HYDROLOGICAL ASSESSMENT FOR THE PROPOSED ALLUVIAL DIAMOND MINE AND ASSOCIATED INFRASTRUCTURE: SAMARA PTY LTD PROSPECTING PROJECT, NORTHERN CAPE PROVINCE

Prepared by

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Executive Summary

Nyamoki Consulting (PTY) LTD was appointed by NDi Geological Consulting (PYT) LTD to conduct hydrological assessment for Samara Diamond alluvial and associated infrastructure Prospecting Right at Sydney on Vaal near Barkley West Town in Northern Cape.

A comprehensive baseline information including rainfall data, depth-duration-frequency design rainfall estimates, evaporation data as well as both regional and local hydrological characteristics was analysed for the proposed prospecting project site.

Peak flows and hydrographs were developed as part of the study and HEC-RAS model was applied to provide an indication of what areas would be inundated by the respective flood flows for the 50 and 100 year events. The result indicated that the whole prospecting area may be inundated by both the 50 and 100 year flood which possess risk for the proposed activity. However, as the nature of alluvial diamond mining, this risk was anticipated and hence prevention and mitigation measures were recommended.

Water quality sampling was conducted on the Vaal River upstream and downstream of the proposed prospecting area. The result indicated that the water was not fit for domestic and potable use as it contained E.coli, total coliforms and high turbidity. Treatment of water was essential before use. The water quality result was therefore recommended to serve as a benchmark for future bi-annual sampling program during the prospecting period.

An analysis of mean annual runoff was undertaken as part of the study using the WR2012 dataset. The WR2012 mean annual estimate of runoff for the study area was high as the proposed area was along the banks of the Vaal River.

The study area's water balance was not greatly influenced by climate imbalance between average evaporation and rainfall as the Vaal River receives high return flows from factories and irrigated areas upstream of the study area. However, caution was advised to prevent flooding of infrastructure during the opening of weirs upstream and also during heavy rainfall on the Vaal River system.

This baseline study indicated that the impacts on the Vaal River resulting from the proposed prospecting activity may be managed to low if and when recommended mitigation measures were implemented.

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1. INTRODUCTION

Nyamoki Consulting (Pty) Ltd has been appointed to conduct a hydrological assessment for the proposed Samara Diamond Alluvial and associated activities Prospecting Right project along the Vaal River at Sydney on Vaal near Barkley West Town in Northern Cape Province of South Africa. The investigation has been undertaken to form part of the Environmental Impact assessment (EIA), associated management plan (EMP) as well as the Integrated Water Use License Application (IWULA), to be submitted to the Department of Water and Sanitation (DWS).

The objective of this study is to determine potential flood risk and impacts for safe placement of infrastructure and to inform the implementation of feasible and cost-effective flood control measure on the project site.

Figure 1 indicates the local setting of the proposed project locality.

Figure 1: Study Locality

2. SCOPE OF WORK

The scope of the work is summarised as follows:

A. Screening and Scoping

- The study commenced with acquisition of review of relevant information related to the study area
- Legislative literature related to the nature of the project was reviewed

B. Hydrology

- Catchment delineation and characterisation was done for quaternary and sub-catchments
- Determination of mean annual precipitation (MAP) and mean annual runoff through analysis of meteorological data for the study area
- Calculation of design precipitation depth for events of 1:50yr and 1:100yr return periods using Design Rainfall software for South Africa (Smithers,2000)
- Calculation of 1:50yr and 1:100yr peak flows using generally recommended methods for South Africa

C. Water quality analysis and monitoring plan

- Analyze water quality based on SANS 241:2015 limits
- Characterize water quality based on Piper Diagrams
- Design and recommend monitoring plan

D. Flood Assessment

- Setting up of HEC-RAS model files in HEC-GeoRAS (US Army Corps of Engineers, 2010)
- Calculation of 1:50yr and 1:100yr floodlines in HEC-RAS model
- Calibration of model to optimize model result

E. Conceptual storm water management plan

- Determining and delineation of clean and dirty water catchments
- Assessment of storm water management measures

G. Impact assessment

- Identification of potential receptors downstream of the site
- Description of surface water impacts and mitigation measures

H. A technical report detailing the achieved scope of work.

3. METHODOLOGY

The study will be conducted through the assessment of Google Earth Satellite imagery, QGIS and site visit to confirm ground truth. Catchment characterisation was done using information from satellite images and analysis of Digital Elevation Model (DEM) created using Google Earth Imagery. Climate data used was obtained from 2012 Water Resource study database of the Water Research Commission (WRC, 2012).

3.1. Materials and Resources used

The following materials and resources were used to conduct this study:

- QGIS
- Design Rainfall software of South Africa (Schulze,2002)
- Google Earth
- HEC-RAS and HEC- GeoRAS (US Army Corps of Engineers, 2010)
- WR2012 database (WRC,2012)
- Microsoft Excel spreadsheets

3.2. Legislation

Reginal information was downscaled to local setting of where Boekenhoutfontein mine is located during this hydrological assessment study as a way to ensuring that the study complies with National, Regional and Local legislation governing the placement of infrastructure with regards to determined floodlines. Nation Water ACT 36 of 1998 and the National Environmental Management Act 107 of 1998 are very important legislations in this study as they govern the use and protection of environment and water resources from developmental activities that may potentially have negative impacts on the environment and water.

The other important legislation for this study was Government Notice (GN) 704 and Best Practice Guidelines (BPG) G1 which guide the minimum requirement for placement of infrastructure along the water course. These legislations stipulate that no mining infrastructure should be constructed 100m from the river or from 1:50 year floodlines. They also stipulate the tasks which should be done for storm water management such as; separation of dirty and clean water systems, controlling and containment of dirty water runoff, prevention or reduction of pollution to water resource etc.

4. DESCRIPTION OF THE RECEIVING ENVIRONMENT

4.1. Hydrological Setting of the Project Site

The study is within the quaternary catchment C91E of the Lower Vaal Water Management Area (WMA). Regional and local hydrology as indicated on **Figure 1** is defined by the Vaal River that drains the study area from quaternary catchment C91B flowing towards Douglas where its joins the Orange River at catchment C92C. Harts River joins the Vaal River at the mouth of the quaternary catchment C91E.

The proposed prospecting is along the banks of the Vaal River which meanders as it passes the study area. There are no noticeable non-perennial streams that flow through the project site.

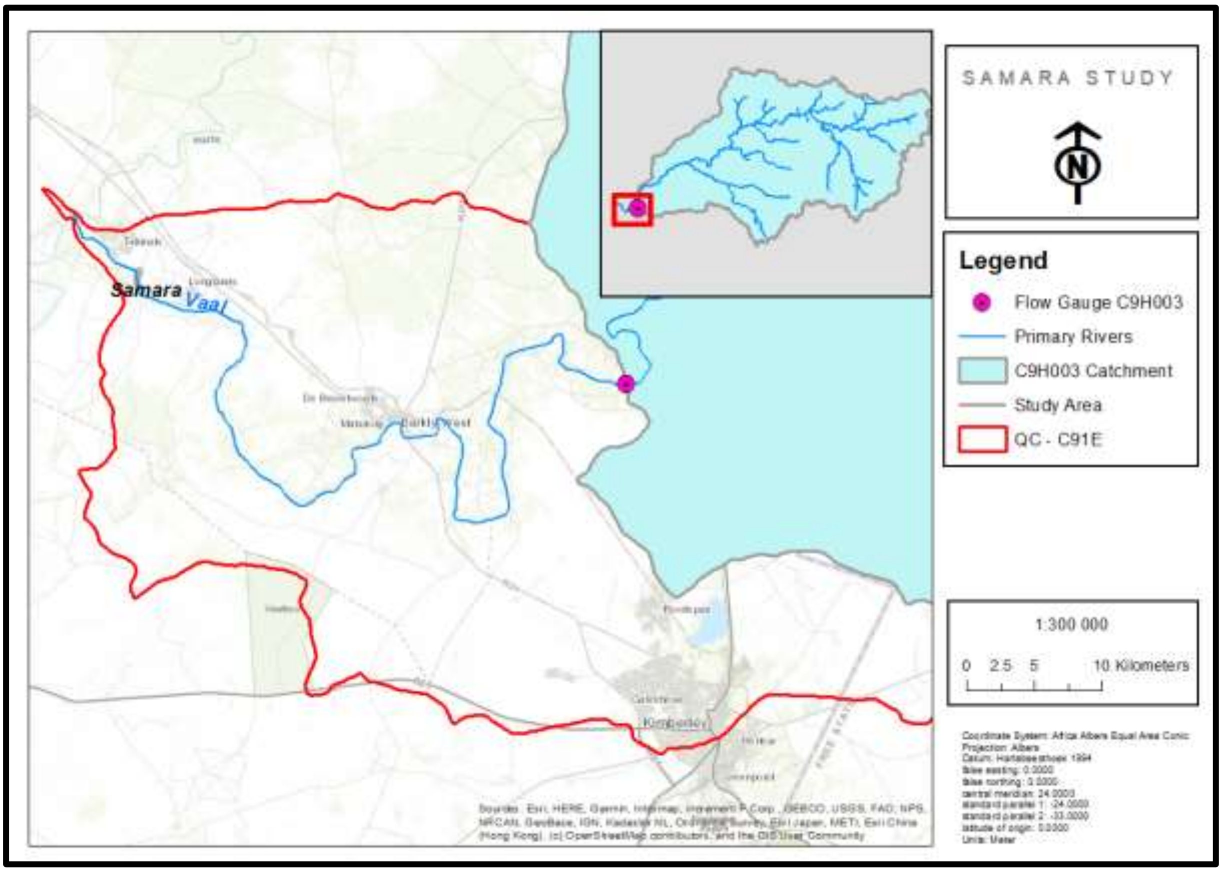

Figure 2: Quaternary Catchment C91E hydrology

4.2. Topography, Elevation and Land Use

Topography and land cover of the site are important as they have impact on the runoff generated during rain events. The study area's topography is relatively flat, with slope ranging primarily between 1% and 10%. The same is true for the proposed project site along the Vaal River.

