is therefore reserved for the attenuation of storm water inflows and not the storage of water for later use.
- To operate the RWPs efficiently, abstraction of storm water from the RWPs needs to occur whenever there is storm water in storage.
- It is assumed that the mine will abstract water from the RWPs at a peak rate matching the excess water generated during the 'wet' monthly water balance. This water will be sprayed onto the mine roads, ore stockpiles and overburden stockpile to control dust.
- Silt traps will prevent the majority of sediment from entering the RWPs. Where finer material collects in the RWPs it will be regularly removed to maintain the stated storm water attenuation capacity is always available.

5.4 MODELLING INPUT DATA

5.4.1 RWP Parameters

The parameters of the proposed RWP and their associated storm water catchments are presented in Table 5-1 below.

Table 5-1: Storm water catchment parameters

Recycle Water Pond	Catchment	Catchment Area (ha)	Allocated CN(II) Value
RWP 13	Plant area, Rom Pads Stockpile	26.6	98
	Gravel Road	0.5	76
	Natural ground	0.5	Insignificant runoff
RWP 14	Gravel haul road	4.0	76
	Open pit	87	76
	Tar road	2.1	98
	Contractors Workshop Area	11.6	98
	Natural ground	3.0	Insignificant runoff
RWP 16	Low Grade Stockpile	21.3	76
	Waste Rock Dumps	129.7	76

The RWP catchment areas were measured from the Storm Water Management Plan undertaken in Section 3.2. SCS Curve Numbers for average antecedent wetness conditions (CN(II)) were allocated to the different catchment surface types. Due to the deep sandy soils of the undisturbed natural ground storm water runoff will be relatively insignificant. Any runoff from those areas is also likely to pond and infiltrate before entering the storm water drainage infrastructure.

5.4.2 Climate

The climate data used for the model was the 74-year Winton (0392148 W) daily rainfall record and the WR2012 evaporation data presented in Section 2.1.

5.5 RWP SIZING

Recycle water ponds were sized using Goldsim daily timestep model. Proposed RWP and their associated stormwater catchments are presented in Table 5-1 and Table 5-2.

Table 5-2: RWP Dimensions

Recycle Water Pond	Volume (m^3)	Nominal Depth (m)	Area (m^2)
RWP 13	14 529	4	3 632.4
RWP 14	65 263	5	13 052.6
RWP 16	82 614	5	16 522.7
Total	162 406	-	33 207

It may be possible to reduce the capacity and area of RWP 16 to fit site-specific constraints, by developing paddocks around the WRDs so that most of the runoff can be lost through evaporation. This option can further be explored during the detailed design stage.

The open pit footprint area including the barrier pillar area will be extensive as mining progresses, as such it is not feasible to design a single PCD that will accommodate all the water generated. It is therefore recommended that pit water be pumped out at the same rate as specified in the water balance. The water balance account for stormwater contribution from the pit from year 1 to 5. It is recommended that after year 5 of mining, the stormwater management plan be revised to accommodate the expansion of the pit.

The contractor’s workshop will be located within the pit’s footprint area during Phase 2 of mining (from year 11 as er mining strips provided by Client) due to the pit expansion therefore they will need to be relocated. It is recommended that the stormwater management plan and the water balance are updated prior to the pit expansion to reflect the later years of the mine.

6. CONCLUSIONS AND RECOMMENDATIONS

This surface water study was undertaken by a suitably qualified and experienced Hydrologist to comply with the NEMA regulations requirements. A summary of the NEMA regulations requirements for technical specialist studies and cross references to the relevant supporting information is presented in Appendix A.

The approach and assumptions for this study are adopted from the 2015 Surface Water Study undertaken by SLR, which is provided in Appendix A.

A SWMP has been developed to ensure compliance with the requirements of GN 704. A geotechnical investigation must be undertaken during a detailed design process to assess the structural integrity of the existing embankment as well as to determine the dam footprint for the lining, compaction, berm and storage estimates. Confirm all the levels (base of dam, full capacity, spillway and freeboard).

A steady state water balance has been developed, to estimate the return water and make up water requirements with the proposed infrastructure. A collection and water management strategy were also defined, where the reuse of process water will be prioritised, thereby ideally reducing the impacts from the project on the surface water resources

The RWPs storm water attenuation capacity has been sized to capture the 24-hour runoff volume having a 1:50 annual exceedance probability. Any spills from the RWPs are to be directed to the open pit for temporary storage and reuse / disposal. When the RWPs are operated in this way the resulting spills will cause minimal disruption to the mining operation as they are infrequent and of relatively small volumes. As there will be no discharge of "dirty" water from the RWPs to the local surface water resources the design and operation of the RWPs is in accordance with GN704.

--	--	--
Pfarelo Siebani	**Pfarelo Siebani**	**Paul Klimczak**
(Report Author)	(Project Manager)	(Reviewer)

EIA REGULATIONS 2017 GNR 327, 325 and 324 Appendix 6 CONTENT OF THE SPECIALIST REPORTS	Completed according to the EIA Regulations	Cross-reference in this Report
(a) details of— the specialist who prepared the report; and the expertise of that specialist to compile a specialist report including a curriculum vitae;	✓	Section 1.4
(b) a declaration that the specialist is independent in a form as may be specified by the competent authority;	✓	Section 1.4
(c) an indication of the scope of, and the purpose for which, the report was prepared	✓	Section 1.4
(CA) an indication of the quality and age of Base Data used for the specialist report	✓	Throughout the report
(CB) a description of existing impacts on the site, cumulative impacts of the proposed development and the levels of acceptable change		N/A
(d) the date and season of the site investigation and the relevance of the season to the outcome of the assessment;		N/A
(e) a description of the methodology adopted in preparing the report or carrying out the specialised process inclusive of equipment and modelling used;	✓	Throughout the report
(f) Details of an assessment of the specific identified sensitivity of the site related to the proposed activity or activities and its associated structures and infrastructure, inclusive of a site plan identifying site alternative.		N/A
(g) an identification of any areas to be avoided, including buffers;		N/A
(h) a map superimposing the activity including the associated structures and infrastructure on the environmental sensitivities of the site including areas to be avoided, including buffers		Figure 3-1
(i) a description of any assumptions made and any uncertainties or gaps in knowledge;	✓	Throughout the report
(j) a description of the findings and potential implications of such findings on the impact of the proposed activity or activities	✓	Section 4.3, Section 5.5 and Section 6
(k) any mitigation measures for inclusion in the EMPr		N/A
(l) any conditions for inclusion in the environmental authorisation;	N/A	N/A
(m) any monitoring requirements for inclusion in the EMPr or environmental authorisation;		N/A

EIA REGULATIONS 2017 GNR 327, 325 and 324 Appendix 6 CONTENT OF THE SPECIALIST REPORTS	Completed according to the EIA Regulations	Cross-reference in this Report
(n) a reasoned opinion— i. whether the proposed activity, activities or portions thereof should be authorised; and (iA) regarding the acceptability of the proposed activity or activities; and ii. if the opinion is that the proposed activity, activities or portions thereof should be authorised, any avoidance, management and mitigation measures that should be included in the EMPr, and where applicable, the closure plan;	Various recommendations are made throughout the report	Section 3.3 and 3.4 Section 4.3 Section 5.5
(o) a summary and copies of any comments received during any consultation process and where applicable all responses thereto; and	✓	Included as part of EIA
(p) any other information requested by the competent authority	✓	Included as part of EIA

7. REFERENCES

- ARC Institute for Soil, Climate and Water, June 2014, "Soil Information for Kudumane Project near Hotazel, Northern Cape".
- Department of Water Affairs, 1988, "Technical Report TR137: Regional Maximum Flood Peaks in Southern Africa".
- Department of Water Affairs and Forestry, 1998. "National Water Act, Act 36 of 1998".
- Department of Water Affairs and Forestry, 1999, "Government Gazette 20118 of June 1999: Government Notice 704 (GN 704)."
- Department of Water Affairs and Forestry (DWAF), September 2004, "National Water Resource Strategy. First Edition".
- Department of Water Affairs and Forestry, 2006, "Best Practice Guideline No. G1: Storm Water Management".
- Food and Agriculture Organisation (FAO) of the United Nations, 2005, "New LoClim - Local climate estimator".
- SANRAL, 2013, "Drainage Manual-Sixth Edition", The South African National Roads Agency Limited, Pretoria.
- Smithers, J.C. and Schulze, R.E., 2002, "Design Rainfall and Flood Estimation in South Africa", WRC Report No. K5/1060, Water Research Commission, Pretoria.
- Water Research Commission, December 2004, "Development of a Raster Database of Annual, Monthly and Daily Rainfall for Southern Africa". Report No. 1156/1/04.
- SLR Consulting (South Africa) (Pty) Ltd, 2021. Groundwater Assessment for the Proposed Mokala Manganese Project, August 2021.
- SLR Consulting (South Africa) (Pty) Ltd, 2015. Surface Water Assessment Study for the Proposed Mokala Manganese Project, October 2015.

APPENDIX A: SURFACE WATER STUDY FOR MOKALA (SLR, 2015)

global environmental solutions

Mokala Manganese Mine

Mokala Surface Water Study

SLR Project No.: 720.09012.00005

Report No.: 001

November 2015

Mokala Manganese (Pty) Ltd

Mokala Manganese Mine

Surface Water Study

SLR Project No.: 720.09012.00005

Report No.: 001

November 2015

Mokala Manganese (Pty) Ltd

DOCUMENT INFORMATION

Title	Mokala Surface Water Study
Project Manager	Ryan Sweetman
Project Manager e-mail	rsweetman@slrconsulting.com
Author	Ryan Sweetman
Reviewer	Paul Klimczak
Client	Mokala Manganese (Pty) Ltd
Date last printed	2015/11/06 03:20:00 PM
Date last saved	2015/11/06 03:14:00 PM
Keywords	Hydrology, Surface Water, Flood-Lines, Water Balance, Channel Realignment
Project Number	720.09012.00005
Report Number	001
Status	Final
Issue Date	November 2015

MOKALA SURFACE WATER STUDY

CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDICES

ACRONYMS AND ABBREVIATIONS

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

Acronyms / Abbreviations	Definition
ARC	Agricultural Research Council
AWC	Available Water Capacity
BEEH	School of Bioresources Engineering and Environmental Hydrology
BPG	Best Practice Guidance
CN	Curve Number
DEM	Digital Elevation Model
DWS	Department of Water and Sanitation
DRU	Daily Rainfall Utility Program
EAP	Environmental Assessment Practitioner
FAO	Food and Agriculture Organisation
EIA	Environmental Impact Assessment
EMP	Environmental Management Plan
GN 704	Government Notice 704
GRAII	Groundwater Resource Assessment Phase II
HEC-RAS	Hydrologic Engineering Centres – River Analysis System
ICFR	Institute for Commercial Forestry Research
IDF	Intensity Depth Frequency
MAE	Mean Annual Evaporation
MAMSL	Meters Above Mean Sea Level
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
MBGL	Meters Below Ground Level
Mm^3	Million Cubic Meters
NEMA	National Environmental Management Act
PCD	Pollution Control Dam
RWP	Recycle Water Pond
PFS	Pre-Feasibility Study
RMF	Regional Maximum Flood
RWD	Return Water Dam
SANRAL	South African National Road Agency
SASRI	South African Sugar Research Institute
SAWS	South African Weather Service
SCS	Soil Conservation Service
SOTER	Soil and Terrain Database
TSF	Tailings Storage Facility
USGS	United States Geological Survey
WMA	Water Management Area
WRC	Water Research Commission
WRD	Waste Rock Dump

MOKALA SURFACE WATER STUDY

1 BACKGROUND AND QUALIFICATIONS OF SPECIALIST CONSULTANT

Contact details: Block 7, Fourways Manor Office Park, Cnr Roos and Macbeth Streets, Johannesburg

Name: Ryan Sweetman

Profession: Civil Engineer (Pr. Eng. 20120067)

Fields of Expertise: River engineering, hydraulics, hydrology and water balance studies

Relevant work experience: See Appendix A

Papers and Publications:

Glynneath Flood Alleviation Scheme: River Bank Stabilisation Works, Design and Construction. Presented to the Chartered Institution of Water and Environmental Management (CIWEM)

1.1 DECLARATION OF INDEPENDENCE

I, Ryan Sweetman, as the appointed independent specialist hereby declare that I:

- act/ed as the independent specialist in this application;
- regard the information contained in this report as it relates to my specialist input/study to be true and correct, and
- do not have and will not have any financial interest in the undertaking of the activity, other than remuneration for work performed in terms of the NEMA, the Environmental Impact Assessment Regulations, 2010 and any specific environmental management Act;
- have no vested interest in the proposed activity proceeding;
- have disclosed, to the applicant, EAP and competent authority, any material information that have or may have the potential to influence the decision of the competent authority or the objectivity of any report, plan or document required in terms of the NEMA, the Environmental Impact Assessment Regulations, 2010 and any specific environmental management Act;
- am fully aware of and meet the responsibilities in terms of NEMA, the Environmental Impact Assessment Regulations, 2010 (specifically in terms of regulation 17 of GN No. R. 543) and any specific environmental management Act, and that failure to comply with these requirements may constitute and result in disqualification;
- have provided the competent authority with access to all information at my disposal regarding the application, whether such information is favourable to the applicant or not; and
- am aware that a false declaration is an offence in terms of regulation 71 of GN No. R. 543.

Note: The terms of reference are included in the following section.

Ryan Sweetman (6th November 2015)

2 INTRODUCTION

2.1 BACKGROUND

SLR Consulting has been tasked by Mokala Manganese (Pty) Ltd (Mokala) to undertake an Environmental Impact Assessment (EIA) and Environmental Management Plan (EMP), for opencast activities associated with the mining of manganese.

Mokala is proposing to establish a new opencast manganese mine on the remaining extent of the farm Gloria 266, 4 km north-west of Hotazel in the Joe Morolong Local Municipality of the Northern Cape Province. A locality map is shown in Figure 2-1, together with the proposed mine infrastructure layout in Figure 2-2. The Mokala Mine project will comprise:

- Open cast activities (Strip mining)
- A dry crushing and screening plant
- Overburden rock stockpile (concurrent rehabilitation)
- Product and run-of mine stockpiles
- Topsoil stockpiles
- Mine related facilities

This report gives an account of the baseline hydrological conditions, a flood study, a channel realignment strategy, a storm water management plan and a site wide water balance to assess the compliance of the proposed infrastructure with the relevant legislation.

2.2 ENVIRONMENTAL LEGISLATION - DWAF GOVERNMENT NOTICE 704

Government Notice 704 (Government Gazette 20118 of June 1999) (hereafter referred to as GN 704), was established to provide regulations on the use of water for mining and related activities aimed at the protection of water resources. The five principle conditions of GN 704 applicable to this project are:

- *Condition 4*, which defines the area in which, mine workings or associated structures may be located, with reference to a watercourse and associated flooding. Any residue deposit, dam, reservoir together with any associated structure or any other facility should be situated outside the 1:100 year flood-line. Any underground or opencast mining, prospecting or any other operation or activity should be situated or undertaken outside of the 1:50 year flood-line, except in relation to a matter contemplated in Condition 10. Where the flood-line is less than 100 metres away from the watercourse, then a minimum watercourse buffer distance of 100 metres is required for infrastructure and activities.

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

- *Condition 6* which describes the capacity requirements of clean and dirty water systems. Clean and dirty water systems must be kept separate and must be designed, constructed, maintained and operated to ensure conveyance of flows of a 1:50 year recurrence event. Clean and dirty water systems should not spill into each other more frequently than once in 50 years on average. Any dirty water dam is to have a minimum freeboard of 0.8 m above full supply level.

- *Condition 7*, which describes the measures that must be taken to protect water resources. All dirty water or substances which may cause pollution should be prevented from entering a water resource (by spillage, seepage, erosion etc) and ensure that water used in any process is recycled as far as practicable.

- *Condition 10* which describes the requirements for operations involving extraction of material from the channel of a watercourse. Measures should be taken to prevent impacts on the stability of the watercourse, prevent scour and erosion resulting from operations, prevent damage to in-stream habitat through erosion, sedimentation, alteration of vegetation and flow characteristics, construct treatment facilities to treat water before returning it to the watercourse, and implement control measures to prevent pollution by oil, grease, fuel and chemicals.

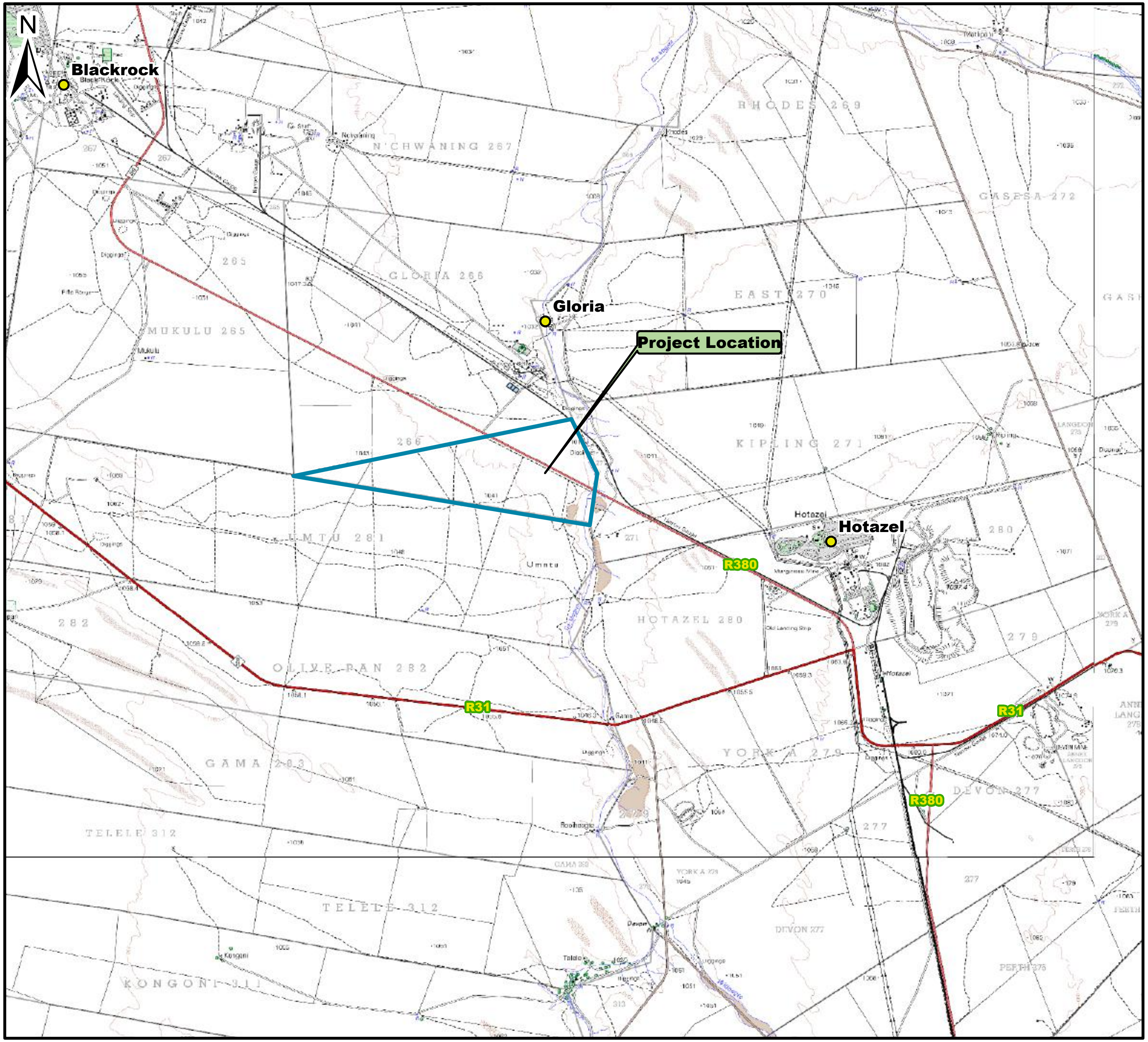
2.3 SCOPE OF WORK AND REPORT STRUCTURE

This Surface Water Study includes the following:

- Baseline Hydrology - Section 3 presents the baseline hydrology of the site and surroundings including climate, storm intensities, regional and local topography, watercourse network, soils, vegetation, groundwater setting, records of flow and mean annual runoff.
- Flood Hydrology - Section 4 presents estimates of the flood hydrology of the Ga-Mogara River in the vicinity of the site including methodologies for peak flow estimation and results which will inform the flood-line modelling and channel realignment strategy.
- Hydraulic Flood Modelling - Section 5 presents hydraulic flood modelling undertaken for the Ga-Mogara River including methodology and modelled flood-lines within the vicinity of the site.
- Channel Realignment Strategy – Section 6 presents recommendations for management of flows within the Ga-Mogara River to prevent inundation of the working pit during flood events.
- Conceptual Storm Water Management Plan - Section 7 presents the recommended storm water management measures to manage flood risks to the operation and minimise risks of polluting

any water resources. This section includes clean and dirty water catchment delineation, channel routing and conceptual sizing of the required storm water infrastructure.

- Site Wide Water Balance – Section 8 presents the water balance for the fully developed mining operation during wet and dry periods in order to inform estimates on re-use rates, makeup water requirement and requirements for discharge.
- Daily Time Step Storm Water Modelling – Section 9 presents the daily time step storm water modelling undertaken to inform the design of the infrastructure to capture and manage excess storm water.



Legend

- Place Names
- Main Road
- Secondary Road
- Track and Hicking Trail
- Railway
- Existing Power Line
- Rec Recreation Ground
- Erosion, sand
- Prominent Rock Outcrop
- Project Location Property Boundary

Kilometers

0 2.5 5

Scale: 1:100 000 @ A4

Projection:Transverse Mercator
WG23

MOKALA SURFACE WATER STUDY

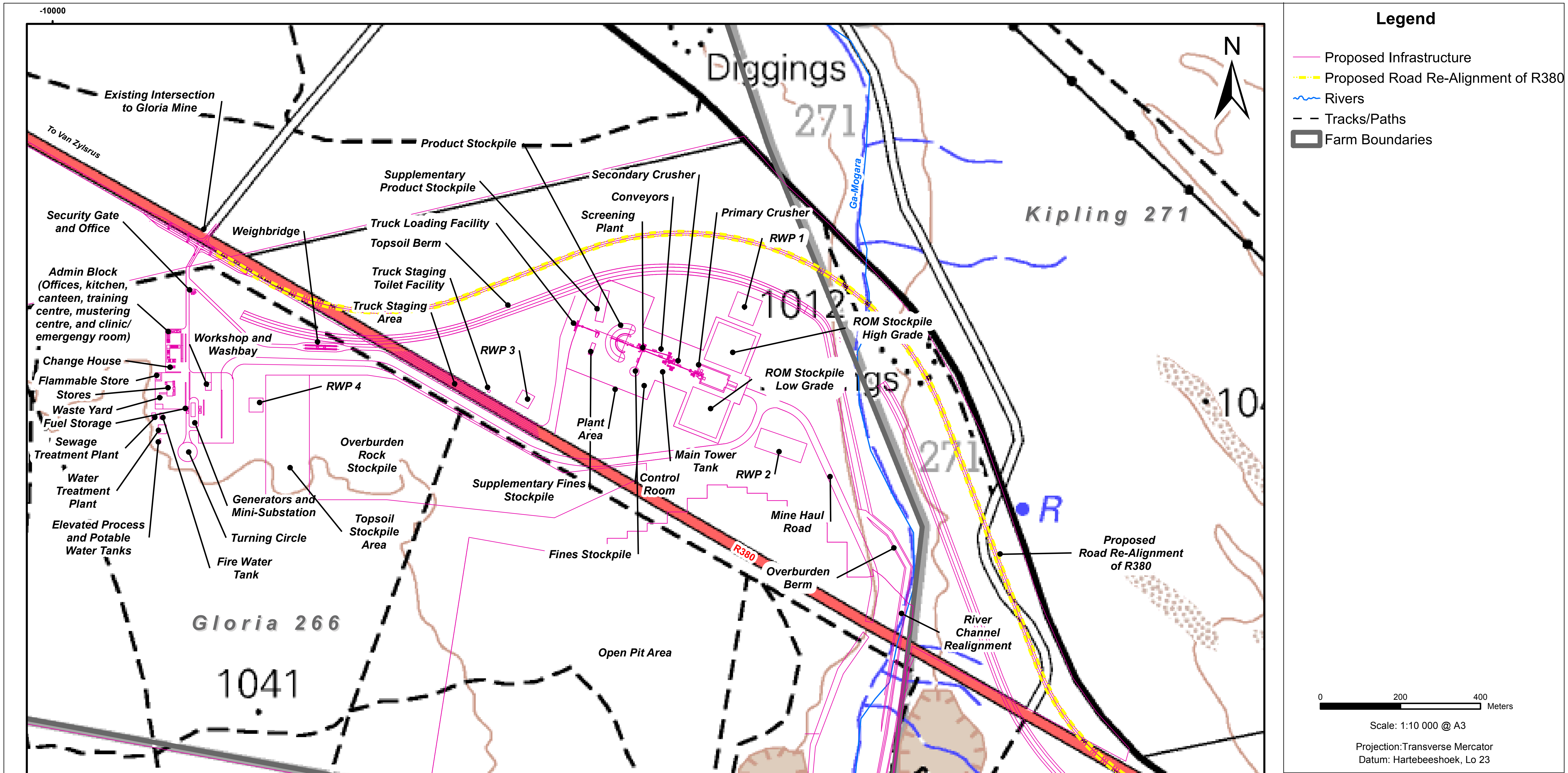
Figure 2.1

Locality Map

SLR

SLR Consulting (Africa) (Pty) Ltd
P O Box 1596, Cramerview, 2060, South Africa
Tel: +27 (11) 467-0945 Fax: +27 (11) 467-0978

720.0912.00005 | October 2015



MOKALA SURFACE WATER STUDY

Figure 2.2

Approved and Proposed Infrastructure

SLR

SLR Consulting (Africa) (Pty) Ltd
P O Box 1596, Cramerview, 2060, South Africa
Tel: +27 (11) 467-0945 Fax: +27 (11) 467-0978

720.0912.00005

October 2015

3 BASELINE HYDROLOGY

3.1 INTRODUCTION

In order to inform the flood studies, design of storm water management measures, and the site wide water balance, an understanding of the baseline hydrology is required. This section presents a comprehensive review of various information sources used to define the baseline climatic and hydrological conditions of the site and surroundings.

3.2 CLIMATE

3.2.1 RAINFALL

No records of rainfall recorded at the site are available and as such rainfall data was extracted from three sources, these include:

- The Daily Rainfall Extraction Utility programme.
- Department of Water and Sanitation (DWS) online database.
- Water Resources of South Africa 2005 Study (WR2005).

Rainfall data was extracted using the Daily Rainfall Utility Program (DRU). This program that was developed by Richard Kunz, from the Institute for Commercial Forestry Research (ICFR), in conjunction with the School of Bioresources Engineering and Environmental Hydrology (BEEH) at the University of KwaZulu-Natal, Pietermaritzburg, South Africa.

DRU assists the user in extracting observed and patched daily rainfall values from a database which was developed by Steven Lynch in the course of a Water Resources Commission (WRC) funded research project (K5/1156) awarded to BEEH. The project, titled “The development of a raster database of annual, monthly and daily rainfall for southern Africa”, was completed in March 2003.

The DRU database consists of more than 300 million rainfall values derived from 11,269 daily rainfall stations. The data originated from many different organisations and individuals, each having their own structure and level of quality control. The three main custodians of rainfall data in South Africa include, *inter alia*, the

- South African Weather Service (SAWS);
- Agricultural Research Council (ARC); and
- South African Sugarcane Research Institute (SASRI).

Rainfall data was also extracted from the DWS online database which is available freely and can be accessed online via the DWS website[1]. The final source of rainfall data was obtained from the Water Resources of South Africa 2005 Study, (WR2005, 2009).

The rainfall data extracted using the DRU program include the two SAWS stations, Winton (0392148 W) and Milner (0393083 W). The rainfall data extracted from the DWS online database was the Kuruman DWS station (D4E004). The rainfall data extracted from the WR2005 database was for the quaternary catchment D41K. Monthly rainfall values from these sources are shown below in Table 3-1.

TABLE 3-1: SUMMARY OF MONTHLY RAINFALL FOR THE PROJECT AREA

MONTH	RAINFALL (mm)			
	Winton - 392148 W	**Milner - 393083 W**	**Kuruman - D4E004**	**WR2005**
January	56.3	59.8	85.3	63.8
February	63.5	63.0	84.7	52.2
March	62.7	72.3	92.7	53.3
April	34.2	39.9	49.1	29.5
May	16.4	19.2	23.9	10.0
June	5.1	9.1	7.5	4.4
July	3.4	1.3	3.7	2.2
August	5.5	5.4	8.4	3.4
September	6.2	6.4	8.0	8.5
October	14.7	19.2	25.9	26.2
November	24.5	31.5	42.9	40.5
December	42.3	44.5	45.9	50.1
Annual	**335**	**372**	**478**	**344**

Of the rainfall stations presented in Table 3-1, the Kuruman station has a 20 year record (1960 – 1980), being the lowest of the gauges used. The Winton and the Milner station however have a larger record which is inclusive of patched and missing data and range from 1878 – 2009. The WR2005 data indicates that the mean annual precipitation (MAP) for the quaternary catchment D41K is 344 mm, which correlates reasonable well with the Winton station.

A summary of the characteristics of the Winton and Milner stations is presented in Table 3-2.

[1] DWS online database : http://www.dwaf.gov.za/hydrology/hymain.aspx

TABLE 3-2: SUMMARY OF STATION DETAILS FROM DRU PROGRAM

Station	Distance from Site (km)	No of years	Reliability (%)	Patched (%)	Missing (%)
Winton - 392148 W	40	104	60	29	11
Milner - 393083 W	19	85	56	32	12

The percentage reliability of a station is related to the amount of actual observed data within the rainfall record. If Winton station is taken as an example, a reliability of 60 percent indicates that of the 104 years of rainfall data recorded for the Winton station, 60 percent of the years make up the actual observed data. The patched data represents rainfall data that has been statistically generated from the observed data, to extend the available rainfall record.

The adopted MAP for the project site was obtained from the Winton station which totals 335 mm, chosen as it has the highest percentage reliability.

A review of the daily rainfall records from the Winton rain gauge shows that the maximum daily rainfall depth between 1878 and 2000 was 138.5 mm, several other high rainfall depths are presented in Table 3-3.

TABLE 3-3: FIVE GREATEST DEPTHS OF RAINFALL RECORDED IN 1 DAY (WINTON STATION)

Date	Rainfall (mm)
15/01/1974	138.5
22/12/1999	125.0
02/03/1920	124.1
01/03/1974	103.5
08/03/1956	101.5

A review of the wettest multi-day periods recorded are presented in Table 3-4, which shows the maximum depth of rain falling over consecutive days, ranging from 1 to 30 days. As can be seen, the greatest depth of rain falling within a 30 day period was 483.6 mm which exceeds the MAP and the greatest depth within a 180 day period was 1014.5 mm which is nearly three times the MAP. It is concluded that whilst MAP in this area is low there has been significant rainfall on occasions.

TABLE 3-4: WETTEST PERIODS RECORDED ON CONSECUTIVE DAYS (WINTON STATION)

Number of Consecutive Days	Total Depth of Rainfall (mm)
1	138.5
2	204.5
3	204.5
4	247.0
5	255.5
6	259.6
7	259.6
15	323.0
30	483.6
60	656.5
120	915.0
180	1014.5

3.2.2 EVAPORATION

Monthly evaporation data was obtained from the Water Resources of South Africa 2005 Study, (WR2005, 2009). The project area lies within evaporation zone 8A, which has a total MAE of 2351 mm. The evaporation obtained is based on Symons pan evaporation measurements and needs to be converted to lake evaporation using factors obtained from WR2005. Table 3-5 gives a summary of the adopted evaporation for the project site.

TABLE 3-5: SUMMARY OF EVAPORATION DATA (WR2005)

Months	Symons Pan Evaporation (mm)	Lake Evaporation Factor	Lake Evaporation (mm)
January	276.9	0.84	232.6
February	209.9	0.88	184.8
March	193.3	0.88	170.1
April	144.1	0.88	126.8
May	114.7	0.87	99.8
June	91.0	0.85	77.3
July	106.0	0.83	88.0
August	153.8	0.81	124.5
September	213.0	0.81	172.5
October	269.7	0.81	218.4
November	248.0	0.82	232.9
December	294.6	0.83	244.5
Total	2351	N/A	1972

3.2.3 WIND AND TEMPERATURE

Wind and temperature was obtained from the Loclim programme (FAO, 2005). The method selected to obtain the wind and the temperature data is based on the nearest neighbour method for which the user defines the search radius and number of stations selected. Below in Table 3-6 is the output from the Loclim programme showing the summary of the temperature and wind speed data representative of the project site, which is based on interpolation from a maximum of the 10 nearest stations.

