forestry, fisheries
& the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

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SPECIALIST DECLARATION FORM – AUGUST 2023

Specialist Declaration form for assessments undertaken for application for authorisation in terms of the National Environmental Management Act, Act No. 107 of 1998, as amended and the Environmental Impact Assessment (EIA) Regulations, 2014, as amended (the Regulations)

REPORT TITLE

Floodlines Assessment Report for the proposed construction and maintenance of New System 1 at Rand Water Vereeniging Treatment Works, installation of approximately 7 km phase 2 Sludge Pipeline in Vereeniging, 1.5 km sludge line in Panfontein and associated infrastructure within the jurisdiction of Sedibeng District Municipality, Gauteng Province.

Kindly note the following:

1. This form must always be used for assessment that are in support of applications that must be subjected to Basic Assessment or Scoping & Environmental Impact Reporting, where this Department is the Competent Authority.
2. This form is current as of August 2023. It is the responsibility of the Applicant / Environmental Assessment Practitioner (EAP) to ascertain whether subsequent versions of the form have been published or produced by the Competent Authority. The latest available Departmental templates are available at https://www.dffe.gov.za/documents/forms.
3. An electronic copy of the signed declaration form must be appended to all Draft and Final Reports submitted to the department for consideration.
4. The specialist must be aware of and comply with '*the Procedures for the assessment and minimum criteria for reporting on identified environmental themes in terms of sections 24(5)(a) and (h) and 44 of the act, when applying for environmental authorisation - GN 320/2020)'*, where applicable.

1. SPECIALIST INFORMATION

Title of Specialist Assessment	Floodlines Assessment Report for the proposed construction and maintenance of New System 1 at Rand Water Vereeniging Treatment Works, installation of approximately 7 km phase 2 Sludge Pipeline in Vereeniging, 1.5 km sludge line in Panfontein and associated infrastructure within the jurisdiction of Sedibeng District Municipality, Gauteng Province.
Specialist Company Name	Ariys Consultant
Specialist Name	Sbongiseni Christian Mazibuko
Specialist Identity Number	861001 5713 082
Specialist Qualifications:	Masters of Science in Hydrology
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Postal address	Same as Physical Address
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Cell phone	068 497 6579

E-mail	info@ariys.co.za / Fhatani@ariys.co.za

2. DECLARATION BY THE SPECIALIST

I, Sbongiseni Christian Mazibuko declare that –

- I act as the independent specialist in this application;
- I am aware of the procedures and requirements for the assessment and minimum criteria for reporting on identified environmental themes in terms of sections 24(5)(a) and (h) and 44 of the National Environmental Management Act (NEMA), 1998, as amended, when applying for environmental authorisation which were promulgated in Government Notice No. 320 of 20 March 2020 (i.e. "the Protocols") and in Government Notice No. 1150 of 30 October 2020.
- I will perform the work relating to the application in an objective manner, even if this results in views and findings that are not favourable to the applicant;
- I declare that there are no circumstances that may compromise my objectivity in performing such work;
- I have expertise in conducting the specialist report relevant to this application, including knowledge of the Act, Regulations and any guidelines that have relevance to the proposed activity;
- I will comply with the Act, Regulations and all other applicable legislation;
- I have no, and will not engage in, conflicting interests in the undertaking of the activity;
- I undertake to disclose to the applicant and the competent authority all material information in my possession that reasonably has or may have the potential of influencing –
  - any decision to be taken with respect to the application by the competent authority; and;
  - the objectivity of any report, plan or document to be prepared by myself for submission to the competent authority;
- All the particulars furnished by me in this form are true and correct; and
- I realise that a false declaration is an offence in terms of Regulation 48 and is punishable in terms of section 24F of the NEMA Act.

Signature of the Specialist

Ariys Consultant (Pty) Ltd

Name of Company:

22 Aug 2025

Date

3. UNDERTAKING UNDER OATH/ AFFIRMATION

I, _ Fhatani Makhuvha_________, swear under oath / affirm that all the information submitted or to be submitted for the purposes of this application is true and correct.

Signature of the Specialist

Ariys Consultant (Pty) Ltd

Name of Company

22/08/2025

Date

Click or tap here to enter text.

Signature of the Commissioner of Oaths

Click or tap to enter a date. 08/08/2025

Date

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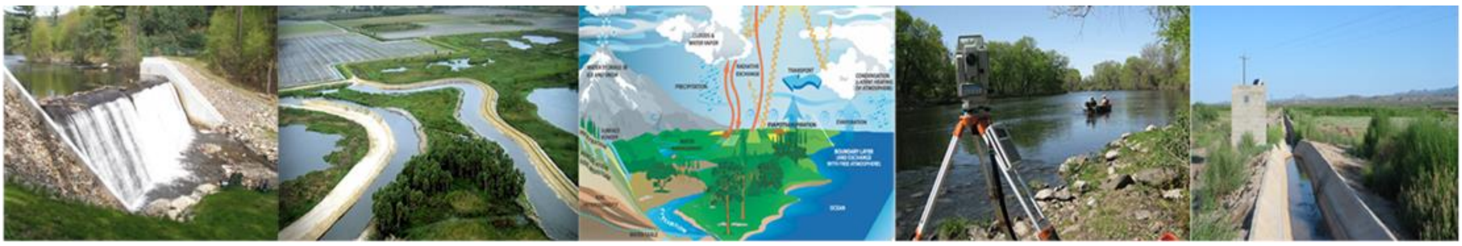
Floodlines Assessment for the proposed construction and maintenance of New System 1 at Rand Water Vereeniging Treatment Works, installation of approximately 7 km phase 2 Sludge Pipeline in Vereeniging, 1.5 km sludge line in Panfontein and associated infrastructure within the jurisdiction of Sedibeng District Municipality, Gauteng Province.

Report: Version – 2nd

28 July 2025

Client Reference: Rand Water New System 1 and Sludgelines – Floodlines Assessment



Floodlines Assessment for the proposed construction and maintenance of New System 1 at Rand Water Vereeniging Treatment Works, installation of approximately 7 km phase 2 Sludge Pipeline in Vereeniging, 1.5 km sludge line in Panfontein and associated infrastructure within the jurisdiction of Sedibeng District Municipality, Gauteng Province.

Report

DOCUMENT VERIFICATION

TITLE: Rand Water New System 1 and Sludgelines – Floodlines Assessment			
Report Number			
Date		**28 July 2025**	
Report Version		**Second**	
Verification	**Name**	**Signature**	**Date**
Author	Sbongiseni Mazibuko (Hydrologist) ***Pr. Sci. Nat:* 011204**		28 July 2025

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LIST OF ACRONYMS

ALOS	Advanced Land Observing Satellite
BA	Basic Assessment
EIA	Environmental Impact Assessment
DEM	Digital Elevation Model
DSM	Digital Simulation Model
DWS	Department of Water and Sanitation
HEC-RAS	Hydrologic Engineering Centre - River Analysis System
JAXA	Japanese Aerospace Exploration Agency
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
NEMA	National Environmental Management Act
NWA	National Water Act
NWRS	National Water Resource Strategy
QGIS	Quantum Geographical Information System
SAWS	South African Weather Station
WR2012	2012 South African Water Resources Study
WTW	Water Treatment Works

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1 INTRODUCTION

1.1 Background

Ariys Consulting (Pty) Ltd was appointed by Selahle Consultancy and Projects (Pty) Ltd to undertake a floodlines assessment for the proposed construction and maintenance of the New System 1 at Rand Water Vereeniging Water Treatment Works (WTW), installation of approximately 7 km phase 2 Sludge Pipeline in Vereeniging, 1.5 km sludgeline in Panfontein and associated infrastructure within the jurisdiction of Sedibeng District Municipality, Gauteng Province of South Africa (Figure 1-1). The proposed Sludge Pipelines construction sites in Vereeniging and Panfontein are susceptible to flooding by the Vaal River and Suikerbosrant.