The study area's elevation ranges from 1016 meters above mean sea level (MAMSL) to 1054 MAMSL. The proposed prospecting right area's topographical elevation is between 1016 to 1023 MAMSL as indicated on **figure 3** below. This is the lowest point on the Vaal River banks and flood plain.

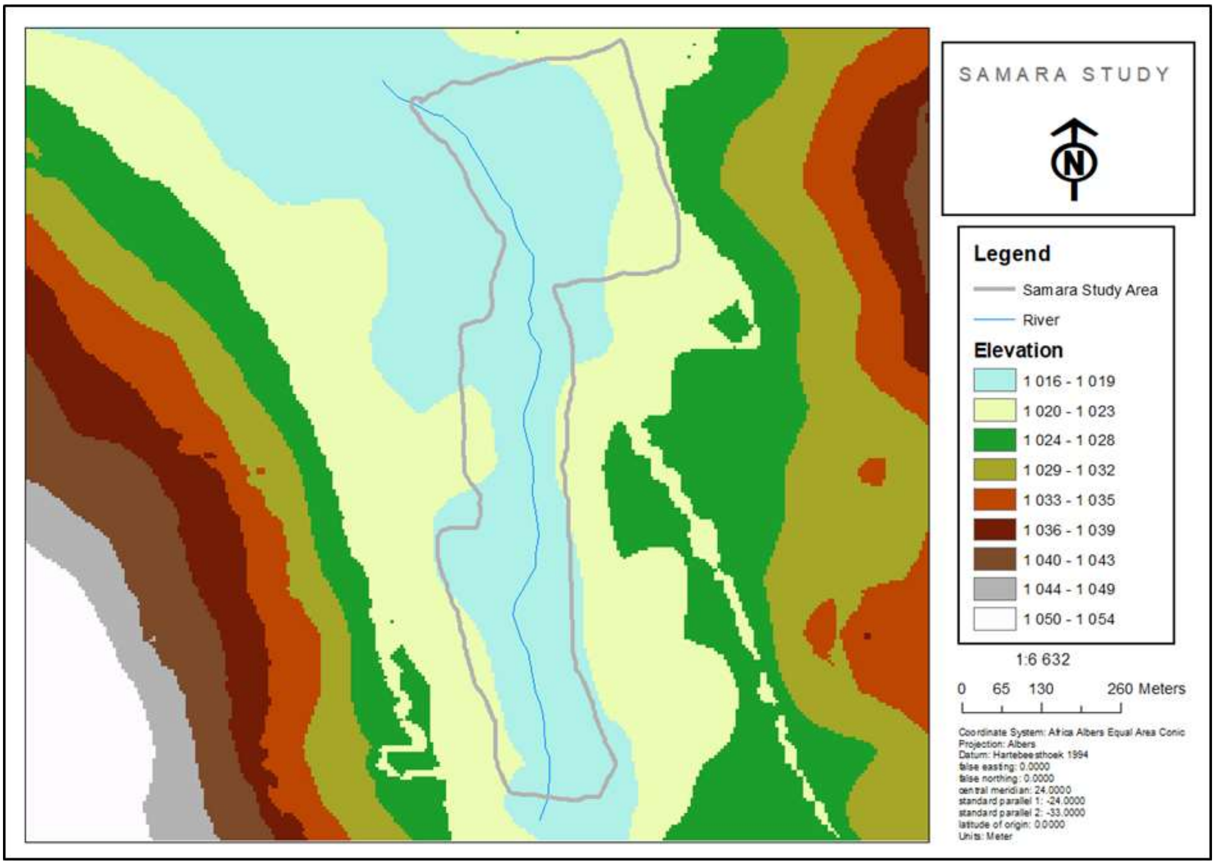

Figure 3: Site Elevation

Land use activities within 1 km radius of the proposed prospecting project are indicated on **Figure 4** below. The area surrounding the proposed prospecting area is known as the "Diamond Veld" due to the high density of diamond alluvial mining. Small residential areas exist just out of the 1 km radius, however no agricultural activities are practiced which indicates that the majority of the residence work in the these diamond fields along the Vaal River.

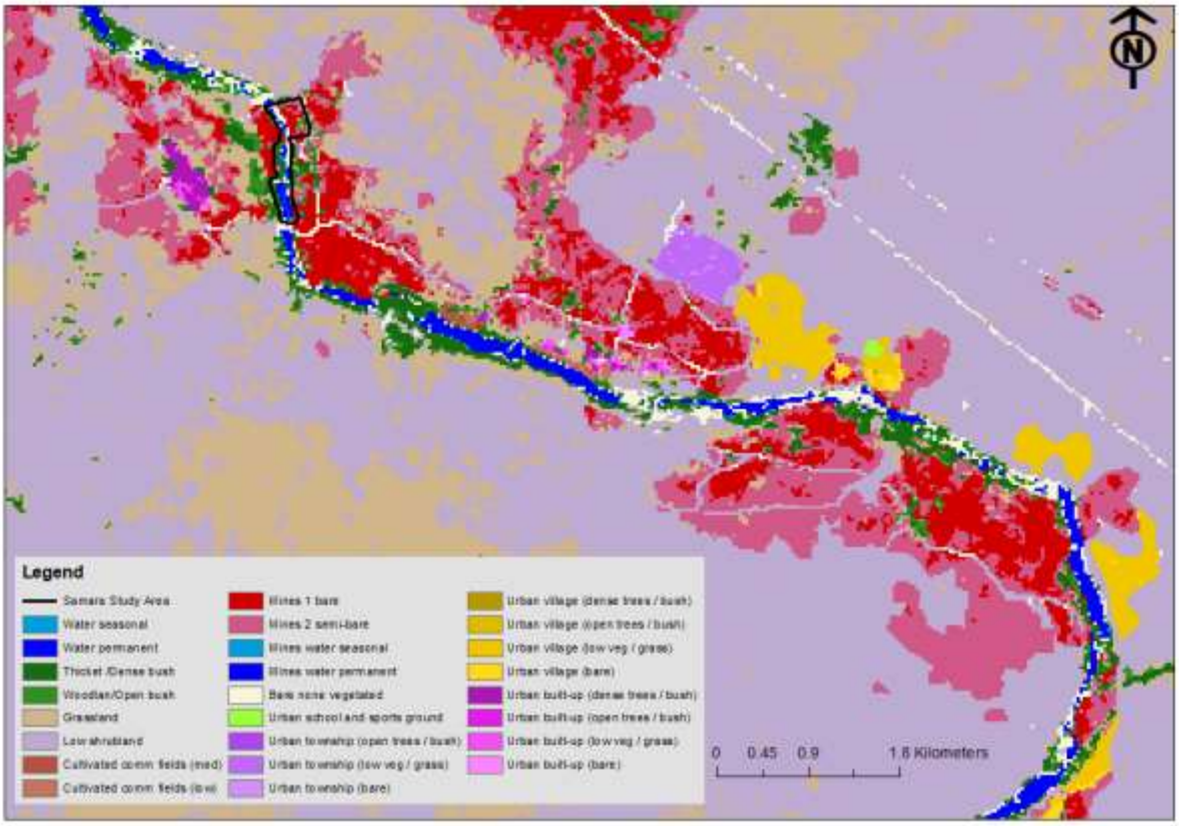

Figure 4: Land Use Activities

4.3. Rainfall

Rainfall data was obtained from the SAWS rainfall station Delportshoop Pol 0323535_W with 46 year record from 1966 to 2011. This station had a Mean Annual Precipitation (MAP) of 441 mm. **Table 1** provides a summary of the average monthly rainfall distribution at this station.