TABLE 3-6: SUMMARY OF TEMPERATURE AND WIND SPEED DATA (LOCLIM PROGRAM)

Months	Average Temperature (ºC)	Minimum Temperature (ºC)	Maximum Temperature (ºC)	Average Wind Speed (km/hour)
January	24.6	17	32	6.12
February	23.7	16.2	31	6.12
March	21	14.3	27.5	5.4
April	17.2	9.6	24.7	3.96
May	13.3	5	21.2	3.96
June	10.6	2	19.5	3.96
July	9.8	1.2	18.2	5.4
August	12.5	3.2	21.7	5.4
September	16.1	7.3	24.7	6.12
October	19.7	11	28.2	5.4
November	21.6	13	30	6.48
December	23.1	15.3	30.7	6.48

3.3 STORM INTENSITY DURATION FREQUENCY (IDF) ESTIMATES

The design storm rainfall depths were obtained from the design rainfall software (Smithers and Schulze, 2002). The programme is able to extract the storm rainfall depths for various recurrence intervals for the six closest rainfall stations as shown below in Table 3-7.

TABLE 3-7: SUMMARY OF SIX CLOSEST SAWS STATIONS

Station Name	SAWS Number	Distance (km)	Record Length (Years)	Mean Annual Precipitation (mm)	Altitude (mamsl)
MUKULU	0392640 W	10.2	28	289	1056
HEUNINGDRAAI	0392680 W	11.4	28	349	1060
SMUTS	0392592 W	13.7	26	333	1073
MILNER	0393083 W	19.1	67	334	1118
KAREEPAN	0393225 W	20.1	36	352	1130
TSINENG (POL)	0393126 W	24.2	31	334	1049

The adopted storm rainfall depth to be used in the peak flow calculations is based on the gridded rainfall depths for the above six stations. The summary of the rainfall depths for the 5 minute duration up to the 1 day storm duration for various recurrence intervals are shown below in Table 3-8.

TABLE 3-8: ADOPTED STORM RAINFALL DEPTHS FOR THE PROJECT SITE (SMITHERS AND SCHULZE, 2002).

Duration	Rainfall Depth (mm)						
(m/h/d)	1:2 year	1:5 year	1:10 year	1:20 year	1:50 year	1:100 year	1:200 year
5 m	7.9	11.3	13.6	16.0	19.2	21.8	24.5
10 m	11.8	16.8	20.4	23.9	28.7	32.5	36.5
15 m	14.9	21.3	25.7	30.2	36.3	41.1	46.1
30 m	19.7	28.1	34.0	39.9	48.0	54.3	61.0
45 m	23.2	33.1	40.0	47.0	56.5	64.0	71.8
1 h	26.1	37.1	44.9	52.7	63.4	71.8	80.6
1.5 h	30.7	43.7	52.9	62.1	74.6	84.6	94.9
2 h	34.5	49.1	59.4	69.7	83.8	94.9	106.5
4 h	39.9	56.7	68.6	80.6	96.8	109.7	123.1
6 h	43.4	61.7	74.7	87.7	105.4	119.4	134.0
8 h	46.1	65.6	79.3	93.1	111.9	126.8	142.2
10 h	48.3	68.7	83.1	97.5	117.2	132.8	149.0
12 h	50.1	71.4	86.3	101.3	121.8	138.0	154.8
16 h	53.2	75.8	91.6	107.6	129.3	146.5	164.4
20 h	55.8	79.4	96.0	112.7	135.5	153.5	172.2
24 h	57.9	82.5	99.7	117.1	140.7	159.5	178.9
1 d	46.6	66.4	80.3	94.2	113.3	128.4	144.0

3.4 HYDROLOGICAL SETTING

3.4.1 INTRODUCTION

South Africa is divided into 19 water management areas (National Water Resource Strategy, 2004), managed by separate water boards. Each of the water management areas (WMA) is made up of quaternary catchments which relate to the drainage regions of South Africa, ranging from A – X (excluding O). These drainage regions are subdivided into four known divisions based on size. For example, the letter A represents the primary drainage catchment, A2 for example will represent the secondary catchment, A21 represents the tertiary catchment and A21D would represent the quaternary catchment which is the lowest subdivision in the WR2005 manual. Each of the quaternary catchments have associated hydrological parameters including area, mean annual precipitation (MAP) and mean annual runoff (MAR) to name a few.

The project area falls within the Lower Vaal WMA with the major rivers located within the mentioned WMA being the Molopo River, Harts River and the Vaal River. All runoff from the project area is eventually drained westward into the Orange River.

3.4.2 REGIONAL HYDROLOGY

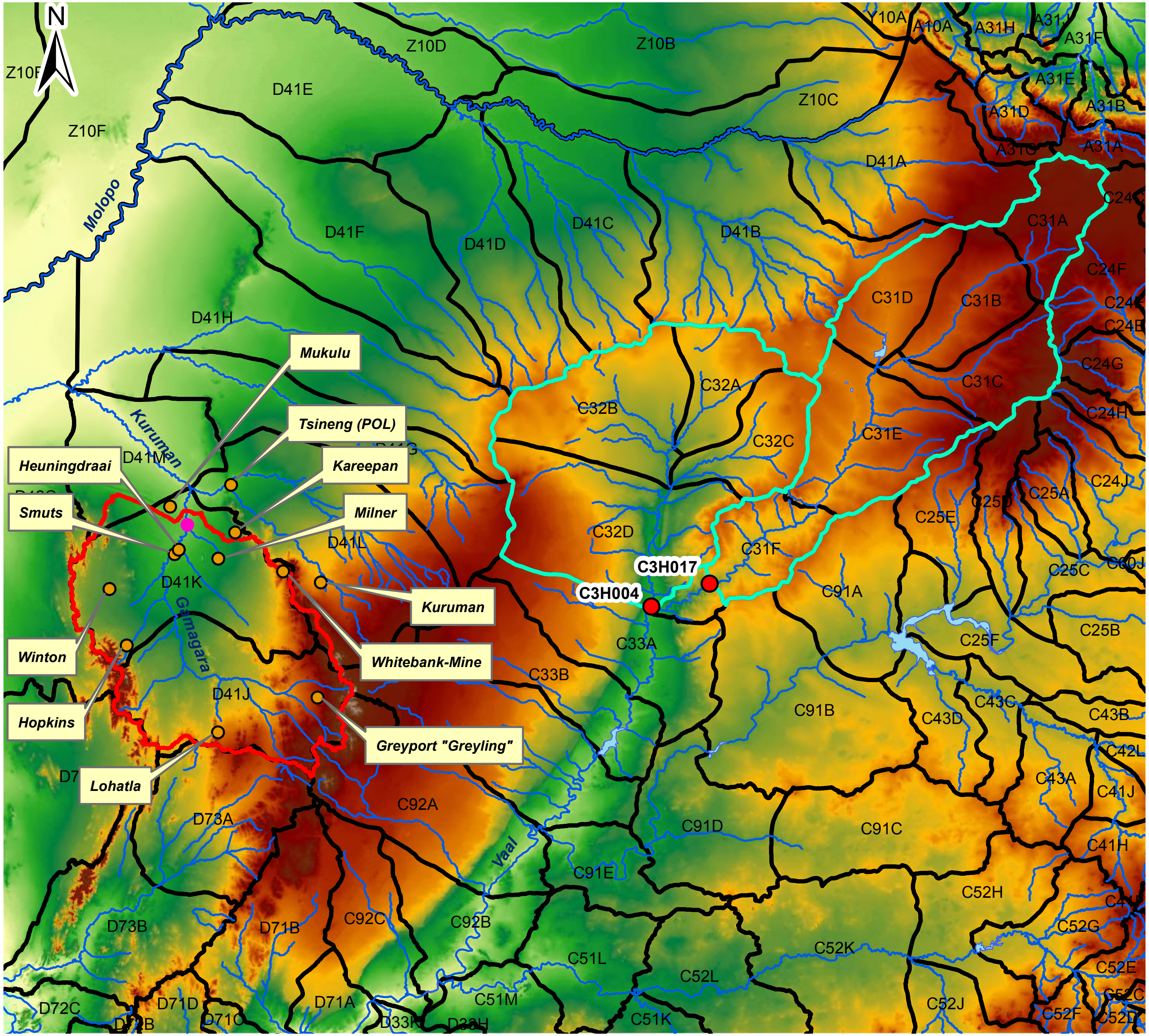
The project area falls within the quaternary catchment D41K which has a gross total catchment area of 4216 km^2, with a net MAR of 1.92 Mm^3. The upstream contributing quaternary catchment to D41K is D41J. Quaternary catchment D41J has a gross total catchment area of 3878 km^2, with a net MAR of 1.75 Mm^3.

The major river within quaternary catchments D41K and D41J is the Ga-Mogara River which flows through the proposed project area. The Ga-Mogara River is an ephemeral river which forms a tributary to the Kuruman River. The Kuruman River flows west joining the Molopo River approximately 250 km from the confluence of the Ga-Mogara River and Kuruman River. The Molopo River drains in a southerly direction eventually joining the Orange River.

The entire Molopo catchment (including D14K and D41J) are classified as endoreic i.e. catchments with large areas which do not contribute to runoff as the watercourses drain to inland pans.

Average elevations at the eastern and western quaternary catchment boundary of D41K range from approximately 1200 mamsl to 1650 mamsl. The elevation drops gradually to 1000 mamsl at the confluence of the Ga-Mogara River and the Kuruman River at the outlet of D41K. The highest elevation is recorded within the eastern and western boundary of D41J, where elevations exceed 1800 mamsl. The hydrological setting of the project site is presented in Figure 3-1. The Digital Elevation Model (DEM) was sourced from the United States Geological Survey (USGS) website[2].

[2] http://hydrosheds.cr.usgs.gov/dataavail.php



Key

- Gauging Stations
- Rainfall Stations
- Project Location
- Quaternary Catchments
- Gauging Station Catchments
- Mokala Catchment
- Dams
- Rivers

Digital Elevation Model (mamsl)

High : 2000

Low : 800

0 20 40 80 120 Kilometers

Scale as shown above

Projection:Transverse Mercator
WGS84

MOKALA SURFACE WATER STUDY

Figure 3.1

Regional Hydrological Setting

SLR

SLR Consulting (Africa) (Pty) Ltd
P O Box 1596, Cramerview, 2060, South Africa
Tel: +27 (11) 467-0945 Fax: +27 (11) 467-0978

720.09012.00005

Februaryl 2015

3.4.3 TOPOGRAPHY

Based on a review of the 20 m contours of the 1:50 000 Topographical Maps of South Africa, the Ga-Mogara catchment is bounded to the west, south and east by a sharp outcrop of hills, with elevations of 1200 mamsl at the foot of these hills up to and exceeding 1700 mamsl in the highest points within these hills. With the exception of these hills, which form a minor part of the catchment, the gradients are gentle <1% and slope from the foot of the hills which is between 1200 – 1300 mamsl to the outlet of the Ga-Mogara catchment at between 1000 and 1020 mamsl.

It is also important to note that within the watercourse, there are areas which form natural depressions, which may encourage ponding during storm events.

3.4.4 WATERCOURSES AND DRAINAGE LINES

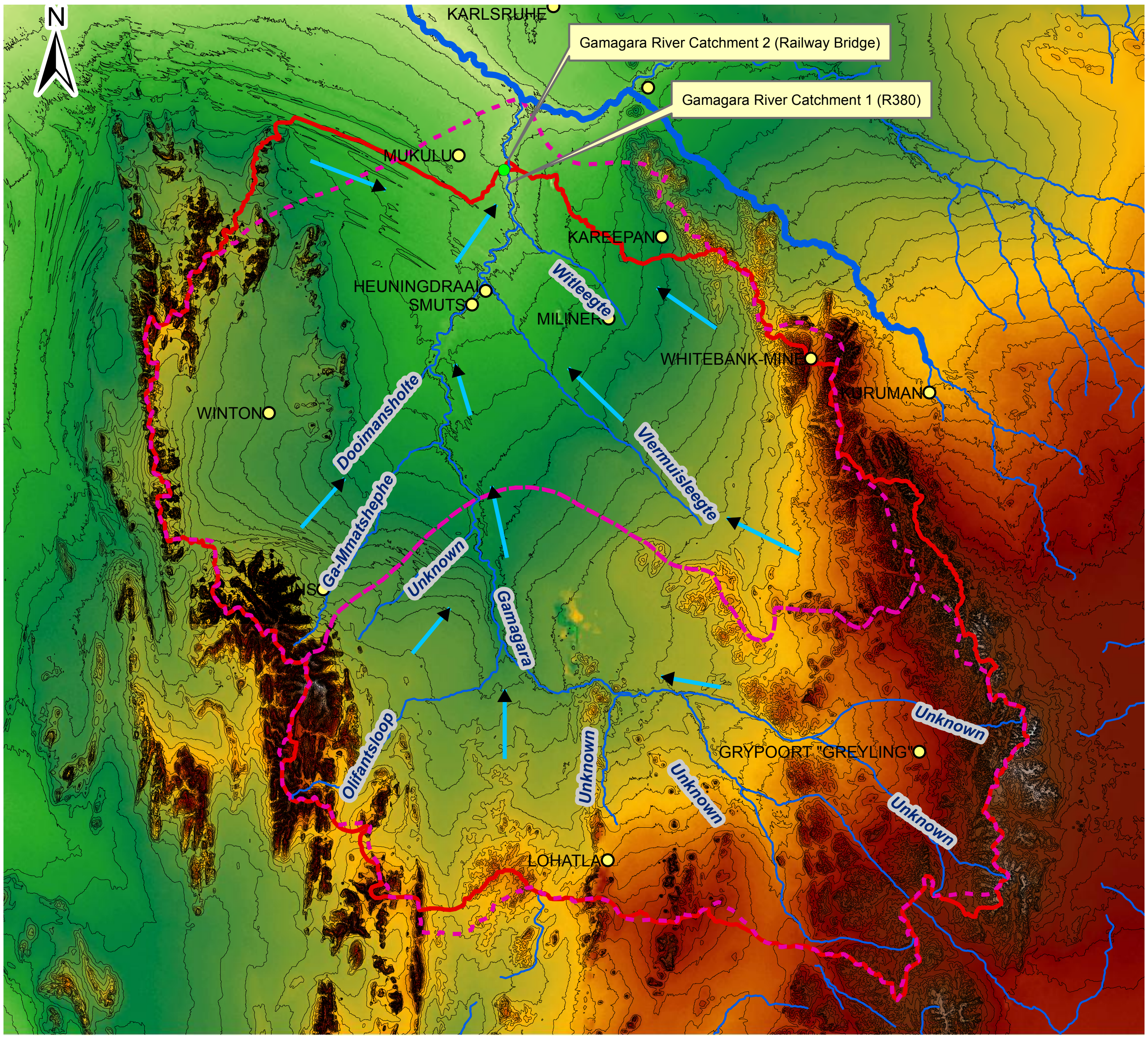
The local hydrology of the Ga-Mogara catchment is presented on Figure 3-2. The Ga-Mogara River and its tributaries are all shown as ephemeral on the 1:50 000 topographical maps. Within the memory of the local farmers the Ga-Mogara River has only flowed on rare occasions, namely during the years 1974, 1976 and 1988. A full assessment of flood flows is provided under Section 4 on flood hydrology. Several minor ephemeral rivers form tributaries of the Ga-Mogara River, these include the Dooimansholte, Ga-Mmatshephe, Olifantsloop, Vlermuisleegte and various other unknown ephemeral rivers. Most notably the Witleegte forms a confluence with the Ga-Mogara immediately upstream of the site.

The catchment areas of the Ga-Mogara River (Table 3-9) were delineated using the ArcHydro tools within ArcGIS, of which input to ArcHydro included the 20 m contours obtained from the 1:50 000 topographical map. It should be noted that these catchments differ slightly from the WR2005 quaternary catchment which are delineated based on the 1:250 000 topographical maps and are less accurate.

TABLE 3-9: SUMMARY OF CATCHMENT AREAS

Catchment Name	Area (km^2)
Ga-Mogara River Catchment 1 (R380 crossing)	8053
Ga-Mogara River Catchment 2 (Railway Bridge)	8054

Any runoff generated on the Mokala site will drain initially in an easterly direction into the Ga-Mogara River.



Key

- Rainfall Stations
- Project Location
- Drainage Direction

RIVER CATEGORIES

- NonPerennial
- Perennial
- Quaternary Catchments
- Catchment Areas
- 20 m Contours

Digital Elevation Model (mamsl)

High : 2000

Low : 800

0 5 10 20 30 Kilometers

Scale as shown above

Projection:Transverse Mercator WGS84

MOKALA SURFACE WATER STUDY

Figure 3.2

Local Hydrology, Topography, Catchments and Drainage Paths

SLR Consulting (Africa) (Pty) Ltd
P O Box 1596, Cramerview, 2060, South Africa
Tel: +27 (11) 467-0945 Fax: +27 (11) 467-0978

720.09012.00005

September 2014

3.4.5 MEAN ANNUAL RUNOFF

The Ga-Mogara River catchment falls both within quaternary catchment D41J and D41K, therefore the mean annual runoff (MAR) will be based on the percentage of the catchment area falling within each of the quaternary catchments. The total estimated MAR for the delineated catchments is shown in Table 3-10 and equates to approximately 0.13 % of the total MAP depth for the project site (335 mm) when applied to the catchment area.

TABLE 3-10: SUMMARY OF MAR FOR CATCHMENTS

Catchment Name	Area (km^2)	TOTAL MAR (Mm^3)
Ga-Mogara River Catchment 1 (R380 road crossing)	8053	3.48
Ga-Mogara River Catchment 2 (Railway Bridge)	8054	3.49
D41J	3878	1.75
D41K	4216	1.92

It is noted that the MAR is derived from a monthly rainfall runoff model applied to the drainage region. With limited flow records for watercourses in the region the model results will have a significant uncertainty. The MAR figure is also a long term average of the catchment annual runoff and so does not necessarily imply there is a constant base flow in the river. The MAR of 3.48 Mm^3 would result in a flow of only 110 l/s if taken to be a constant year round flow, being a very small flow for catchment of some 8000 km^2. In reality runoff from the Ga-Mogara River will be associated with a few large intermittent events separated by many years of zero flow as anecdotal evidence suggests.

3.4.6 VEGETATION

The project area falls within the Kathu Bushveld and Gordonia Duneveld. The Kathu Bushveld is open savannah with *Acacia erioloba* currently known as the *Vachellia erioloba* (Camel thorn), *Diospyros lycioides* (Karroo bluebush), and *Lycium hirsutum* (River honey-thorn) dominating the shrub layer and a highly variable grass layer. The Gordonia duneveld typically occurs on the undulating dunes, and consists of open shrubland with grasslands on the ridges and *Acacia haematoxylon* (Grey camel thorn) currently known as *Vachellia haematoxylon,* on the dune slopes. *Acacia mellifera* (Black thorn) currently known as *Vachellia mellifera*, is prominent on the lower slopes and *Rhigozum trichotomum* (Three thorn) is found between the dunes.

From a site visit (3rd July 2014) it was observed that most of the areas, especially the watercourses are covered by grass (both long and short), as shown in Figure 3-3. The vegetation surrounding the project area is made up of a mixture of grassland, shrubland and trees, as shown in Figure 3-4.

FIGURE 3-3: TYPICAL VEGETATION IN GA-MOGARA CHANNEL (JUNE 2014)

FIGURE 3-4: TYPICAL VEGETATION IN THE VICINITY OF THE MOKALA SITE (JUNE 2014)

The fairly dense vegetation cover, with the exception of the actual mine site, will reduce the runoff potential within the Ga-Mogara catchment as the vegetation cover intercepts some of the rainfall.

3.4.7 SOILS

Dominant soil types within quaternary catchment D41K and D41J are made up of Chromic Cambisols to the western parts and Ferralic Arenosols to the eastern parts. Calcic Solonchaks soils occur within the centre parts of the quaternary catchments.

Cambisols cover a large portion of the world's area (approximately 1.5 billion hectares), thus occurring in a wide variety of environments. These soils are characterised as having good structural stability, high porosity, good water holding capacity and good drainage.

Ferralic Arenosols belong to the soil group Arenosols. These soils are characteristic of having a loamy sand to a coarse type texture, for depths of about 1 m. The pore spaces for these soils are usually large, allowing for free drainage and increased permeability. The available water capacity (AWC) is therefore low.

Solonchaks belong to the soil group that have a high concentration of soluble salts. These can occur in low lying areas or depressions where there exists a strong capillary rise of saline groundwater.

The soils classification was extracted from the Soil and Terrain Database (SOTER) (v1.0) for South Africa[3], whilst general description of the soil group was obtained from the (Major Soils of the World) website[4] for the above soil description.

3.4.8 GROUNDWATER

The groundwater baseline information is included in the report SLR Consulting (South Africa) (Pty) Ltd, Groundwater Assessment for the Proposed Mokala Manganese Project, October 2015.

---

[3] http://www.isric.org/projects/soter-south-africa

[4] http://www.isric.org/isric/webdocs/docs/major_soils_of_the_world/start.pdf

4 FLOOD HYDROLOGY

4.1 INTRODUCTION

In order to inform flood-line modelling and the design of channel realignment and flood protection measures at the site, an understanding of the flood hydrology of the Ga-Mogara River catchment is required. As discussed in Section 3 (Baseline Hydrology), the Ga-Mogara catchment is bounded to the west, south and east by a sharp outcrop of dolomitic and arenaceous (sandy) hills, whilst the majority of the catchment is relatively flat with deep freely draining soils which generate very little runoff. Evidence of springs can be identified at the foot of the dolomitic outcrops, but any flow appears localised to that area and quickly seeps into the soils in the flatter areas.

The Ga-Mogara River does not flow regularly and anecdotal evidence concludes that flow events are limited to only a few exceptional occasions since the 1970's. For such a catchment, typical best practice methods for flood estimation are not considered to accurately represent the flood hydrology. For example estimates using the Alternative Rational method, Standard Design Flood and Regional Maximum Flood return estimates of peak flows in excess of 100 m^3/s for a 1:2 year event which contradicts anecdotal evidence i.e. significant flow has only occurred on a few exceptional occasions in 40 years. Therefore, this flood hydrology study includes a review of both regional and local hydrological information, anecdotal evidence from historical flood events and flow estimates using regional methodologies for flood hydrology in ungauged catchments.

4.2 HISTORICAL FLOOD EVENTS

Evidence from local farmers suggests that notable flows within the Ga-Mogara River occurred between 1974 and 1976 and again in 1988. It is not certain if and when flows occurred prior to 1974 but, given that between 1974 and 2014, significant flows have occurred within 3 years out of 40 years, the probability of flow within the river in any one year is estimated to be 1:13.

A photo taken during the 1976 event is presented in Figure 4-1, notable features from which are:

- The photo is taken of a road crossing at Kipling farm in the vicinity of the existing R380 road crossing at the Mokala site.
- Downstream of the crossing, the width of flow is 20-30m;
- Several culverts are evident beneath the road;
- A shallow (<0.5m) and narrow (<2m) section of flow has breached the road deck.

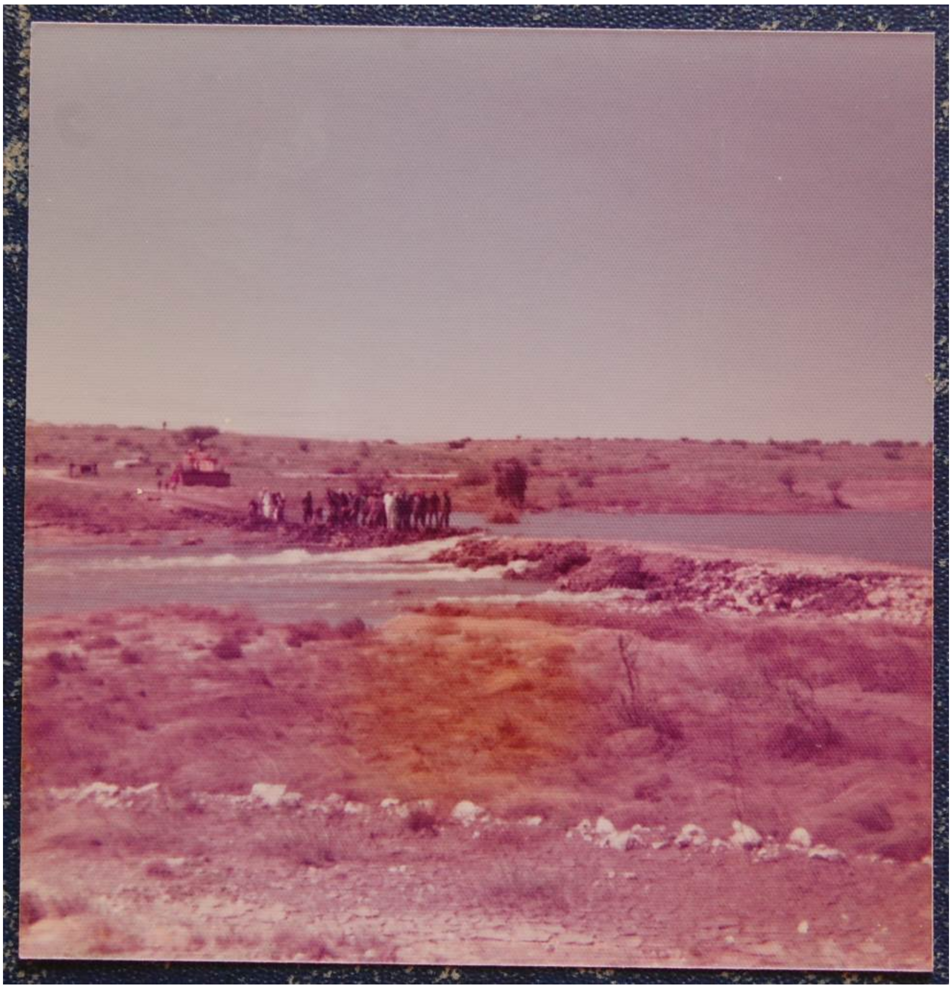


FIGURE 4-1: PHOTO OF ROAD CROSSING AT KIPLING FARM (1976) FACING EAST

The R380 river crossing was visited during the site visit (3rd July 2014) and comprised 14 x 1m diameter corrugated iron culverts below the road deck as shown in Figure 4-2.

FIGURE 4-2: PHOTO OF R380 ROAD CROSSING AT KIPLING FARM (JULY 2014) FACING WEST

It is not certain whether the R380 river crossing was upgraded between 1976 and 2014 but it is possible to estimate the flow through the existing crossing which would cause slight overtopping of the road deck as shown in 1976 (Figure 4-1). Using the HEC-RAS model, discussed further in Section 5, it is estimated that a flow of 35 m^3/s would cause slight overtopping of the road deck whereas 20 m^3/s would be conveyed through the culverts.

Typically, the design capacity (i.e. number and diameter of culverts) of a road crossing will be increased when a road crossing is upgraded, so if anything, a flow estimate of 35 m^3/s for the 1976 flows can be regarded as high but will be suitable for adoption as a conservative estimate of flows.

From the above discussion of historical flows it is concluded that the probability of the Ga-Mogara River flowing is 1:13 in any given year with a corresponding flow in the region of 35 m^3/s.

4.3 FLUVIAL GEOMORPHOLOGY

Fluvial geomorphology is the study of watercourse processes and the landforms which they create. Using the detailed aerial photography and topographical survey data, it is possible to identify the likely extent of flooding within the channel and then cross reference it to flood-lines hydraulically modelled using HEC-RAS to identify which flows best fit the visual evidence within the channel. Further details of the hydraulic flood modelling are presented in Section 5.

Figure 4-3 presents the modelled flood-lines for flows of 100 m^3/s and 250 m^3/s which are compared against the extent of the darker brown alluvial soils and dense grass cover which demark the channel from the typical lighter orange soils found elsewhere within this area and are considered an indication of the extent of the largest flood event which has occurred in recent history at this location. It is estimated from this evidence that the largest flow is likely to be <250 m^3/s.

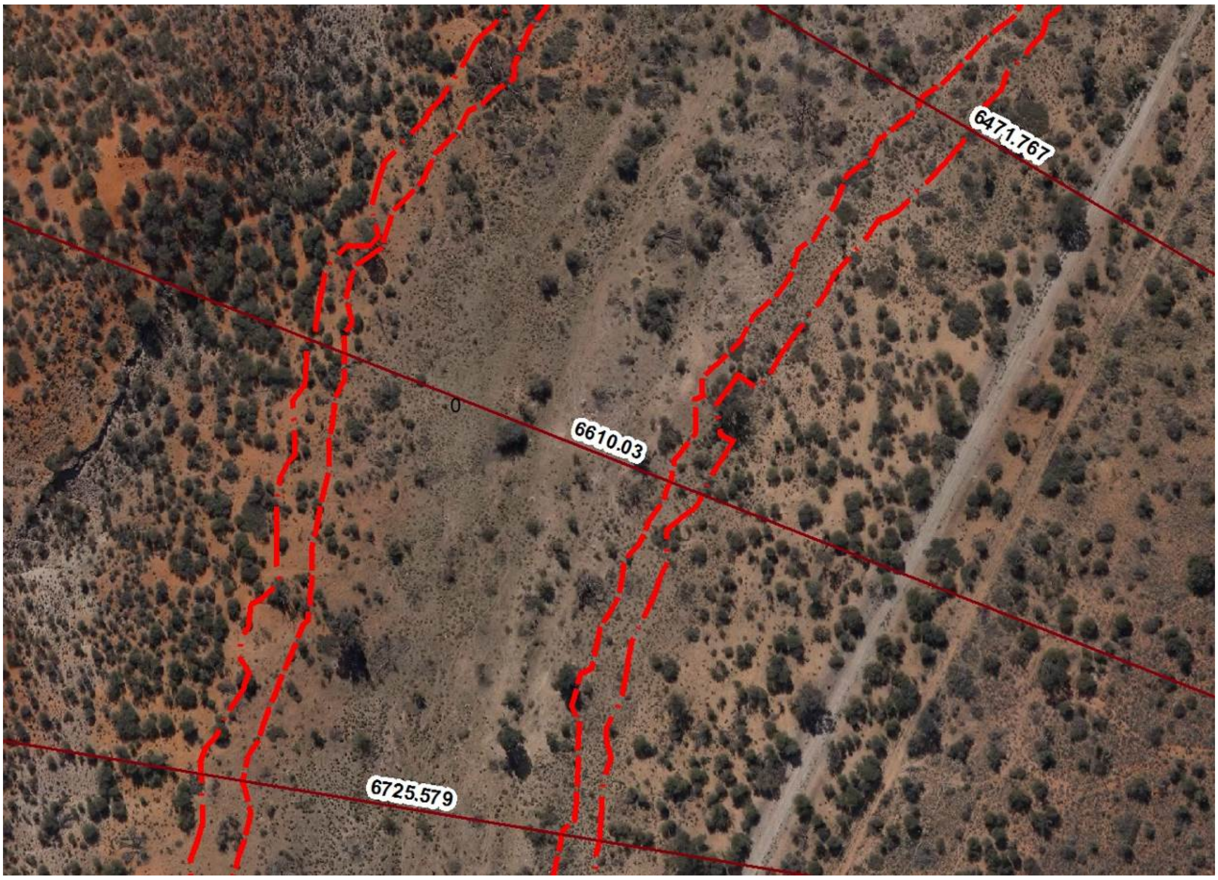


FIGURE 4-3: MODELLED FLOOD-LINES FOR 100 M^3/S AND 250 M^3/S ON AERIAL PHOTOGRAPHY

Figure 4-4 presents cross-sections taken from the HEC-RAS model for flows of 100 m^3/s and 250 m^3/s. As can be seen, the extent of the largest flow event within this channel is marked by steeper sides scoured out by erosion during an event and bounded by flatter banks adjacent to the main channel. Again, it is estimated by this approach that the largest flow which has historically occurred at this location is likely to be <250 m^3/s.