This study, therefore, aims to determine the potential risk of flooding of the proposed infrastructure by the Vaal River and Suikerbosrant. The results from this study will provide specialist inputs in support of the Basic Assessment (BA) requirements for the 2014 (as amended) Environmental Impact Assessment (EIA) Regulations in terms of the National Environmental Management Act (NEMA Act 103 of 1998 - as amended) as well as to support Water Use Licence Application (WULA) required in terms of the National Water Act (NWA) (Act No. 107 of 1998). These listed compliance requirements are agreed upon based on the study's scope and terms of reference.

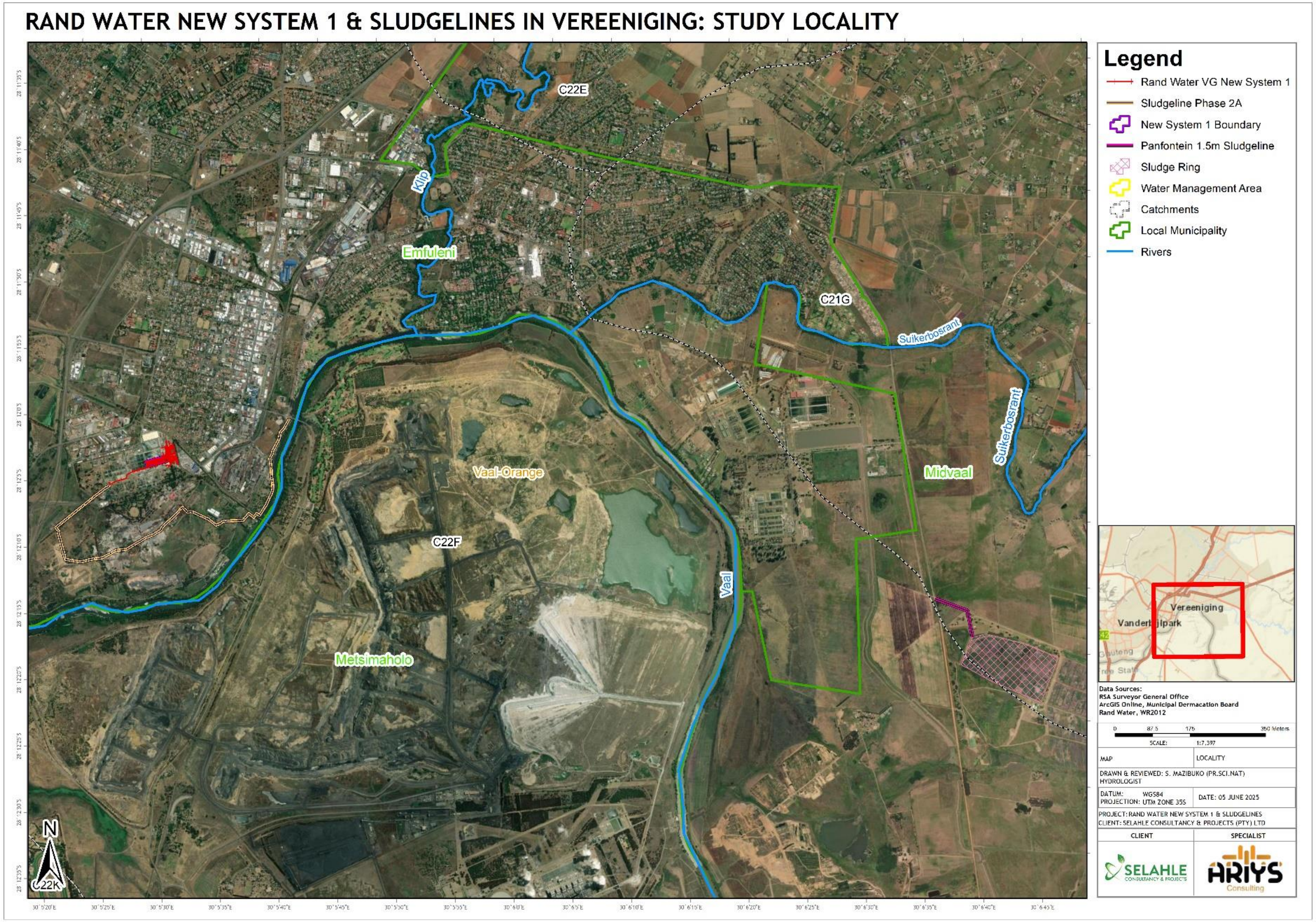

Figure 1-1: Study locality

2 SCOPE OF WORK

The scope of work for the water balance study is defined as follows:

1. Site Visit and Data Collection:
    - A site visit to identify elements that affect flood estimation and routing; and
    - Collect relevant data and information relating to the study in the development context.
2. Baseline Hydrology:
    - Catchment delineation and physiographic setting;
    - Hydroclimatic characterisation through the calculation of the design rainfall;
    - Calculation of the 1:50 and 1:100-yr peak flow volumes for the Suikerbosrant, and
    - Deriving applicable peak flow volumes based on the Vaal Dam releases during the flood (1:100-year return period events).
3. Floodline Modelling:
    - Catchment geometry data preparation using topographical data;
    - Floodline modelling using 1D HEC-RAS hydraulic software, and
    - Placing and mapping the proposed infrastructure relative to the derived floodlines.
4. Reporting:
    - A report deliverable that presents the detailed results of the activities mentioned above and the recommendations will be made based on the study's findings.

3 METHODOLOGY

3.1 Desktop Study and Site Visit

A site walkover was conducted on the 26th of May 2025 to identify elements that might be affected due to the proposed activities associated with the construction of the treatment facility and sludgelines. During this site visit, the riparian reaches of the Vaal River and Suikerbosrant were also assessed to identify features that may affect the flood simulation and the culverts that will be changed due to the proposed infrastructure. The information derived from this site visit was also used to guide the interpretation of the flood modelling results. Applicable local, regional and national regulations and best practice guidelines for constructing the Water Treatment Works (WTW) facilities were reviewed. This review was aimed at ensuring the proposed developmental activities are compliant with relevant and up-to-date laws.

Hydrometeorological data used to define the expected hydrological regimes of the development site were collected and analysed to formulate a baseline understanding of local drivers of hydrological processes. Satellite imagery retrieved via Google Earth Pro was used to derive land catchment characteristics that describe the existing conditions, which could affect the calculation of the peak flow volumes and elements that could be affected.

3.2 Baseline Hydrology

Baseline hydrometeorological data describing the regimes for the area were obtained from the South African Water Resources Study WR2012 database (Bailey and Pitman, 2015) and the Daily Rainfall Data Extraction Utility (Lynch, 2004). These estimated the Mean Annual Precipitation (MAP) of the study site and the design rainfall storm for the centroid of the delineated catchment of the Suikerbosrant. The WR2012 database was also used to determine the area's prevailing Mean Annual Evaporation (MAE).