Table 1: Average Monthly Rainfall

Month	**Rainfall (mm)**
Jan	71.5
Feb	71.7
Mar	83.4
Apr	37.6
May	16.4
Jun	8.4
Jul	1.9
Aug	5.4
Sep	4.7
Oct	11.6
Nov	38.4
Dec	63
Total	**414**

4.4. Return Period Rainfall Depth

Design storm estimates for Delportshoop Pol 0323535_W station for various return periods and storm durations were sourced from the Design Rainfall Estimation Software for South Africa, developed by the University of Natal in 2002 as part of a WRC project K5/1060 (Smithers and Schulze, 2002). Design Rainfall version 3 software of 2012 was used for this project and the result is presented in Error! eference source not found.. This method uses a Regional L-Moment Algorithm (RLMA) in conjunction with a Scale Invariance approach to provide site specific estimates of design rainfall (depth, duration and frequency), based on surrounding station records. WRC Report No. K5/1060 provides more detail on the verification and validation of the method.

Table 2: Rainfall Depth

Return Period (yrs)	Rainfall Depth (mm)
2	50
5	70.8
10	85.4
20	100.1
50	120.2
100	135.2
200	158.8

In this project, the RLMA technique was selected due to it being based on localised observed data which are specific to the site location and are more conservative for the return period of interest (50-year event).

4.5. Evaporation

Evaporation data is represented on **Table 4.** This data was sourced for WR2012 which provided catchment C91E monthly evaporation distribution (Class S-Pan) for the period 1975 - 2009. North West as a province experience high levels of evaporation due to elevated solar radiation levels. The average annual evaporation is approximately 1947 mm with the highest evaporation of more than 243 mm occurs in December and the lowest of 68 mm in June. The monthly evaporation exceeds precipitation and this has contributed in the less number of tributaries to the Vaal River within the study area.

Table 3: Monthly S-pan Evaporation (mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
Evaporation (mm)	243	182	170	125	93	68	88	118	171	216	233	240	1947

4.6. Climate Condition

The study area falls within the Highveld climatic zone which is semi-arid. The area experiences summer rainfall which commence in October and ends in April. The pick rainfall months are December to March while the lowest rainfall months are June, July and August.

Figure 5 illustrates the average climate for the study area, and the significant difference between rainfall and potential evaporation is visibly illustrated. The rainfall deficit to evaporation is high, which explains the limited number of rivers within the study area.

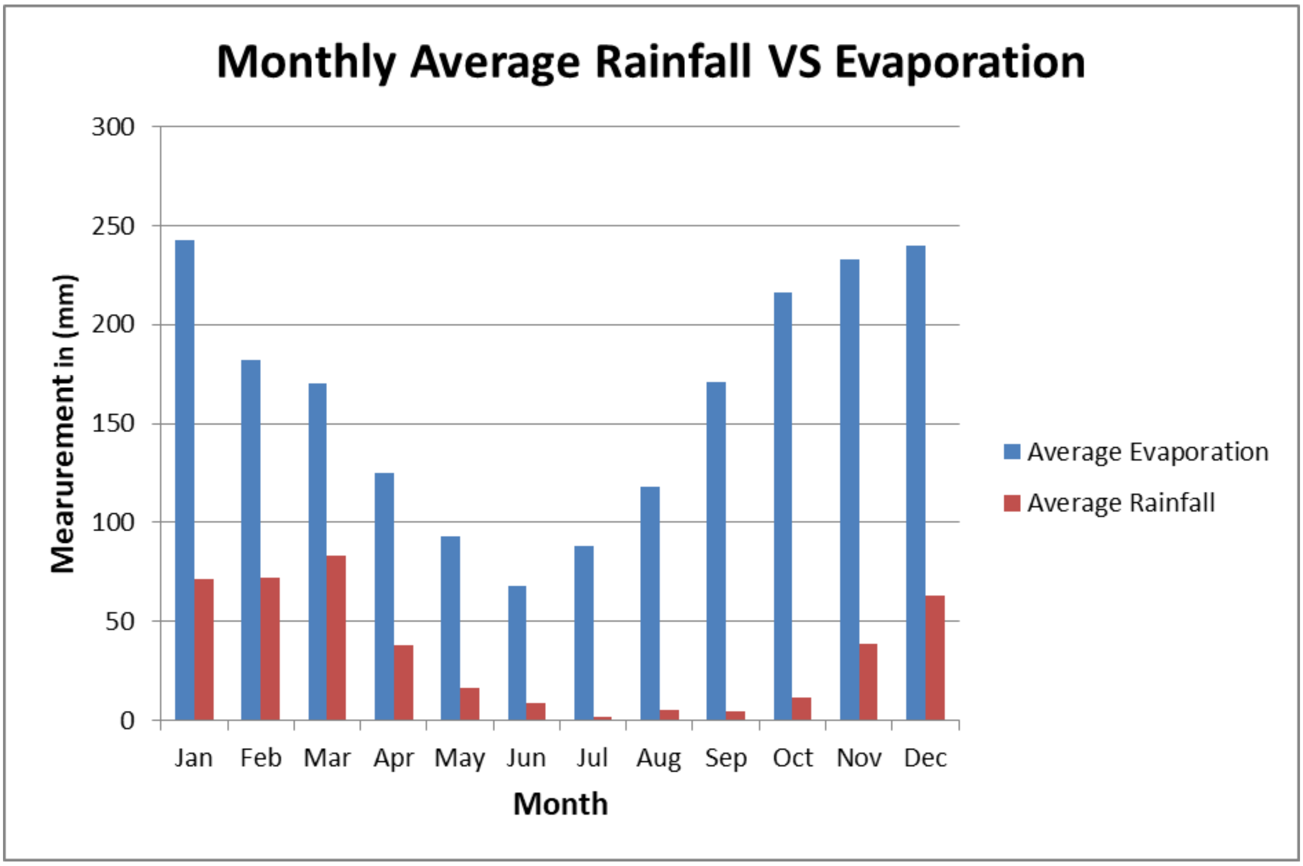

Figure 5: Average Climate

5. FLOOD ANALYSIS

The aim of the flood modelling undertaken as part of this study was to fulfil the requirements of the National Water Act (Act 36 of 1998) and more particularly, Government Notice 704 (Government Gazette 20118 of June 1999) (hereafter referred to as GN 704). The final mining plan will need to consider the specific provisions of GN704. The principle condition of GN 704 applicable to this project with regards to flooding is summarised as follows:

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

In order to satisfy the Gazette notice referred to above, it was necessary to determine the peak flows for the design floods with return period of 1:50 and 1:100. The flood line was then delineated in order to arrive at a determination if the mining location meets the Gazette conditions of being located more than the 1:100 flood line and 100 metres away from the watercourse.

5.1. Design Rainfall

An important input required for the estimation of design floods is design rainfall. Design rainfall values were extracted for the project area using the Design Rainfall Utility developed by Smithers and Schulze (2000) and are listed in the tabulation for the project area.

Table 4: Design rainfall for Samara Study Area

Duration	Return Period (years) Design rainfall Depth (mm)						
	1 : 2	1: 5	1: 10	1: 20	1: 50	1: 100	1: 200
5 m	7.6	10.5	12.5	14.5	17	19	21
10 m	11.2	15.6	18.5	21.4	25.2	28.1	31.1
15 m	14.1	19.6	23.3	26.9	31.7	35.4	39.1
30 m	18	25	29.7	34.3	40.5	45.2	49.9
45 m	20.8	28.8	34.3	39.6	46.7	52.1	57.6

1 h	23	31.9	37.9	43.8	51.6	57.6	63.7
1.5 h	26.5	36.8	43.7	50.5	59.5	66.4	73.4
2 h	29.3	40.7	48.4	55.9	65.9	73.5	81.2
4 h	33.9	47	55.9	64.6	76.1	84.9	93.9
6 h	36.9	51.1	60.8	70.3	82.8	92.4	102.2
8 h	39.2	54.3	64.6	74.6	87.9	98.1	108.5
10 h	41	56.9	67.6	78.2	92.1	102.8	113.6
12 h	42.6	59.1	70.3	81.2	95.7	106.8	118
16 h	45.3	62.7	74.6	86.2	101.6	113.4	125.3
20 h	47.4	65.7	78.2	90.3	106.4	118.8	131.3
24 h	**49.3**	**68.3**	**81.2**	**93.8**	**110.6**	**123.4**	**136.4**
1 d	39.6	55	65.4	75.5	89	99.3	109.8
2 d	47.7	66.1	78.6	90.8	107	119.4	132
3 d	53.1	73.6	87.5	101.1	119.2	133	147
4 d	56.5	78.4	93.2	107.7	126.9	141.6	156.5
5 d	59.4	82.3	97.8	113.1	133.3	148.7	164.4
6 d	61.8	85.6	101.8	117.7	138.7	154.7	171.1
7 d	63.9	88.6	105.3	121.7	143.4	160.1	176.9

5.2. Design Flood

According to Smithers and Schulze (2001) design floods can be estimated using two main approaches, the rainfall based methods and through analysis of streamflow data. These are well illustrated in the **Figure 6** below.