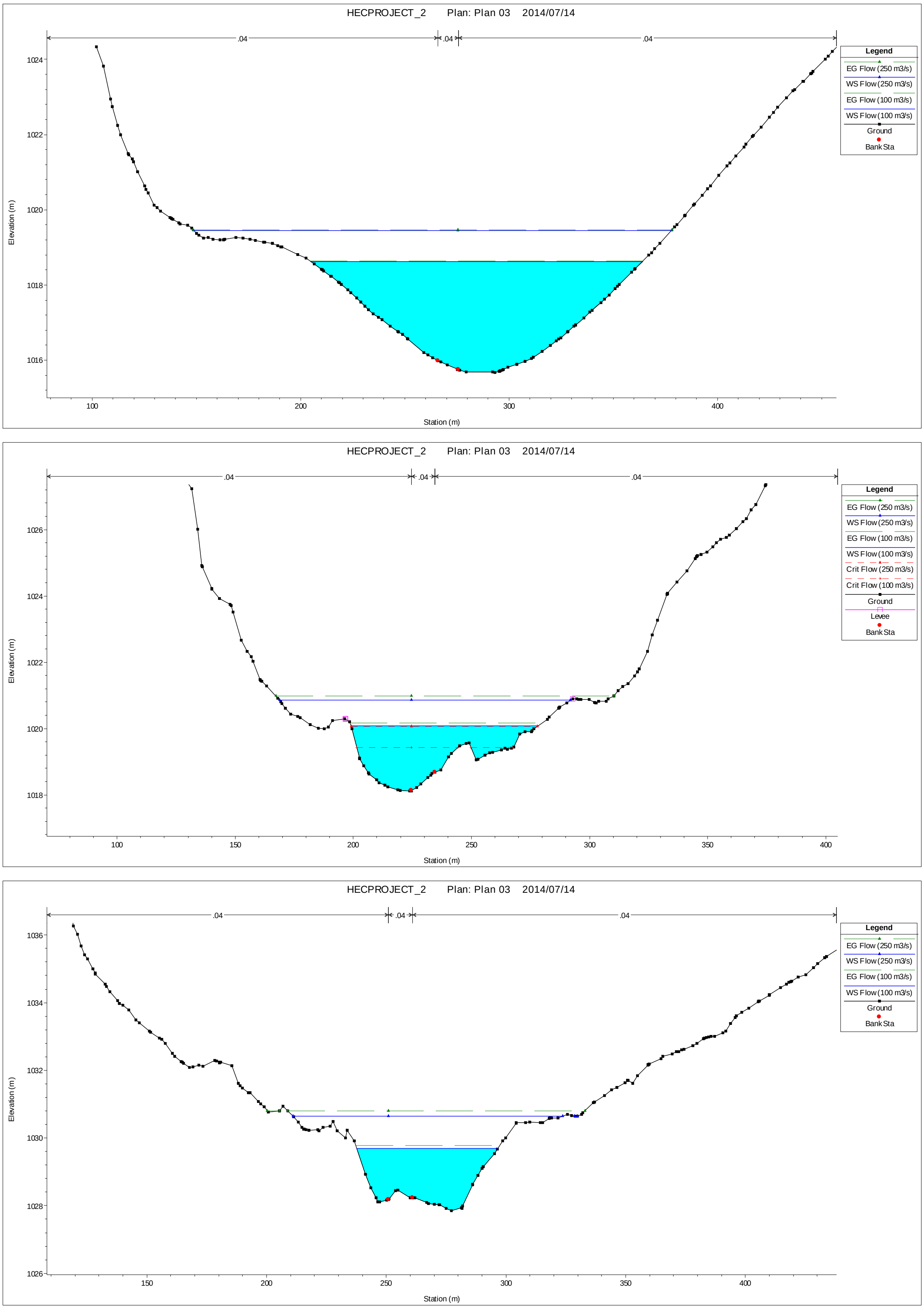


FIGURE 4-4: HEC-RAS CROSS-SECTIONAL OUTPUT SHOWING THE MODELLED FLOW OF 100 AND 250 M3/S

As indicated above, the maximum historical flow within the channel is expected to be <250 m^3/s. Using the growth curve for this region from TR137 Regional Maximum Flood Peaks in Southern Africa (Kovacs, 1988), the maximum peak flows for smaller events can be estimated, as presented in Table 4-1.

TABLE 4-1: MAXIMUM ESTIMATES OF FLOW BASED ON EVIDENCE OF HISTORICAL FLOODING AND REGIONAL GROWTH CURVES FROM TR137

Event	Q_T/Q_{RMF} Ratio	Maximum Estimate of Peak Flow (m^3/s)
RMF	1.000	<250
1:200	0.638	<160
1:100	0.506	<127
1:50	0.398	<100

4.4 ANALYSIS OF RAINFALL RECORDS

Given the large area of the Ga-Mogara catchment, the relatively flat terrain and freely draining soils, it would be expected that the highest flows are triggered by extended periods of rainfall generating runoff from the entire catchment e.g. frontal rainfall systems, rather than runoff from single intense storm events e.g. convective rainfall systems, which would, by nature, be less aerially extensive. This is substantiated by analysis of the daily rainfall records for Winton as presented in Figure 4-5 and Figure 4-6, which shows that 1974, 1976 and 1988 (when the river was seen to flow) were some of the wettest multi-day periods recorded. The 180 day totals correlate better against the flow events than the 30 day totals which indicates that flow events are the result of longer duration rainfall events.

Further comparisons between rainfall and flow events indicate that flow is likely to occur when rainfall exceeds 520 mm in 180 days which has happened 3 times since 1974 and 5 times since 1926. In terms of rainfall, it is concluded that the probability of there being sufficient rainfall to trigger flow events within the Ga-Mogara is between 1:13 years (3 times in 40 years) and 1:15 (5 times in 74 years).

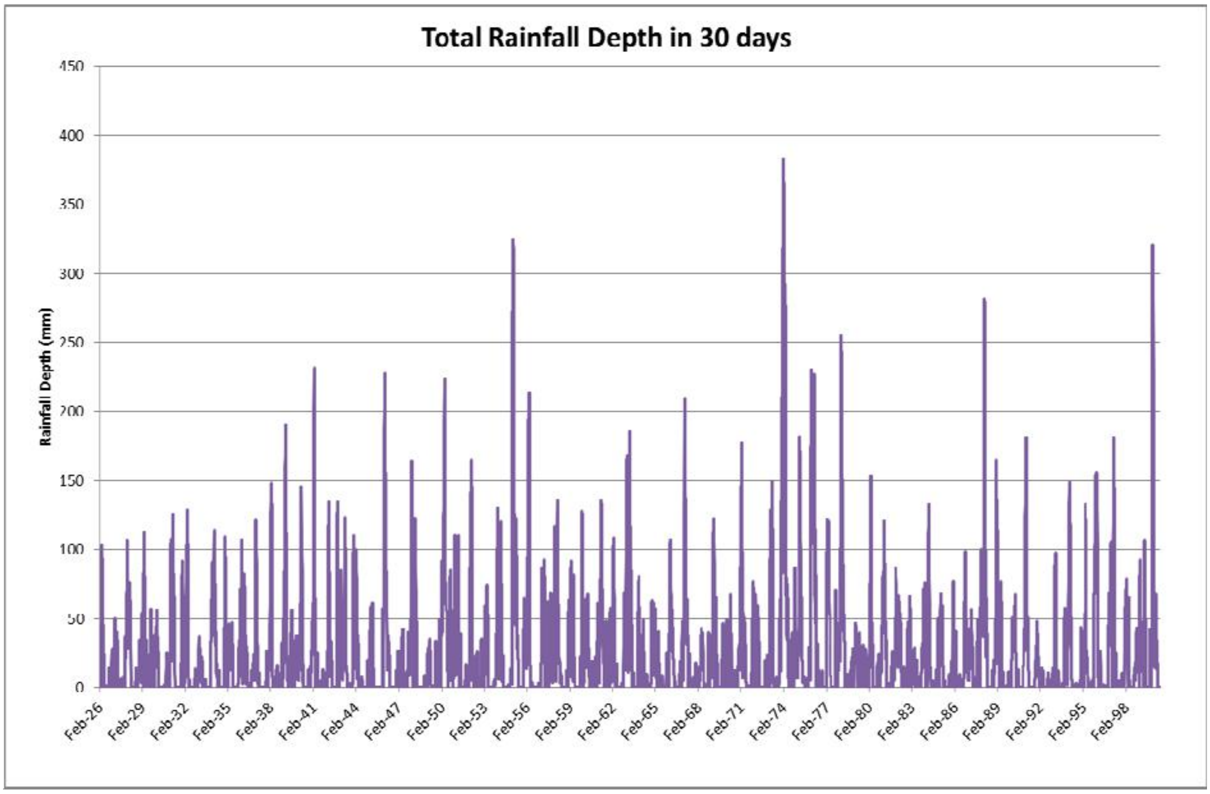


FIGURE 4-5: TOTAL RAINFALL ACROSS 30 CONSECUTIVE DAYS 1926-2000 (WINTON 0392148_W)

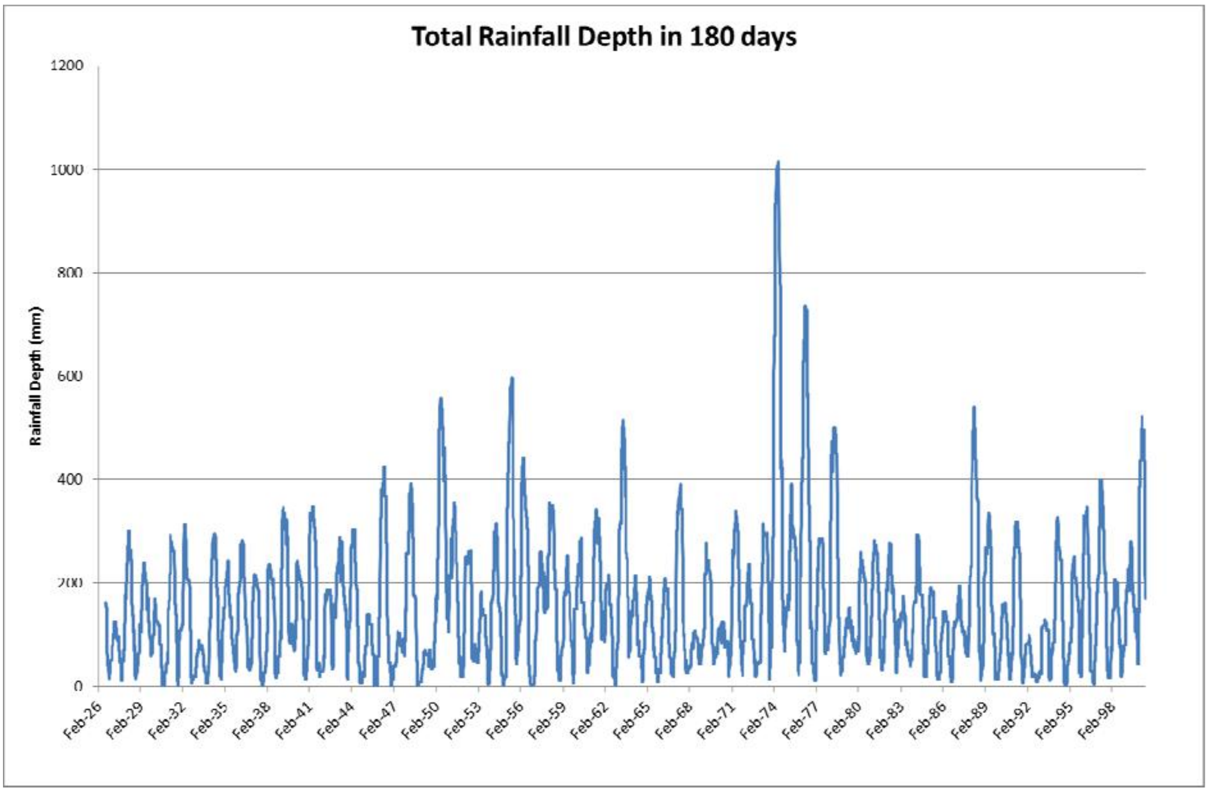


FIGURE 4-6: TOTAL RAINFALL ACROSS 180 CONSECUTIVE DAYS 1926-2000 (WINTON 0392148_W)

Further analysis of daily rainfall records from five different rainfall stations (as shown on Figure 3-2) within the large (8 000 km^2) Ga-Mogara catchment between 1973 and 1976, concluded that there was substantial variation in rainfall depths observed across the catchment during both single day and multiday rainfall events.

As shown in Table 4-2, the largest depth of rainfall recorded in a single day was 138.5 mm, which occurred during 15 January 1974 however on the same day minimal rainfall was observed in 2 of the 5 gauges and the average across all stations was only 42.6 mm indicating the restricted locality of this rainfall event. As show in Table 4-3, the most intense rainfall event across the entire catchment was on 2 December 1973 when on average 75.6 mm of rain fell across the catchment. The areal reduction factor for a single day event appears to be in the region of 70% (worst case scenario) whereas for multiday events it is in the region of 80% (worst case scenario).

TABLE 4-2: VARIATION IN SINGLE DAY RAINFALL EVENT ACROSS GA-MOGARA CATCHMENT

Date	No. Days	Station and Number					
		Lohotla	Hopkins	Greyport Greyling	Winton	Whitebank Mine	Average All Stations *(% of Max)*
		0321032_W	0356285_W	0357774_W	0392148_W	0393476_W	
02 Dec 1973	1	85	83	9	97.5	**103.5**	75.6 (73%)
15 Jan 1974	1	60	0	10	**138.5**	4.5	42.6 (31%)
01 Mar 1974	1	81.2	70	25.5	**103.5**	55	67.0 (65%)
14 Dec 1975	1	N/A	34.5	N/A	**61.5**	19	38.3 (62%)

TABLE 4-3: VARIATION IN MULTI-DAY RAINFALL EVENT ACROSS GA-MOGARA CATCHMENT

Date	No. Days	Station and Number					
		Lohotla	Hopkins	Greyport Greyling	Winton	Whitebank Mine	Average All Stations *(% of Max)*
		0321032_W	0356285_W	0357774_W	0392148_W	0393476_W	
01 Dec 1973	3	85	123.2	79.5	**127.5**	111.5	105.3 (84%)
14 Jan 1974	2	104.0	92.0	10.0	**204.5**	21.0	86.3 *(42%)*
27 Jan 1974	3	70.0	70.5	133.0	69.0	**178.5**	104.2 *(58%)*
28 Feb 1974	4	165.0	147.0	175.0	**207.0**	153.0	169.4 *(82%)*
15 Dec 1975	4	N/A	**156.0**	N/A	128.5	92.0	125.5 *(80%)*
13 Apr 1976	3	49.5	15.0	N/A	**68.0**	67.0	49.9 *(73%)*

4.5 STATISTICAL ANALYSIS OF NEARBY FLOW GAUGING STATIONS

There are no flow gauging stations on the Ga-Mogara River however 2 stations were identified approximately 200 km east of the site which may be used to improve understanding of flood hydrology within this region. The relative locations of the catchments served by the stations are shown on Figure 3-1 and further details of these catchments and how they compare with the Ga-Mogara River are presented in Table 4-4.

TABLE 4-4: COMPARISON OF NEARBY FLOW GAUGING STATIONS CATCHMENTS WITH STUDY CATCHMENT

Catchment Name	Ga-Mogara River Catchment 2 (Railway Bridge)	Droe Harts River (C3H004)	Harts River (C3H017)
Area (km^2)*	8054	10 237	10 688
10 - 85 Slope*	0.003	0.002	0.001
Vegetation**	Karoo types	Grassvelds and Karoo types	Grassvelds and Karoo types
Soils**	Moderate to deep sand	Moderate to deep sandy loam	Moderate to deep clay loam
Geology**	Dolomite and arenaceous strata	Dolomite, tillite and shale	Tillite and shale
Catchment Shape	Pear Catchment Shape	Pear Catchment Shape	Elongated Catchment Shape
Gauging Station	N/A	C3H004	C3H017
Record Length	N/A	13 years (1924 – 1946)	11 years (1995 – 2011)

**measured from topographical data*
***based on WR2005 data*
****based on Water Affairs records*

The annual maximum flows for each flow gauging station are presented in Table 4-5 below.

TABLE 4-5: ANNUAL MAXIMUM FLOWS IN NEARBY CATCHMENTS

Droe Harts River C3H004	
Year	**Flow (m^3/s)**
1924	58.207
1925	19.645
1926	19.645
1927	66.786
1928	69.329
1929	161.536
1931	111.67
1933	69.329
1934	38.446
1936	135.732
1937	75.819
1939	46.738
1941	52.334
1942	63.062
1944	104.088
1946	90.633

Harts River C3H017	
Year	**Flow (m^3/s)**
1995	71.876
1997	83.336
1998	55.642
1999	5.110
2000	101.562
2002	17.876
2004	34.123
2005	200.96
2006	146.472
2007	16.913
2009	66.396
2010	91.657
2011	35.43

Whilst these catchments are relatively nearby to the Ga-Mogara and have similar catchment areas, the soils and geology are generally less permeable and the flow regime appears markedly different from the Ga-Mogara, for example the annual maximum flows are typically >19 m^3/s in C3H004 and >16 m^3/s in C3H017 whereas the typical annual maximum flow within the Ga-Mogara is zero (it has only flowed on a few exceptions since the mid-1970s). Nonetheless an analysis of the flow from these stations will be useful to provide an indication of the regional upper limit of flows which could be expected within the Ga-Mogara. By fitting the General Extreme Value Distribution to the two gauges' annual maxima time series flows were estimated for various annual exceedance probabilities as presented in Table 4-6.

TABLE 4-6: FLOW ESTIMATES FOR VARIOUS ANNUAL EXCEEDANCE PROBABILITIES FOR GAUGES C3H004 AND C3H4017 (GENERAL EXTREME VALUE DISTRIBUTION)

Annual Exceedance Probability	Flow (m^3/s)	
	C3H004	C3H017
1:200	251	554
1:100	216	430
1:50	185	330
1:35	147	228
1:20	121	168
1:10	97	118
1:5	80	86
1:2	66	62

Of the two catchments, catchment C3H004 has the more permeable soils and geology and is therefore most similar to the Ga-Mogara catchment. Based on the flows estimated for C3H004 above, and scaled to catchment area, the flows estimated in the Ga-Mogara River at the Mokala mine site would be 170 m^3/s for a 1:100 year event and 146 m^3/s for a 1:50 year event. Given that more permeable soils and geology are found in the Ga-Mogara, and the fact that significant flow events in the Ga-Mogara are exceptional, rather than occurring routinely every year, these flow estimates are considered to be the upper limit.

4.6 REGIONAL MAXIMUM FLOOD (RMF) METHOD

The Regional Maximum Flood (RMF) method is an empirical method based on maximum flood peaks recorded at more than 500 sites in Southern Africa. The flood peaks were plotted against catchment area and assigned a regional specific K value relating peak flow to catchment area. The Drainage Manual (SANRAL, 2013) advises that empirical methods are considered less accurate than those obtained by statistical or deterministic methods. Furthermore, the RMF method allows estimation of flows which are the *"upper realistic limit for every region and for specific catchments with lower runoff coefficients the K-value can be adjusted downwards".*

Using the RMF method with a regional K value of 2.8 returns flows of 403 m^3/s and 518 m^3/s, having respective annual exceedance probabilities of 1:50 and 1:100, for the Ga-Mogara catchment at the Mokala Mine site. Comparison of the peak flows for catchments C3H004 and C3H017 estimated by frequency analysis (as presented in Table 4-6) against estimates of peak flows using the RMF method, presented in Table 4-7, indicate that K-values of 1.7 and 2.2 return a better fit than the standard K value for this area of 3.4.

TABLE 4-7: RMF FLOW ESTIMATES FOR CATCHMENTS C3H004 (K = 1.7) AND C3H017 (K = 2.2)

Annual Exceedance Probability	Flow (m^3/s)	
	C3H004 (K = 1.7)	C3H017 (K = 2.2)
RMF	488	799
1:200	312	511
1:100	247	405
1:50	195	319

Applying the K-value from catchment C3H004 to the Ga-Mogara catchment, allows an estimate of peak flows by the RMF Method for the Ga-Mogara River at the Mokala Mine site, as presented in Table 4-8.

TABLE 4-8: RMF FLOW ESTIMATES FOR GA-MOGARA RIVER AT THE MOKALA MINE SITE (K = 1.7)

Annual Exceedance Probability	Flow (m^3/s)
	K = 1.7
RMF	400
1:200	251
1:100	198
1:50	154

The Ga-Mogara (R380) Catchment 1 and the Ga-Mogara (Railway Bridge) Catchment 2 are approximately equal in size and therefore the RMF results shown above are applicable to both the catchments.

4.7 APPLICATION OF GROWTH CURVES TO HISTORICAL FLOOD EVENTS

Under Section 4.5 the statistical analysis of annual maxima data from flow gauging stations C3H004 and C3H017 was discussed. Although the associated catchments are in the same region as the Ga-Mogara catchment, and therefore experience a similar climate, they have a much greater runoff potential. The flows with a 1:50 and 1:100 annual exceedance probability estimated for gauge C3H004 were scaled on catchment area to give an upper limit of flows that could be expected at the Mokala Mine site. As flows occurred every year at gauge C3H004, while at the Mokala Mine site flow in the Ga-Mogara River are rare, this approach will overestimate flows at the site.

An approach that would result in a more realistic estimate of flows involves applying to the Ga-Mogara River the parameters of the statistical distribution fitted to the annual maxima data from gauges C3H004 and C3H017. The shape of the distribution fitted to the two gauges is represented by the rate of increase of flows with different annual exceedance probabilities (Q_T). This is known as a 'growth curve' with the flow at an annual exceedance probability of 1:2 (Q_2) normally taken to have a ratio of 1 being the annual average flood.

In Section 4.2, anecdotal evidence of historical floods was used to estimate a conservative flow rate 35 m^3/s, having an annual exceedance probability of 1:13. As the Ga-Mogara River does not flow on an annual basis a flow with an annual exceedance probability of 1:2 is not defined. The growth curve derived from the gauges C3H004 and C3H017 was therefore calculated from the annual exceedance probability of 1:13 (Q_{13}). The resulting flow estimates for the Ga-Mogara River are presented in Table 4-9 below.

TABLE 4-9: FLOWS IN THE GA-MOGARA RIVER ESTIMATED FROM GROWTH CURVES TRANSFERRED FROM GAUGES C3H004 AND C4H017

Annual Exceedance Probability	Q_T/Q_{13} (Growth Curve)	Flow (m^3/s)
1:200	2.174	76.1
1:100	1.819	63.7
1:50	1.506	52.7
1:20	1.149	40.2
1:13	1.000	35.0

4.8 CONCLUSIONS AND RECOMMENDATIONS

Table 4-10 presents a summary of the 1:50 and 1:100 year flows in the Ga-Mogara River at Mokala estimated by various methods as discussed above.

TABLE 4-10: SUMMARY OF FLOW ESTIMATES FOR THE GA-MOGARA RIVER AT MOKALA MINE

Annual Exceedance Probability	Fluvial Geomorphology (m^3/s) (Section 4.3)	Statistical Analysis of C3H004 (m^3/s) (Section 4.5)	RMF Method (m^3/s) (Section 4.6)	Historical Flows and Growth Curve (m^3/s) (Section 4.7) Recommended Design Flows
1:200	-	<198	251	**76**
1:100	<127	<170	198	**64**
1:50	<100	<146	154	**53**

Of the methods used, the most robust estimates are considered to be those based on anecdotal evidence and local growth curves, which are supported by the fluvial geomorphology and statistical analysis estimates. The RMF method estimates are considered least accurate, returning flows that are much higher than the other methods.

It is recommended that the design flows for the Ga-Mogara River adopted for modelling of flood lines and sizing of the channel realignment are those estimated using the historical flows and growth curves as given in Table 4-10. While the recommended flows take into account a comprehensive review of available data, it should be noted that there remains significant uncertainties associated with flood estimation within an ungauged catchment, even more so for a watercourse with a catchment area in excess of 8 000 km^2 which only flows during exceptional conditions. It is recommended that these uncertainties are managed by applying a 1 m freeboard to design levels for any infrastructure within close proximity to the Ga-Mogara River, including the proposed channel realignment and any flood protection berms.

To improve the certainty of the flow estimates it is recommended that the following data is collected when there is a flow event in the reach of the Ga-Mogara River passing the Mokala mine site.

- Survey of rack marks (high water mark) after the flow event with supporting photographs
- Measurement of the flow rate using a portable flow meter if it is safe to do so

5 HYDRAULIC FLOOD MODELLING

5.1 INTRODUCTION

In order to inform compliance to the GN704 regulations it is necessary to define the flood lines having a 1:50 and 1:100 annual exceedance probability for the baseline condition of any watercourses on the site. Flood modelling is also required to inform the design of any proposed infrastructure which will be located within the channels or floodplains of the watercourses. The only watercourse on the Mokala Mine site is the Ga-Mogara River which flows in a northerly direction along the eastern edge of the site.

5.2 METHODOLOGY

The numerical hydraulic modelling program, HEC-RAS Version 4.1, was used to undertake the flood modelling work. The program was developed by the United States Hydraulic Engineering Centre and is the industry standard river modelling software in use around the world. The software allows the user to perform one-dimensional steady and unsteady flow simulations for natural river channels. The HEC-GeoRAS software was used to import and export data from a digital elevation model in the ArcGIS software package. This allows river cross sections to be automatically generated for the model and the resulting flood lines to be plotted in ArcGIS. The digital elevation model was generated from 0.5 m contour data of the study reach provided by the Client. The river centre line was taken to follow the channel low point as defined by the survey data.

The flood flows recommended under Section 4 were used for the flood modelling work. These flows are given in Table 5-1 below and constitute the upstream boundary condition of the model. A normal depth flow regime was used for the model’s downstream boundary condition.

TABLE 5-1: FLOOD FLOWS USED IN THE HYDRAULIC MODELLING

Annual Exceedance Probability	Flood Flows (m^3/s) (Section 4.7)
1:200	**76**
1:100	**64**
1:50	**53**

The modelled reach extent and section locations for the baseline and developed scenarios are shown in Figure 5-2 and Figure 5-3. The reach of the Ga-Mogara River passing through the Mokal Mine site was modelled. The downstream extent of the model was limited by the extent of the available survey data. To account for this the downstream boundary of the model was given a constant bed slope matching that of the channel at the end of the reach.

For the baseline scenario there is only one structure in the river channel being the R380 road crossing as shown in Figure 5-1 and Figure 4-2. This is a low level crossing with the parameters given in Table 5-2.

Although the Mokala Mine infrastructure will mainly be located outside of the 100 m river buffer there will be a need for some development in the river channel. It is proposed that the existing R380 road crossing is to be demolished and relocated 900 m downstream of its current location as shown in Figure 2-2. The Client's infrastructure consultant, AECOM SA (Pty) Ltd, is responsible for the design of the new road crossing. The parameters of the proposed road crossing are given in Table 5-2. It is also proposed to temporarily realign the river channel over a distance of 900 m adjacent to the mine's open cast pit. The channel realignment strategy is discussed further under Section 6.

FIGURE 5-1: R380 ROAD CROSSING

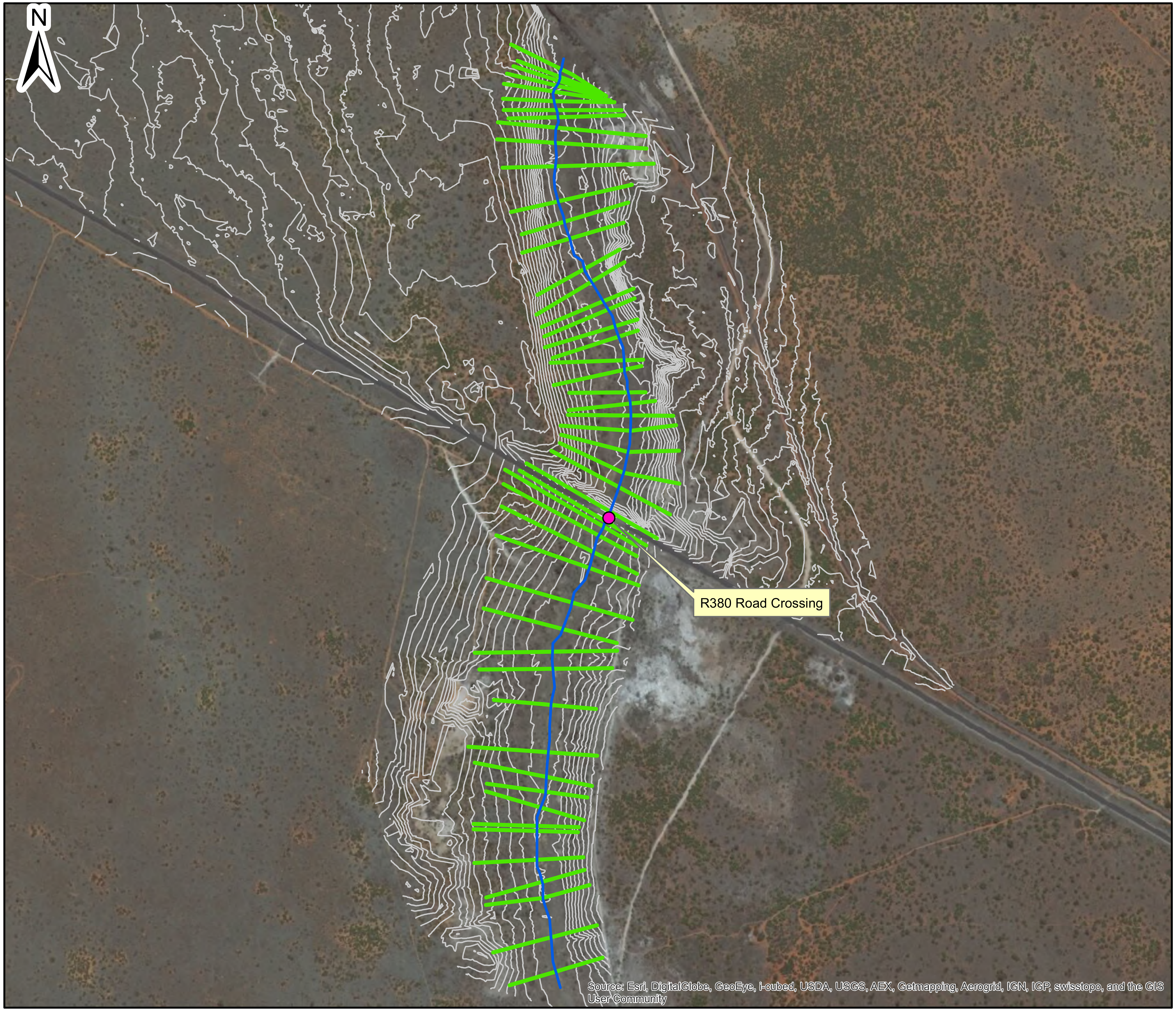
TABLE 5-2: PARAMETERS OF RIVER CROSSINGS

Name	Number of Openings	Culvert Diameter (m)	Culvert Spacing's on Centre (m)	Deck Thickness (m)	Deck Width (m)
Existing R380 Road Crossing	14	1.00	2.6	0.50	11.0
Proposed New Road Crossing	17	1.20	1.50	0.80	9.4

The roughness of the channel bed needs to be entered into the model such that the energy losses along the river channel can be calculated during the simulation. The manning's roughness coefficient 'n' is used to define the channel roughness in the model with guidance on selecting an appropriate value given in Table 3-1 of the HEC-RAS Hydraulic Reference Manual Version 4.1, 2010.

Due to the rarity of flow in the river a dense cover of grass has developed in the channel along with a sparse extent of bushes and some trees. This vegetation, combined with a channel bed that is wide (approximately 50 m) and flat, results in a channel roughness more akin to a flood plain than a river channel. An average manning's value of 0.035 is recommended for a flood plain with high grass cover. A conservative value of 0.040 was used in the modelling as there was no opportunity for calibration. Due to the uniformity of the river bed vegetation and cross-section the same manning's value was applied to the whole study reach. A manning's value of 0.034 was used for the temporary channel realignment for the reasons given in Section 6.5.1.

As only the peak flood levels are of interest to this study the model was run as a steady state simulation using the recommended flood flows. Attenuation of the flood peak flows, due to in channel storage, have been accounted for in the estimation of the flood flows used in the modelling.