Catchment area delineation was based on the 30 m Digital Simulation Model (DSM) data derived from Advanced Land Observing Satellite (ALOS) (JAXA, 2018). These datasets were also used to derive physical characteristics of the catchment that affect the calculation of peak flows, such as the catchment area, average slope, the longest river course, and the time of concentration. The delineated catchment boundary was used to clip land use and land cover, as well as the soil types within the study area, so that they could be quantified in terms of their contribution. A 5 m contour data from the Surveyor General Office was extracted to develop a Digital Simulation Model (DSM) to define the river channel geometry and route the flood waters in the 1D hydraulic model through HEC-RAS (US Army Corps of Engineers, 2025). This topography was used to base the model simulation results.

3.3 Peak Flow Volumes

The appropriate methodology to calculate peak flows depends on the size of the catchment and hydrological data (e.g., stream flow) for a particular catchment. The methods used to calculate the peak discharge values are associated with the small to medium catchments. Methodologies for using the Rational Method (RM), Alternative Rational Method (RM2), Standard Design Flood (SDF), Unit Hydrograph (UH) and Midgley and Pitman (MIPI) Methods are explained in the South African Drainage Manual (SANRAL, 2013). The peak flow volumes for the 1:50 and 1:100-year return periods were calculated for the Suikerbosrant area based on the deterministic and empirical methods because no stream flow gauges are available, while flood water releases guidelines from the Vaal Dam were used for the Vaal River floodline determination. The sub-sections below present the description of the applicable methods used.

3.3.1 Rational and Alternative Methods

The equation for calculating peak flows using the Rational Method (RM) is based on a runoff coefficient, the catchment's average rainfall intensity and the catchment's effective area (recommended for small catchments less than 15 km^2) that contributes largely to runoff generation after the heavy storm's rainfall has exceeded infiltration. The deterministic RM equation is given by $Q = CiA$ where Q is peak flow volume (m^3/s), c is a dimensionless runoff coefficient, *i* is the catchment average rainfall intensity (mm/hr) and *A* is the effective catchment area (m^2). All catchment factors influencing rainfall-runoff relations after a storm event are defined and represented by the runoff coefficient (c). The calibration of the runoff coefficients for the drainage area is guided by an understanding of the effective runoff-generating processes, soil and land cover attributes derived from various sources, and catchment physical surveys of the site linked with the prevalent rainfall regimes of the areas. Parameters included in the Rational Method are summarised in Table 3-1 together with the calibration guidelines.

These factors are accumulated to account for (i) slope, (ii) soil permeability and (iii) vegetation cover type of the catchment based on (1) rural, (2) urban, and (3) lakes setting. Steeper slopes affect the generation of more runoff than flat, gentle slopes. The permeability of soils are classified into (i) very permeable with high infiltration rates resulting in less runoff (Group A), (ii) permeable with moderate infiltration rates generating moderate runoff (Group B), (iii) Group C soils are semi-permeable with low infiltration and immoderate to high runoff and (iv) impermeable soils with very low infiltration rates resulting in higher runoff (Group D). Dense forest, dense bush and wood (Group A), thin bush and cultivated land (Group B), grassland (Group C) and bare surfaces (Group D) result in less, moderately low, moderately high and very high runoff volumes, respectively.

Design rainfall depths are one of the critical inputs into the alternative RM in the computation of the rainfall intensity. The storm rainfall depths for different time durations (up to 24 hours) of varying return periods were obtained from the Design Rainfall Estimation (DRE) program for this study (Smithers and Schulze, 2003). The catchments' applicable average design rainfall intensity was determined using the time of concentration, point rainfall intensity, and average rainfall intensity of the study area.

Table 3-1: Calibration guide for runoff coefficients for the Rational Method (source: SANRAL, 2013)

Rural (C_1)					Urban (C_2)	
Component	Classification	Mean annual rainfall (mm)			Use	Factor
		< 600	600 - 900	> 900		
Surface slope (C_s)	Vleis and pans (<3%)	0,01	0,03	0,05	*Lawns*	
	Flat areas (3 to 10%)	0,06	0,08	0,11	- Sandy, flat (<2%)	0,05 – 0,10
	Hilly (10 to 30%)	0,12	0,16	0,20	- Sandy, steep (>7%)	0,15 – 0,20
	Steep areas (>30%)	0,22	0,26	0,30	- Heavy soil, flat (<2%)	0,13 – 0,17
					- Heavy soil, steep (>7%)	0,25 – 0,35
Permeability (C_p)	Very permeable	0,03	0,04	0,05	*Residential areas*	
	Permeable	0,06	0,08	0,10	- Houses	0,30 – 0,50
	Semi-permeable	0,12	0,16	0,20	- Flats	0,50 – 0,70
	Impermeable	0,21	0,26	0,30		
					Industry	
Vegetation (C_v)	Thick bush and plantation	0,03	0,04	0,05	- Light industry	0,50 – 0,80
					- Heavy industry	0,60 – 0,90
	Light bush and farm lands	0,07	0,11	0,15	*Business*	
					- City centre	0,70 – 0,95
	Grasslands	0,17	0,21	0,25	- Suburban	0,50 – 0,70
	No vegetation	0,26	0,28	0,30	- Streets	0,70 – 0,95
					- Maximum flood	1,00

Classification	Soil Factors		Vegetation Factors		Runoff Potential
	Soil Permeability	c-value	Vegetation Cover	c-value	
Group A	Very permeable	0.01 - 0.05	Forest, dense bush and wood	0.03 - 0.05	Very Low
Group B	Permeable	0.06 - 0.10	Thin bush and cultivated land	0.07 - 0.15	Moderlately Low
Group C	Semi-permeable	0.12 - 0.20	Grassland	0.17 - 0.25	Moderlately High
Group D	Impermeable	0.21 - 0.30	Bare surface (no vegetation)	0.26 - 0.30	Very High

3.3.2 Standard Design Flood Method

The SDF method is based on a calibrated discharge coefficient for a recurrence period of 2 to 100 years. Calibrated discharge parameters are based on historical data and were determined for 29 homogeneous basins in South Africa. The other inputs used in the SDF method for calculating the maximum discharge values of 1:50 and 1:100-yr are the catchment area, the length of the longest river course, the catchment height difference, the annual maximum rainfall, and the average days when thunder was heard.

3.3.3 Midgely and Pitman Method (MIPI)

The empirical method developed by Pitman and Midgley (1971) was initially derived from the original Synthetic Unit Hydrograph (SUH) and relates peak discharge to catchment size, slope, and distance from the drainage point to the centroid of the catchment (Campbell, 1986). The MIPI method uses 10-unit hydrographs for 10 zones in South Africa. The method does not consider overland flow as a component separate from streamflow, but only finds the total longest flow path.

A comparison of the computed peak flow volumes for the Suikerbosrant was conducted by plotting the probability distribution for each method and choosing the one which fits the 1:1 relationship. The selected peak flow volumes for the 1:50 and 1:100-yr floodlines were routed in the 1D hydraulic model to the point of confluence with the Vaal River.

3.3.4 Vaal Dam Release Volumes

The Vaal Dam receives inflows from the Upper Vaal River basin, and these are attenuated during the flows by 26% (662,4754 × 10^6 m^3) of its full supply level flood absorption storage. A flood frequency analysis conducted by DWS indicated that the time of concentration for the Upper Vaal River is 118 hrs, resulting in the peak flow volume of 4 700 m^3/s for the 1:100-yr recurring events. Various requirements had to be met to ensure that efficient and effective management of floods from this dam is achieved. These include (i) ensuring that Vereeniging is not flooded, (ii) water not reaching the bridge deck at General Hertzog and Gold Club bridges, and (iii) meeting Rand Water flow rates. Under conditions, outflow of 1 800 m^3/s must be maintained under small to medium flow conditions which correspond to 1:10-yr recurrent events. This flow volume was used to simulate the floodline for the Vaal River as a means of evaluating its flooding risk to the proposed sludgeline.