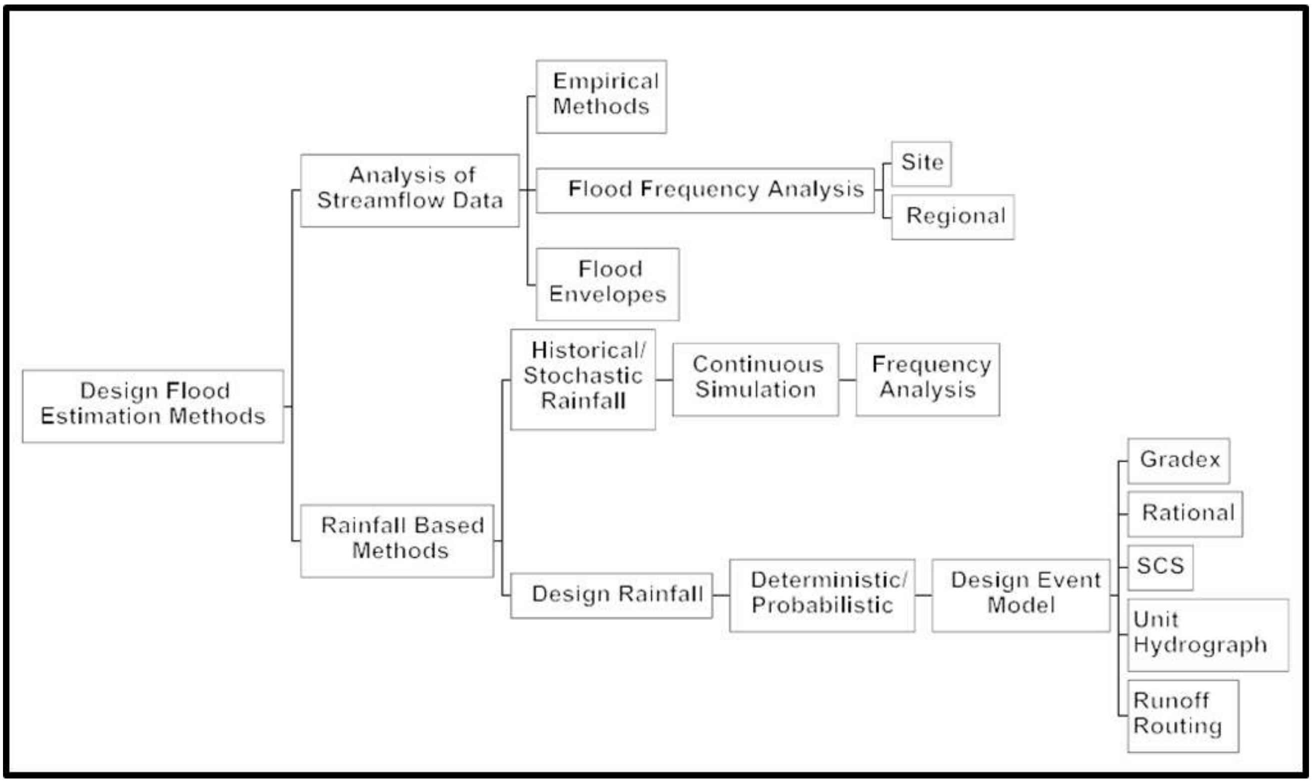

Figure 6: Methods for estimating design floods (after Smithers and Schulze, 2001)

Where long records of streamflow are available at a site, a frequency analysis of observed data may be performed to estimate design floods. The procedures for direct frequency analysis of observed peak discharge often involves selecting and fitting an appropriate theoretical probability distribution to the data. These procedures are referenced in standard hydrology texts (e.g. Chow et al., 1988; Stedinger et al., 1993).

Design flood estimations for the study area were performed by frequency analysis of data in the upstream station (C9H003) (Figure 1.2), this is because there is available data of sufficient length and quality. A regional approach was then employed by extrapolating the identified peaks to determine design floods for quaternary catchment C91E which covers the study area.

Flow Station C9H003 on the Vaal upstream the study area has got flow data from 1909 to recent (112 years). The flood frequency analysis data and the return periods are given in the **Table 5** below:

Table 5: C9H003 Flood Frequency Analysis

Exceedance Probability (%)	50	20	10	5	2	1	0.5
Return Period (years)	1 : 2	1: 5	1: 10	1: 20	1: 50	1: 100	1: 200
Design Floods (m^3/s)	21	57	133	282	770	1556	4224

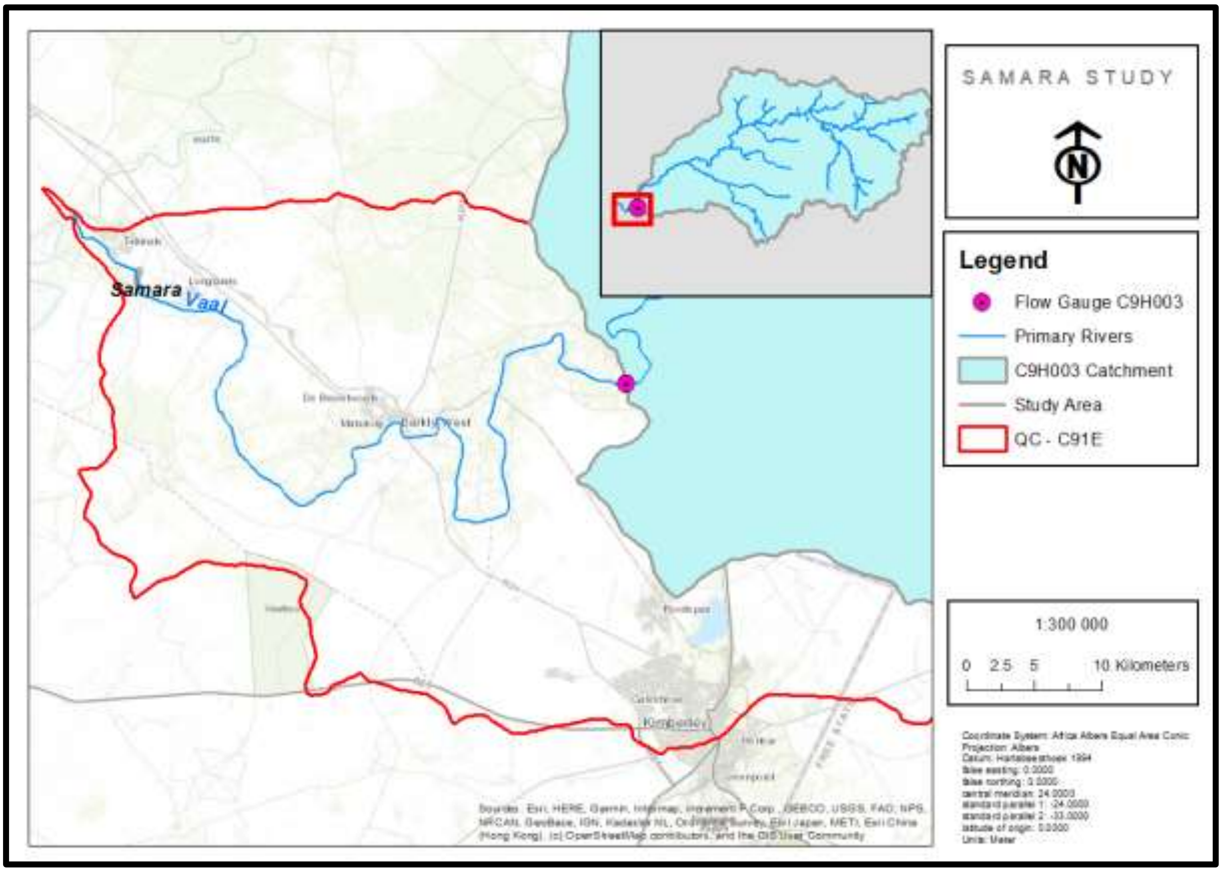

Figure 7: Flow Gauge C9H003 Catchment

5.3. Hydraulic Modelling

The HEC-RAS Model (US Army Corp of Engineers) was used to undertake the 1-dimensional hydraulic modelling to determine the extent of the 1:50 and 1:100 year return period flood events. HEC-RAS is a hydraulic programme designed to perform one-dimensional hydraulic calculations for a range of applications, from a single watercourse to a full network of natural or constructed channels. The software is used worldwide and has consequently been thoroughly tested through numerous case studies.

The calculated water levels (Floodlines) depends on the accuracy of the assumptions used and the quantity and quality of the relevant input data in terms of river/stream cross-sections, flow rates, roughness coefficients, reach lengths and junctions. The better the quality of the data, the more accurate the results will be.

In order to setup the HEC-RAS model for hydraulic modelling, and ensure high accuracy, elevation points (Figure 8) were collected from Google Earth and were used to derive a Digital Elevation Model (DEM) in HEC-GeoHMS using ArcMap. The elevation points were then converted to DEM using an inverse distance weighting method (Figure 9). This formed the basis for geometric input data into the model.

HEC-RAS uses the Manning's roughness coefficient (n) in hydraulic calculations in order to assess the frictional impact that soils and the land cover has on the water flow velocities and discharge. The roughness coefficients for the hydraulic modelling were assigned to the river channels and river banks according to the classification by Chow (1959). The cross sections which were used as input geometric data for the study area for which floodlines are to be delineated are presented in **Figure 10**.