Key

- River
- Cross Sections
- Contours
- Hydraulic Structures

0 100 200 300 Meters

Projection: Transverse Mercator
Datum: WGS 84

MOKALA SURFACE WATER STUDY

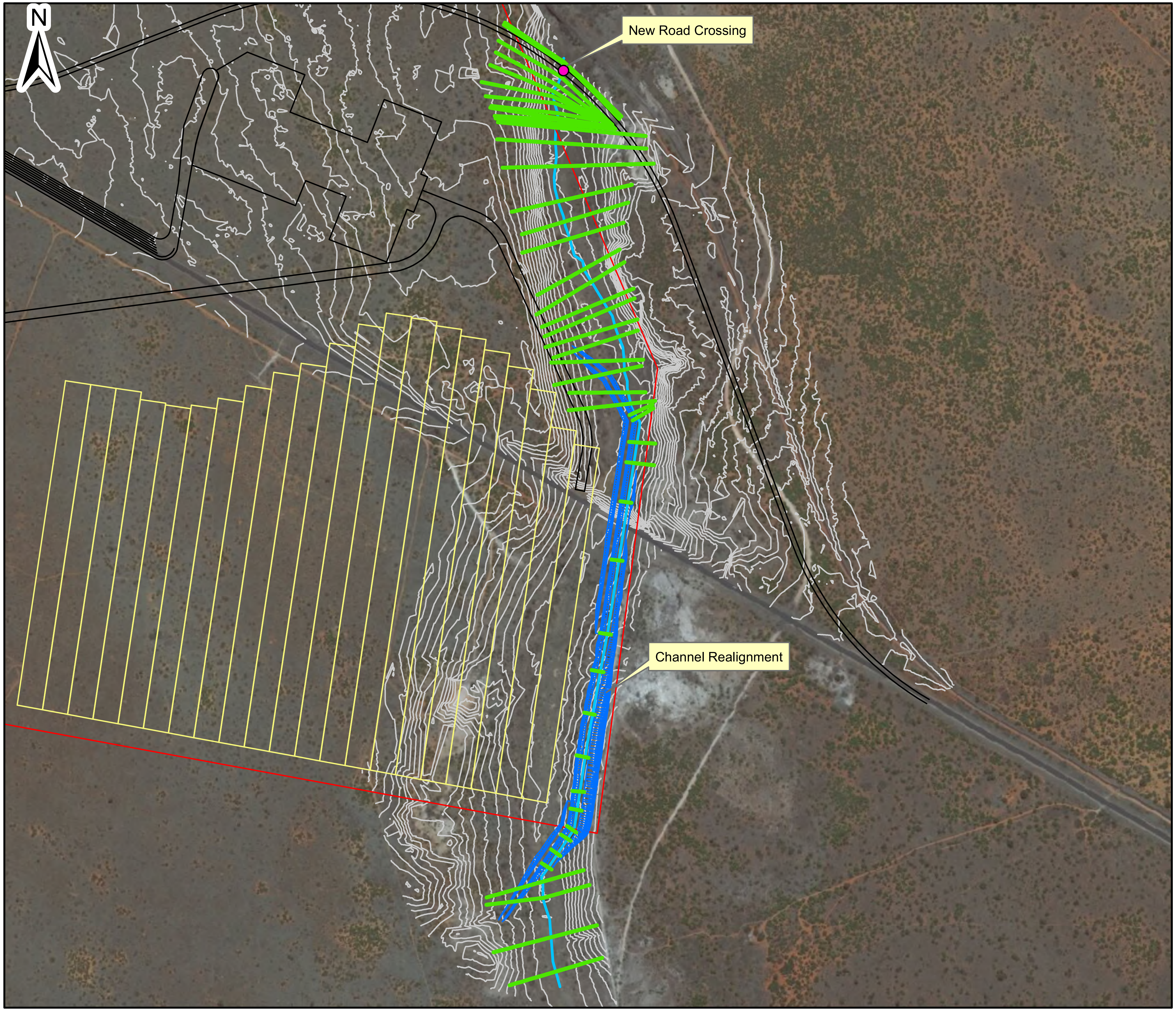
Figure 5.2

Model Extent and Setup (Pre-Development Scenario)

SLR

SLR Consulting (Africa) (Pty) Ltd
P O Box 1596, Cramerview, 2060, South Africa
Tel: +27 (11) 467-0945 Fax: +27 (11) 467-0978

720.09012.00005 | February 2015



Key

- Hydraulic Structure
- Cross Sections
- Pit Strips
- Channel Realignment
- Mine Infrastructure
- Property Boundary
- River
- Contours

0 100 200 300 Meters

Projection: Transverse Mercator
Datum: WGS 84

MOKALA SURFACE WATER STUDY

Figure 5.3

Model Extent and Setup (Post-Development Scenario including New Road Crossing and River DIversion)

SLR

SLR Consulting (Africa) (Pty) Ltd
P O Box 1596, Cramerview, 2060, South Africa
Tel: +27 (11) 467-0945 Fax: +27 (11) 467-0978

720.09012.00005

February 2015

5.3 CONCLUSIONS AND RECOMMENDATIONS

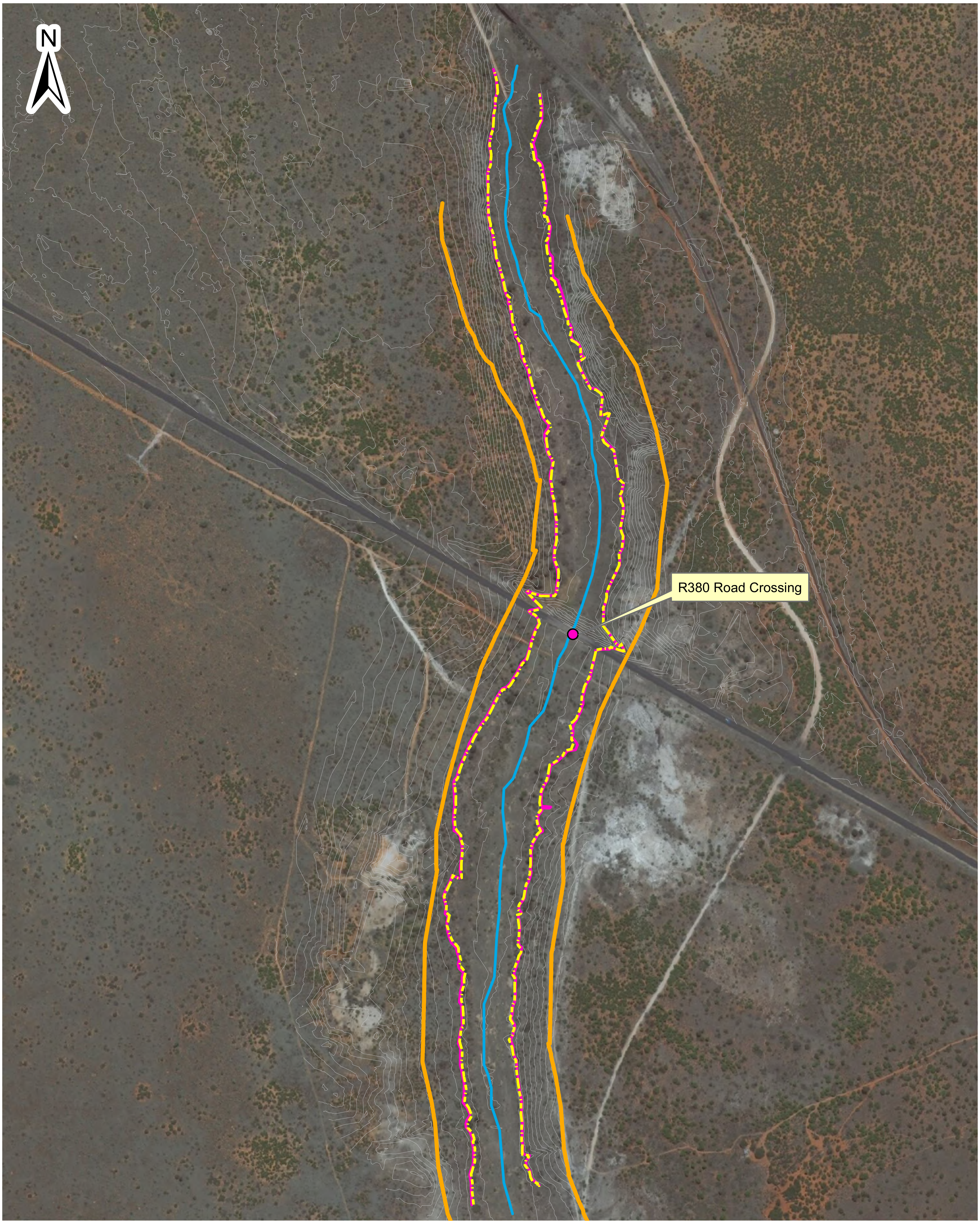
The modelling generated the flood lines shown in Figure 5-4 for the base line scenario and those shown in Figure 5-5 for the developed scenario. It can be seen that the flood lines with a 1:100 annual exceedance probability are within the river channel 100 m buffer. The 100 m buffer will therefore apply in terms of the GN704 regulations. It is noted that the 1:100 and 1:50 flood lines are close together. This is caused by the wide flat river bed where only a small increase in water elevation will result in a large increase in flow conveyance.

The key results of modelling the temporary channel realignment are presented in Table 5-3 below. This information was used to inform the conceptual design of the channel realignment. The modelling also showed that the proposed new R380 road crossing was not overtopped by a flood event having a 1:50 annual exceedance probability showing its compliance with the design requirement of having at least a 1:25 annual exceedance probability of being overtopped.

TABLE 5-3: CHANNEL REALIGNMENT MODELLING RESULTS

Annual Exceedance Probability	Flood Flows (m^3/s) (Section 4.8)	Freeboard from modelled water level to berm crest (m)	Areal average flow velocity (m/s)
1:200	**76**	**0.54**	**1.52**
1:100	**64**	**0.74**	**1.44**
1:50	**53**	**0.95**	**1.35**

The accuracy of the hydraulic flood modelling results are dependent on the flood flow estimates and the manning's values used in the modelling. The uncertainty in flood flow estimates could be improved by gathering additional data on any future flow events as recommended in Section 4.8. Until such data is gathered and analysed it is recommended that the uncertainty is managed by applying a 1 m freeboard to design flood levels. Data on flows in the river channel could also be used to calibrate the hydraulic model by altering the manning's roughness values. The impact on flood levels due to the uncertainty in the manning's values will be much less than the uncertainty in the flood flows.



KEY

- Hydraulic Structures
- 50 Year Flood Line
- 100 Year Flood Line
- 100m Buffer
- River
- Contours

0 100 200 300 Meters

Scale: 1:11000 @ A3

Projection: Transverse Mercator
Datum: WGS1984

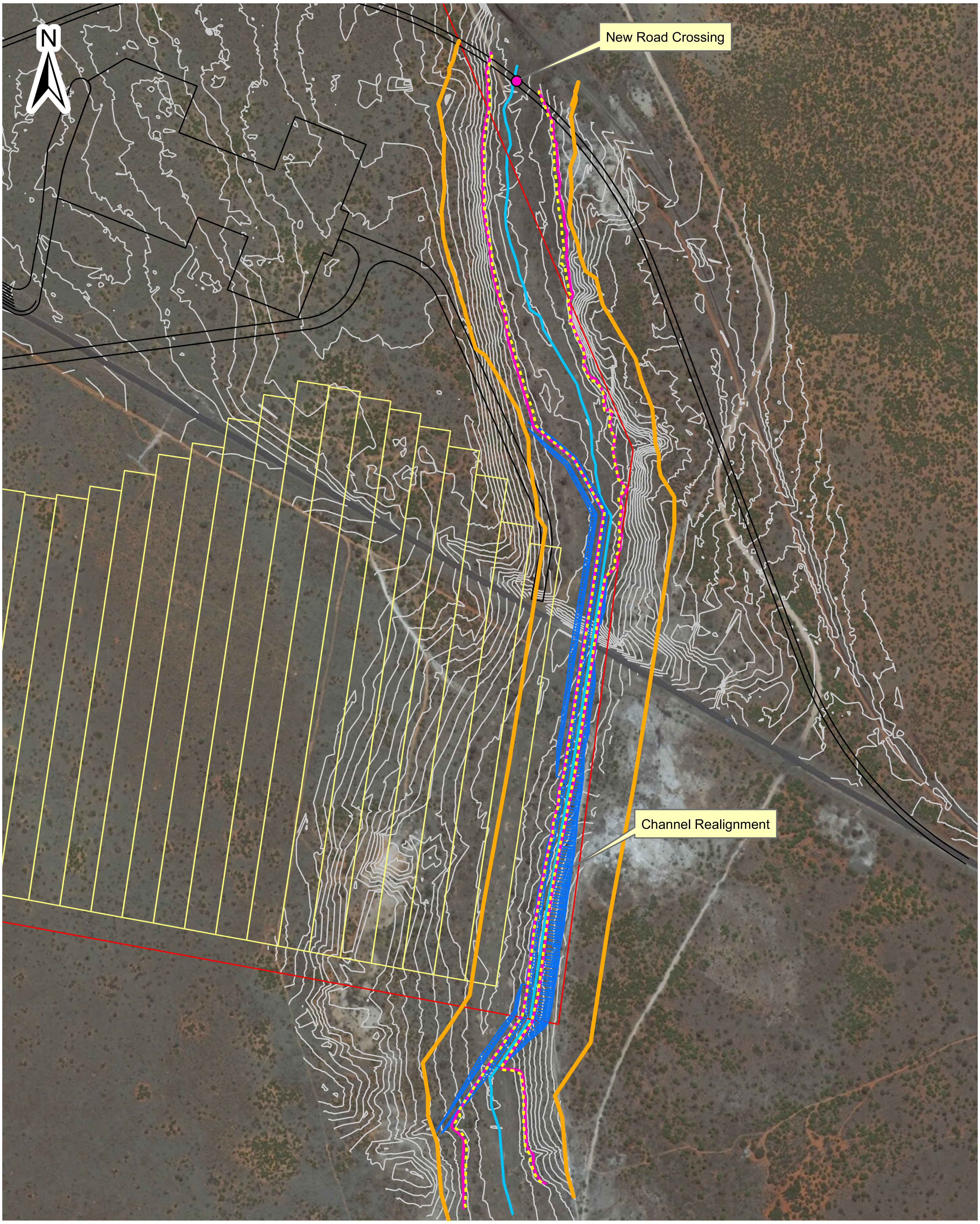
MOKALA SURFACE WATER STUDY

Figure 5.4

50 and 100 Year Flood Lines for Pre-Development Scenario

SLR
SLR Consulting (Africa) (Pty) Ltd
P O Box 1596, Cramerview, 2060, South Africa
Tel: +27 (11) 467-0945 Fax: +27 (11) 467-0978

720.09012.00005 | February 2015



KEY

- Hydraulic Structure
- 100m Buffer
- 50 Year Flood Line
- 100 Year Flood Line
- Pit Strips
- Channel Realignment
- Mine Infrastructure
- Property Boundary
- River
- Contours

0 100 200 300 Meters

Scale: 1:11000 @ A3

Projection: Transverse Mercator
Datum: WGS1984

MOKALA SURFACE WATER STUDY

Figure 5.5
50 and 100 Year Flood Lines for Post-Development Scenario (New Road Crossing and Channel Realignment)

SLR

SLR Consulting (Africa) (Pty) Ltd
P O Box 1596, Cramerview, 2060, South Africa
Tel: +27 (11) 467-0945 Fax: +27 (11) 467-0978

720.09012.00005 | February 2015

6 GA-MOGARA CHANNEL REALIGNMENT STRATEGY

6.1 INTRODUCTION

Mokala Manganese (Pty) Limited (Mokala) is planning to mine a Manganese ore body on the remaining extent of the farm Gloria 266, which is located adjacent to the Ga-Mogara River, an ephemeral tributary of the Kuruman River in the Lower Vaal Water Management Area (Quaternary Drainage Region D41). Mining will be carried out in an open pit that will be progressed in 50 m wide strips running parallel with the river channel, Figure 2-2. The first strip will be mined adjacent to the river with progressive strips being developed in a westerly direction away from the river. Mined strips will be backfilled with the overburden from subsequent strips, on a roll-over mining basis.

The Mokala Mine property boundary extends on to the eastern bank of the Ga-Mogara River. The Manganese ore body also extends across the river and beyond the Mokala Mine property boundary. Maximising access to the ore on the property requires extending the open pit rim within the Ga-Mogara River 100 m buffer and the river channel its self. If this is to happen it would be necessary to realign the river channel for a distance of 900 m. Two alternative options were considered when assessing the case for a channel realignment.

- No channel realignment - Mining is undertaken outside of the river's 100 m buffer.
- Channel Realignment (temporary and permanent) - The flow in the river is realigned from its natural course, over a distance of 900 m, by excavating a new channel into the eastern bank of the river. This will maximise access to the ore body on the property.

The conceptual level design of the channel realignment will be discussed in Section 6.3 to 6.6 followed by a motivation for the preferred option considering the environmental impacts and economic benefits in Section 6.7.

6.2 APPLICABLE LEGISLATION

Mining activities in the vicinity of a watercourse are to comply with the GN704 regulations issued by the Department of Water Affairs (DWA) under the NATIONAL WATER ACT, 1998. The following GN704 clauses relate to the Mokala open pit.

- Clause 4(b) – "*except in relation to a matter contemplated in regulation 10, carry on any underground or open cast mining, prospecting or any other operation or activity under or within the 1:50 year flood-line or within a horizontal distance of 100 meters from any watercourse or estuary, whichever is the greatest*;"

- Clause 5 – "*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 course.*"
- Clause 6(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*;"
- Clause 6(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 reoccurrence of 50 years*."
- Clause 10(1) – "*No person may –*
  - *a) extract sand, alluvial minerals or other materials from the channel of a watercourse or estuary, unless reasonable precautions are taken to-*
    - *i. ensure the stability of the watercourse or estuary is not affected by such operations;*
    - *ii. prevent scouring or erosion of the watercourse or estuary which may result from such operations or work incidental thereto;*
    - *iii. prevent damage to in-stream riparian habitat through erosion, sedimentation, alteration of vegetation or structure of the water course or estuary, or alteration of the flow characteristics of the watercourse or estuary; or*
  - b) *establish any slimes dam or settling pond within the 1:50 year flood-line or within a horizontal distance of 100 meters of any watercourse or estuary*."

As the proposed pit outline falls within the existing watercourse it does not comply with the requirements of Clause 4(b). Section 10 of GN704 is therefore taken to apply to the mining operations, with any diversion of the watercourse having to comply with Clause 10(1). With regard to the flooding of the pit with clean water, Clauses 6(b) and 6(f) are taken to apply, where this is required to be limited to a reoccurrence of 50 years on average.

6.3 DESIGN INFORMATION

6.3.1 DESIGN FLOOD FLOWS

The flood having an average reoccurrence interval of 50 years was estimated to have a discharge of 53 m^3/s in the flood study, Section 4.8. Due to the uncertainties in the estimation of the flood peak it was recommended that a 1m freeboard allowance is applied to the resulting water levels. The 1:200 year flood flow was estimated as 76 m^3/s, which hydraulic modelling (Section 5) has shown will result in a 0.5 m freeboard in the proposed realigned channel discussed below. Over the mine's 15 year life there is a 1 in 4 chance of an event less frequent than the 1:50 year occurring.

6.3.2 LOW FLOWS

To avoid altering the flow characteristics of the river any channel realignment needs to maintain the low flows in the river. The Ga-Mogara River is ephemeral, only flowing with a reoccurrence interval of around 13 years on average at the Mokala Mine site. Although there is no flowing water visible at the surface it was necessary to established whether there is a perennial flow of water beneath the river bed in the fluvial sediments. The following information sources were used to understand the subsurface flow conditions.

- Boreholes drilled on the property were used to develop a conceptual geological section through the river channel. Figure 6-1.
- River bed test pits undertaken on 14th April 2015, Appendix B.
- The soil specialist was consulted on evidence of a shallow water table from the river bed soil classification. (Terra Africa Environmental Consultants, July 2015)
- The ecology specialist was consulted on whether the ecosystem in the river channel was dependent on a shallow water table. (Ecological Management Services, August 2015)

10 test-pits were dug at 4 locations along the channel on centreline and approximately 30 m left and right of centreline using a TLB to a depth of 3 m. The soil horizons were profiled and sent to a laboratory for indicators, grading analysis and moisture contents. All horizons consisted of fine materials, with low moisture contents and no water table was intercepted. The findings of the test pits are summarised in Tables Table 6-1, Table 6-2 and Table 6-3 below.

TABLE 6-1 SUMMARY OF RIVER TEST PITS UNDERTAKEN ALONG THE WESTERN EDGE OF THE RIVER CHANNEL

Thickness	Description	Moisture Content %	% Passing the 0.425mm Sieve
300-600mm	Dry sandy Topsoil	6.50%	89.00%
1300-2500mm	Dry light coloured sand	-	-
400mm	Dry Pebble Layer with calcrete nodules	-	-

TABLE 6-2 SUMMARY OF RIVER TEST PITS UNDERTAKEN ALONG THE CENTRE OF THE RIVER CHANNEL

Thickness	Description	Moisture Content %	% Passing the 0.425mm Sieve
300-650mm	Dry to slightly moist in places sandy topsoil with Calcrete nodules	3.70%	99.00%
1050 - 1700mm	Brown to black stiff moist and in places dry clay becoming silty clay at WH 3 near R380 road	10.30%	81.00%
500 - 700mm	Pebbles with Calcrete Nodules	3.10%	98.00%

TABLE 6-3 SUMMARY OF RIVER TEST PITS UNDERTAKEN ALONG THE EASTERN EDGE OF THE RIVER CHANNEL

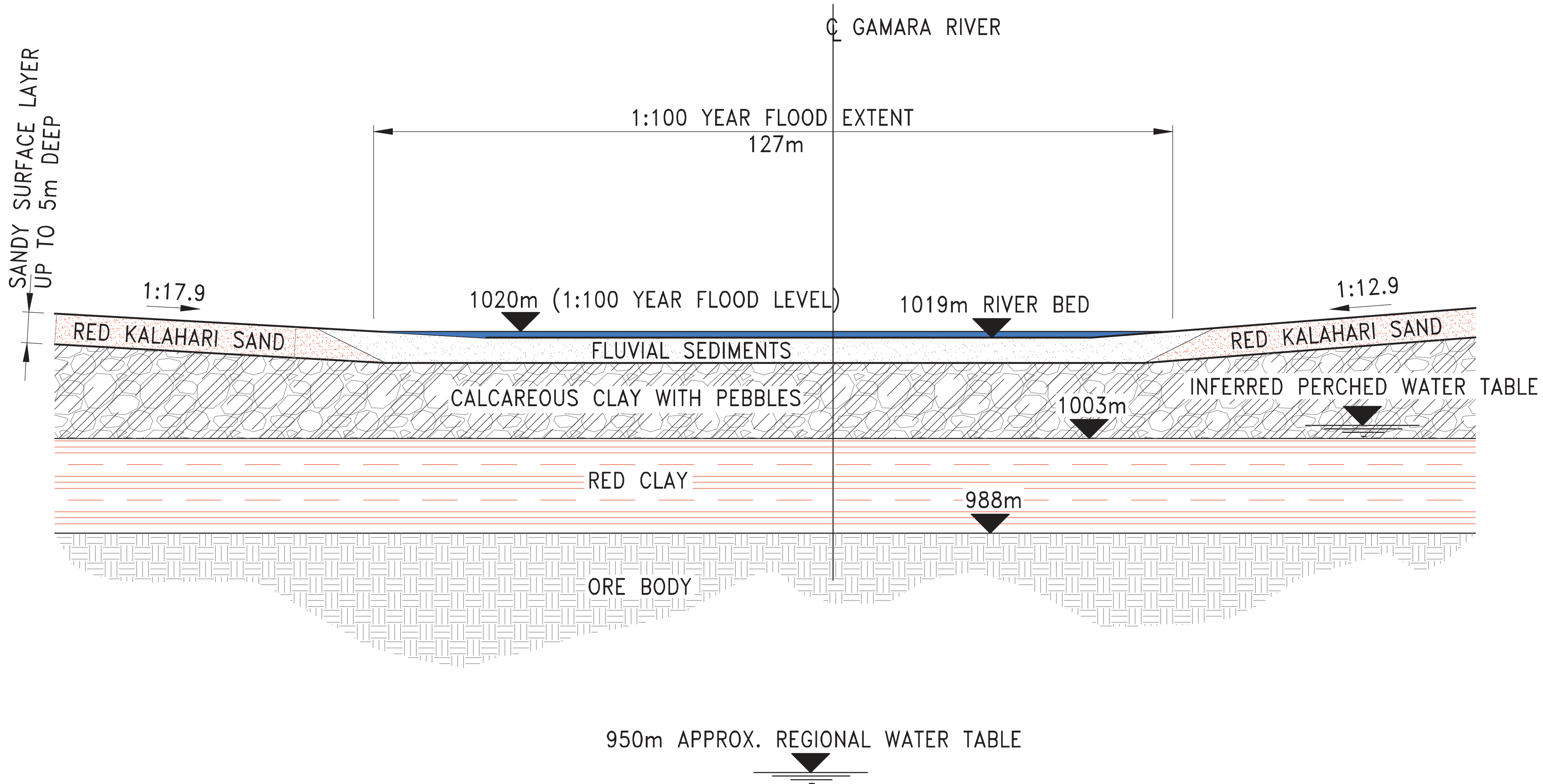
Thickness	Description	Moisture Content %	% Passing the 0.425mm Sieve
400-700mm	Dry Sandy Topsoil	6.80%	90.00%
1100-1700mm	Light Calcarious to silty sand in places, fine dry calcrete, silty sand with calcrete nodules and greyish stiff dry clay layer	5.25%	99.00%
200-800mm	Dry hard calcrete nodules in granular sand	-	-

A perched water table was identified at least 15 m beneath the river bed, the depth of which indicates that the river loses surface water flow to ground water as opposed to gaining water from a shallow water table. As there is no shallow water table beneath the river bed, and very flat river bed gradients of less than 0.17 %, it can be said that there is no significant subsurface flow in the river. This is supported by the classification of the soil in the river bed as Kinkelbos, which does not possess the characteristics of a wetland soil. In addition the ecologist did not find evidence of an ecosystem dependent on the presence of a perennial shallow water table. The dense grass cover in the river bed clearly stands out from the surrounding vegetation where shrubs and trees predominate. This can be explained by both the change in the substrate that makes up the river bed and the advantage grass has in accessing shallow soil moisture over shrubs and trees which are better at accessing deeper water sources.

It is hypothesised that the main source of flow in the Ga-Mogara River is the range of dolomitic hills in the upper reaches of the catchment, approximately 120 km upstream of the site. The remainder of the catchment will contribute relatively little to the surface flow in the river due to its flat terrain and deep sandy surface. During extended wet periods runoff from these dolomitic hills progressively fills both the subsurface and surface storage in the river channel, resulting in a wetting front that moves down stream.

As shown in the conceptual geological section, approximately 3 m of fluvial sediments is taken to overlay a thick layer of low permeability calcareous clay. Before flow in the river can be sustained the layer of fluvial sediments needs to be saturated. As the river bed forms a local depression, runoff and seepage from the surrounding slopes will play a part in wetting up the fluvial sediments. During extended wet periods the water balance in the sediments may result in their saturation facilitating the passage of flow from upstream. During an average wet season the fluvial sediments will carry greater levels of moisture than the surrounding terrain but are unlikely to saturate due to the high evapotranspiration rate and seepage into the clay layers below.

It can therefore be said that if the seepage from the proposed channel realignment does not exceed that of the existing river channel there will be no adverse impact on low flows in the Ga-Mogara River from realigning the river channel. It has also been established that there is no perennial flow of water within the fluvial sediments that could be cut off by the realignment of the river channel. The channel realignment will therefore have no adverse impact on the quantity of water in the Ga-Mogara River passing the Mokala Mine site.



LEGEND:

1007m — DENOTES METERS ABOVE MEAN SEA LEVEL

SLR
Johannesburg Office
METAGO HOUSE
FOURWAYS MANOR OFFICE PARK
CORNER ROOS AND MACBETH STREETS
FOURWAYS
JOHANNESBURG, SOUTH AFRICA
T: +27 (11) 467-0945
F: +27 (11) 467-0978
www.slrconsulting.com

MOKALA SURFACE WATER STUDY

CONCEPTUAL GEOLOGICAL SECTION THROUGH THE GAMAGARA RIVER AT THE MOKALA MINE SITE

Date : OCT 2015	Scale : 1:1000
Project No : 720.09012.00005	FIGURE 6-1

6.3.3 CONSTRAINTS ON CHANNEL DESIGN

The following constraints apply to the design of the channel realignment.

- The channel bed slope is to match that of the natural river channel.
- The channel edge is to be offset 10 m from the mine's eastern property boundary to allow access along the boundary line.
- The mining operation requires a 40 m offset from the top edge of the proposed open pit and the channel realignment works extent.
- The above constraints give a 48 m wide corridor within which to construct the channel realignment works and flood protection berm.

Due to the constrained site the new channel will need to be significantly narrower than the natural river channel. This will have the following implications:

- The channel will need to be straight, with a regular cross section, and free of vegetation to achieve the required conveyance.
- The narrower channel will result in higher flow velocities resulting in the need for engineered erosion protection measures.
- Being an engineered channel there will be an ongoing maintenance requirement after mine closure.

To avoid an ongoing maintenance liability the channel realignment needs to closely match the existing river channel shape, morphology, soils and vegetation. It is therefore proposed to construct a temporary engineered channel to allow the mining of the ore within the river's 100 m buffer. After a period of approximately 3 years the open pit adjacent to the river will have been backfilled removing the need for the 40 m offset between the pit edge and the channel realignment works. The additional space will then allow a permanent channel realignment to be constructed that closely matches the existing river channel.

6.3.4 TOPOGRAPHY

The design was undertaken using a topographic survey of the site from which 0.5 m contours had been generated. The channel realignment was located with reference to the proposed Mokala open pit outline and the property boundary.

6.3.5 GROUND CONDITIONS

The ground conditions that could be encountered along the proposed channel realignment were inferred from exploratory boreholes drilled on the site as well as from surface features observed during a site visit (26th August 2014).

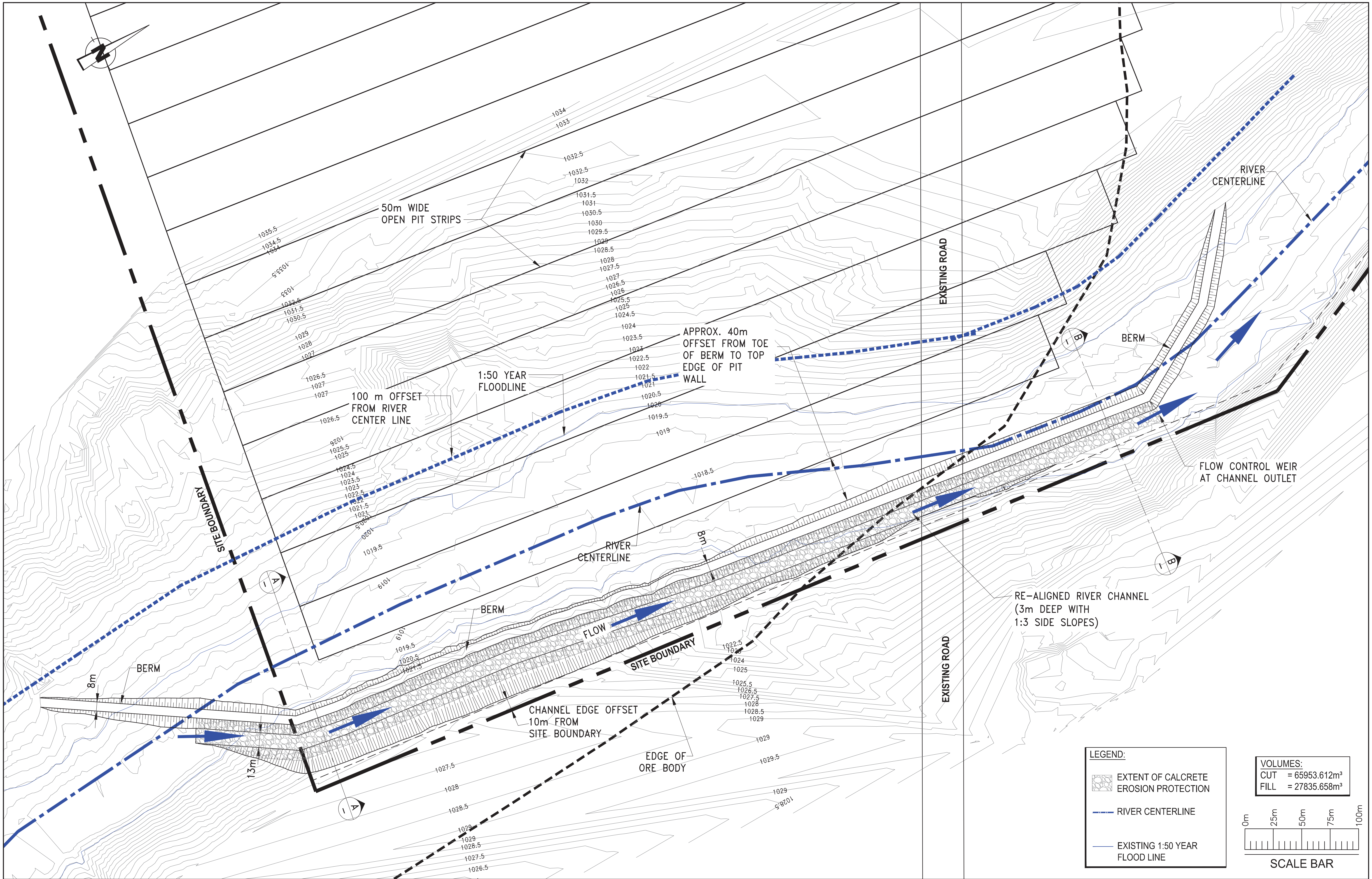
The bed and banks of the Ga-Mogara River consist of a layer of fluvial sediments up to 3 m thick overlaying calcrete and calcareous clay. From site observations and the relatively steep topography the calcrete appears to outcrop along the eastern bank of the Ga-Mogara River.

The proposed channel realignment will require the excavation of the eastern bank of the Ga-Mogara River where there is evidence of a calcrete outcrop.

6.4 DESIGN LIFE

As discussed in Section 6.3.3 above it is proposed to construct a temporary engineered channel realignment for approximately the first 3 years of the mining operation after which a permanent channel will be constructed closely matching the existing river channel shape, morphology, soils and vegetation.

The design and construction of the temporary channel is governed by the requirement to convey the design flows without failure as opposed to its long term integrity. Assuming the existing river channel morphology has reached equilibrium with the encountered flow regime, replicating this in the permanent channel realignment will result in a robust design that is likely to have a life in excess of 100 years without maintenance. Once the permanent channel realignment is constructed Mokala will have the remaining 12 years if the mining operation to ensure the natural vegetation establishes adequately. Taking the chance of a flow event occurring in any given year as 1:13 there is a 62% probability of a flow event occurring in the permanently realigned river channel during the remaining 12 years of the mining operation.