3.4 Floodline Modelling and Floodline Delineation

Hydraulic parameters and the channel geometry of the modelled Vaal River and Suikerbosrant sections were derived from the terrain analysis. Cross-sections were prepared using RAS Mapper software as input to the HEC-RAS flood model. Visual assessment of the 2025 satellite imagery was used to delineate current land use, while the information derived during the site visit and the 2022 LULC (Geoterra Image (Pty) Ltd, 2024) to interpret the riparian zones for setting Manning's coefficient values (Chow, 1959) of the cross-sections in the hydraulic model for all modelled river sections. The roughness of the floodplain is used in hydraulic model calculations to account for the frictional impacts that land cover has on the flood routing patterns, thus enabling the assessment of the friction losses on flow velocities, discharge and cross-section flow area of a modelled river segment

Flood lines were generated using the corresponding peak flow volume values based on the flood water releases from the Vaal Dam and the computed peak flow volumes of the 1:50 and 1:100-yr return periods for Suikerbosrant. For the Vaal River, these volumes were derived from the Flood Operating Rule study conducted by DWS and implemented in the operation of the Vaal Dam. Flood inundation extents were extracted after routing, converted to polylines, and mapped through Geographic Information System (GIS) software for interpretation.

3.5 Assumptions and Limitations

The following constraints may have affected this hydrological assessment:

- A desktop approach was implemented to establish the topographic setting using geocoded points based on the “best available” elevation data from Google Earth Pro. Using 5 m contour data might have limited proper representation of the river centreline, which is accumulating floodwaters and overtopping the river banks.
- Bridges and culverts along the Vaal River were not incorporated into the modelling as the dimensions could not be measured. Thus, routing only accounted for the steady state flow conditions as the river dimensions (width) don’t change significantly along the modelled section.
- Visual assessment of satellite imagery retrieved through Google Earth Pro might have indicated varying land cover features, which might impact flooding depending on the season and land use. Only developments were assumed not to impact Manning’s n directly compared to other surface features.
- Limitations of high-resolution survey data and the changes that might have occurred in the riparian landscape can directly affect the simulated flood as they account for inactive flow areas that affect how flood water flows through a modelled river section.

4 DESKTOP ASSESSMENT

The dataset and information obtained during the desktop phase are as follows:

4.1 Data Used

The following dataset and tools were used to derive the results of the study:

- **5 m contour data** – for river geometry data used to route flood waters,
- **KMZ files** – for the location and placement of the proposed infrastructure development,
- **WR2012 dataset** – defining hydrological regimes of the study site,
- **HEC-RAS version 6.7** – Hydraulic model set-up and simulation of floodlines,
- **2022 LULC** – for classification of the dominant land use and land cover, and
- **QGIS** – Editing spatial data and mapping, and
- **Google Earth Pro –** for retrieving satellite imagery dated January 2025.

4.2 Legislation and Guidelines

4.2.1 The National Water Act

The NWA aims to provide for the management of the national water resources to achieve sustainable water use for the benefit of all water users. This act requires that the quality of water resources be protected, as well as the integrated management of water resources, with the delegation of powers to institutions at the regional or catchment level. The purpose of the Act is to ensure that the nation's water resources are protected, used, developed, conserved and managed in ways which take into account (relevant to this study):

- Protecting aquatic and associated ecosystems and their biological diversity,
- Reducing and preventing pollution and degradation of water resources,
- Managing floods and droughts.

Section 19 of the National Water Act (Act No. 36 of 1998) (NWA) sets out the principles for "an owner of the land, a person in control of the land or a person who occupies or uses land" to:

- Cease, modify or control any act or process causing pollution,
- Comply with any prescribed waste standard or management practice,
- Contain or prevent the movement of pollutants,
- Eliminate any source of pollution,
- Remedy the effects of the pollution, and
- Remedy the effects of any disturbance to the bed and banks of a watercourse.

It also describes the actions that the catchment management agency can take to enforce the requirements of the NWA. Section 26 (1) of the NWA provides for the development of regulations that:

- Require the use of incoming and discharging water from a water resource to be monitored, measured and recorded,
- Regulate or prohibit any activity to protect a water resource or in-stream or riparian habitat, and
- Prescribe the outcome or effect that must be achieved through management practices for the treatment of waste, or any class of waste, before it is discharged or deposited into or allowed to enter a water resource.

5 BASELINE HYDROLOGY

5.1 Physiographic Setting and Climate

Located along the Vaal River's reaches, the area's total drainage includes the upper tree reaches, which have a series of impoundments, including Grootdraai and Vaal Dam in the downstream reaches. During heavy and highly intensive rains, the Vaal Dam attenuates the generated floodwaters as part of the water resource. A site visit was conducted to identify the area's dominant land use and land cover features and the riparian conditions that play a vital role in attenuating the floodwater during flooding events and for identifying sensitive surface water receptors in the project areas. Grassland, build-up areas, bare land and sparse trees dominate the riparian reaches of the modelled section of the Vaal River, while other patches of varying dry irrigation farming were observed. These features were delineated from the 2023 satellite imagery to create a land use land cover shape file to set Manning's n values in the model. The dominant and specific land use and land cover features are shown in Figures 5-4 and 5-5. The initial boundary conditions used in the hydraulic model setup were based on the calculated average slope for the river segment in the upstream reaches without a rating curve and known surface water.

The headwater reaches of Suikerbosrant are elevated at about 1 905 meters above mean sea level (mamsl) while the lowest river outlet is at 1 427 mamsl. The topographic setting of the study, derived from a 30 m ALOS Digital Simulation Model (DSM), is graphically represented in Figure 5-1. The slope of a catchment is an essential characteristic in calculating the flood peak flow volumes. Generally, steeper slopes produce higher runoff volumes and high velocities and shorten the critical duration of flood-inducing storms, thus leading to higher rainfall intensities. On steep slopes, soil layers are shallower due to less development and fewer depressions, all of which cause a more rapid runoff. The result is that infiltration is reduced and flood peaks are consequently even higher.

Slope analyses for the modelled areas used in the study area are graphically presented in Figure 5-2. The figure shows that the headwater reaches are highly elevated and rivers that drain runoff flow in deep-incised drainage channels with moderately steep slopes. This suggests that flood waters downstream of the headwater reaches have high flow velocities and erosive potential due to the effects of slopes. Detailed longitudinal profile of the Suikerbosrantin is shown in Figure 5-3.