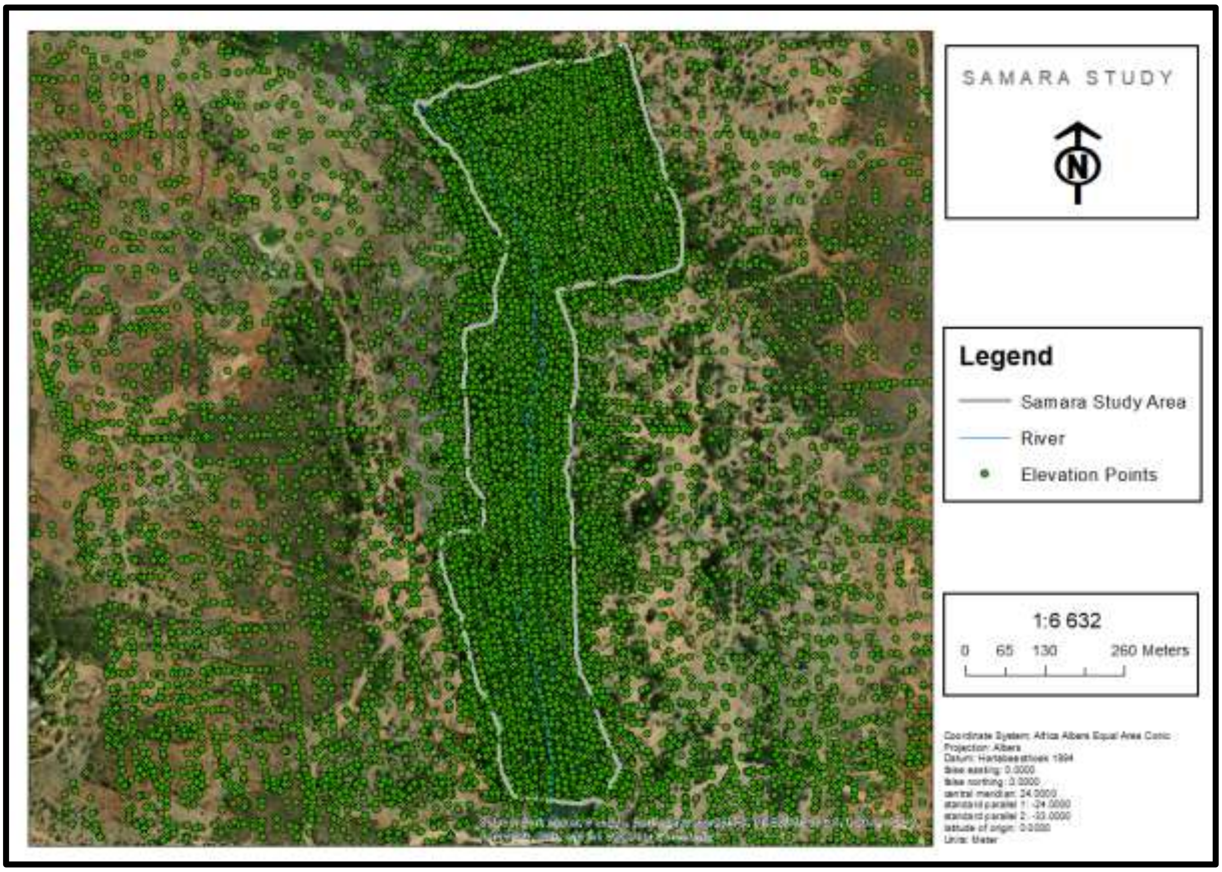

Figure 8: Elevation Points Collected

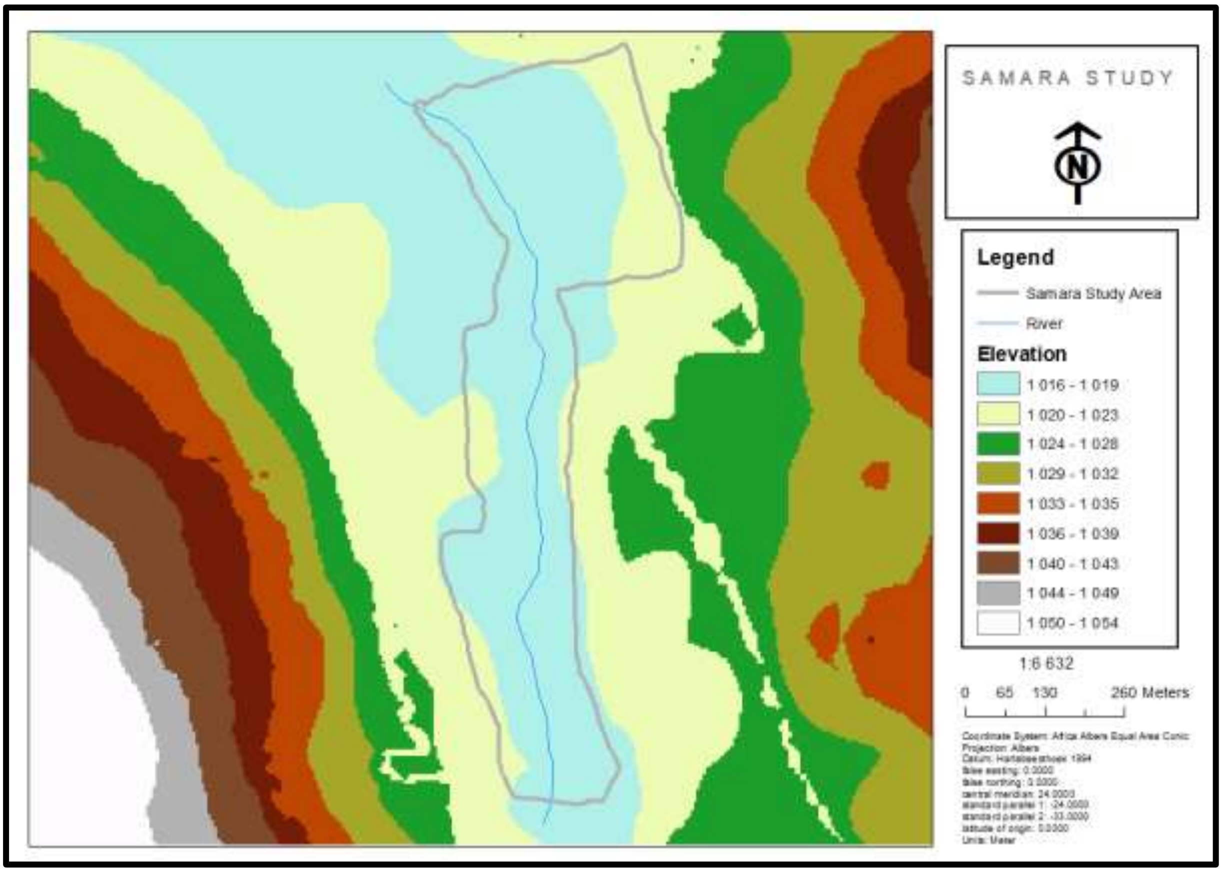

Figure 9: Digital Elevation Model 5m resolution

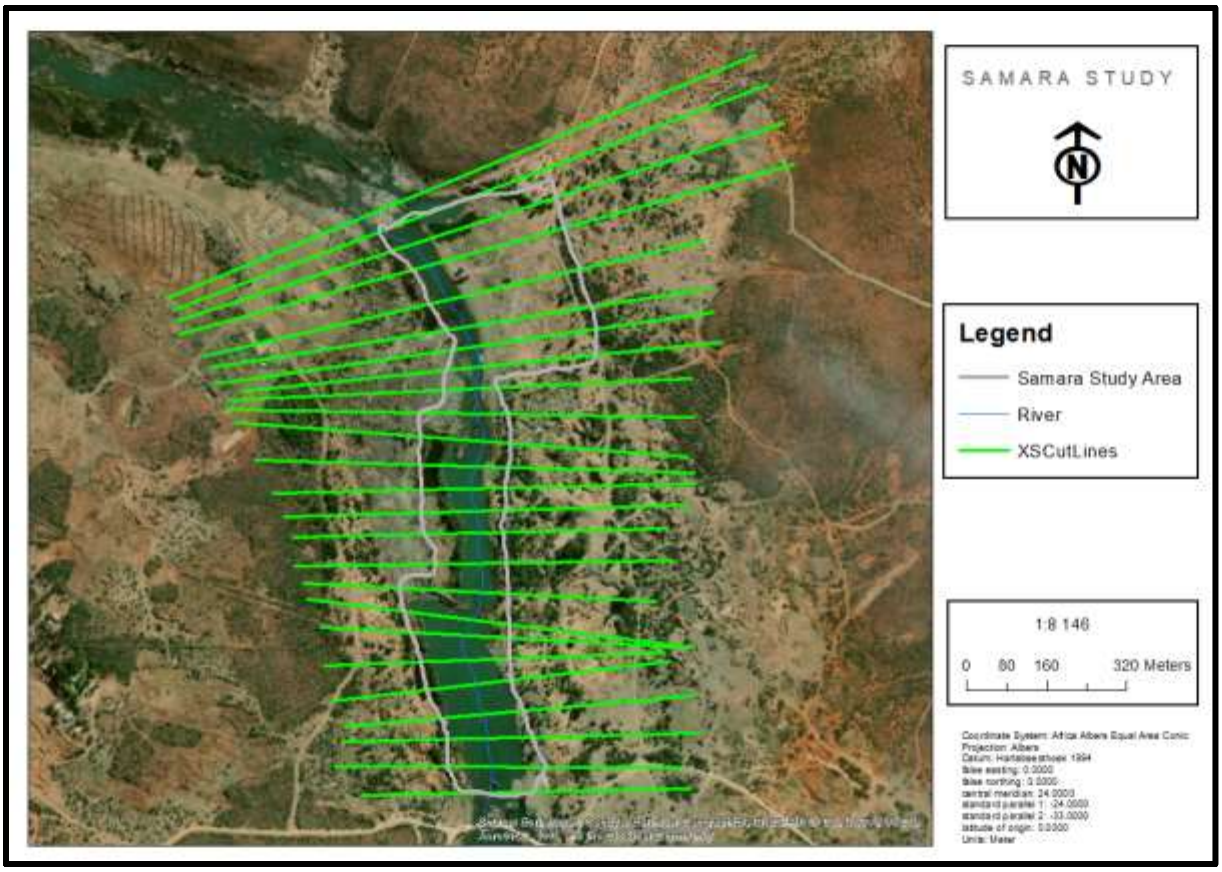

Figure 10: Cross Sections Cutline

5.4. Design Flood Estimation

The 1:50 and 1:100 year design floods estimated using the flood frequency analysis method, and further extrapolated to the study area using the regional approach are presented in the **Table 6** below.

Table 6: Estimated design flood peaks

Site Name	Catchment Area (km²)	Design flood peaks (M³/s)	
		1: 50 year	1: 100 year
Vaal River at C9H003	121070	770	1556
Vaal River at outlet C91E (Study site)	1507	86	174

5.5. Flood Delineations

The 1:50 and 1:100 year flood line delineated and mapping for the Vaal River at the Samara study site is given is **Figure 11.** The mining is still a proposed activity and therefore the delineated floodlines are for planning purposes to ensure that all mining activities and infrastructure are not within the floodlines.

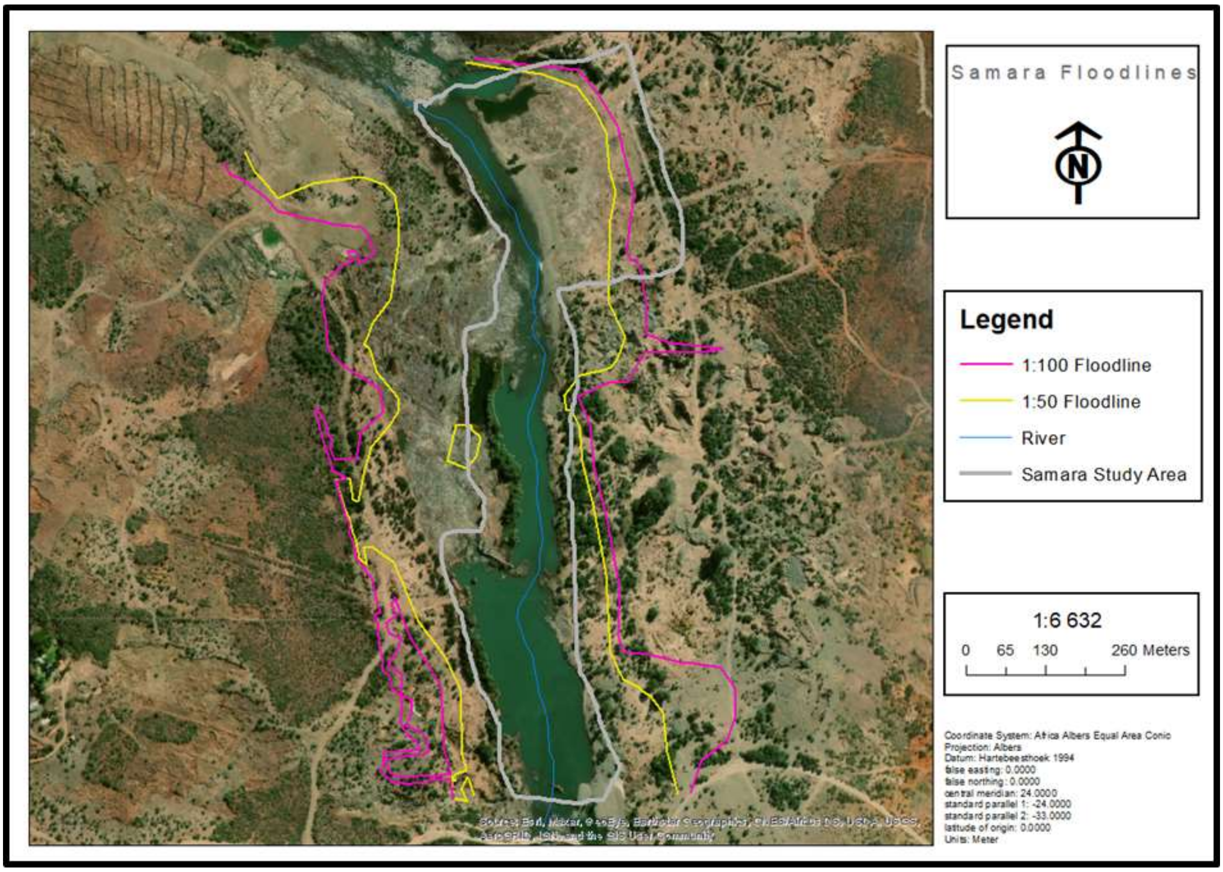

Figure 11: Floodlines

6. CONCEPTUAL STORM WATER MANAGEMENT PLAN

The aim of this storm water management plan (SWMP) is to fulfil the requirements presented in Government Notice 704 (Government Gazette 20118 of June 1999) which deals with the separation of clean and dirty water. The conceptual storm water management plan will form a necessary part of the Integrated Water Use License Application (IWULA), to be submitted to the Department of Water and Sanitation (DWS). This storm water management plan also complies with the principles presented in the DWS Best Practice Guideline G1 for Storm water Management.

6.1. DWAF GOVERNMENT NOTICE 704

The Department of Water Affairs and Forestry (now the Department of Water and Sanitation), established GN 704 to provide regulations on the use of water for mining and related activities aimed at the protection of water resources. There are important definitions in the regulation which require understanding.

6.1.1. IMPORTANT DEFINITIONS IN GN 704

- **Clean water system:** This includes any dam, other form of impoundment, canal, works, pipeline and any other structure or facility constructed for the retention or conveyance of unpolluted water.