SLR
Johannesburg Office
METAGO HOUSE
FOURWAYS MANOR OFFICE PARK
CORNER ROOS AND MACBETH STREETS
FOURWAYS
JOHANNESBURG, SOUTH AFRICA
T: +27 (11) 467-0945
F: +27 (11) 467-0978
www.slrconsulting.com

MOKALA SURFACE WATER STUDY

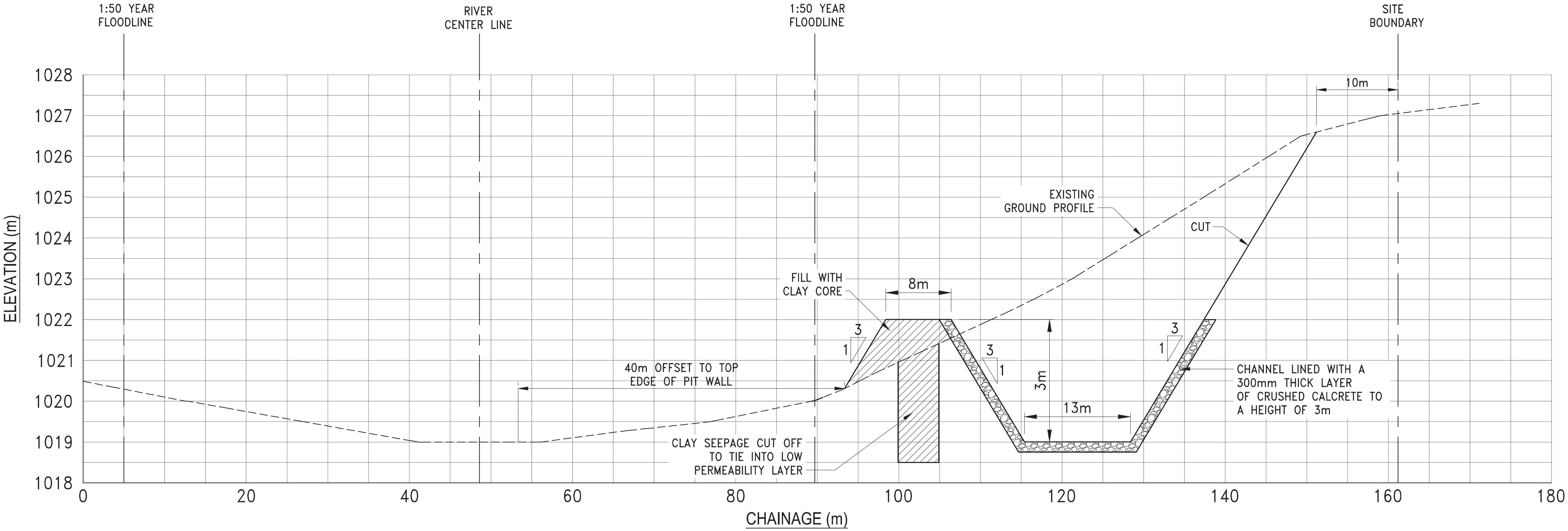
PLAN ON TEMPORARY CHANNEL RE-ALIGNMENT

Date : OCT 2015

Scale : 1 : 3 000

Project No : 720.09012.00005

FIGURE 6 -2



SECTION A-A

SCALE:
HORIZONTAL = 1:500
VERTICAL = 1:100

SLR
Johannesburg Office
METAGO HOUSE
FOURWAYS MANOR OFFICE PARK
CORNER ROOS AND MACBETH STREETS
FOURWAYS
JOHANNESBURG, SOUTH AFRICA
T: +27 (11) 467-0945
F: +27 (11) 467-0978
www.slrconsulting.com

MOKALA SURFACE WATER STUDY

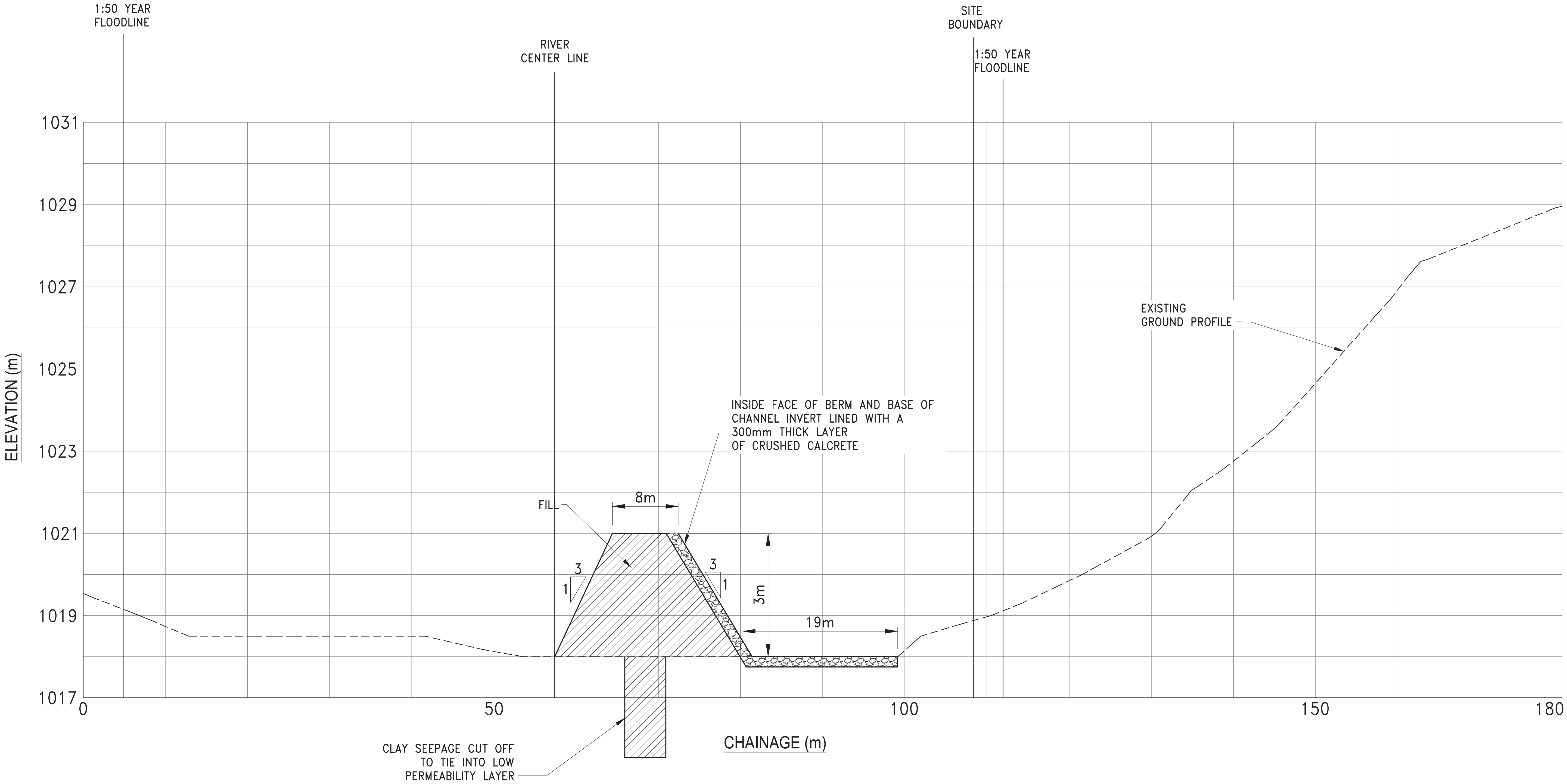
SECTION A-A ON TEMPORARY CHANNEL RE-ALIGNMENT

Date : OCT 2015

Scale : AS SHOWN

Project No : 720.09012.00005

FIGURE 6-3



SECTION B-B

SCALE:
HORIZONTAL = 1:500
VERTICAL = 1:100

SLR
Johannesburg Office
METAGO HOUSE
FOURWAYS MANOR OFFICE PARK
CORNER ROOS AND MACBETH STREETS
FOURWAYS
JOHANNESBURG, SOUTH AFRICA
T: +27 (11) 467-0945
F: +27 (11) 467-0978
www.slrconsulting.com

MOKALA SURFACE WATER STUDY

SECTION B-B ON TEMPORARY CHANNEL RE-ALIGNMENT

Date : OCT 2015

Scale : AS SHOWN

Project No : 720.09012.00005

FIGURE 6-4

6.5 TEMPORARY CHANNEL REALIGNMENT DESIGN

A conceptual plan and section of the proposed channel realignment are presented in Figure 6-2, Figure 6-3 and Figure 6-4. The river channel is to be realigned along the eastern boundary of the Mokala mine site to maximise access to the ore body on the property. The channel realignment berm ties into the western bank of the Ga-Mogara River at both the upstream and downstream ends. Mokala Mine requested that the upstream end of the channel realignment be extended beyond the property boundary. It is understood that Mokala have agreed this with the adjacent land owner. As a result of the channel realignment the river will be realigned from its natural course over a distance of 900 m.

6.5.1 HYDRAULICS

Manning's equation was used to size the channel realignment for the 53 m^3/s (1:50 year) design flow and 1m freeboard requirement. A Manning's number of 0.034 was used to represent the channel roughness, being applicable to natural straight streams with no rifts or deep pools, or stone lined artificial channels where flow depths are between 1 and 2m deep. Assuming a steady flow regime to be acting the resulting flow in the channel has an average velocity of 1.35 m/s and is subcritical.

The realigned channel has a constant bed slope of 0.17 % starting and ending at the same level as that of the existing river bed. The channel depth is therefore a function of the existing channel bed and the ground profile through which it traverses. The capacity of the realigned channel can therefore only be altered by changing the base width and side slope gradient. Taking the channel side slopes to be 1:3, a 13 m base width is required to convey the design flow within a minimum 3 m deep channel. Modelling showed that the 76 m^3/s 1:200 year flood would be conveyed by the channel with a 0.5 m freeboard.

6.5.2 EROSION PROTECTION

Changing the existing channel section, which has an approximate base width of 50 m and 1:18 side slopes, to a section with only a 13 m base width and 1:3 side slopes increases the design flow average velocity from 1 m/s to 1.35 m/s. This is because reducing the available flow area requires an increase in flow depth and velocity to achieve the same conveyance capacity. If the current river morphology is taken to be in equilibrium with the experienced flow regime any changes to the flow regime will result in the channel morphology wanting to change to a new equilibrium position. Therefore to ensure the diversion channel maintains its geometry it needs to be constructed to withstand these erosional forces.

An assessment was made of the diameter of non-cohesive particles that would just resist lifting off the channel bed and sides when subject to the design flow regime in the realigned channel. This was undertaken using the Shields parameters as recommended in the SANRAL Drainage Manual 6th

Edition. In the equations the particle density was taken to be 2.65 tonnes/m^3, typical of clacrete. The resulting particle diameter needs to be exceeded by 50% of the particles in the grading curve. The channel side slopes were taken as 1:3. The equations give the limiting particle diameter as 30mm for the channel bed and 35mm for the channel side slopes. A possible material for the channel erosion protection layer could be crushed calcrete, excavated from the river channel and pit.

Where the realigned channel re-enters the existing river channel the different water surface elevations will locally accelerate the flows increasing the risk of localised channel erosion. It is therefore proposed to install a low weir to constrain the water level change to a restricted channel where enhanced erosion protection measures can be provided. Such a weir could be constructed from large blocks of solid stone arising from the mining operation or smaller stone in gabion baskets.

To minimise erosion associated with turbulence the realigned channel inlets and outlets have been aligned with the existing channel flow directions and any channel direction changes are carried out over gradual curves.

6.5.3 CONSTRUCTION

As the channel is to be excavated out of the eastern bank of the river it is likely to pass through a substantial calcrete outcrop and so may require blasting. To prevent seepage from the channel into the adjacent pit a clay cut off will be installed along the western edge of the realigned channel. This will be deep enough to tie into the low permeability clay and calcrete layers beneath the fluvial sediments. Berms will be required where the realigned channel ties into the existing river channel. These will be constructed from suitable excavated material with an impermeable clay core. An 8 m wide access track will run along the western edge of the realigned channel and on the top of the berms.

6.6 PERMANENT CHANNEL REALIGNMENT

A conceptual section on the proposed temporary and permanent channel realignments are shown in Figure 6-5 and Figure 6-6 below. Once the section of the pit adjacent to the river channel has been backfilled an additional 40 m width will be available to form the permanent channel realignment giving an overall channel width of approximately 80 m. Backfilling the pit with clay overburden will create a thick water impermeable barrier preventing seepage into the pit. Overfilling that part of the pit adjacent to the channel will ensure that the finished ground level remains proud of the river bed after consolidation of the fill has occurred. In effect a wide low clay berm will form the western bank of the permanent channel realignment.

Increasing the width of the channel enables the required conveyance to be achieved without significantly increasing the flow velocities above that experienced in the existing river channel. Maintaining the same flow regime as the existing river channel allows the use of the natural fluvial sediments without risk of damage to the channel from erosional forces. The greater conveyance capacity of the channel will also allow the reintroduction of natural vegetation without adverse effects on flood levels. Within the greater available width the natural morphology of the existing channel can also be replicated, including a low flow channel, pools and curvature in plan.

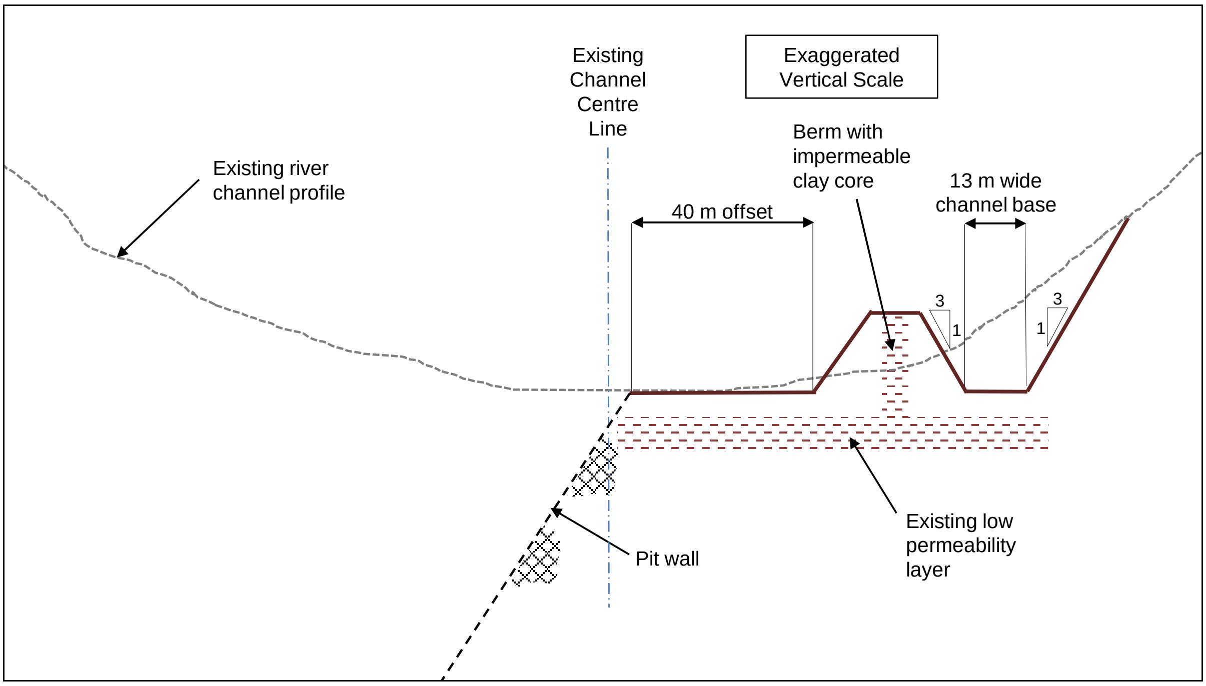


FIGURE 6-5 CONCEPTUAL SECTION ON TEMPORARY CHANNEL REALIGNMENT

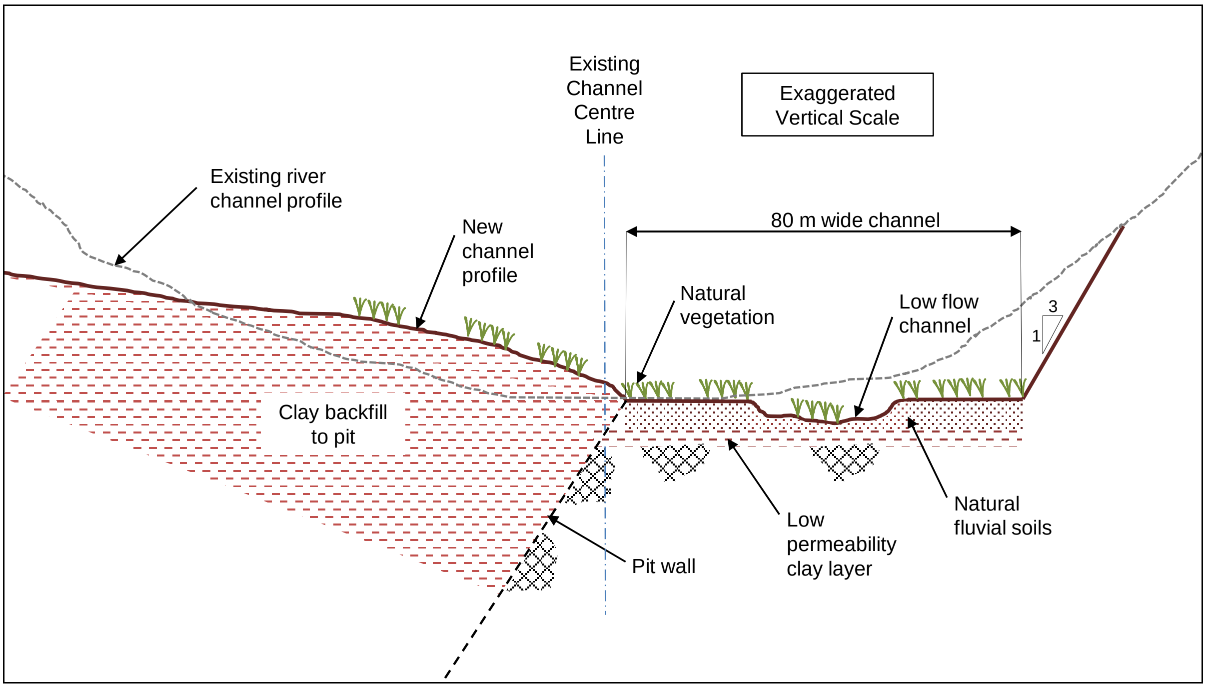


FIGURE 6-6 CONCEPTUAL SECTION ON PERMANENT CHANNEL REALIGNMENT

6.7 ECONOMIC AND ENVIRONMENTAL APPRAISAL

A financial appraisal undertaken by the Mokala Manganese (Pty) Limited has shown that the mine will not be viable if the pit extent is restricted to being outside of the river's 100 meter buffer as this will result in a loss of approximately 2 million tons of ore.

The environmental impacts of both the temporary and permanent channel realignment have been assessed using the methodology presented in Appendix C with the results summarised in Table 6-4 and Table 6-5. The criteria for which the mitigated impacts were assessed are discussed below.

It is noted that the Ga-Mogara river has only been recorded as flowing during 3 out of the past 40 years, and only during the wet season. There is also no evidence of a water table / perennial flow beneath the river bed or any associated fluvial ecology. Any works to realign the channel will therefore be carried out in a dry river bed negating the need to consider environmental impacts associated with working in a flowing river that sustains fluvial and riparian ecology.

6.7.1 TEMPORARY CHANNEL ENVIRONMENTAL IMPACTS (MITIGATED)

Loss of water from channel: It has been established that there is no perennial flow of water within the fluvial sediments that could be cut off by the channel realignment. By ensuring seepage from the proposed channel realignment does not exceed that of the existing river channel there will be no impact on the quantity of water passing the temporary channel realignment.

Loss of habitat: As the temporary channel realignment is an engineered channel the natural habitat on the effected reach of the river will be temporarily lost.

Alteration of the high flow characteristics: As the temporarily realigned channel has a smaller cross section than the existing river channel flood flows will be deeper and have higher velocities through the effected channel reach.

Scouring and erosion: The temporarily realigned channel will be designed to resist erosional forces over its design life of approximately 3 years. Any damage that does occur during its life will be repaired by the Mokala Mine.

Loss of natural land form: As the temporary channel realignment is an engineered channel the natural land form of the existing river channel will be temporarily lost.

TABLE 6-4 IMPACT ASSESSMENT FOR THE TEMPORARY CHANNEL REALIGNMENT

Impact	Severity / nature	Duration	Spatial scale / extent	Consequence	Probability of Occurrence	Significance
Loss of water from channel	L	L	L	L	L	L
Loss of habitat	H	L	L	M	H	M
Alteration of the high flow characteristics	H	L	L	M	H	M
Scouring and erosion	L	L	L	L	L	L
Loss of natural land form	H	L	L	M	H	M
H – High, M – Medium, L - Low						

6.7.2 PERMANENT CHANNEL ENVIRONMENTAL IMPACTS (MITIGATED)

Loss of water from channel:	It has been established that there is no perennial flow of water within the fluvial sediments that could be cut off by the channel realignment. By ensuring seepage from the proposed channel realignment does not exceed that of the existing river channel there will be no impact on the quantity of water passing the temporary channel realignment.
Loss of habitat:	The existing river bed soils will be conserved and used within the permanent channel realignment. Native flora will be re-introduced and maintained within the channel over the remaining 12 years of the mine's life.
Alteration of the high flow characteristics:	With the permanent channel realignment having a cross sectional area closely matching that of the existing river channel, flow depths and velocities will not be significantly different to those in the existing river channel.
Scouring and erosion:	The permanent channel realignment will be constructed to mimic the existing river channel thereby ensuring the erosion and sedimentation processes are close to an equilibrium position. During the first few flow events one would expect there to be some minor redistribution of fluvial sediments as the channel finds its natural equilibrium position.
Loss of natural land form:	The permanent river channel realignment will be constructed to mimic the natural river channel morphology as closely as possible including natural curvature in plan. There will therefore be minimal loss of the natural land form.

TABLE 6-5 IMPACT ASSESSMENT FOR THE PERMANENT CHANNEL REALIGNMENT

Impact	Severity / nature	Duration	Spatial scale / extent	Consequence	Probability of Occurrence	Significance
Loss of water from channel	L	H	L	M	L	L
Loss of habitat	L	H	L	M	L	L
Alteration of the high flow characteristics	L	H	L	M	L	L
Scouring and erosion	L	H	L	M	L	L
Loss of natural land form	L	H	L	M	L	L
H – High, M – Medium, L - Low						

6.8 CONCLUSIONS AND RECOMMENDATIONS

The Mokala Mine will not be feasible at start up without the ability to access the manganese ore beneath the Ga-Mogara 100 m buffer. To access the quantity of ore required the Ga-Mogara river channel will need to be realigned with a temporary engineered channel for approximately 3 years. Once the pit adjacent to the river channel has been backfilled a permanent channel realignment can be constructed that closely matches the existing river channel with regard to soils, ecology and fluvial morphology.

The temporary channel realignment will have a relatively high environmental impact but only for a short duration of 3 years and with a limited extent. The significance of its impact has therefore being classified as medium. It is then proposed to construct a permanent channel realignment, the impacts of which will be mitigated by replicating the existing river channel soils, ecology and fluvial morphology. The significance of the permanent channel realignment impacts have therefore been classified as low. It can also be said that by following the proposed channel realignment strategy Mokala Mine will have taken the reasonable precautions required by Clause 10(1) of GN704 (Section 6.2 above) when undertaking a mining activity within the channel of a watercourse.

On the basis that the long term environmental impacts of the proposed channel realignment strategy are low there is no reason as to why the activity should not be authorised. The channel realignment strategy along with the associated mitigation measures are to be included in the environmental authorisation for this activity as well as the project Environmental Management Programme (EMPr). There should be a requirement to monitor and encourage the successful re-establishment of the flora in the permanent river channel for the remainder of the life of the mine. If a flow event does occur during the life of the mine then the impact on the channel realignment should be assessed and any necessary repairs undertaken by the mine. Due to the rarity of flows in the river channel it is not feasible to monitor flows when they do occur. The permanent channel realignment is to be designed and constructed such that Mokala Manganese (Pty) Limited will have no maintenance liability after mine closure.

7 CONCEPTUAL STORM WATER MANAGEMENT PLAN

The proposed storm water management infrastructure for the project was developed by AECOM SA (Pty) Ltd and is presented at a conceptual level of detail in the Storm Water Management Report held in Appendix D. Drawing FE-005-503-110-100-001-P-00, presented in Annexure 2 of the report, gives the general layout of the storm water management infrastructure and the distinction between clean and dirty water catchments.

Storm water runoff from dirty water catchments is to be captured and retained such that it does not contaminate clean water resources in accordance with the requirements of GN704. The total area from which runoff is to be captured and managed on the mine, including the total footprint of the pit, amounts to 1.95 km^2. During the life of the mine this is the maximum area that will be associated with any loss of catchment runoff. Under Section 3.4.5 the total catchment area upstream of the mine site is given as 8 053 km^2, having a mean annual runoff (MAR) of 3.48 Mm^3. Prorating by area the Mokala Mine will result in a loss of 0.02% of MAR to the catchment. In reality the greatest proportion of the catchment runoff will come from the range of hills (Section 3.4.3) in the upper reaches of the catchment with very little resulting from the flat, sandy, terrain in the vicinity of the mine site. The actual loss to MAR caused by the Mokala Mine will therefore by much less than that calculated by prorating on area. It can therefore be said that the Mokala Mine’s impact on catchment runoff is negligible. The impact on stream flows in the Ga-Mogara River due to the proposed river channel realignment are discussed separately under Section 6.

8 SITE WIDE WATER BALANCE

8.1 INTRODUCTION

A 'wet' and 'dry' monthly water balance model has been developed to understand flows within the Mokala Mine's operational water circuit for a dry month (no rainfall, winter evaporation rate) and the wettest month of the year (February).

The water balance focuses on the fully developed mine, it is steady state and no consideration is given to changes in flows resulting from progressive development of infrastructure, climatic variability or changes in production rate, or storage (e.g. start-up water). Average monthly values for rainfall and evaporation rates are used in the model.

The water balance estimates the typical flows, and volumetric requirements of make-up water or availability of surplus water. The dry water balance will indicate the maximum amount of make-up water that could be required by the mine, while the wet water balance will show the maximum amount of surplus water that could be generated. As the mine has no inter seasonal storage capacity an annual average water balance has not been considered (the mine does not have the capacity to store significant quantities of surplus water from a wet period for use in a dry period).

The modelled water balance circuit includes water inflows, losses and transfers for the following aspects of the operation:

- Open Pit;
- Plant;
- Recycle Water Ponds (RWP);
- Sewage Treatment Plant;
- Administration Blocks, Workshop and Stores;

8.2 WATER QUALITY CLASSIFICATION

The separation of clean and dirty water is discussed in the Storm Water Management Report under Section 7. The mine's operational water circuit aims to ensure that dirty water is recycled and re-used within the mining operations in preference to abstracting and polluting clean water resources.

8.3 METHODOLOGY

A spreadsheet model was used to represent the flows within the operational water circuit using information obtained from the following sources:

- Flow Process Diagram, drawing number FE-004-403-110-100-001-P-01, held in Appendix E.

- Storm Water Management Report, report number 60330971-01, held in Appendix D.
- Storm Water Management Plan, drawing number FE-005-503-110-100-001-P-00, held in Appendix D.
- SLR Consulting (South Africa) (Pty) Ltd, Groundwater Assessment for the Proposed Mokala Manganese Project, October 2015. (Groundwater Report)

Water sources (inflows) were taken as:

- Groundwater ingress into the open pit.
- Rainfall runoff in the open pit;
- Potable water supply
- Rainfall runoff from dirty catchments which is conveyed to RWPs;
- Direct rainfall onto the RWP;
- Make up water.

Water sinks (losses) were taken as:

- Evaporation from surface area of RWP's.
- Losses from the sewerage treatment plant.
- Losses from the potable water distribution network.
- Dust suppression.
- Mining water losses.
- Wash down water losses.

Monthly rainfall and open water evaporation values were taken from Section 3 – Baseline Hydrology.

Average monthly runoff coefficients for the various land surface types on the mine were estimated using the Soil Conservation Services (SCS) rainfall runoff method applied to the daily rainfall time series from the Winton (392148 W) gauge. The SCS method Curve Numbers (CN-II) used in the analysis are given in **Error! Reference source not found.**. In this analysis CN values were fixed for average antecedent wetness conditions (AMC-II) as an average wet month is being considered in the water balance.

8.4 ASSUMPTIONS AND INPUT PARAMETERS

The water balance assumes the following:

- All infrastructures is fully developed, no consideration is given to changes in flows resulting from progressive development of infrastructure, variations in climate, changes in production rate or storage (e.g. start-up water).
- Due to the inherent uncertainty in estimating pit ground water inflows a minimum and maximum estimate is given in the Groundwater Report, being 2.5 l/s and 5.1 l/s respectively.

The lower estimate is applied to the ‘dry’ water balance while the upper estimate is applied to the ‘wet’ water balance to give a conservative range of flows. An evaporation rate is applied to 50% of the pit area open at any one time to account for evaporation of ground water inflows at the seepage face.

- No rainfall is applied for the ‘dry’ water balance while the average monthly value of 63.5 mm (February) is used for the ‘wet’ water balance.
- An average of the evaporation rates for June, July and August is used in the ‘dry’ water balance, being 97 mm, while the monthly average evaporation rate for February is used for the ‘wet’ water balance, being 185 mm.
- The area taken for the open pit is that for two strips, being the average of the strip lengths shown on the layout plan and a fixed 50 m width. Due to the use of the strip mining method only two strips will be open at any one time.
- No consideration is given to storage in the water balance, i.e. flow in = flow out.
- Pump testing undertaken as part of the groundwater study gave the best available yield for borehole GL27 as approximately 36 000 l/d. However long term pumping will result in the depletion of the groundwater resource. The cone of drawdown from pit dewatering has been shown not to significantly impact on the tested borehole. For the water balance it is assumed that there is only one borehole available for water supply with the stated yield capacity.
- Borehole water will have to be treated to potable standards with reverse osmosis (RO). The RO plant is taken to have a 75% recovery rate. Brine from the RO plant is to be directed to the RWP 4 (Ref.16).
- Ground water inflows to the pit will not be suitable for RO treatment due to the high suspended solids content.
- External water requirements will be supplied from the Vaal Ga-Mogara Water Supply Scheme.

The input parameters used for the water balance are presented in Table 8-1.

TABLE 8-1: WATER BALANCE INPUT PARAMETERS

Parameter	Description	Source
Mine water requirements	• Potable Water – 62 350 l/d • Mining Water Consumption – 40 000 l/d • Plant Dust Suppression – 49 396 l/d • Plant Wash Down – 961 l/d	• Flow Process Diagram, drawing number FE-004-403-110-100-001-P-01
Dirty water catchment areas	• RWP 1 (Ref. 13) o Plant area / roads - 11.6 ha o Natural ground – 3.6 ha • RWP 2 (Ref. 14) o Gravel haul road – 4.0 ha o Open pit – 7.5 ha o Overburden stockpile – 18.3 ha • RWP 3 (Ref. 15) o Tar road – 2.1 ha o Natural ground – 0.9 ha • RWP 4 (Ref. 16) o Mine offices – 5.0 ha o Natural ground – 0.8 ha	• Catchment areas measured from the Storm Water Management Plan, drawing number FE-005-503-110-100-001-P-00
Recycle Water Pond surface areas	• RWP 1 – 2 655.6 m^2 • RWP 2 – 6 822.0 m^2 • RWP 3 – 480.7 m^2 • RWP 4 – 1 144.6 m^2	• Areas measured from the Storm Water Management Plan, drawing number FE-005-503-110-100-001-P-00
Open pit groundwater inflows	• Lower estimate 2.5 l/s • Upper estimate 5.1 l/s	• Groundwater Assessment for the Proposed Mokala Manganese Project, October 2015
Average monthly runoff coefficients (W - denotes Wet Month, D - denotes Dry Month)	• Plant area, gravel roads, open pit and overburden stockpile – W(0.13)/D(0.06) • Tar roads and mine offices – W(0.73)/D(0.64) • Natural ground (Deep sand with grass cover) – W(0.0)/D(0.0)	• Section 8.3 - Methodology

8.5 CONCLUSIONS

The dry and wet water balances are presented in Figure 8-1 and Figure 8-2 below.

The dry water balance indicates that the Vaal Ga-Mogara Water Supply Scheme will be required to supply potable water to the site, in the order of 1 075 m^3/month, during dry periods. There will be no need to import plant makeup water due to the availability of pit ground water inflows and the recycling of the waste water treatment plant (WWTP) effluent. As the plant recycles its water internally its actual daily water use is only that which is required to replaces any losses and not the stated mining water consumption of 40 000 l/d. There will be an excess of 2 882 m^3/month available from RWP 2 (Ref.14) for use as dust suppression on the mine roads and overburden stockpile.