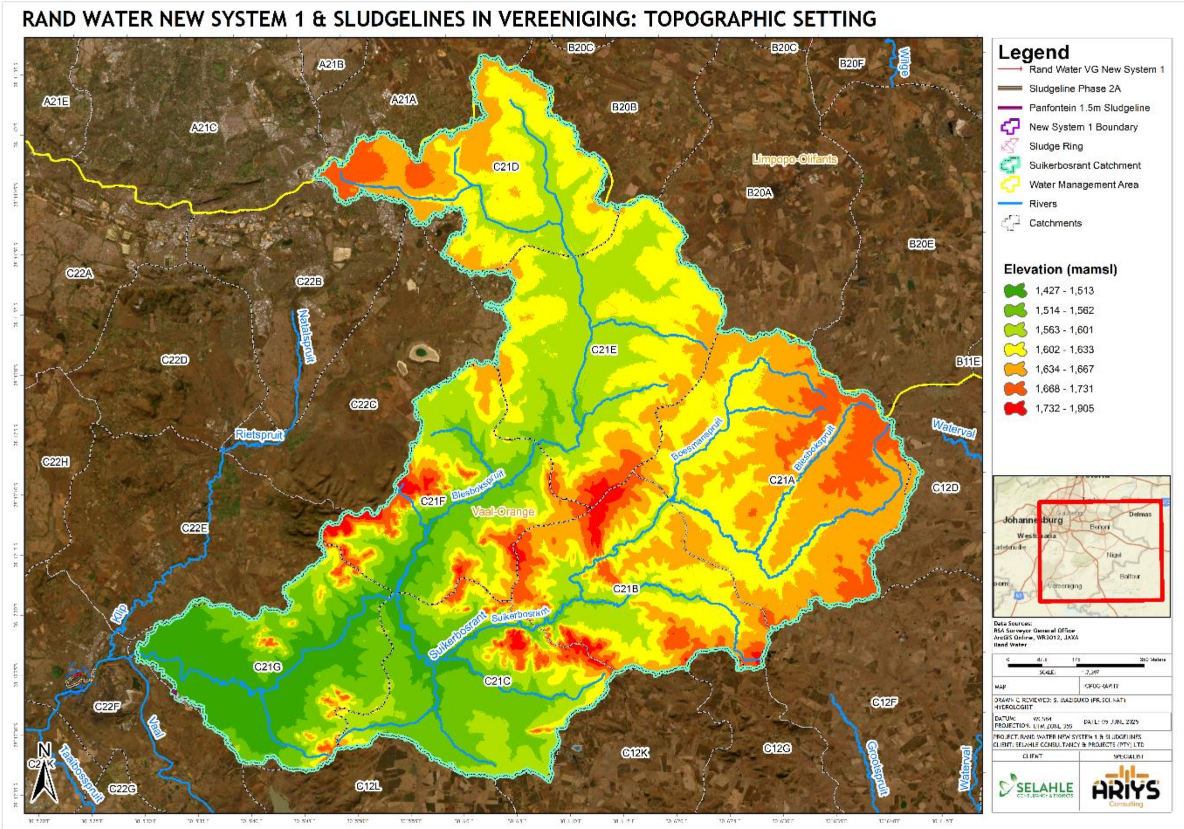

Figure 5-1: Topographic setting of the Suikerbosrant catchment

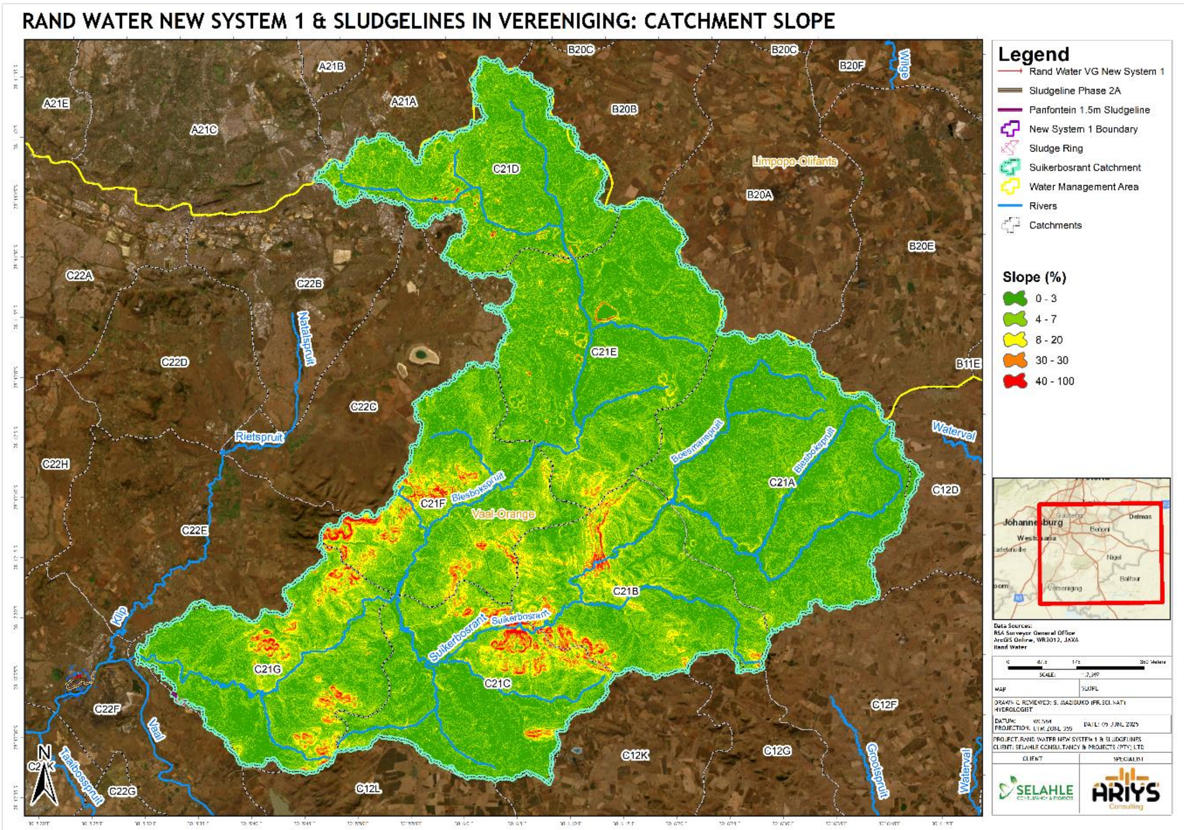

Figure 5-2: Slope patterns of the Suikerbosrant catchment

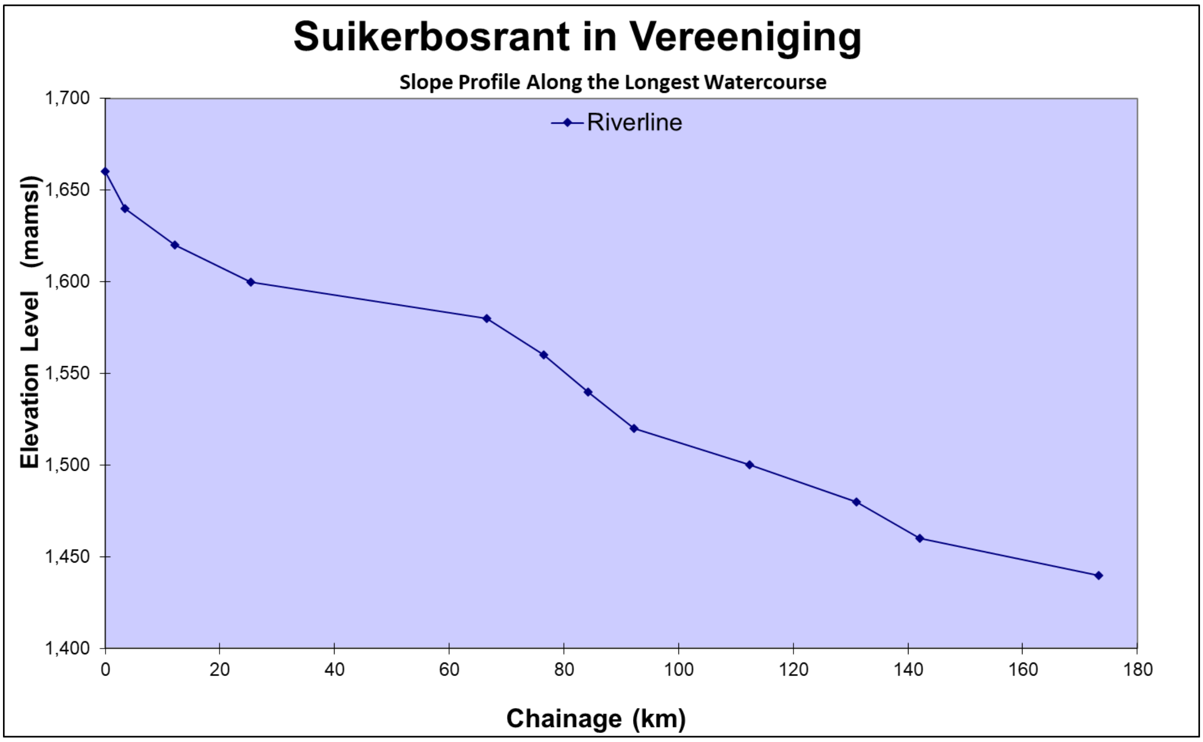

Figure 5-3: Longitudinal profile of the Suikerbosrant

The generic and dominant land cover and land use features within the Suikerbosrant drainage areas are presented in Figure 5-4. The figure shows that the upper reaches of the catchment are densely developed with urban, industrial and mining areas, while the centroid and areas along the catchment outlet have grassland and both irrigated and cultivated land. These conditions suggest that large volumes of runoff are expected to be generated in the headwater reaches due to modified land cover, which reduces infiltration, while the middle and lower areas are expected to generate less and infiltrate more rainwater based on the topography and land cover. The riparian areas along the tributaries and the main rivers within this drainage have grass and swampy features, which allow for the attenuation of floodwater after storm events. Across the project's proposed construction site (WTW infrastructure and Panfontein sludge lines), there are industrial and urban developments as well as the rural setting characterised by grassland and cultivated land (see Figure 5-5).