- **Dirty water system:** This includes any dam, other form of impoundment, canal, works, pipeline, residue deposit and any other structure or facility constructed for the retention or conveyance of water containing waste.
- **Dirty area:** This refers to any area at a mine or activity which causes, has caused or is likely to cause pollution of a water resource (i.e. polluted water)

6.1.2 APPLICABLE CONDITIONS IN GN 704

The principle conditions of GN 704 applicable to the development of a SWMP for the site 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.
- *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 such that these systems do not spill into each other more than once in 50 years.
- *Condition 7* describes the measures which must be taken to protect water resources. All dirty water or substances which cause or are likely to cause pollution of a water resource either through natural flow or by seepage are to be mitigated.

6.2. CLEAN AND DIRTY WATER CATCHMENTS

Clean water and dirty water catchments are categorised as follows:

Table 7: Clean and Dirty water Areas

Description	Area (ha)	Ineffective Area(ha)	Dirty or Clean
Mining Area	25.49	25.49	Dirty
Top Soil Stockpile	1	1	Dirty
Waste Dump	1	1	Dirty
Contractor's Camp	0.2	0.2	Clean
Domestic Waste Facility	1	1	Dirty
Water Reservoir	0.5	0.5	Clean
Chemical storage	0.04	0.04	Dirty
Diesel Storage	0.02	0.02	Dirty
Ablution Facility	0.0016	0.0016	Dirty

On-site office	0.08		Clean
Access Roads	Available road to be used	Available road to be used	Moderate
Vehicle Parking	1		Moderate

Surface water runoff from dirty areas should be collected and contained in order to ensure that the following objectives are met:

• Minimisation of contaminated areas and reuse of dirty water (wherever possible)

• Prevention of overflows and minimisation of seepage losses from storage facilities (such as polluted dams)

• Prevention of further deterioration of water quality

• Separation of dirty water in terms of degree of contamination (very dirty water should be kept separate from moderately dirty water)

6.3. STORM WATER MANAGEMENT INFRASTRUCTURE

On account of no present prospecting activities on site, an absence of infrastructure and no detail yet on the proposed activities, it is not possible to develop a storm water management plan for the site as design information essential for determining the storm water infrastructure capacity to adequately contain dirty water is largely unavailable.