As pit groundwater inflows and storm water are not going to be treated for potable water use the wet water balance also requires potable water to be imported from the Vaal Ga-Mogara Water Supply

Scheme. With respect to the supply of potable water there is therefore no difference between the dry and wet water balance results. The wet water balance does however result in a total of 9 344 m^3/month of storm water entering the four RWP during an average wet month (February). This results in 14 116 m^3/month of excess water, which will be disposed of by spraying onto the overburden stockpile and mine roads. A more detailed look at quantifying the excess water resulting from storm water inflows is given under Section 9.

The water balance therefore shows that during both wet and dry periods the mine will rely on the Vaal Ga-Mogara Water Supply Scheme for the supply of potable water. It is recommended that further investigation is undertaken to give more certainty to the yield of any water supply boreholes drilled on the site such that the extent to which the mine will rely on external water sources can be more accurately quantified. Further work could also be undertaken to look at collecting and treating pit ground water inflows to a potable standard.

All though the dry water balance indicates that no external plant makeup water will be required during dry periods, there is a high degree of uncertainty around the pit ground water inflows. The mine should therefore plan for replacing the 2 941 m^3/month of water sourced from the pit from the Vaal Ga-Mogara Water Supply Scheme. The recycled water used by the Plant will require replacing with fresh water from time to time.

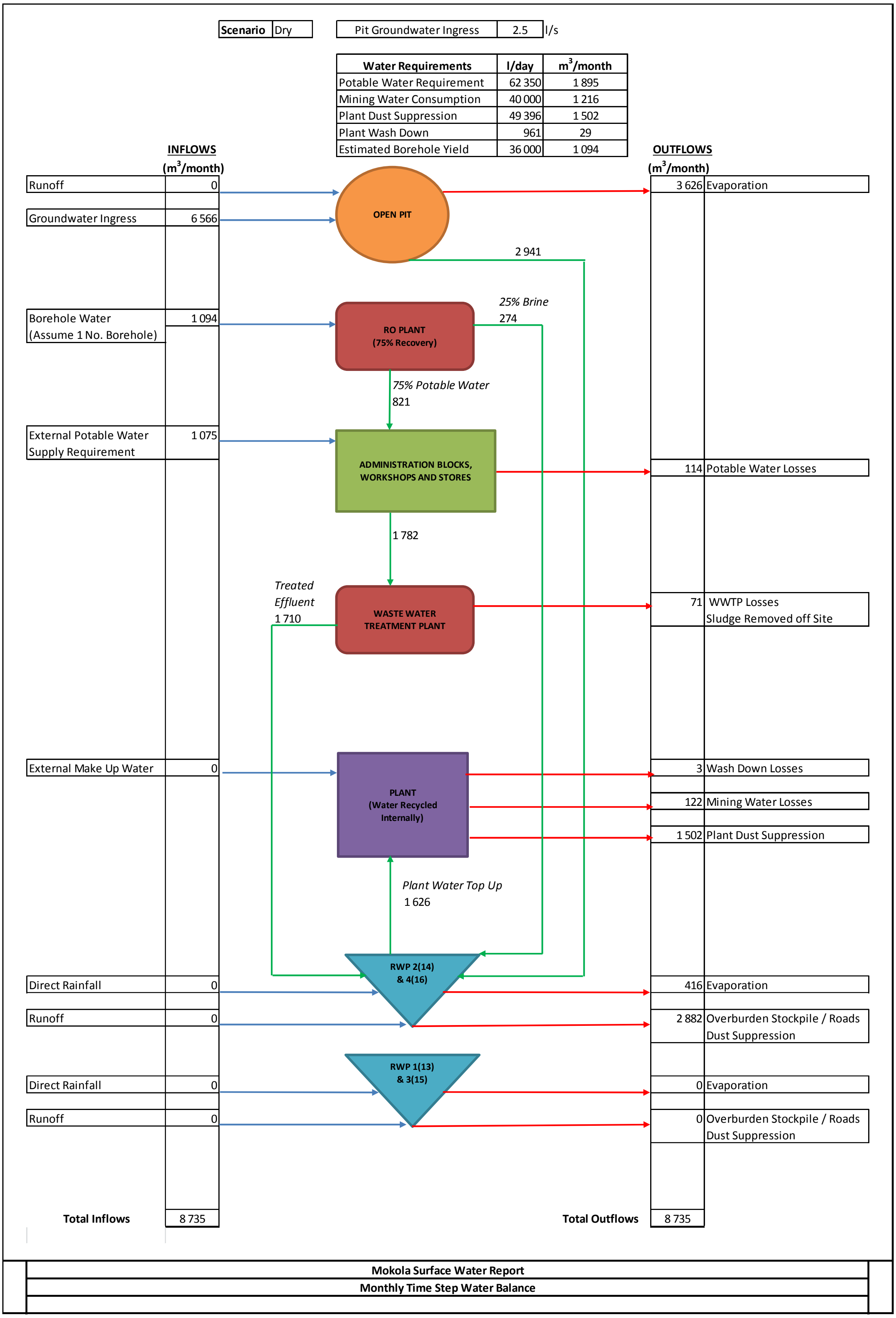
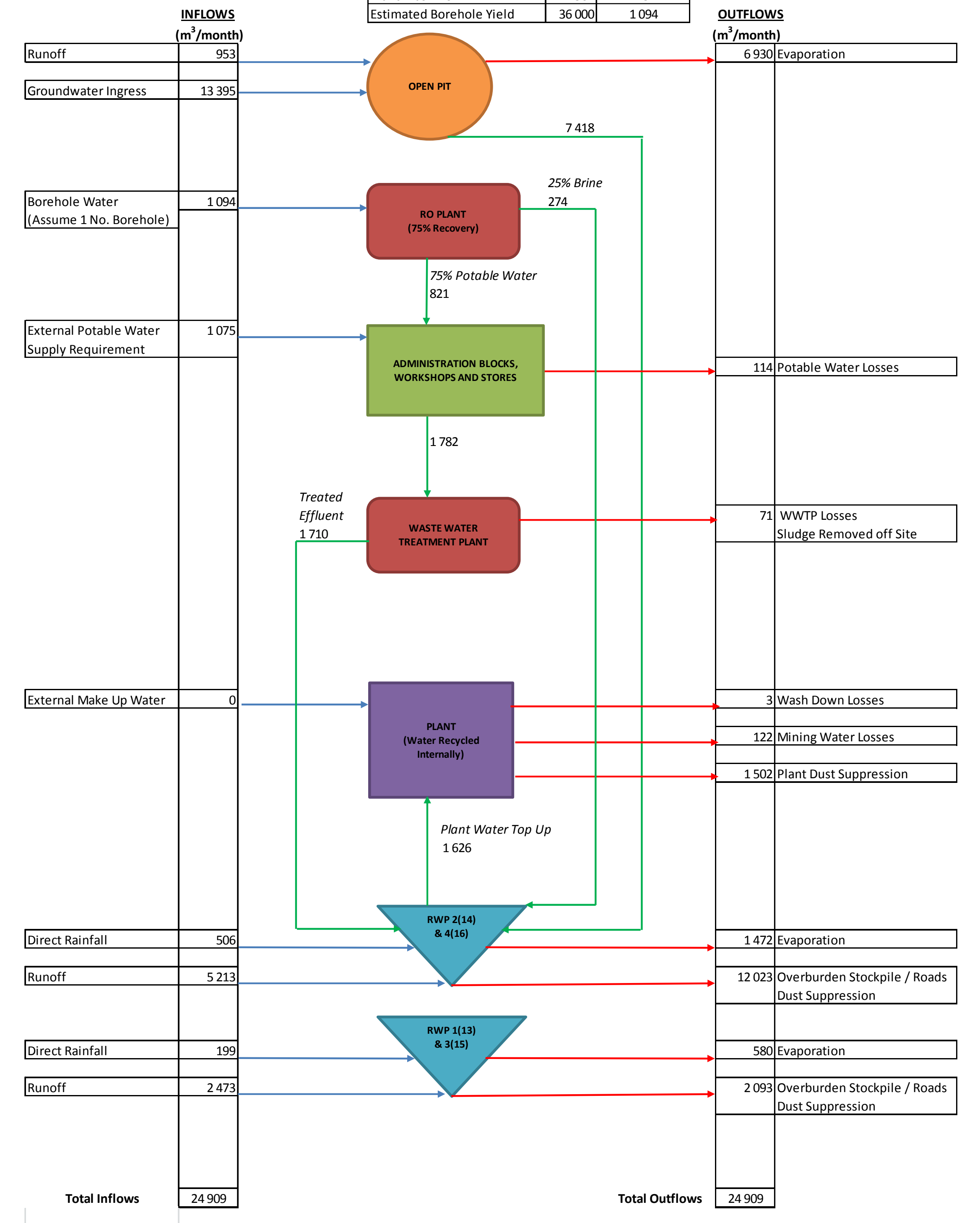


FIGURE 8-1 DRY WATER BALANCE

Scenario	Wet

Pit Groundwater Ingress	5.1	l/s

Water Requirements	l/day	m^3/month
Potable Water Requirement	62 350	1 895
Mining Water Consumption	40 000	1 216
Plant Dust Suppression	49 396	1 502
Plant Wash Down	961	29
Estimated Borehole Yield	36 000	1 094



Mokola Surface Water Report

Monthly Time Step Water Balance

FIGURE 8-2: WET WATER BALANCE

9 DAILY TIME STEP STORM WATER MODELLING

9.1 INTRODUCTION

AECOM SA (Pty) Ltd have produced a conceptual design of the Mokala Mine storm water management infrastructure presented in Appendix D. As part of this a number of recycle water ponds (RWP) have been included for capturing storm water runoff from catchments classified as 'dirty' to control the risk of dirty water mixing with clean water. The RWP therefore function as pollution control dams (PCD) in terms of the applicable legislation. The purpose of this section is to demonstrate that the RWP comply with the applicable legislation by applying daily time step storm water modelling methods.

9.2 APPLICABLE LEGISLATION

The design and management of pollution control dams (PCD) is to be undertaken in accordance with the GN704 regulations issued by the Department of Water and Sanitation (DWS) under the NATIONAL WATER ACT, 1998. The following clause (6(d)) in GN704 relates to the design of PCDs.

"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;"

Further guidance on this requirement can be gained from the DWS document 'Best Practice Guidance for Water Resource protection in the South African Mining Industry (BPG) – Pollution Control Dams, Section 6.4.3'. In this document it defines the allowable PCD spillage frequency as being a spill every 50 years on average. This is equivalent to stating that a PCD should be designed such that there is less than a 1 in 50 chance of a spill occurring in any given year. In addition to this, the document recommends the following:

- *"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 reuse 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 storm water 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, rather prolonged wet conditions."*

9.3 MODELLING INPUT DATA

The parameters of the proposed RWP and their associated storm water catchments are presented in **Error! Reference source not found.** and **Error! Reference source not found.** below.

TABLE 9-1: RECYCLE WATER POND PARAMETERS

Recycle Water Pond	Volume (m^3)	Nominal depth (m)	Area (m^2)
RWP 1 (Ref.13)	7 966.7	3	2 655.6
RWP 2 (Ref.14)	20 466.1	3	6 822.0
RWP 3 (Ref.15)	1 442.2	3	480.7
RWP 4 (Ref.16)	3 433.9	3	1 144.6
Totals	**33 309.0**	**-**	**11 103.0**

TABLE 9-2: STORM WATER CATCHMENT PARAMETERS

Recycle Water Pond	Catchment	Catchment Area (ha)	Allocated CN(II) Value
RWP 1 (Ref.13)	Plant area / gravel roads	11.6	76
	Natural ground	3.6	Insignificant runoff
RWP 2 (Ref.14)	Gravel haul road	4.0	76
	Open pit	7.5	76
	Overburden stockpile	18.3	76
RWP 3 (Ref.15)	Tar road	2.1	98
	Natural ground	0.9	Insignificant runoff
RWP 4 (Ref.16)	Mine offices	5.0	98
	Natural ground	0.8	Insignificant runoff

The RWP catchment areas were measured from the Storm Water Management Plan held in Appendix D. SCS Curve Numbers for average antecedent wetness conditions (CN(II)) were allocated to the different catchment surface types with reference to Table 3E.3 of the SANRAL Drainage Manual 6th Edition. Due to the deep sandy soils of the undisturbed natural ground storm water runoff will be relatively insignificant. Any runoff from those areas is also likely to pond and infiltrate before entering the storm water drainage infrastructure. The climate data used for the model was the 74-year Winton (0392148 W) daily rainfall record and the WR2005 evaporation data presented in Table 3-5.

9.4 METHODOLOGY

Daily time step storm water modelling is undertaken using the software package GoldSim. The SCS method is used to calculate the portion of the rainfall that contributes to runoff for each of the catchment surface types. A soil water budgeting procedure is used to vary the SCS CN(II) value in accordance with the antecedent catchment moisture conditions. The storm water reports to the RWP where a daily balance is calculated for water in storage, evaporation, abstractions and spills. The model is run over the 74 year rainfall time series and the frequency of spills from the RWPs analysed.

For this level of study the model was simplified by treating all four RWPs as one pond having a total storm water storage volume of 33 309.0 m^3, a nominal depth of 3 m and a surface area of 11 103.0 m^2. The following assumptions were made on how the RWPs are operated.

- It is assumed that all dry weather flows entering the RWPs are abstracted at a rate matching the inflow rate. The RWP storage is therefore reserved for the attenuation of storm water inflows and not the storage of water for later use.
- To operate the RWPs efficiently abstraction of storm water from the RWPs needs to occur whenever there is storm water in storage.
- It is assumed that the mine will abstract water from the RWPs at a peak rate matching the excess water generated during the ‘wet’ monthly water balance. This water will be sprayed onto the mine roads, ore stockpiles and overburden stockpile to control dust. From Figure 8-2 the total monthly quantity of excess water generated at the RWPs is 14 116 m^3/month for the wet water balance of which 5 351 m^3/month is associated with dry weather flow. The quantity to be abstracted that is associated with storm water is therefore 8 765 m^3/month which is equivalent to 288 322 l/day or 3.34 l/s.
- Silt traps will prevent the majority of sediment form entering the RWPs. Where finer material collects in the RWPs it will be regularly removed to maintain the stated storm water attenuation capacity is always available.

9.5 MODELLING RESULTS

The General Extreme Value distribution with probability weighted moment estimators was fitted to the total annual maximum daily runoff volumes generated by the model as presented in Figure 9-1. This enabled the 24 hour runoff volume having a 1:50 annual exceedance probability to be estimated as 33 309 m^3. The RWPs have been sized in order to capture this volume of runoff.

Any spills from the RWPs are to be directed to the open pit for temporary storage and reuse / disposal. To assess the likelihood and quantity of spills from the RWPs the annual volumes spilled were read from the model and analysed by calculating their reoccurrence interval and plotting an annual spill volume exceedance curve, Figure 9-2 and Figure 9-3.

The total annual spill volumes from the RWPs are typically associated with one or two large storm events during a year. The resulting spill volumes will therefore occur as single events rather than spread throughout the wet season. It can be seen that there is a low frequency of spills to the open pit (only 6 spill events during the 74 year rainfall time series) and when spills do occur their volume is relatively small compared to the size of the open pit.

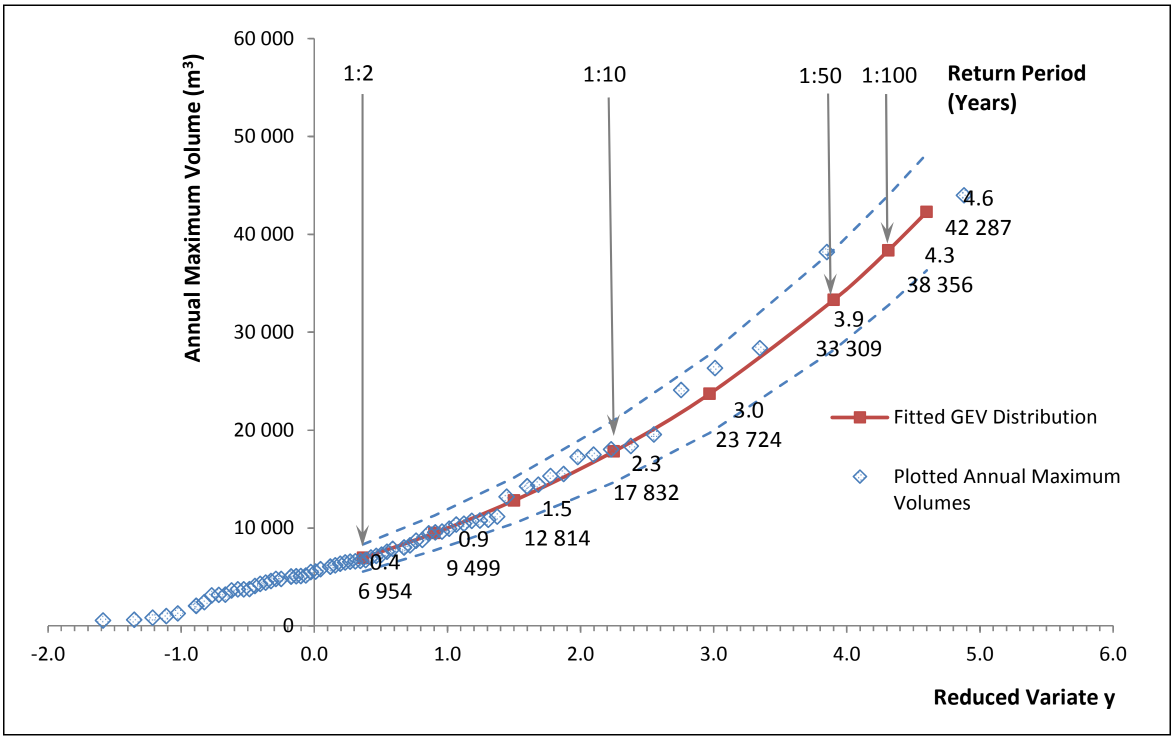


FIGURE 9-1 TOTAL ANNUAL MAXIMUM DAILY RUNOFF VOLUMES

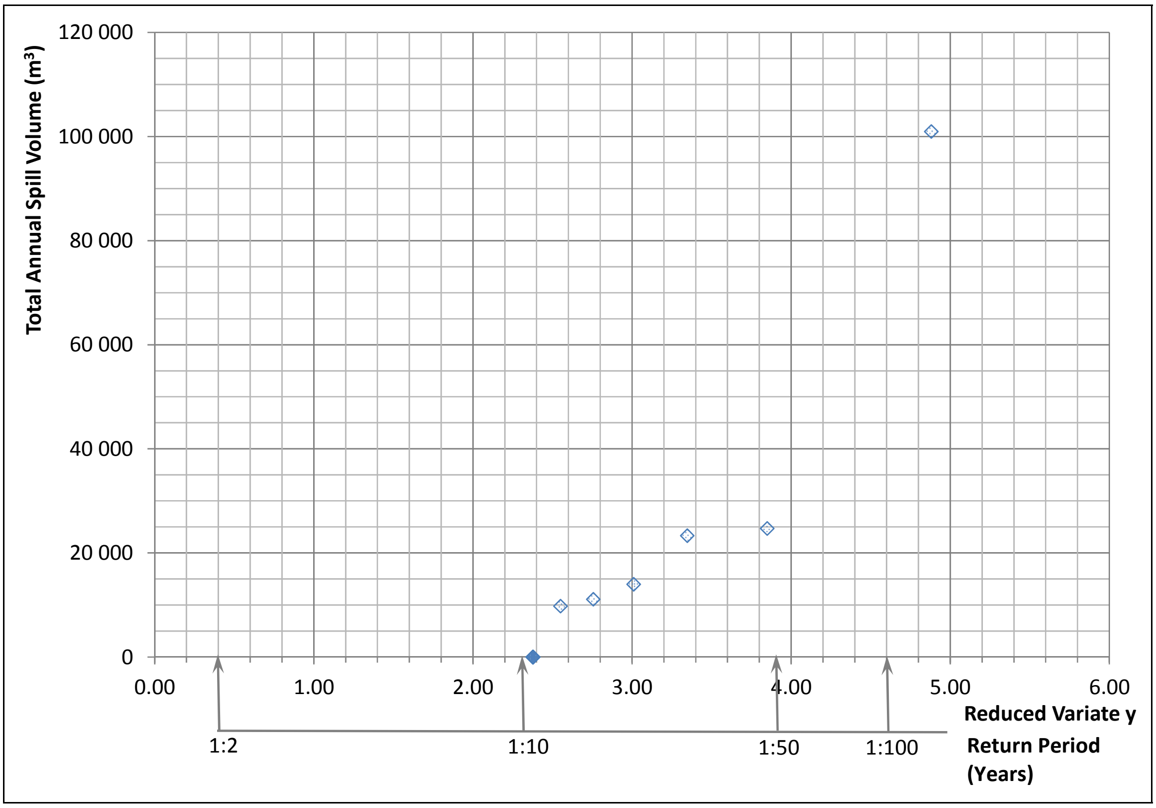


FIGURE 9-2 TOTAL ANNUAL SPILL VOLUME FREQUENCY ANALYSIS

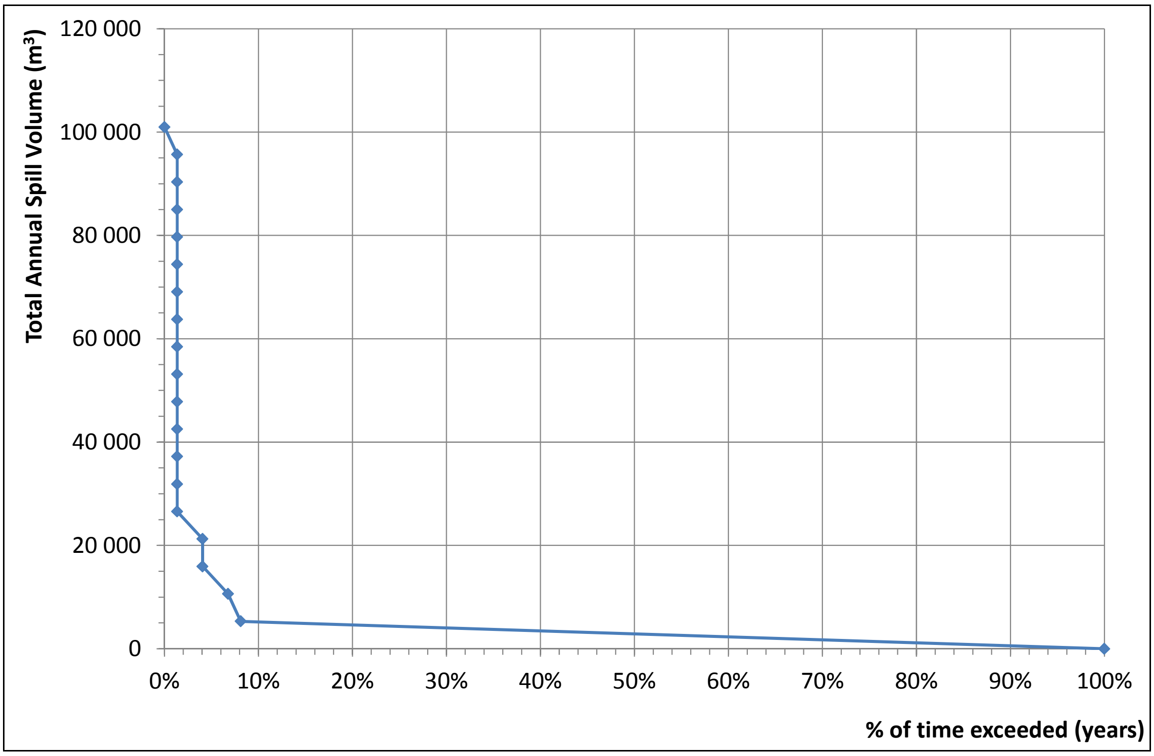


FIGURE 9-3 ANNUAL SPILL VOLUME EXCEEDANCE CURVE

9.6 CONCLUSIONS

The combined RWP storm water attenuation capacity has been sized to capture the 24 hour runoff volume having a 1:50 annual exceedance probability. Any spills from the RWPs are to be directed to the open pit for temporary storage and reuse / disposal. When the RWPs are operated in this way the resulting spills will cause minimal disruption to the mining operation as they are infrequent and of relatively small volumes. As there will be no discharge of “dirty” water from the RWPs to the local surface water resources the design and operation of the RWPs is in accordance with GN704.

10 COMMENTS FROM INTERESTED AND AFFECTED PARTIES

Table 10-1below gives the responses to comments from Interested and Affected Parties (IAPs) relating to the management of surface water at the mine.

INTERESTED AND AFFECTED PARTIES	DATE COMMENTS RECEIVED	ISSUES RAISED	RESPONSE
Comment raised by Louis Hauman	15 April 2015 at the public scoping meeting	The Ga-Mogara drainage channel is going to flow again in 2025.	Thank you for your input. Anecdotal evidence from local farmers indicates that the Ga-Mogara River has only flowed during 3 out of the past 40 years at the Mokala Mine site. It can therefore be estimated that there is a 1:13 chance of the river flowing at the Mokala Mine site in the year 2025 if only natural rainfall / runoff process are considered.
		In your report it needs to be clearly indicated what amount of water is required for dust suppression.	The amount of water required for dust suppression is stated in the Mokala Surface Water Study report.
		The impact that the project will have on the river flow must be calculated.	The impacts that the project will have on the river flows are stated in the Mokala Surface Water Study report.
Issues raised by Raisibe Sekepane from the Department of Mineral Resources	21 April 2015 at the pre-application meeting	In terms of the water system on-site, will it be a closed loop?	Yes. The intension is to manage all dirty and recycle water on-site in accordance with Regulation 704 (4 June 1999).

TABLE 10-1 RESPONSES TO IAP COMMENTS

Ryan Sweetman Pr. Eng.
(Project Manager)

Paul Klimczak Pr.Sci.Nat.
(Project Reviewer)

Ryan Sweetman Pr. Eng.
(Author)

11 REFERENCES

- ARC Institute for Soil, Climate and Water, June 2014, “Soil Information for Kudumane Project near Hotazel, Northern Cape”.
- Daily Rainfall Extraction Utility, Version 1.4, Richard Kunz (ICFR), 2004.
- Department of Water Affairs, 1988, “Technical Report TR137: Regional Maximum Flood Peaks in Southern Africa”.
- Department of Water Affairs and Forestry, 1998. “National Water Act, Act 36 of 1998”.
- Department of Water Affairs and Forestry, 1999, “Government Gazette 20118 of June 1999: Government Notice 704 (GN 704).”
- Department of Water Affairs and Forestry (DWAF), September 2004, “National Water Resource Strategy. First Edition”.
- Department of Water Affairs and Forestry, 2006, “Best Practice Guideline No. G1: Storm Water Management”.
- Food and Agriculture Organisation (FAO) of the United Nations, 2005, “New LoClim - Local climate estimator”.
- SANRAL, 2013, “Drainage Manual-Sixth Edition”, The South African National Roads Agency Limited, Pretoria.
- Smithers, J.C. and Schulze, R.E., 2002, “Design Rainfall and Flood Estimation in South Africa”, WRC Report No. K5/1060, Water Research Commission, Pretoria.
- Soil and Terrain Database (SOTER) (v1.0) for South Africa
- Water Research Commission, December 2004, “Development of a Raster Database of Annual, Monthly and Daily Rainfall for Southern Africa”. Report No. 1156/1/04.
- WR2005, 2009, “Water Resources of South Africa, 2005 Study (WR2005)”, WRC Report No. TT 380/08, Water Research Commission, Pretoria.

- Water Geoscience Consulting, June 2010, “Regional Groundwater Assessment for the Northern Cape Manganese Company (Pty) Ltd”.
- HEC-RAS Hydraulic Reference Manual Version 4.1, 2010
- SLR Consulting (South Africa) (Pty) Ltd, Groundwater Assessment for the Proposed Mokala Manganese Project, October 2015.
- Ecological Management Services, Biodiversity Survey Report for the proposed Mokala manganese mine layout, August 2015.
- Terra Africa Environmental Consultants, Mokala Manganese Project Soil, Land Use and Land Capability Report, July 2015

APPENDIX A: CURRICULUM VITAE OF SPECIALIST CONSULTANT

Ryan Thomas Sweetman
Senior Civil Engineer

Curriculum Vitae

Qualifications

MSAICE	2012	Member of the South African Institution of Civil Engineers (PrEng)
MICE	2006	Member of the Institution of Civil Engineers (CEng)
MSc	2001	Sustainable Management of the Water Environment
BEng	2000	Civil Engineering

Key Areas of Expertise

Project management	Acted as design manager on a £24M flood alleviation scheme in the UK.
Construction supervision	Has supervised a number of projects including a £5M flood alleviation scheme. (Monitored the contractor's quality, safety and environmental performance).
Contract documentation	Has developed numerous contract documents for construction projects using FIDIC, GCC and NEC forms of contract.
Civil design and options appraisal	Has experience in the design of drainage, retaining walls, dams and river engineering works.
Environmentally sensitive design	Worked under a UK Environment Agency framework contract for 10 years which required all designs to be in accordance with UK environmental best practice.
River modelling, hydrology and water resource yield analysis	Has experience in the use of HECRAS river modelling software, flood hydrology and water resource yield analysis using WRYM. Rainfall runoff modelling in GoldSim.

Summary of Experience and Capability

Ryan has 13 years of experience in engineering consulting with a focus on water management. His experience covers a broad range of skills from river engineering and modelling to contract documents and construction supervision. Prior to joining SLR he had spent 10 years working in the UK for Halcrow Group Ltd and 2 years in South Africa for Knight Piesold. He has a solid understanding of project management having held the position of design manager on a £24M flood alleviation scheme in the UK. While in South Africa he has gained experience in dam engineering, hydropower and water resource yield analysis.

Recent Project Experience

Project	Date	Ryan's Role
South Deep Mine Return Water Dam Options Appraisal, South Africa – Gold Fields	2014	Responsible for appraising options to bring an existing RWD into compliance with GN704 and the mine's water use licence. Developed a rainfall runoff model in GoldSim to inform the design of options.
South Deep Mine Storm Water Management, South Africa – Gold Fields	2013/14	Responsible for the design of storm water management infrastructure complying with GN 704 and acted as project manager for construction.
Metolong Dam and Raw Water Pump Station, Lesotho - Sinohydro	2012	Responsible for developing a Quality Management Plan for the contractor, Sinohydro.
Hydrological Study and Hydropower Potential Assessment, Mozambique - Hidroeléctrica de Cahora Bassa	2011/12	Major contribution to a study defining the flood hydrology and hydropower potential of the Cahora Bassa Dam on the Zambezi River, Mozambique.
Refurbishment of Seven Dams, Eastern Cape, South Africa - Department of Water Affairs	2011/13	Coordination of civil and mechanical sub-consultants, provision of contract documents using the FIDIC conditions of contract, monthly cash flow forecasting and reporting.
Edwaleni Power Station Penstock re-painting, Swaziland - Swaziland Electricity Company	2011	Responsible for the production of the tender documents for a FIDIC Short Form contract.
Ezulwini Valley Water Supply Project, Swaziland - Department of Water Affairs	2011	Responsible for the investigation of options to source water from an existing hydroelectric power station, reporting and presentation of the findings to the Client.
Neckartal Dam and Irrigation Scheme, Namibia - Namibian Government	2010/11	Assisted with the development of FIDIC tender documents on this R1.8 billion project to construct an 80m high roller compacted concrete dam on the Fish River.
Carlisle Flood Alleviation Scheme, UK - Environment Agency	2007/10	Design Manager on this £24M scheme. Managed a team of structural and geotechnical engineers and CAD technicians to produce scheme drawings to a challenging programme with design on-going during construction.
Padiham Weir Improvement, UK - Environment Agency	2010	Responsible for the design and construction supervision of a £300K scheme to partially lower a 2m high concrete weir and construct a 40m long rock ramp downstream to facilitate fish passage.
Glynneath Flood Alleviation Scheme, UK - Environment Agency	2003/7	Significant input into this £5M scheme from feasibility to construction. Responsible for monitoring the contractor's quality, safety and environmental performance during construction.