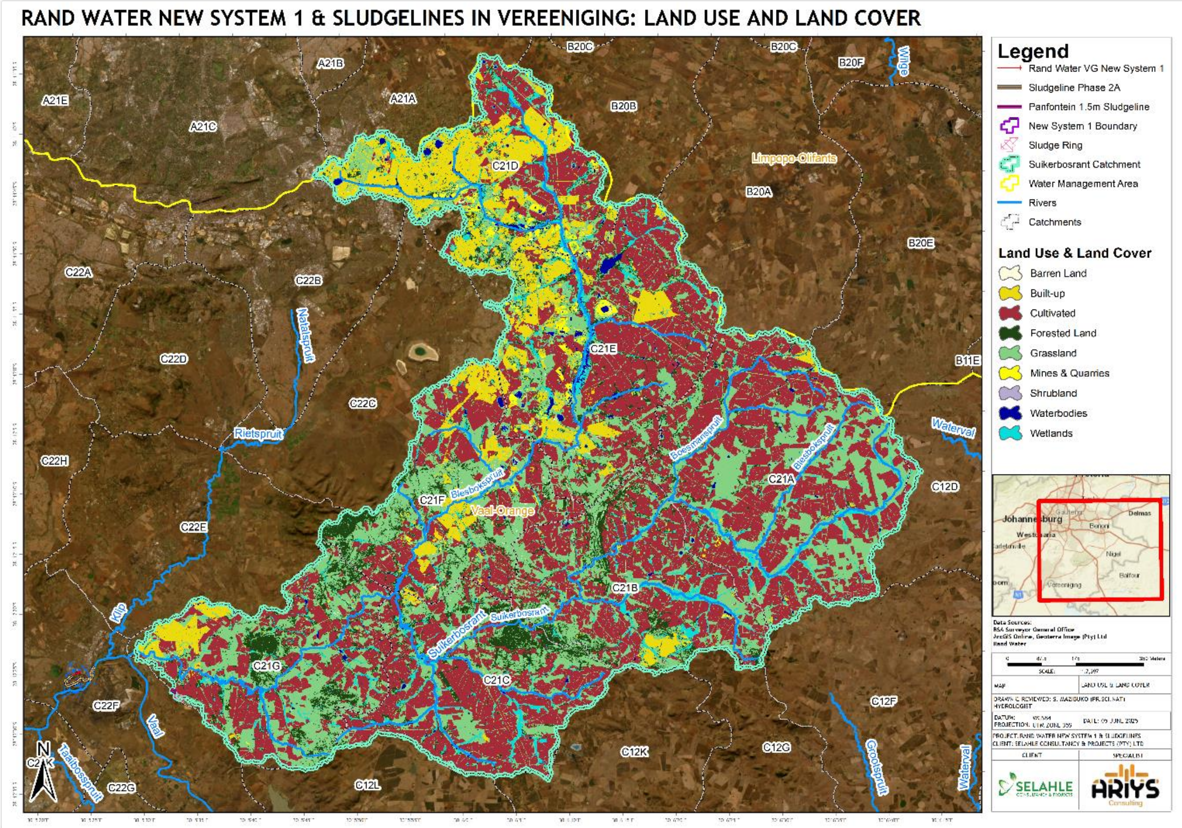

Figure 5-4: Dominant land use and land cover of the Suikerbosrant catchment

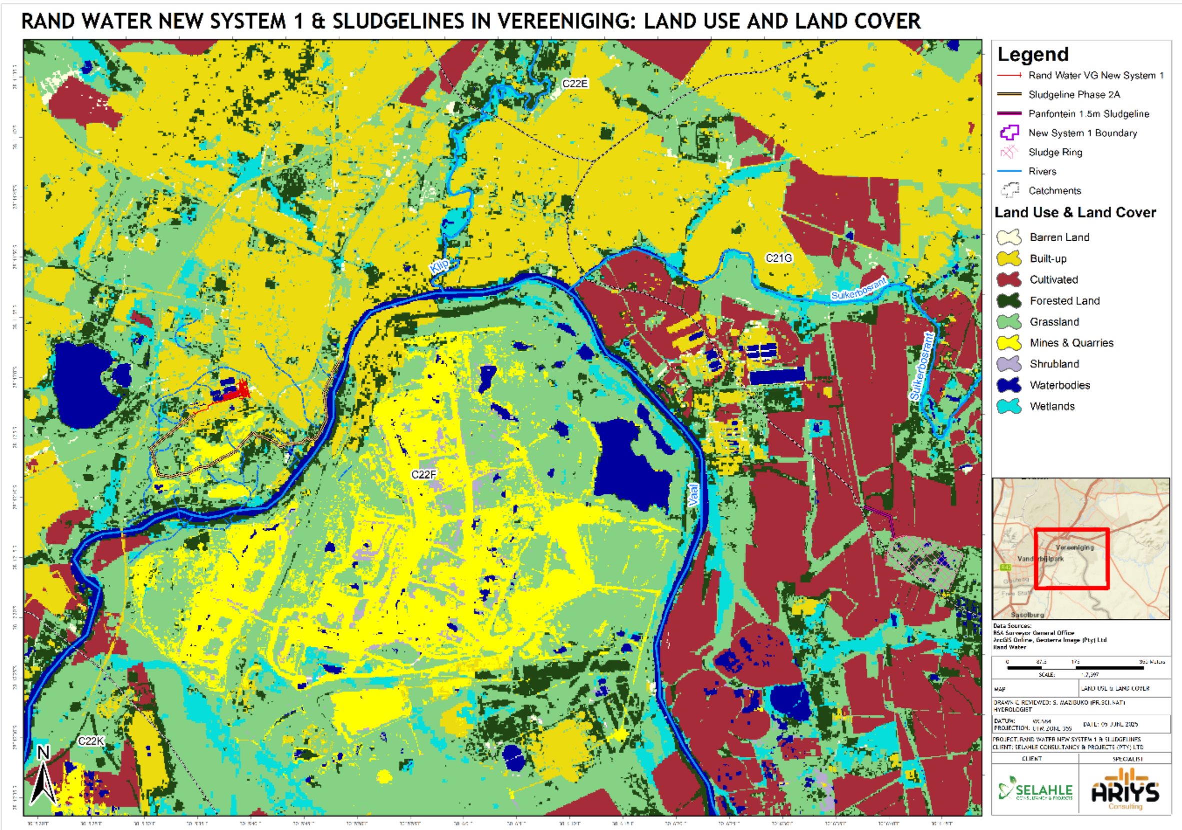

Figure 5-5: Dominant land use and land cover around the project area

The study area is typically characterised by a temperate climate (Cwb), Koppen-Geiger (Kottek, 2006), which is generally characterised by dry, cold winters and wet, periodic summers. Long-term-average temperature records for a station located in Vereeniging indicate that the coldest month (July) experiences a minimum of 5°C, while hot summers record the maximum temperature of 28°C (see Figure 5-6).

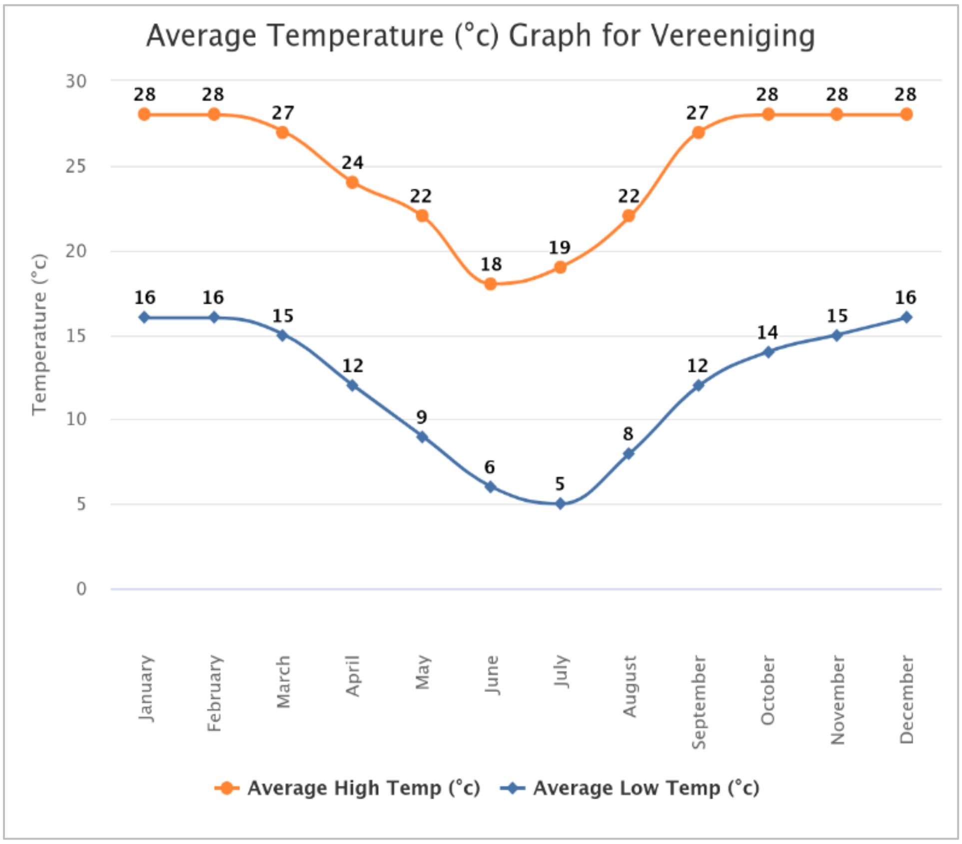

Figure 5-6: Average minimum and maximum temperatures for Vereeniging

5.2 Rainfall and Evaporation

The entire project falls within quaternary catchment C22F of the upper Vaal River, which forms part of the Vaal-Orange Water Management Area. However, the total drainage area for the Suikerbosrant catchment average-based rainfall records from the 90-year record WR2012 study (Bailey & Pitman, 2015) indicates that the area experiences a Mean Annual Precipitation (MAP) of 694 mm while the Mean Annual Evaporation (MAE) is 1 500 mm. The statistical distribution of monthly rainfall and evaporation is presented in Figure 5-7, which indicates these variables' high seasonality.