7. WATER QUALITY MONITORING PLAN

Water quality sampling was conducted for the physical, chemical and microbiological quality on 2 points along Vaal River as indicated on **Figure 12**. Sampling point 1 was at 28°27'1.88486"S and 24°19'35.19155"E while sampling point 2 at 28°26'20.34345"S and 24°19'28.61313"E coordinates. This sampling was design to capture the impact of land use activities on Vaal River before proposed mining project area and also just downstream of the mining area.

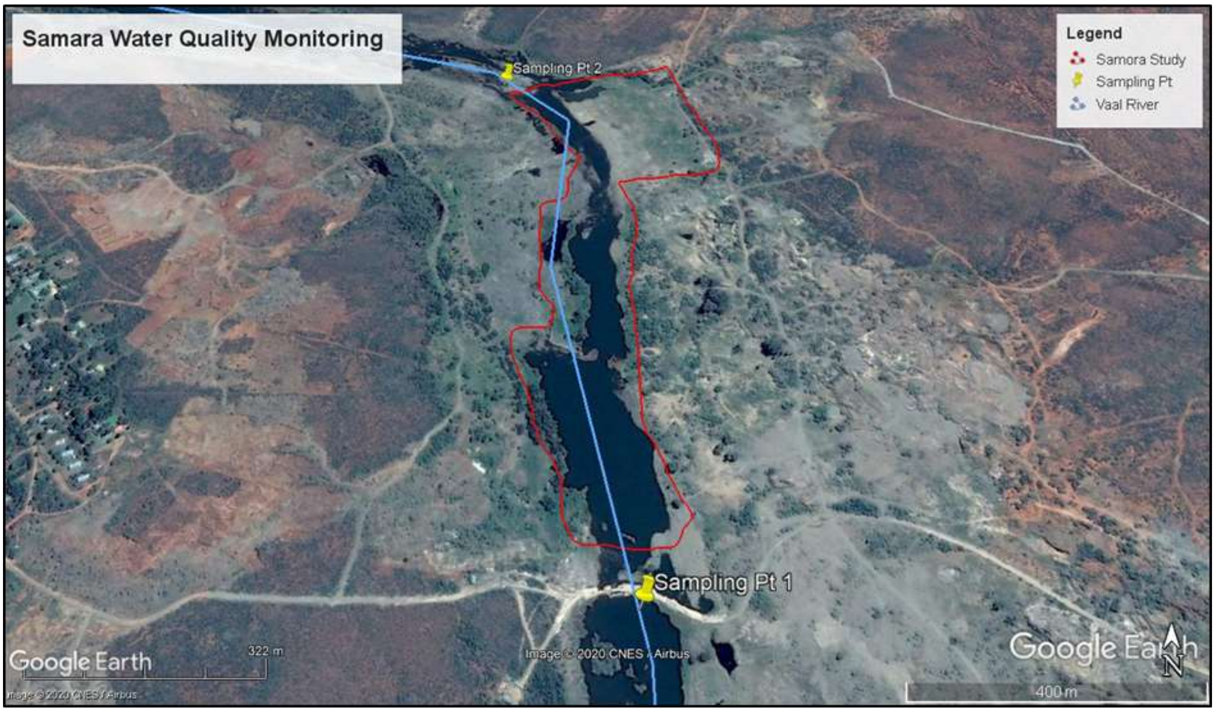

Figure 12: Water Quality Sampling

The water quality samples were taken on the 29 July 2020 and sent to Aquatico Scientific (Pty) Ltd laboratory for analysis. The water quality results were compared to SANS 241-1:2015 Drinking Water Standard (SABS, 2015) and DWS/WRC 1998 Domestic Water Supplies Standard as indicated on **Table 8** below.

Table 8: DWS/WRC Classification System of Suitability for Domestic Water Use

Class 0	Ideal water quality-suitable for lifetime use.
Class 1	Good water quality-suitable for use, rare instances of negative effects.
Class 2	Marginal water quality-conditionally acceptable. Negative effects may occur in some sensitive groups.
Class 3	Poor water quality-unsuitable for use without treatment. Chronic effects may occur.
Class 4	Dangerous water quality-totally unsuitable for use. Acute effects may occur.

Water sample result is summarised below while the sample certificates are attached on **Annexure A**:

The water quality for Samara Vaal River Sampling Point 1 was described as neutral (pH 6.0-8.5), non-saline (TDS < 450 mg/l) and hard (total hardness 200 - 300 $CaCO_3$) with E.coli and total coliforms detected.

Compliance with the 'SANS 241-1:2015 Drinking Water Standard (SABS, 2015)' guidelines was described as follows:

Chronic health Risk: All compliant

Acute health Risk: Non-compliant due to E.coli 7 CFU/100ml (> 0 CFU/100ml)

Operational (non-health): Non-compliant due to Total coliforms 12 CFU/100ml (> 10 CFU/100ml), Turbidity 1.94 NTU (>1.00 NTU)

Aesthetic (non-health): All compliant

In terms of the classification system of the 'Quality of Domestic water supplies' (WRC, 1998) the quality was classified as follows:

Drinking: Class 2 – Marginal due to E.coli, Total coliforms, turbidity

Bathing: Class 2 - Marginal due to Total Hardness

Washing: Class 2 - Marginal due to Total Hardness

Food Preparation: Class 2 – Marginal due to E.coli, Total coliforms and Turbidity

Aesthetic: Class 2 - Marginal due to Turbidity

According to the Langelier Saturation Index, the water is slightly scale forming and corrosive.

Based on the assessment of variables analysed in comparison to 'SANS 241-1:2015 Drinking Water Standard (SABS, 2015)' and 'Quality of Domestic water supplies' (WRC, 1998), the tested water sample was **Not Fit** for use as potable water and domestic use. Treatment for intended use was therefore essential before use with E.coli, Total coliforms and Turbidity as variables to be treated.

The water quality for Samara Vaal River Sampling Point 2 could also be described as alkaline/basic (pH >8.5), non-saline (TDS < 450 mg/l) and hard (total hardness 200 - 300 CaCO3) with E.coli and total coliforms detected.

Compliance with the 'SANS 241-1:2015 Drinking Water Standard (SABS, 2015)' guidelines was described as follows:

Chronic health Risk: All compliant

Acute health Risk: Non-compliant due to E.coli 3 CFU/100ml (> 0 CFU/100ml)

Operational (non-health): Non-compliant due to Turbidity 1.25 NTU (> 1.00 NTU)

Aesthetic (non-health): All complaint

In terms of the classification system of the 'Quality of Domestic water supplies' (WRC, 1998) the quality was classified as follows:

Drinking: Class 2 – Marginal due to E.coli and Turbidity

Bathing: Class 2 – Marginal due to Total Hardness

Washing: Class 2 - Marginal due to Total Hardness

Food Preparation: Class 2 - Marginal due to E.coli, Turbidity and Total Hardness

Aesthetic: Class 2 - Marginal due to Turbidity

According to the Langelier Saturation Index, the water was slightly scale forming and corrosive.

Based on the assessment of variables analysed in comparison to 'SANS 241-1:2015 Drinking Water Standard (SABS, 2015)' and 'Quality of Domestic water supplies' (WRC, 1998), the tested water sample was **Not Fit** for use as potable water and domestic use. Treatment for intended use is essential for E.coli and Turbidity variables.

It is recommended that the current sampling site and result be used as a benchmark for future bi-annual sampling program which will be used to monito the impacts of the prospecting activity on the Vaal River.

8. MEAN ANNUAL RUNOFF

8.1. MEAN ANNUAL AND MONTHLY RUNOFF

The Mean Annual Runoff (MAR) for the catchment associated with the site was estimated using the mean monthly WR2012 naturalised flow, which is an update to the Water Resources of South Africa 2005 study (WR2005, 2009). Naturalised flow is obtained by removing man-made influences such as dams, irrigation schemes and abstractions. In this case, mining operation is the only activity which affects the natural hydrology in the catchment as there are no activities such as irrigation, return flows.

In assessing the mean annual and monthly runoff of the site, the rainfall-runoff response was assumed to be the same as the regional rainfall-runoff response as determined for the quaternary catchment C91E in which the site falls.

8.1.1. WR2012

The WR2012 mean annual estimate of runoff for the catchment associated to the site has been decreased from 2005 – 2009 by 4.6 % as it was 2.4 million m³ for the period 1920-1989, 2.16 Mm³ in 2004 and 2.06 M m³ for the period 1920 to 2012 (WR, 2012).

The average monthly variation in MAR for the catchment C33C is represented by **Figure 13** below. The catchment has not streamflow reduction activities and also abstractions on its rivers.