Publications

Glynneath Flood Alleviation Scheme: River Bank Stabilization Works, Design and Construction. Presented to the Chartered Institution of Water and Environmental Management (CIWEM)

APPENDIX B: GA-MOGARA RIVER BED TEST PITS

Mokala Manganese
River, Weighbridge and Workshop Test Pit Logs

Date Logged 14.04.2015

Logged By K. Byrne

Test Pit No	Chainage (m)	From (mm)	To (mm)	Description	Photographs
River Testpit Logs					
TP1 - TP3 at Borehole WH 2					
			At WH2	General Note - hard calcrete outcrop on surface 52m east of river centreline - outcrop rising steeply to the east	
TP1	WH 2 West	0	-600	Sandy, slightly moist, loose, loose topsoil with roots.	
		-600	-2400	Dry sand with calcrete nodules displaying some striation and also randomly distributed	
TP 2	WH2 Centre	0	-600	Sandy, slightly moist , loose topsoil with calcrete nodules and root material	    
		-600	-1800	Dark brown to black, greyish moist to dry stiff to very stiff clay clay	
		-1800	-2500	Dry loose pebble bed with calcrete nodules	
TP 3	WH2 - 20m East of Watercourse Centre	0	-500	Light, dry, sandy topsoil	  
		-500	-1600	Light coloured dry calcarious sand of extermely fine texture.	
		-1600	-2400	Dry calcrete becoming harder with refusal to the TLB bucket at -2400	
TP4 - TP6 at Mid-point along River between WH2 and WH 3					
TP 4	Mid-point on centre of watercourse - lowest point on river cross section	0	-650	Sandy, slightly moist , loose topsoil with root material	  
		-650	-1700	Medium stiff brown to greyish dry clay with calcrete nodules interspersed in the clay matrix	
		-1700	-2300	Dry pebble bed with calcrete nodules and refusal to the TLB bucket at -2300	
TP5	20m west of mid-point on centre of watercourse	0	-500	Light coloured dry, loose to clean alluvial sand with root material	 
		-500	-1800	Dry, brown to greyish clayey sand	
		-1800	-2200	Dry pebble bed marker with calcrete nodules	
TP6	20m east of mid-point on centre of watercourse	0	-400	Dry sandy topsoil with some roots	  
		-400	-1800	Light coloured, calcarious sand to silty sand	
		-1800	-2000	Pebble bed, calcrete nodules	
TP7 - TP9 at Borehole WH 3					
TP7	WH 3 - 14m west of watercourse centre	0	-300	Loose, dry, yellowish aeolian sand with root material and an approximately 10 to 15mm calcarious leachate band at the bottom of the layer	   
		-300	-2800	Dry light coloured sand	
TP8	WH3 - on centreline of watercourse	0	-300	Dry silty, sandy, loose topsoil with roots	    
		-300	-800	Dry greyish, silty, clay sand with roots	
		-800	-2000	Dry greyish, silty, clay sand down to pebble bed at -2000	
		-2000	-2500	Dry pebble bed - Note - single composite sample taken for pebble bed with greyish silty sand matrix as per -300 to -800	
TP 9	WH 3 - 20m east of watercourse centre	0	-700	Dry, sandy aeolian topsoil with root material	    
		-700	-900	Dry, pebble bed with calcarious leachate / layer with calcarious leached nodules	
		-900	-2400	Greyish, stiff, dry clayey to silty sand with calcarious nodules	
		-2400		Clean, dry granular river sand encountered - sample taken of this material as this type of clean sand was not encountered in earlier holes	
TP10 at a Position 100m below the R380 Culvert at a position where the Watercourse Centreline is 25m off the Centre of the proposed Canal					
TP 10	Centre River 100m below R380 Culvert - Canal 25m off river centreline	0	-300	Dry topsoil with grass roots	 
		-300	-500	Clean river sand	
		-500	-1200	Brownish, greyish, dry clayey, silty sand	
		-1200	-1500	Brownish, greyish, dry clayey, silty sand with striations of calcrete nodules and calcrete nodules in sand matrix	
		-1599	-2400	Brownish, greyish, dry clayey, silty sand with a possible pebble marker at -2400 but beyond reach of the TLB	

APPENDIX C: ENVIRONMENTAL IMPACT ASSESSMENT METHODOLOGY

METHODOLOGY FOR DETERMINING THE SIGNIFICANCE OF ENVIRONMENTAL IMPACTS

The proposed method for the assessment of environmental issues is set out in the following table. Part A of the table provides a list of criteria that can be selected in order to rank the severity, duration and spatial scale of an impact. The consequence of the impact is determined by combining the selected criteria ratings allocated for severity, spatial scale and duration in part B of the table. The significance of the impact is determined in Part C of the table whereby the consequence determined in part B is combined with the probability of the impact occurring. The interpretation of the impact significance is given in Part D.

This assessment methodology enables the assessment of environmental issues including: cumulative impacts, the severity of impacts (including the nature of impacts and the degree to which impacts may cause irreplaceable loss of resources), the extent of the impacts, the duration and reversibility of impacts, the probability of the impact occurring, and the degree to which the impacts can be mitigated. This assessment method was used to assess impacts associated with all project alternatives.

CRITERIA FOR ASSESSING IMPACTS

PART A: DEFINITION AND CRITERIA*		
Definition of SIGNIFICANCE		**Significance = consequence x probability**
Definition of CONSEQUENCE		**Consequence is a function of severity, spatial extent and duration**
Criteria for ranking of the SEVERITY of environmental impacts	**H**	Substantial deterioration (death, illness or injury). Recommended level will often be violated. Vigorous community action.
	M	Moderate/ measurable deterioration (discomfort). Recommended level will occasionally be violated. Widespread complaints.
	L	Minor deterioration (nuisance or minor deterioration). Change not measurable/ will remain in the current range. Recommended level will never be violated. Sporadic complaints.
	L+	Minor improvement. Change not measurable/ will remain in the current range. Recommended level will never be violated. Sporadic complaints.
	M+	Moderate improvement. Will be within or better than the recommended level. No observed reaction.
	H+	Substantial improvement. Will be within or better than the recommended level. Favourable publicity.
Criteria for ranking the DURATION of impacts	**L**	Quickly reversible. Less than the project life. Short term
	M	Reversible over time. Life of the project. Medium term
	H	Permanent. Beyond closure. Long term.
Criteria for ranking the SPATIAL SCALE of impacts	**L**	Localised - Within the site boundary.
	M	Fairly widespread – Beyond the site boundary. Local
	H	Widespread – Far beyond site boundary. Regional/ national

PART B: DETERMINING CONSEQUENCE					
			SEVERITY = L		
DURATION	Long term	**H**	**Medium**	**Medium**	**Medium**
	Medium term	**M**	**Low**	**Low**	**Medium**
	Short term	**L**	**Low**	**Low**	**Medium**
			SEVERITY = M		
DURATION	Long term	**H**	**Medium**	**High**	**High**
	Medium term	**M**	**Medium**	**Medium**	**High**
	Short term	**L**	**Low**	**Medium**	**Medium**
			SEVERITY = H		
DURATION	Long term	**H**	**High**	**High**	**High**
	Medium term	**M**	**Medium**	**Medium**	**High**
	Short term	**L**	**Medium**	**Medium**	**High**
			L	**M**	**H**
			Localised Within site boundary Site	Fairly widespread Beyond site boundary Local	Widespread Far beyond site boundary Regional/ national
			SPATIAL SCALE		

PART C: DETERMINING SIGNIFICANCE					
PROBABILITY (of exposure to impacts)	Definite/ Continuous	**H**	**Medium**	**Medium**	**High**
	Possible/ frequent	**M**	**Medium**	**Medium**	**High**
	Unlikely/ seldom	**L**	**Low**	**Low**	**Medium**
			L	**M**	**H**
			CONSEQUENCE		

PART D: INTERPRETATION OF SIGNIFICANCE	
Significance	**Decision guideline**
High	It would influence the decision regardless of any possible mitigation.
Medium	It should have an influence on the decision unless it is mitigated.
Low	It will not have an influence on the decision.

***H = high, M= medium and L= low and + denotes a positive impact.**

APPENDIX D: STORM WATER MANAGEMENT REPORT

MOKALA MANGANESE MINE

STORM WATER MANAGEMENT REPORT

PREPARED BY:

AECOM SA (Pty) Ltd

2 Maryvale Road

Westville

3629

CONTACT PERSON

Mr K Hoffman

Tel No: 031 204 3800

PREPARED FOR:

MOKALA MANGANESE MINE (Pty) Ltd

66 Park Lane

Sandton

CONTACT PERSON

Mr K Byrne

Tel No: 011 2188221

TITLE	:	***MOKALA MANGANESE MINE, STORM WATER MANAGEMENT REPORT***
Project Team	:	*AECOM (Pty) Ltd*
Client	:	*Mokala Manganese (Pty)Ltd.*
AECOM Project No	:	*60330971*
Status of Report	:	*Final*
AECOM Report No	:	*60330971-01*
Key Words	:	*Stormwater Design, Stormwater Management , Catchment Areas*
Date of this Issue	:	*9th October 2015*

For AECOM (Pty) Ltd

Compiled by	:	K. Hoffman		09-10-2015
		Initials & Surname	Signature	Date
Reviewed by	:	T. Ramlal		09-10-2015
		Initials & Surname	Signature	Date
Approved by	:	D. Pillay		09-10-2015
		Initials & Surname	Signature	Date

TABLE OF CONTENTS

Page No

1. INTRODUCTION

Mokala Manganese (Pty) Limited has appointed AECOM SA (Pty) Ltd. as the consulting civil engineers, to undertake the storm water management design for the manganese plant.

1.1 LOCATION

The site, covering the remaining extent of farm Gloria 266, is approximately 450ha in size. It is located approximately 4km North West of the town of Hotazal in the Northern Cape Province of South Africa.

Facility	X	Y
Mokala Manganese Mine	3 023 596.972	-11 291.340

See annexure 1 for Mine Layout.

1.2 PURPOSE OF REPORT

This report provides an overview of the planning and design of the surface drainage management for this proposed development, which includes both contaminated, uncontaminated water and flood protection measures. Various catchment areas have been identified on the mine and is detailed within Annexure 2 - Storm Water Management Layout.

2. SITE CHARACTERISTICS

The site is relatively flat with a gentle slope towards the North East. The elevation on site varies from 1040m to 1100m above mean sea level. The highest topographical features (koppies and ridges) in the vicinity of the mine are the Korannasberg, approximately 44 km west of the site, and the Kurumanheuwels, approximately 66 km south east of the site.

The site is bordered by one main non-perennial drainage line, namely the Gamagara River (along the eastern boundary).

2.1 REGIONAL CLIMATE

Climate data for weather recording stations in the vicinity of the site were provided by SLR Consulting. The location and details of the stations used are detailed in Table 1-1.

Station Name	SAWS Number	Distance (km)	Record Length (Years)	Mean Annual Precipitation (mm)	Altitude (mamsl)
MUKULU	0392640 W	10.2	28	289	1056
HEUNINGDRAAI	0392680 W	11.4	28	349	1060
SMUTS	0392592 W	13.7	26	333	1073
MILNER	0393083 W	19.1	67	334	1118
KAREEPAN	0393225 W	20.1	36	352	1130
TSINENG (POL)	0393126 W	24.2	31	334	1049

Table 1-1 Summary of Six Closest SAWS Stations (Source: SLR Consulting)

2.2 DEPTH-DURATION

The design storm rainfall depths were developed by SLR Consulting using design rainfall software (Smithers and Schulze, 2002). The six closest rainfall stations, as shown in Table 1-1, were used to extract storm rainfall depths for various recurrence intervals. This data is represented in **Table 1-2 Rainfall Depths** below.

Duration	Rainfall Depth (mm)						
(min/h)	1:2 year	1:5 year	1:10 year	1:20 year	1:50 year	1:100 year	1:200 year
5 min	7.9	11.3	13.6	16	19.2	21.8	24.5
10 min	11.8	16.8	20.4	23.9	28.7	32.5	36.5
15 min	14.9	21.3	25.7	30.2	36.3	41.1	46.1
30 min	19.7	28.1	34	39.9	48	54.3	61
45 min	23.2	33.1	40	47	56.5	64	71.8
1 h	26.1	37.1	44.9	52.7	63.4	71.8	80.6
1.5 h	30.7	43.7	52.9	62.1	74.6	84.6	94.9
2 h	34.5	49.1	59.4	69.7	83.8	94.9	106.5
4 h	39.9	56.7	68.6	80.6	96.8	109.7	123.1
6 h	43.4	61.7	74.7	87.7	105.4	119.4	134
8 h	46.1	65.6	79.3	93.1	111.9	126.8	142.2
10 h	48.3	68.7	83.1	97.5	117.2	132.8	149
12 h	50.1	71.4	86.3	101.3	121.8	138	154.8
16 h	53.2	75.8	91.6	107.6	129.3	146.5	164.4
20 h	55.8	79.4	96	112.7	135.5	153.5	172.2
24 h	57.9	82.5	99.7	117.1	140.7	159.5	178.9

Table 1-2 24hr Rainfall Depths (mm) (Source: SLR Consulting)

3. STORMWATER DESIGN

Due to the nature of the operations on the mine, it is imperative that there is a delineation of stormwater on site between “Contaminated Stormwater”, and “Uncontaminated Stormwater / Clean Stormwater”. The clean and dirty stormwater systems were designed in accordance with the provisions of Regulation 704, 4 June 1999 (Regulation 704) for water management on mines.

3.1 UNCONTAMINATED STORMWATER / CLEAN STORMWATER

There are large areas within and around the site that will not be disturbed by the mining operations and as a result the stormwater runoff from these areas will not be conveyed to the recycle ponds. The uncontaminated stormwater runoff generated from these areas will be intercepted by a series of appropriately sized channels and earth berms (refer to details below). This runoff will discharge at ground level onto natural open areas through 5m v-drain chutes.

It must be noted that the climate is extremely arid and as a result any stormwater runoff which ponds in the small natural depressions or clean water accumulation areas will be permitted to infiltrate naturally.

3.2 CONTAMINATED STORMWATER / DIRTY WATER

The stormwater runoff generated within areas that are disturbed by the mining operations will be dealt with as contaminated stormwater and will typically be of a turbid nature with suspended solids. The contaminated stormwater will be controlled on site via a series of trapezoidal drains and earth berms and contained within lined recycle ponds 13, 14, 15 and 16 (refer to typical detail below **Figure 5** and **Annexure 2**).

In between the contaminated stormwater areas, there exist large areas where clean stormwater will be allowed to infiltrate naturally. These areas are classified as infiltration paddocks. These infiltration areas reduce the volume of clean stormwater unnecessarily reporting to the recycled water ponds and being contaminated, in turn reducing the size of the recycle water ponds required.

The respective elements of the contaminated stormwater drainage system are designed such that the contamination of the clean stormwater system is limited to a 1:50 year chance in any given year.

Stormwater runoff from the disturbed areas includes:

- Plant area;
- Waste rock dump site;
- Product transport road;

- Access road to stockpiles (haul road);
- HDV truck park; and
- Administration area.

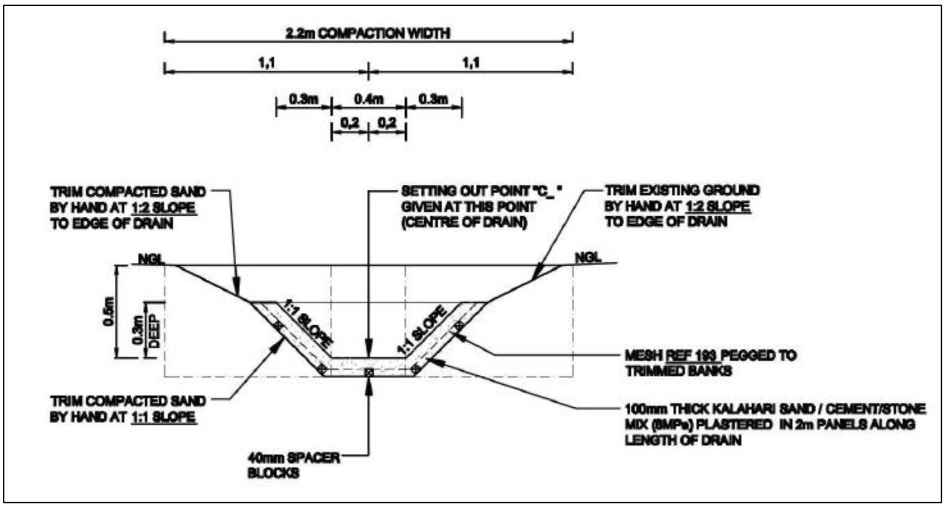


Figure 1: Typical detail of trapezoidal drain

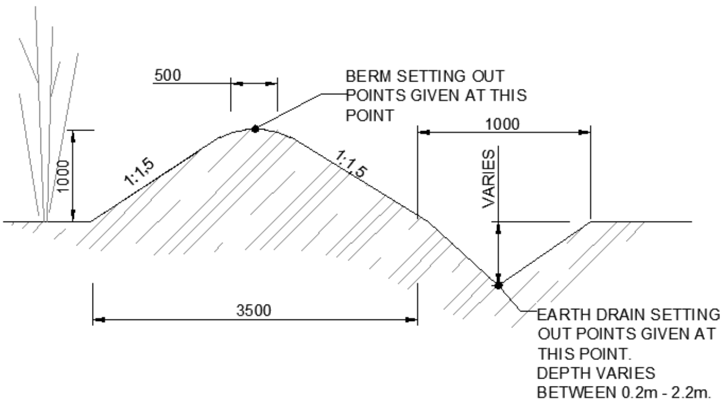


Figure 2: Typical detail of earth berm

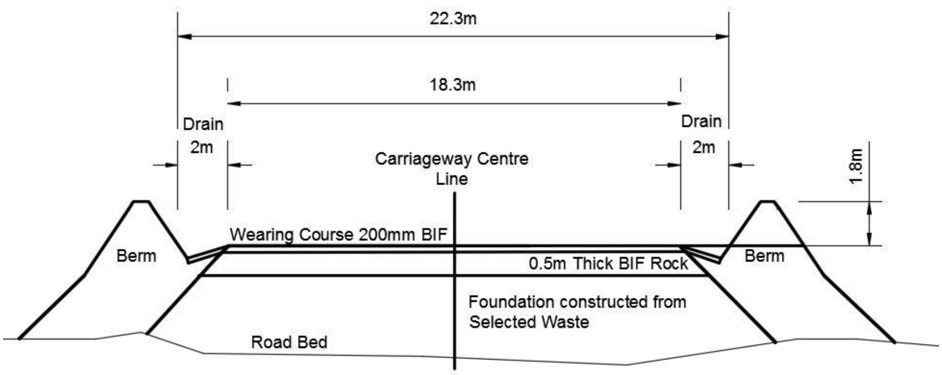


Figure 3: Typical section through haul road

The main access and product transport road has been designed with a 2.5% cross-fall with 1V in 2H banks and v-drains (Refer to Figure 4). This surfacing is specific to areas that are subjected to different vehicles types and vehicle movements. Refer to concept drawings for details on the surfacing and corresponding layerworks.

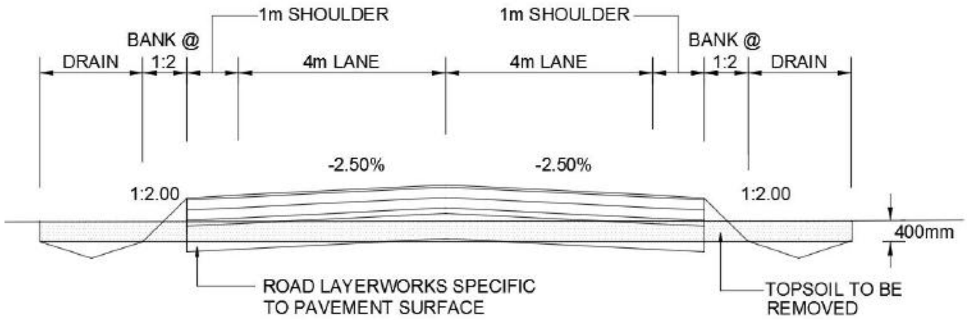


Figure 4: Typical Cross-Section through product transport road

3.3 Stormwater Calculations

The **contaminated** network has been sized based on a 1 in 50 year flood event covering areas that will be disturbed by the mining activities. The design storm rainfall figures were provided by **SLR Consulting**, as per Table 1-2.

The Rational Method was adopted combined with the figures in Table 1-2 above to calculate the maximum rate of discharge per disturbed area. Subsequently, the recycled stormwater ponds and channels were designed accordingly.

Rational Method: $Q = C*I*A$

Q = the maximum/peak rate of run-off

C = run-off coefficient (specific to area)

I = rainfall intensity (figures obtained from SLR Consulting)

A = area of catchment in hectares.

3.4 Recycle Stormwater Storage Ponds

Pond 13 is designed to contain a capacity of 7,966m^3. It will accommodate surface water, from rainfall and runoff, from all elements within the plant area. In the event of the pond being overtopped, overflow will be pumped to pond 14.

Pond 14 is designed to contain a capacity of 20,466m^3. It will accommodate surface water, from rainfall and runoff, from the stockpile access road (haul road), the contaminated topsoil storage/stockpile area and overflow from pond 13. Additionally, groundwater inflow from the mine pit will be pumped to the pond as well as all surface water, from rainfall and runoff, within the mine pit. The depth and capacity of the pond will be altered accordingly to accommodate the additional inflow from the mine pit if needed.

Pond 15 is designed to contain a capacity of 1,442m^3. It will accommodate surface water, from rainfall and runoff, from the truck staging area, product transport road and contaminated surrounds.

Pond 16 is designed to contain a capacity of 3,433m^3. It will accommodate surface water, from rainfall and runoff, from the HDV truck park, administration area, main store and workshop. Surface water run-off generated from the roofing and LDV car park at the administration area, typically classified as uncontaminated stormwater, will be relatively marginal in volume and will not warrant the expenditure required to delineate the flows. This run-off too will be contained in pond 16.

Sedimentation and silt traps – Silt traps will be positioned at the pond inlets to prevent excessive sedimentation from entering the ponds. Prior to discharging the stormwater runoff into the pond, sediments that are suspended in the stormwater runoff will be allowed to settle within the basin of the silt trap. These silt traps will be concrete lined and designed for ease of maintenance by motorised bobcat machines. Maintenance will be achieved by including access ramps for the bobcats. See **Figure 6** below.

Mine Pit Surface Water - the water inflow from the mine pits is inconsistent, varying from season to season, but can be substantial after heavy downpours. There is also a necessity to collect the water that may become trapped in the mine pits for environmental reasons. To this extent, water from the mine pits will be pumped out of the pits into pond 14, as mentioned above. Pond 14 will be located near the plant yard adjacent to the haul road intersection, however, may have to be replicated or moved as mining moves along the pit and the laying out of pumping lines becomes too long.

It is important to note that water from the mine pit will mainly be available after a significant rainfall event, although some groundwater infiltration is expected.

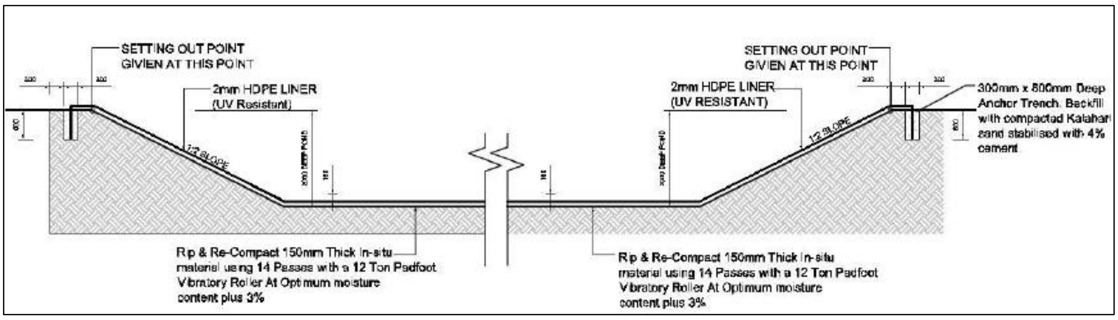


Figure 5: Typical detail of recycle stormwater pond

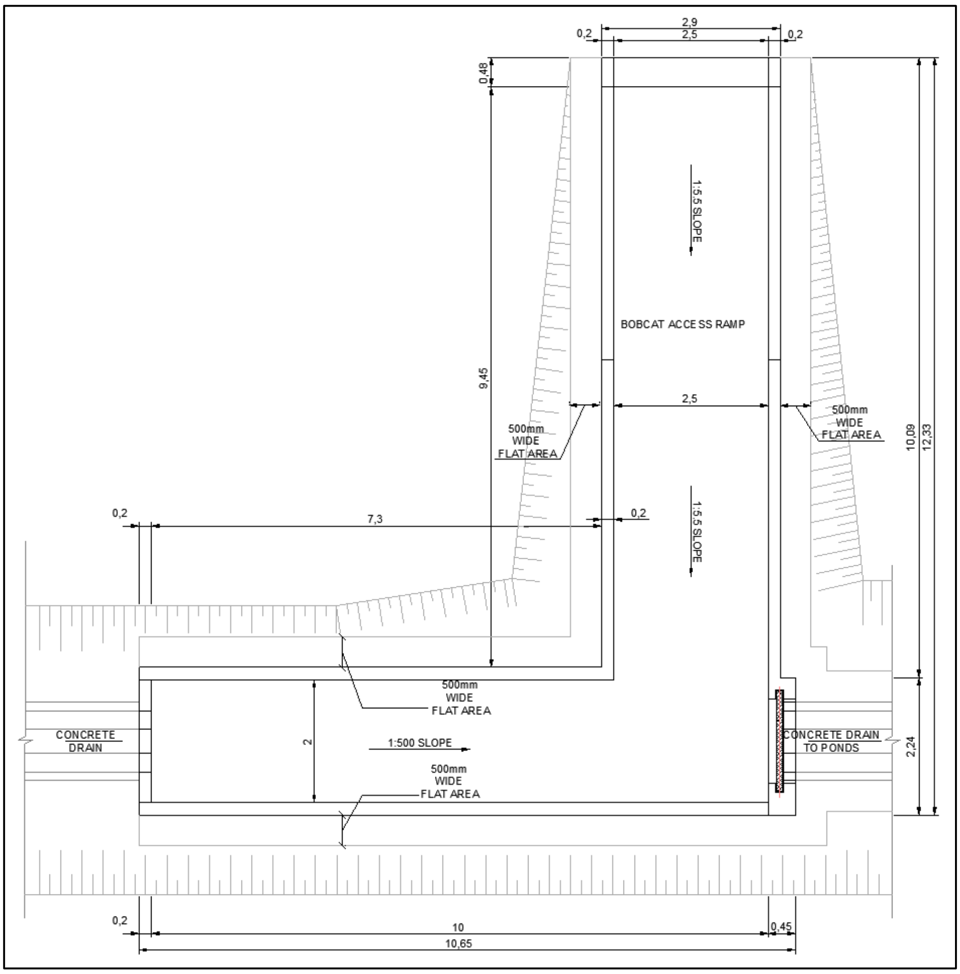


Figure 6: Typical detail of recycle stormwater pond silt trap

4. CONCLUSION

The facets of engineering detailed in this report have been based on a generally accepted criteria, along with sound engineering principles and assumptions and conforms to Regulation 704.

5. REFERENCES

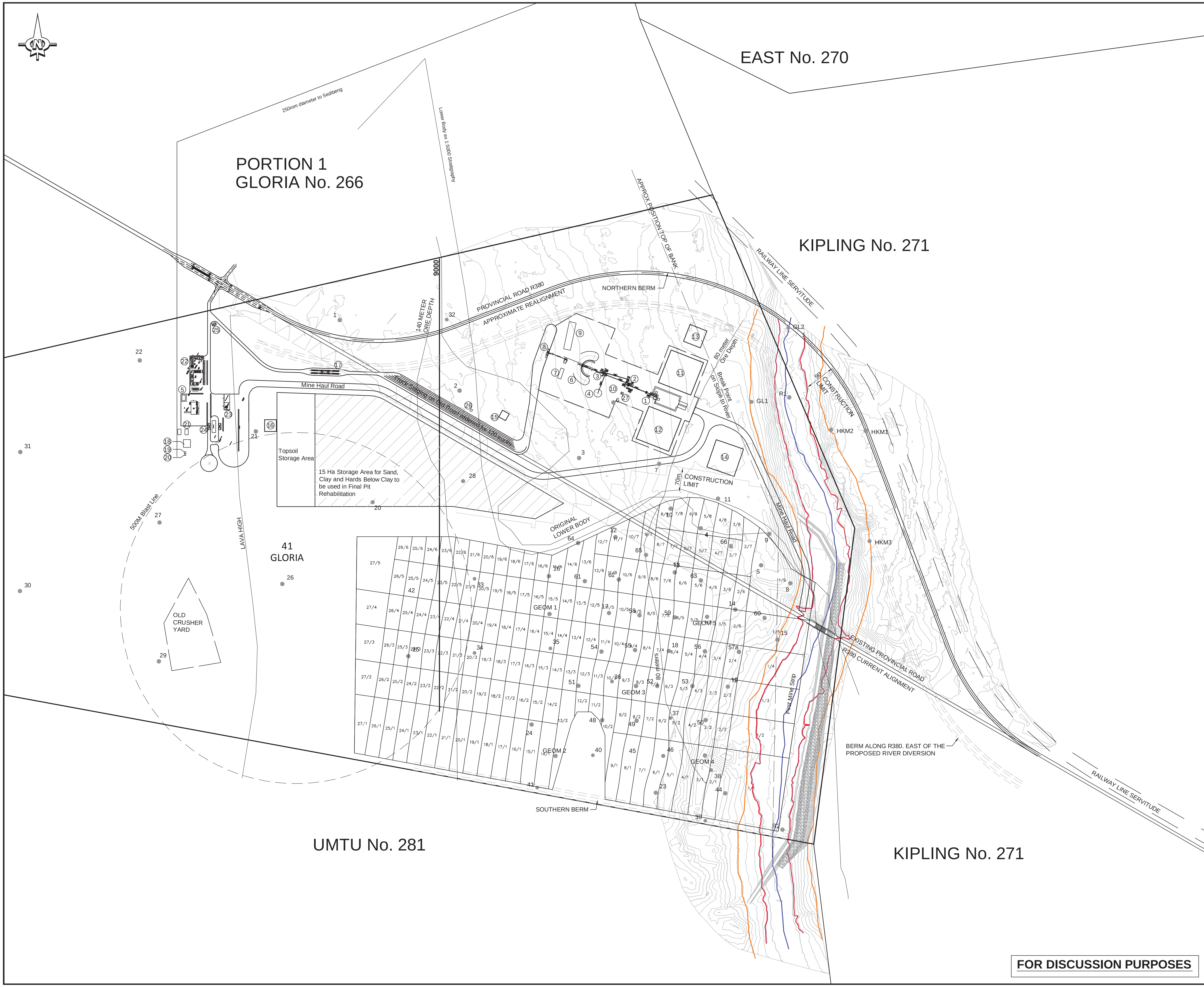
(i) The South African National Roads Agency SOC Limited, Drainage Manual, 6th Edition.

(ii) SRK Consulting –SRK Consulting: Smartt-Rissik Monthly Water Balance update, dated September 2013).

(iii) Regulations on use of water for mining and related activities aimed at the protection of water resources, dated June 1999,

ANNEXURE 1

GENERAL LAYOUT



FOR DISCUSSION PURPOSES

AECOM PROJECT NO.: 60330971

KEY

1. PRIMARY CRUSHER
2. SECONDARY CRUSHER
3. SCREENING PLANT
4. FINES PRODUCT STOCKPILE 2000T
5. FLAMMABLE STORE
6. PRODUCT STOCKPILE 2800T
7. FINES STOCKPILE 5000T
8. FINAL TRUCK LOADING AREA
9. ADDITIONAL SUPLEMENTARY 28,000T PRODUCT STOCKPILE
10. CONTROL ROOM
11. ROM STOCKPILE HIGH GRADE
12. ROM STOCKPILE LOW GRADE
13. RECYCLE POND
14. RECYCLE POND
15. RECYCLE POND
16. RECYCLE POND
17. WEIGHBRIDGE
18. RO PLANT
19. ELEVATED PROCESS WATER BAFFLED TANK
20. ELEVATED POTABLE WATER BAFFLED TANK
21. SEWERAGE TREATMENT PLANT
22. ADMIN BLOCK
23. WORKSHOP
24. FUEL STORAGE
25. SECURITY GATE & OFFICE
26. TRUCK STAGING TOILET FACILITY
27. MAIN TOWER TANK

LEGEND

- 100m BUFFER
- 1:100 YR FLOOD LINE
- 1:50 YR FLOOD LINE
- RIVER CENTRE LINE

REV	DATE	REVISION DESCRIPTION	DRAW
15	2015.10.13	MINE STRIPS, HERITAGE SITES, BERMS	KH
14	2015.04.01	MINE STRIPS, RAILWAY SERVITUDE SAND STORAGE AREA, BERMS	KH
13	2015.01.28	RADIAL STACKER, BERM, PLANT, HAUL ROAD BOREHOLES, RAMP & PLATFORM	KH
12	2014.11.10	MINE STRIPS, HAUL ROAD, PCD'S, TRUCK STAGING AREA, WEIGHBRIDGE, PLANT YARD	KH
11	2014.10.23	ADDITION OF SURVEY AND FLOOD LINES	KH

THE MASTER HELD AT THE AECOM DURBAN OFFICE BEARS THE ORIGINAL SIGNATURE OF APPROVAL.