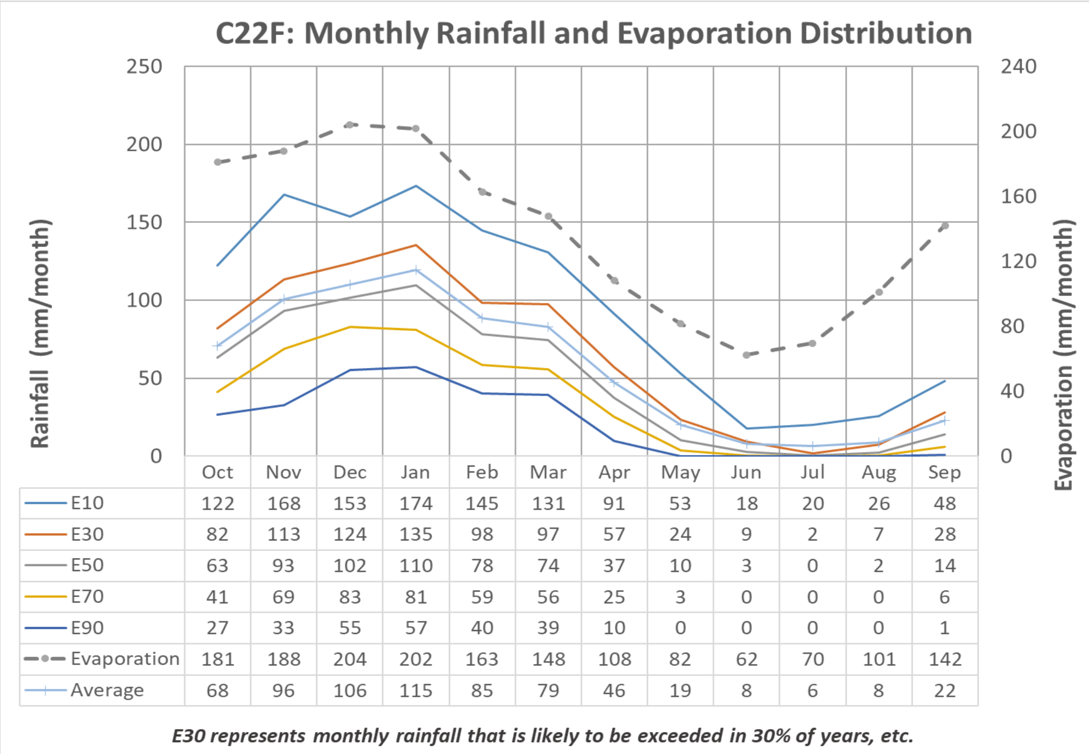

Figure 5-7: Seasonal distribution of rainfall and evaporation (Bailey and Pitman, 2015)

Table 5-1: Monthly evaporation for the study area

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
181	188	204	202	163	148	108	82	62	70	101	142

5.3 Design Rainfall

The design rainfall depths for the centre position of the area were obtained from the Design Rainfall Estimation (DRE) software (Smithers and Schulze, 2003). The program extracts the storm rainfall depths for various return periods for the six closest South African Weather Services (SAWS) rainfall stations – relative to the centroid of the study area (**Error! Reference source not found.**). Rainfall records from these stations are interpolated to compute the expected rainfall depths for various return periods shown in **Error! Reference source not found.**. These calculate the peak flows for the Suikerbosrant catchment area, evaluated for flood lines through the Alternative Rational Method.