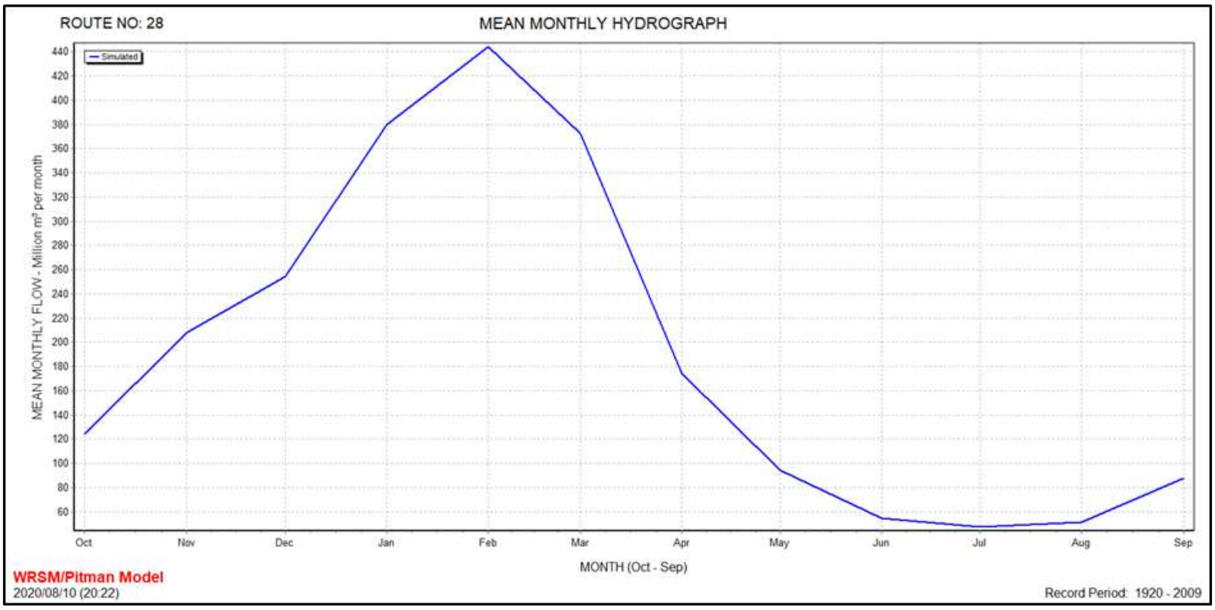

Figure 13: Mean monthly runoff for the site using WR2012 (1920 TO 2009)

For this project, WR2012 quaternary runoff data (Middleton and Bailey, 2012) was downscaled in order to obtain representative site runoff. The Mean Annual Runoff (MAR) was calculated using method:

- This was calculated using the simple equation: Site runoff = (site area *quaternary catchment runoff) / quaternary catchment area.
- The MAR of the prospecting area was 3.48 Mm^3 as calculated from the equation above.

Table 9 shows the percentages of MAR for Samara Prospecting Right catchment only equites to is higher than the catchment's MAR. This is because the prospecting area is largely on the Vaal River with only few hectares out for the water course. The activity has a potential to reduce the stream flow as it's on the banks of the river and therefore prevention and mitigation measures should be followed.

Table 9: Samara Prospecting Area MAR

Quaternary Catchment C91E Area (KM^2)	**Baseline** **Quaternary Catchment C91E MAR (Mm^3)**	**Samara Prospecting Catchment Area (KM^2)**	**Samara Prospecting Catchment MAR** **(Mm^3)**
1507	2.06	0.2549	3.48

9. WATER BALANCE

The static water balance is critical to assessing the site-wide water balance from an environmental or overall water use perspective. Ordinarily, a monthly water balance model would be set-up for the dry months (May – September) and for the wet months (October – April) to facilitate this assessment. The Vaal River does not only depend on rainfall as there are high volumes of return flow from industries, irrigated areas and many more. It is therefore a tedious exercise to determine the water balance without necessary return flow data. However, the site manager should keep himself/herself up to date with the events upstream of the catchment such as high flows from Bloemhof Dam, opening and closing of weirs upstream as they will definitely affect the prospecting activity.

10. RISK ASSESSMENT

There are many impacts that mining activities may have on the environment and the surface water resource system in particular. It is therefore important to assess what level of risk is, so that necessary steps can be taken to mitigate the risk. **Table 10** has been adopted from the "Best Practice Guideline A1.1: Small Scale Mining Practices August 2006".

Table 10: Impact Significance Assessment

	Low impact	Medium impact	High impact	Severe impact
Frequency	Single event, unlikely to be repeated e.g. spillage	Not regular, but does happen more than once	Regular, but intermittent e.g. soakaways; drains	Continuous e.g. leaks; infiltration
Extent	Limited to only in the mining area	Local water resources. Limited to a 5 km radius of mining area.	Catchment area. Limited to a 50 km radius of mining area.	Wider (regional/national) Can spread to other provinces or regions
Duration	Short term - 0-6 month. Events that will not happen more than once in 6 months	Medium term Up to 1 year	Long term - 5 years	Permanent - No mitigation will shorten impact duration
Intensity	Negligible/Very low Minor disturbances to aquatic ecosystems or local water resources; impact temporary	Low Important but easily controlled by routine management actions	Medium Impacts experienced as temporary or continual loss of amenity or deterioration in water quality and can extend over both small and large areas.	High Impacts serious and requires frequent management attention and remedial action. Large scale effects on water resources; aquatic ecosystems and other water users
Probability	Improbable Low probability.	Probable Distinct probability.	Highly probable Most likely.	Definite Will occur regardless of prevention or mitigatory methods.

Risk assessment and mitigation involves identification of the types of water users found in the area as well as identification of risk which the mining activities may result in the area. The study area is within the diamond veld as indicated before. There are old and current mining activities upstream, downstream and on both sides of the river banks and therefore this study will just add to the number.

The mining activity included; clearing of vegetation, excavations ponds, stockpiling areas, and slime dams, processing plant, mechanical workshop, camp site, ablution area and car/vehicle parking area. **Table 11** illustrates impacts, significance and mitigation measures associated with the project. Impact significance is ranked based on their weight on **Table 10** but it should be noted that prospecting activities are normally associated with low impacts.

Table 11: Surface Water Impact Assessment

Potential Environmental Impact	Activity	Impact significance before Prospecting			Recommended Mitigation Measures	Impact significance after Prospecting		
		Low	Moderate	High		Low	Moderate	High
Vegetation and soil cleared from site and roadway could obstruct natural drainage	Site clearing and pathways		✓		Overburden that is removed should be spread at suitable location and immediately rehabilitated taking into account natural drainage paths	✓		
Fuel/toxic materials could be spilled and pollute local water resources	Drilling of exploration boreholes, and excavation		✓		Measures should be in place to contain any spills and allow safe collection and disposal of waste	✓		
Run off and drainage from stockpiles continue to yield acidic water	Core logging and storing of sample bags		✓		Drilling logs are placed in a designated container while stockpiles will be stored in a roofed area to prevent rain and sun exposure	✓		
Excavated ponds may collect and also divert runoff	Excavation			✓	Backfilling of excavated pond, pits and roads, thus levelling the area	✓		
Fuel/toxic materials could be spilled and pollute local water resources	Erection and operation of 4 feet process plant		✓		Ensure that fuel leakage is monitored and fixed urgently and that any spillage is reported to the site manager	✓		
Changing and diverting the water course	Pathways and excavation		✓		Stabilise the banks and beds of the rivers within the study area	✓		
Run off from latrines and domestic waste could pollute surface water resources	Dumping				The contractors should stipulate appropriate waste collection area and also use disposable latrines which should be disposed of in a designated municipal area			

Potential impacts associated with the proposed prospecting activity has been listed, assessed and ranked as low. These impacts are ranked low provided that the mitigation measures are implemented.

11. CONCLUSIONS AND RECOMMENDATIONS

Comprehensive baseline information including rainfall data, depth-duration-frequency design rainfall estimates, evaporation data as well as both regional and local hydrological characteristics have been considered for the proposed prospecting project site. Peak flows and hydrographs were developed as part of this study. The HEC-RAS model was applied to provide an indication of what areas would be inundated by the respective flood flows for the 50 and 100 – year events. The result as presented on section 5 of the report indicates that the whole prospecting area may be inundated by both the 50 and 100 year flood.

The overall results of the flood modelling results illustrate the maximum floods anticipated for the peak flows for 1:100 year event along the study site present risk to the proposed activity.

Water quality sampling was conducted on the Vaal River upstream and downstream of the proposed prospecting area. The result indicated that the water was not fit for domestic and potable use as it contained E.coli, total coliforms and high turbidity. Treatment of water was essential before use. This water quality result will be used as a benchmark for future bi-annual sampling program during the prospecting period.

An analysis of mean annual runoff was undertaken as part of the study using the WR2012 dataset. The WR2012 mean annual estimate of runoff for the study area was high as the proposed area is along the banks of the Vaal River.

The study area's water balance was not greatly influenced by climate imbalance between average evaporation and rainfall as the Vaal River receives high return flows from factories and irrigated areas upstream of the study area. However, caution should be exercised to prevent flooding of infrastructure during the opening of weirs upstream and also during heavy rainfall on the Vaal River system.

This baseline study therefore indicates that the impacts on the Vaal River resulting from the proposed prospecting can be managed to low if and when recommended mitigation measures are implemented.

Project Manager/Author

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ANNEXURE A