AECOM

DURBAN OFFICE
2 MARYVALE ROAD
WESTVILLE
TEL: +27 (0)31 204 3800
FAX: +27 (0)31 204 3818
REG. No. 1966/006628/07

DISCIPLINE: ENGINEERING SERVICES

CLIENT: MOKALA MANGANESE MINE (Pty) LIMITED

PROJECT DESCRIPTION: PROPOSED MOKALA MANGANESE MINE

DRAWING TITLE: GENERAL LAYOUT

FUNCTION	NAME	SIGNATURE
DESIGNED BY	K. HOFFMAN	N/A
DRAWN BY	K. HOFFMAN	N/A
DESIGN CHECKED BY	D. PILLAY	N/A
DRAWING CHECKED BY	D. PILLAY	N/A

APPROVAL - CONSULTANT

NAME	D. PILLAY	SIGNATURE	
DATE		PROFESSIONAL REG No.	201270383

DRAWING STATUS CODES:
D=DRAFT F=FINAL R=REPORT
P=PRELIMINARY C=CONSTRUCTION
T=TENDER A=AS-BUILT/RECORD

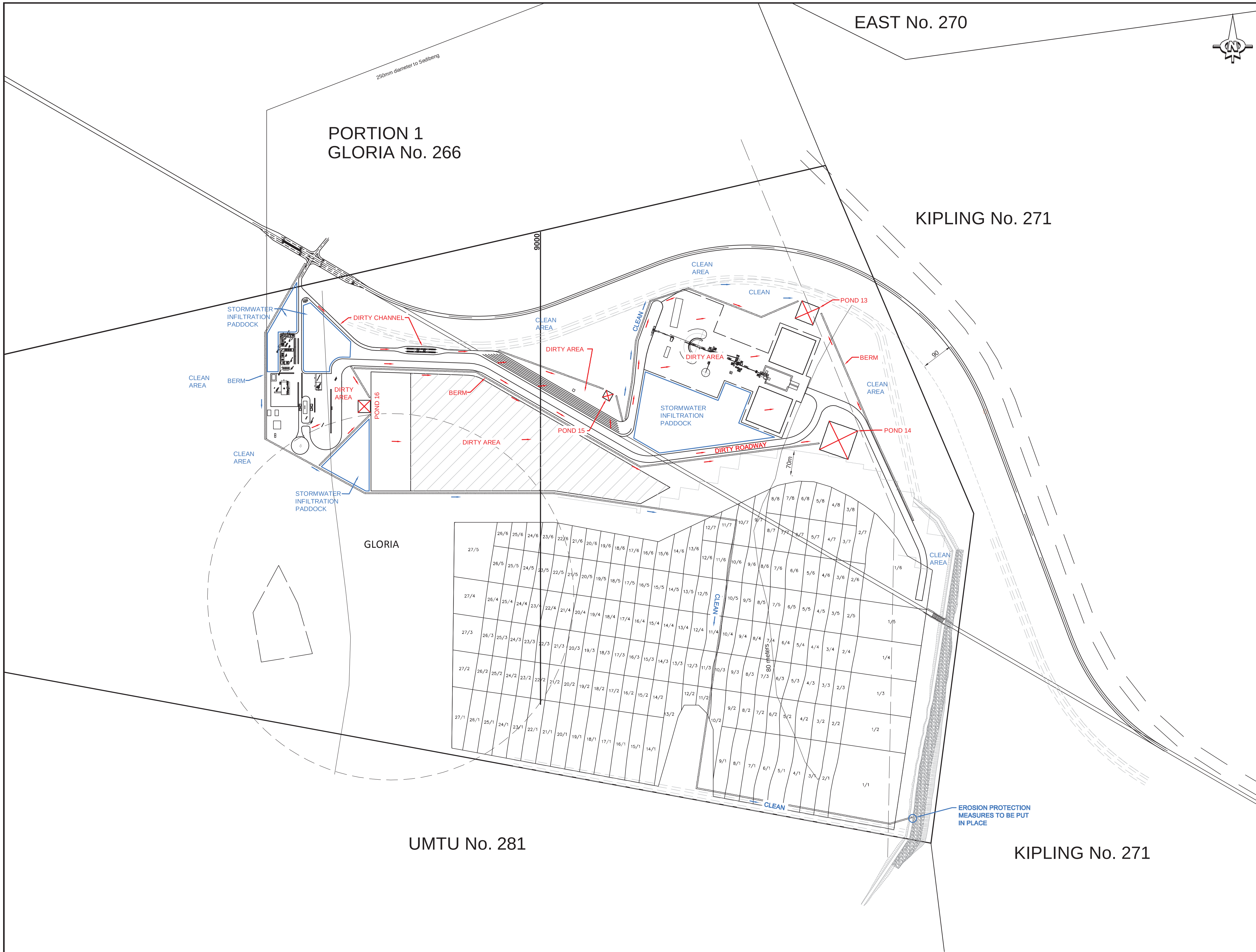
FIRST ISSUE DATE	SCALE	SHEET	SHEET SIZE
2014.12.03	1:5000	1 OF 1	A1

DRAWING NUMBER

PHASE	AREA	SUB-AREA	DISCIPLINE	ACTIVITY	TASK	STATUS	REVISION
FE	008	801	110	100	001	P	15

ANNEXURE 2

STORM WATER MANAGEMENT LAYOUT



STORM WATER MANAGEMENT LAYOUT
SCALE 1:5000

FOR DISCUSSION PURPOSES

AECOM PROJECT NO. : 60330971

LEGEND

CLEAN STORMWATER
DIRTY STORMWATER

REV	DATE	REVISION DESCRIPTION	DRAW

THE MASTER HELD AT THE AECOM DURBAN OFFICE BEARS THE ORIGINAL SIGNATURE OF APPROVAL.

AECOM

DURBAN OFFICE
2 MARYVALE ROAD
WESTVILLE

TEL: +27 (0)31 204 3800
FAX: +27 (0)31 204 3818
REG. No. 1966/006628/07

DISCIPLINE
ENGINEERING SERVICES

CLIENT
MOKALA MANGANESE MINE (Pty) LIMITED

PROJECT DESCRIPTION
PROPOSED MOKALA MANGANESE MINE

DRAWING TITLE
STORM WATER MANAGEMENT

FUNCTION	NAME	SIGNATURE
DESIGNED BY	K. HOFFMAN	N/A
DRAWN BY	K. HOFFMAN	N/A
DESIGN CHECKED BY	D. PILLAY	N/A
DRAWING CHECKED BY	D. PILLAY	N/A

APPROVAL - CONSULTANT

NAME	D. PILLAY	SIGNATURE	
DATE		PROFESSIONAL REG No.	201270383

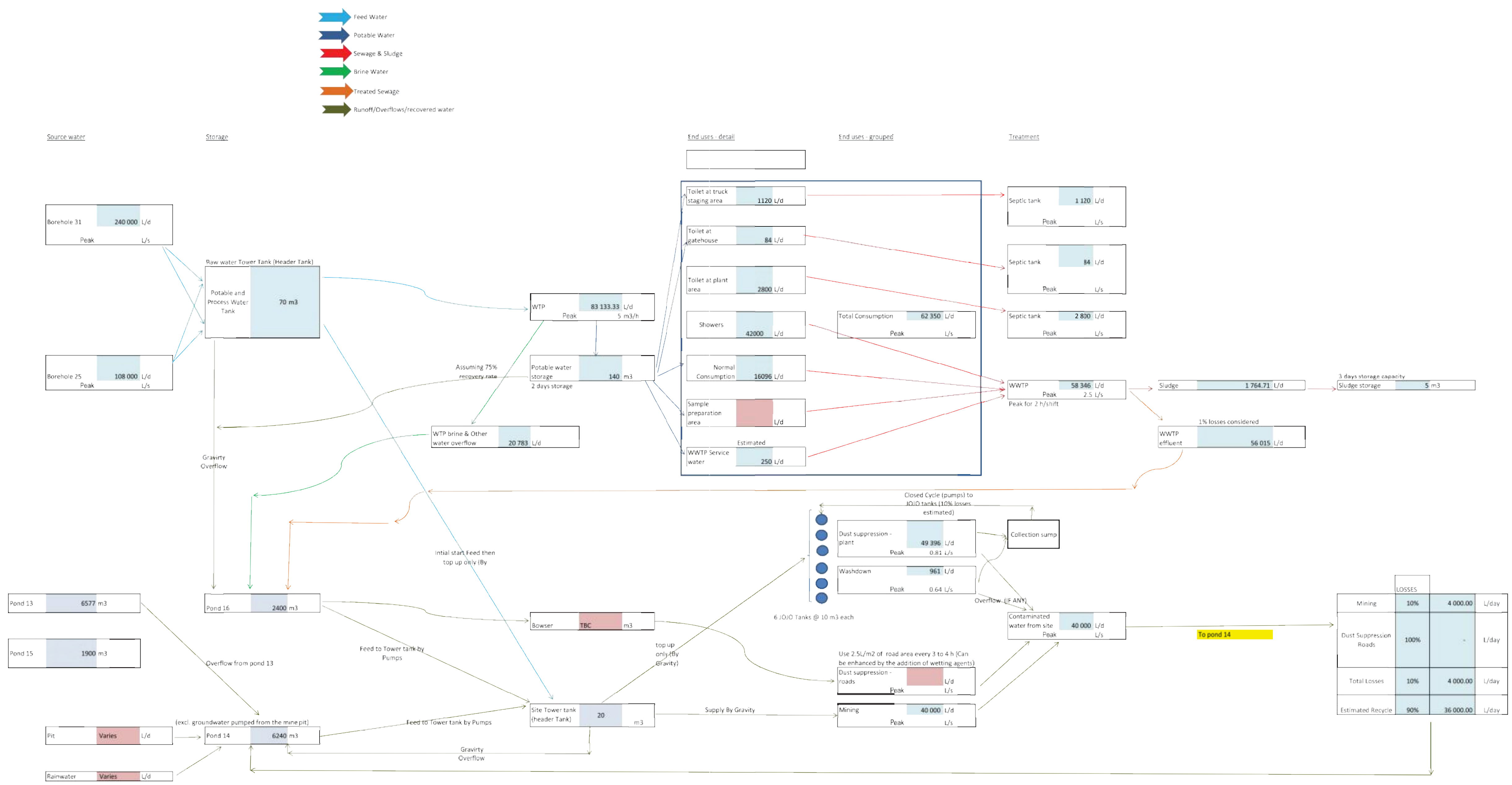
DRAWING STATUS CODES:
D=DRAFT F=FINAL R=REPORT
P=PRELIMINARY C=CONSTRUCTION
T=TENDER A=AS-BUILT/RECORD

FIRST ISSUE DATE: 2015.02.06
SCALE: 1:5000
SHEET: 1 OF 1
SHEET SIZE: A1

DRAWING NUMBER

PHASE	AREA	SUB-AREA	DISCIPLINE	ACTIVITY	TASK	STATUS	REVISION
FE	005	503	110	100	001	P	00

APPENDIX E: FLOW PROCESS DIAGRAM



WATER BALANCE FLOW PROCESS DIAGRAM
SCALE NTS

FOR DISCUSSION PURPOSES

AECOM PROJECT NO. : 60330971

REV	DATE	REVISION DESCRIPTION	DRAW
01	23-10-2015	WATER BALANCE REVISED	KH

THE MASTER HELD AT THE AECOM DURBAN OFFICE BEARS THE ORIGINAL SIGNATURE OF APPROVAL.

AECOM

DURBAN OFFICE
2 MARYVALE ROAD
WESTVILLE

TEL: +27 (0)31 204 3800
FAX: +27 (0)31 204 3818
REG. No. 1966/006628/07

DISCIPLINE
ENGINEERING SERVICES

CLIENT
MOKALA MANGANESE MINE (Pty) LIMITED

PROJECT DESCRIPTION
PROPOSED MOKALA MANGANESE MINE

DRAWING TITLE
FLOW PROCESS DIAGRAM

FUNCTION	NAME	SIGNATURE
DESIGNED BY	K. HOFFMAN	N/A
DRAWN BY	K. HOFFMAN	N/A
DESIGN CHECKED BY	D. PILLAY	N/A
DRAWING CHECKED BY	D. PILLAY	N/A

APPROVAL - CONSULTANT

NAME	D. PILLAY	SIGNATURE	
DATE		PROFESSIONAL REG No.	201270383

DRAWING STATUS CODES:
D=DRAFT F=FINAL R=REPORT
P=PRELIMINARY C=CONSTRUCTION
T=TENDER A=AS-BUILT/RECORD

FIRST ISSUE DATE		
2015.02.06		
SCALE	SHEET	SHEET SIZ
AS SHOWN	1 OF 1	A1

DRAWING NUMBER

PHASE	AREA	SUB-AREA	DISCIPLINE	ACTIVITY	TASK	STATUS	REVISION
FE	004	403	110	100	001	P	01

SLR Consulting (Africa) (Pty) Ltd

RECORD OF REPORT DISTRIBUTION

SLR Reference:	720.09012.00005
Title:	Mokala Surface Water Study
Report Number:	001
Proponent:	Mokala Manganese (Pty) Ltd

Name	Entity	Copy No.	Date issued	Issuer
Kelly Byrne	Mokala	1	6th November 2015	RTS
Library	SLR	1	6th November 2015	RTS

JOHANNESBURG

Fourways Office

P O Box 1596, Cramerview, 2060,

SOUTH AFRICA

Unit 7, Fourways Manor Office Park,

1 Macbeth Ave (On the corner with Roos Street), Fourways, Johannesburg,

SOUTH AFRICA

T: +27 (0)11 467 0945

APPENDIX B: MOKALA STORMWATER MANAGEMENT PLAN (AECOM, 2015)

MOKALA MANGANESE MINE

STORM WATER MANAGEMENT REPORT

PREPARED BY:

AECOM SA (Pty) Ltd

2 Maryvale Road

Westville

3629

PREPARED FOR:

MOKALA MANGANESE MINE (Pty) Ltd

66 Park Lane

Sandton

CONTACT PERSON

Mr K Hoffman

Tel No: 031 204 3800

CONTACT PERSON

Mr K Byrne

Tel No: 011 2188221

TITLE	:	***MOKALA MANGANESE MINE, STORM WATER MANAGEMENT REPORT***
Project Team	:	*AECOM (Pty) Ltd*
Client	:	*Mokala Manganese (Pty)Ltd.*
AECOM Project No	:	*60330971*
Status of Report	:	*Final*
AECOM Report No	:	*60330971-01*
Key Words	:	*Stormwater Design, Stormwater Management , Catchment Areas*
Date of this Issue	:	*9th October 2015*

For AECOM (Pty) Ltd

Compiled by	:	K. Hoffman		09-10-2015
		Initials & Surname	Signature	Date
Reviewed by	:	T. Ramlal		09-10-2015
		Initials & Surname	Signature	Date
Approved by	:	D. Pillay		09-10-2015
		Initials & Surname	Signature	Date

TABLE OF CONTENTS Page No

1. INTRODUCTION

Mokala Manganese (Pty) Limited has appointed AECOM SA (Pty) Ltd. as the consulting civil engineers, to undertake the storm water management design for the manganese plant.

1.1 LOCATION

The site, covering the remaining extent of farm Gloria 266, is approximately 450ha in size. It is located approximately 4km North West of the town of Hotazal in the Northern Cape Province of South Africa.

Facility	X	Y
Mokala Manganese Mine	3 023 596.972	-11 291.340

See annexure 1 for Mine Layout.

1.2 PURPOSE OF REPORT

This report provides an overview of the planning and design of the surface drainage management for this proposed development, which includes both contaminated, uncontaminated water and flood protection measures. Various catchment areas have been identified on the mine and is detailed within Annexure 2 - Storm Water Management Layout.

2. SITE CHARACTERISTICS

The site is relatively flat with a gentle slope towards the North East. The elevation on site varies from 1040m to 1100m above mean sea level. The highest topographical features (koppies and ridges) in the vicinity of the mine are the Korannasberg, approximately 44 km west of the site, and the Kurumanheuwels, approximately 66 km south east of the site.

The site is bordered by one main non-perennial drainage line, namely the Gamagara River (along the eastern boundary).

2.1 REGIONAL CLIMATE

Climate data for weather recording stations in the vicinity of the site were provided by SLR Consulting. The location and details of the stations used are detailed in Table 1-1.

Station Name	SAWS Number	Distance (km)	Record Length (Years)	Mean Annual Precipitation (mm)	Altitude (mamsl)
MUKULU	0392640 W	10.2	28	289	1056
HEUNINGDRAAI	0392680 W	11.4	28	349	1060
SMUTS	0392592 W	13.7	26	333	1073
MILNER	0393083 W	19.1	67	334	1118
KAREEPAN	0393225 W	20.1	36	352	1130
TSINENG (POL)	0393126 W	24.2	31	334	1049

Table 1-1 Summary of Six Closest SAWS Stations (Source: SLR Consulting)

2.2 DEPTH-DURATION

The design storm rainfall depths were developed by SLR Consulting using design rainfall software (Smithers and Schulze, 2002). The six closest rainfall stations, as shown in Table 1-1, were used to extract storm rainfall depths for various recurrence intervals. This data is represented in **Table 1-2 Rainfall Depths** below.

Duration	Rainfall Depth (mm)						
(min/h)	1:2 year	1:5 year	1:10 year	1:20 year	1:50 year	1:100 year	1:200 year
5 min	7.9	11.3	13.6	16	19.2	21.8	24.5
10 min	11.8	16.8	20.4	23.9	28.7	32.5	36.5
15 min	14.9	21.3	25.7	30.2	36.3	41.1	46.1
30 min	19.7	28.1	34	39.9	48	54.3	61
45 min	23.2	33.1	40	47	56.5	64	71.8
1 h	26.1	37.1	44.9	52.7	63.4	71.8	80.6
1.5 h	30.7	43.7	52.9	62.1	74.6	84.6	94.9
2 h	34.5	49.1	59.4	69.7	83.8	94.9	106.5
4 h	39.9	56.7	68.6	80.6	96.8	109.7	123.1
6 h	43.4	61.7	74.7	87.7	105.4	119.4	134
8 h	46.1	65.6	79.3	93.1	111.9	126.8	142.2
10 h	48.3	68.7	83.1	97.5	117.2	132.8	149
12 h	50.1	71.4	86.3	101.3	121.8	138	154.8
16 h	53.2	75.8	91.6	107.6	129.3	146.5	164.4
20 h	55.8	79.4	96	112.7	135.5	153.5	172.2
24 h	57.9	82.5	99.7	117.1	140.7	159.5	178.9

Table 1-2 24hr Rainfall Depths (mm) (Source: SLR Consulting)

3. STORMWATER DESIGN

Due to the nature of the operations on the mine, it is imperative that there is a delineation of stormwater on site between “Contaminated Stormwater”, and “Uncontaminated Stormwater / Clean Stormwater”. The clean and dirty stormwater systems were designed in accordance with the provisions of Regulation 704, 4 June 1999 (Regulation 704) for water management on mines.

3.1 UNCONTAMINATED STORMWATER / CLEAN STORMWATER

There are large areas within and around the site that will not be disturbed by the mining operations and as a result the stormwater runoff from these areas will not be conveyed to the recycle ponds. The uncontaminated stormwater runoff generated from these areas will be intercepted by a series of appropriately sized channels and earth berms (refer to details below). This runoff will discharge at ground level onto natural open areas through 5m v-drain chutes.

It must be noted that the climate is extremely arid and as a result any stormwater runoff which ponds in the small natural depressions or clean water accumulation areas will be permitted to infiltrate naturally.

3.2 CONTAMINATED STORMWATER / DIRTY WATER

The stormwater runoff generated within areas that are disturbed by the mining operations will be dealt with as contaminated stormwater and will typically be of a turbid nature with suspended solids. The contaminated stormwater will be controlled on site via a series of trapezoidal drains and earth berms and contained within lined recycle ponds 13, 14, 15 and 16 (refer to typical detail below **Figure 5** and **Annexure 2**).

In between the contaminated stormwater areas, there exist large areas where clean stormwater will be allowed to infiltrate naturally. These areas are classified as infiltration paddocks. These infiltration areas reduce the volume of clean stormwater unnecessarily reporting to the recycled water ponds and being contaminated, in turn reducing the size of the recycle water ponds required.

The respective elements of the contaminated stormwater drainage system are designed such that the contamination of the clean stormwater system is limited to a 1:50 year chance in any given year.

Stormwater runoff from the disturbed areas includes:

- Plant area;
- Waste rock dump site;
- Product transport road;

- Access road to stockpiles (haul road);
- HDV truck park; and
- Administration area.

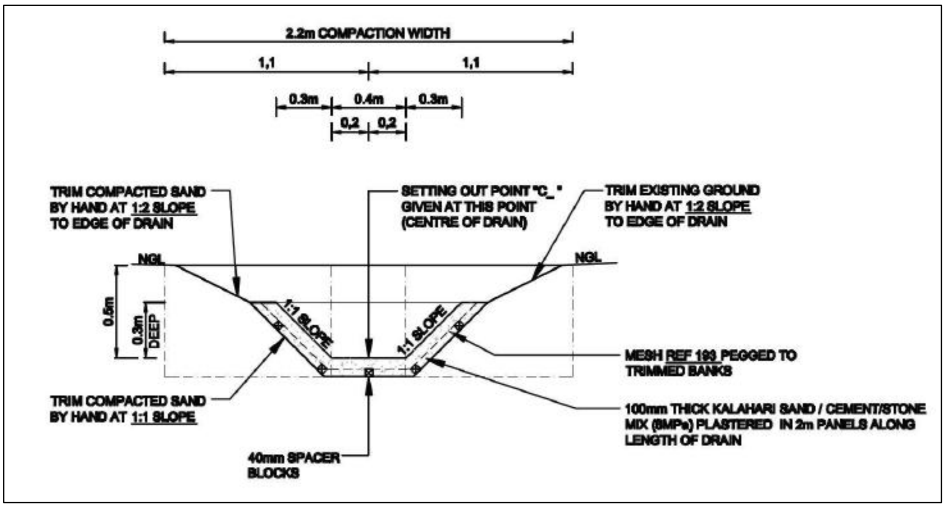


Figure 1: Typical detail of trapezoidal drain

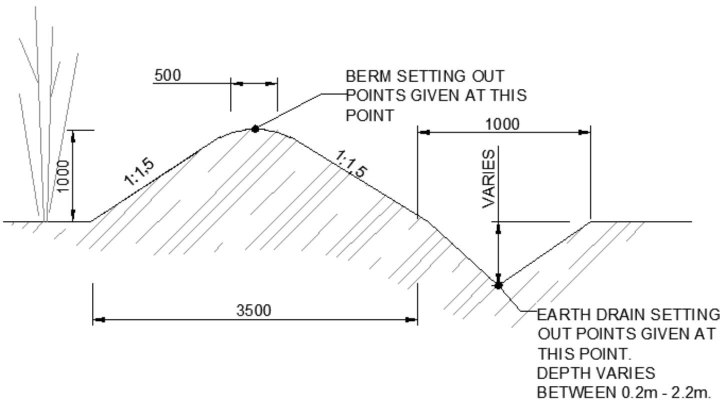


Figure 2: Typical detail of earth berm

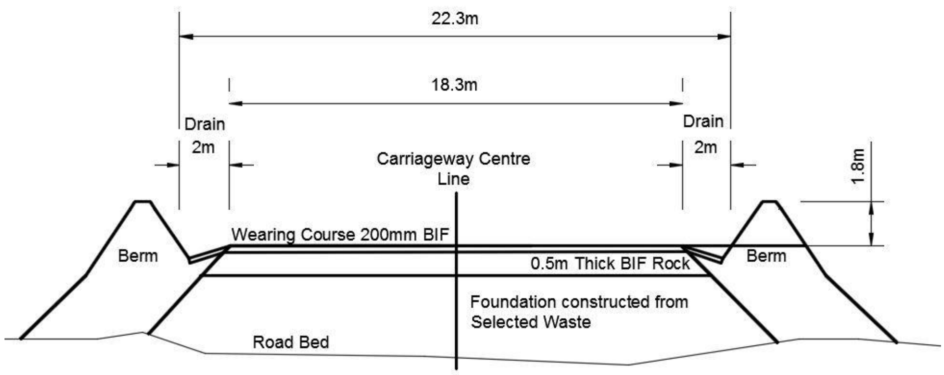


Figure 3: Typical section through haul road

The main access and product transport road has been designed with a 2.5% cross-fall with 1V in 2H banks and v-drains (Refer to Figure 4). This surfacing is specific to areas that are subjected to different vehicles types and vehicle movements. Refer to concept drawings for details on the surfacing and corresponding layerworks.

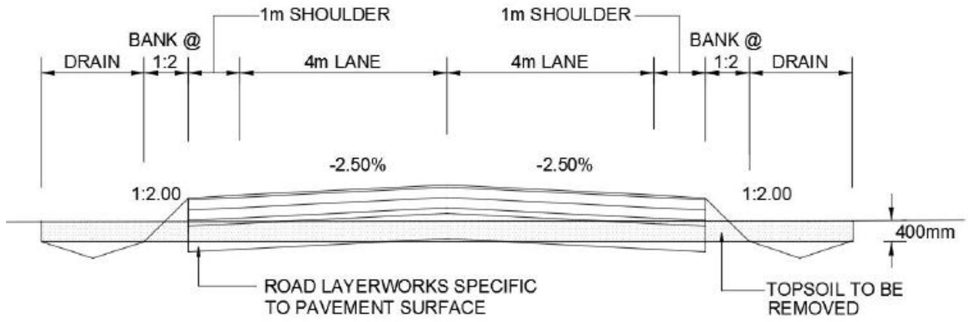


Figure 4: Typical Cross-Section through product transport road

3.3 STORMWATER CALCULATIONS

The **contaminated** network has been sized based on a 1 in 50 year flood event covering areas that will be disturbed by the mining activities. The design storm rainfall figures were provided by **SLR Consulting**, as per Table 1-2.

The Rational Method was adopted combined with the figures in Table 1-2 above to calculate the maximum rate of discharge per disturbed area. Subsequently, the recycled stormwater ponds and channels were designed accordingly.

Rational Method: Q = C*I*A

Q = the maximum/peak rate of run-off

C = run-off coefficient (specific to area)

I = rainfall intensity (figures obtained from SLR Consulting)

A = area of catchment in hectares.

3.4 RECYCLE STORMWATER STORAGE PONDS

Pond 13 is designed to contain a capacity of 7,966m^3. It will accommodate surface water, from rainfall and runoff, from all elements within the plant area. In the event of the pond being overtopped, overflow will be pumped to pond 14.

Pond 14 is designed to contain a capacity of 20,466m^3. It will accommodate surface water, from rainfall and runoff, from the stockpile access road (haul road), the contaminated topsoil storage/stockpile area and overflow from pond 13. Additionally, groundwater inflow from the mine pit will be pumped to the pond as well as all surface water, from rainfall and runoff, within the mine pit. The depth and capacity of the pond will be altered accordingly to accommodate the additional inflow from the mine pit if needed.

Pond 15 is designed to contain a capacity of 1,442m^3. It will accommodate surface water, from rainfall and runoff, from the truck staging area, product transport road and contaminated surrounds.

Pond 16 is designed to contain a capacity of 3,433m^3. It will accommodate surface water, from rainfall and runoff, from the HDV truck park, administration area, main store and workshop. Surface water run-off generated from the roofing and LDV car park at the administration area, typically classified as uncontaminated stormwater, will be relatively marginal in volume and will not warrant the expenditure required to delineate the flows. This run-off too will be contained in pond 16.

Sedimentation and silt traps – Silt traps will be positioned at the pond inlets to prevent excessive sedimentation from entering the ponds. Prior to discharging the stormwater runoff into the pond, sediments that are suspended in the stormwater runoff will be allowed to settle within the basin of the silt trap. These silt traps will be concrete lined and designed for ease of maintenance by motorised bobcat machines. Maintenance will be achieved by including access ramps for the bobcats. See **Figure 6** below.

Mine Pit Surface Water - the water inflow from the mine pits is inconsistent, varying from season to season, but can be substantial after heavy downpours. There is also a necessity to collect the water that may become trapped in the mine pits for environmental reasons. To this extent, water from the mine pits will be pumped out of the pits into pond 14, as mentioned above. Pond 14 will be located near the plant yard adjacent to the haul road intersection, however, may have to be replicated or moved as mining moves along the pit and the laying out of pumping lines becomes too long.

It is important to note that water from the mine pit will mainly be available after a significant rainfall event, although some groundwater infiltration is expected.

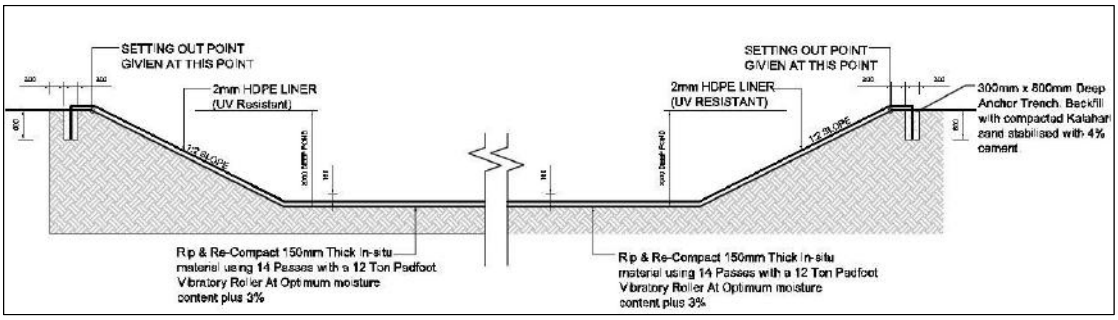


Figure 5: Typical detail of recycle stormwater pond

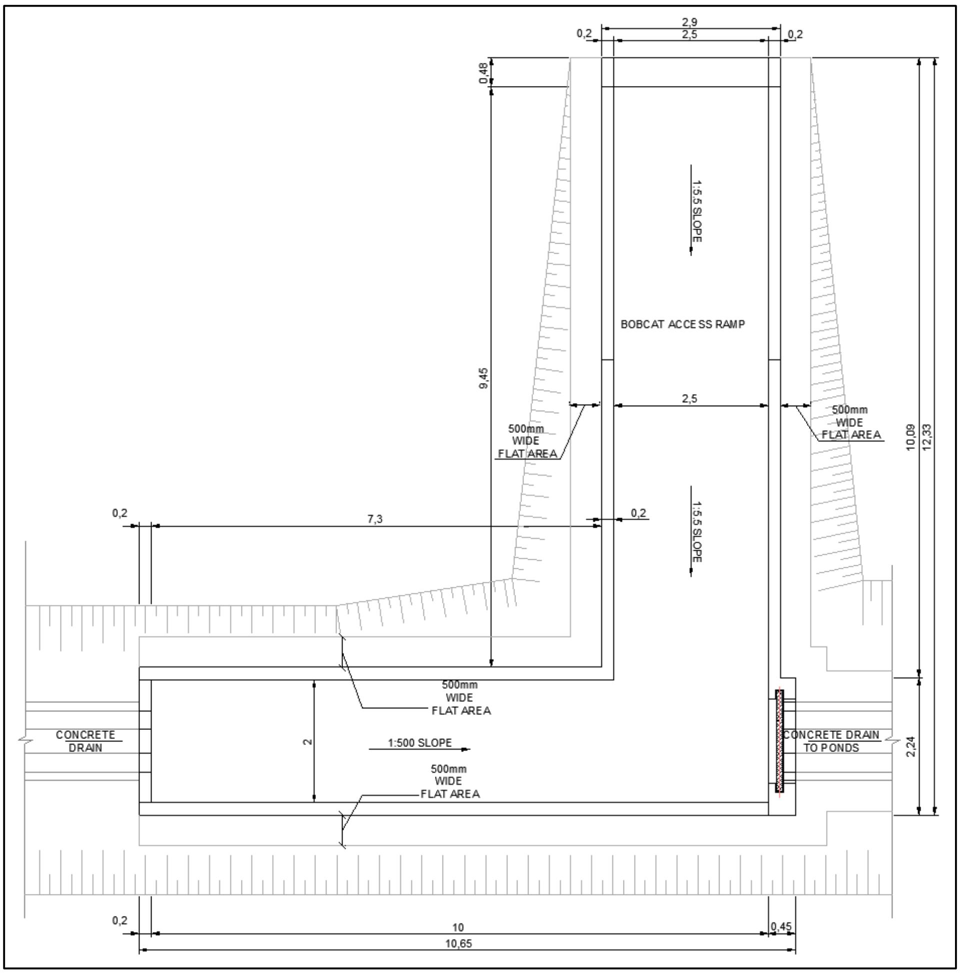


Figure 6: Typical detail of recycle stormwater pond silt trap

4. CONCLUSION

The facets of engineering detailed in this report have been based on a generally accepted criteria, along with sound engineering principles and assumptions and conforms to Regulation 704.

5. REFERENCES

(i) The South African National Roads Agency SOC Limited, Drainage Manual, 6th Edition.

(ii) SRK Consulting –SRK Consulting: Smartt-Rissik Monthly Water Balance update, dated September 2013).

(iii) Regulations on use of water for mining and related activities aimed at the protection of water resources, dated June 1999,

ANNEXURE 1

GENERAL LAYOUT

ANNEXURE 2

STORM WATER MANAGEMENT LAYOUT

AFRICAN OFFICES

South Africa

CAPE TOWN
T: +27 21 461 1118

JOHANNESBURG
T: +27 11 467 0945

DURBAN
T: +27 11 467 0945

Namibia

WINDHOEK
T: + 264 61 231 287