Table 5-2: Summary of the six closest SAWS rain gauge stations for the study area

Station Name	SAWS Number	Distance (km)	Records (yrs)	MAP (mm)	Altitude (mams)
KRAAL (SAR)	0439755_W	5	62	665	1580
RIETFONTEIN	0440035_W	11	41	686	1645
HEIDELBERG I	0476630_W	14	92	726	1560
HEIDELBERG-PS	0476660_W	14	61	712	1560
VLAKFONTEIN	0439764_W	16	78	684	1555
BALFOUR (MAG)	0440129_W	18	95	688	1615

Table 5-3: Summary of the design rainfall depths for various return periods

Duration	Gridded Design Rainfall Depths (mm)					
	1:2 yr	1:5 yr	1:10 yr	1:20 yr	1:50 yr	1:100 yr
5 min	11	15	18	21	26	31
10 min	16	22	26	31	38	44
15 min	20	27	33	39	48	55
30 min	25	34	41	49	60	70
45 min	28	39	48	56	69	81
1 h	31	43	53	62	77	89
1.5 hrs	36	50	60	72	88	102
2 hrs	40	55	67	79	97	113
4 hrs	47	65	79	94	115	134
6 hrs	52	72	87	103	127	148
8 hrs	56	77	93	111	137	159
10 hrs	59	82	99	117	144	167
12 hrs	62	85	103	122	151	175
16 hrs	66	92	111	131	162	188
20 hrs	70	97	117	139	171	198
24 hrs	73	101	122	145	178	207
1 day	63	88	106	126	155	179
2 day	76	106	128	151	186	216
3 day	85	118	142	169	208	242
4 day	94	130	157	186	229	266
5 day	101	139	169	200	246	286
6 day	107	148	179	213	262	304
7 day	113	156	188	224	275	320

5.4 Peak Flow Volumes

Peak flow volumes used to route flood waters in the Vaal River were based on the expected water releases from the Vaal Dam, using the design volumes expected in the catchment. These peaks were informed by the flood risk assessment done for the Vaal Dam, with consideration of the expected peak flows that enter the dam once the full flood absorption capacity has been exceeded. DWS developed the Vaal Dam flood operation rules with consideration of the downstream impacts and water abstraction points by Rand Water.

For the Suikerbosrant, the calculated peak flow volumes for the 1:50 and 1:100-yr events were based on the catchment attributes derived using various datasets to characterise factors affecting runoff generation. These included the 2022 LULC (Geoterra Image (Pty) Ltd, 2024) and soil types (Schütte et al., 2023), which were quantified for the drainage area to determine their spatial area relative to the catchment size. The key variables used to calibrate the runoff coefficient for all drainage areas are summarised in Table 5-4.

The summary of the peak flow volumes using the methods explained in section 3.3 is given in Table 5-5 while the probability fit for these volumes is shown in Figure 5-8. Peak flow volumes derived from the Standard Design Flood method were selected for routing in the hydraulic model. These estimated the peak of 1 233 m^3/s for 1:50-yr and 1 519 m^3/s for 1:100-yr events.

Table 5-4: Hydrological variables used in the Rational Method for peak flow calculation

Suikerbosrant : CHARACTERISTICS

Catchment Area and Slope:

Total:	A	=	3499	km^2	Dolomitic areas in effective catchment:				
Ineffective:	A_i	=	0	km^2	Part of A_e considered as dolomitic:	A_d	=	0	km^2
Effective:	A_e	=	3499	km^2	Reduction factor	k	=	0.46	
Mean steepness of A_e	S_A	=	17.90	%	Flood peak reduction coefficient	f_d	=	1.00	

Watercourse Properties:

Longest Watercourse:					Mean Slope:			
Natural channel	L_1	=	176.30	km	Mean slope of L_1	S_1	=	0.000935
Total length	L	=	176.30	km	Mean slope of L_{total}	S_L	=	0.000935
Distance to centre of A	L_c	=	58.00	km	(distance, along channel, to a point closest to the centre of catchment)			

Time of Concentration (T_c):

TYPE OF FLOW	TIME OF CONCENTRATION (hours)			where			
Natural channel	$t_{c1} = \tau\,[0.87 \cdot L_1^2 / (1000 \cdot S_1)]^{0.385}$	52.20	52.0	A_e	=	3499	to calculate τ
Overland	$t_{c2} = 0{,}6 \cdot [\, r \cdot L_2 / (S_2)^{0.5}\,]^{0.467}$	0.00		τ	=	1.0	corr according to size of A
				r	=	0.40	roughness factor

Typical r values	Pavement	0,02	Bare soil	0,1	Poor grass	0,3	Average grass & Cultivated land	0,4	Dense grass	0,8

Rainfall-Runoff Properties:

Veld Type Zones	(HRU 1/72 fig.F1)	4	
Relative Weight (%)		100%	

Catchment Coverage as Required for Rational Method:

Rural	Urban	Lakes
85%	8%	7%

Suikerbosrant Basin

Soil Permeability:	%A	Land-Cover:	%A	Rainfall:	
Very Permeable (A)	7%	Forest, Dense bush & wood	7%	Mean Annual Rainfall (mm)	694
Permeable (B)	49%	Thin Bush, Cultivated land	45%	Extreme point rainfall region	3
Semi-Permeable (C)	22%	Grassland	40%	Coastal (**C**) or Inland (**I**)	I
Impermeable (D)	22%	Bare surface	8%	Winter (**W**) or Summer (**S**)	S

Table 5-5: Summary of the calculated peak flow volumes

Utility Programs for Drainage
Flood calculations

Sinotech

Project name:	Rand Water New System 1 and Sludgeline - Floodlines
Analysed by:	SC Mazibuko (Pr.Sci.Sci.)
Name of river:	Suikerbosrant
Description of site:	Drainage to Vaal River
Filename:	C:\Users\user\Desktop\Rand Water New System 1 and Sludgeline\Rand Water New System 1 and Sludgeline.fld
Date:	22 July 2025

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Summary of peak flows (m^3/s)

Method	1:2	1:5	1:10	1:20	1:50	1:100	1:200	Design year
Rational 1	266.58	382.90	509.79	660.46	899.01	1156.20		100
Rational 2	336.43	482.02	607.36	748.47	955.15	1145.23		100
Unit hydrograph	171.58	283.23	413.00	577.65	876.70	1220.49		100
Standard design flood	163.25	451.09	668.20	896.13	1233.41	1518.56		100
Empirical			825.36	951.26	1328.96	1678.69		100

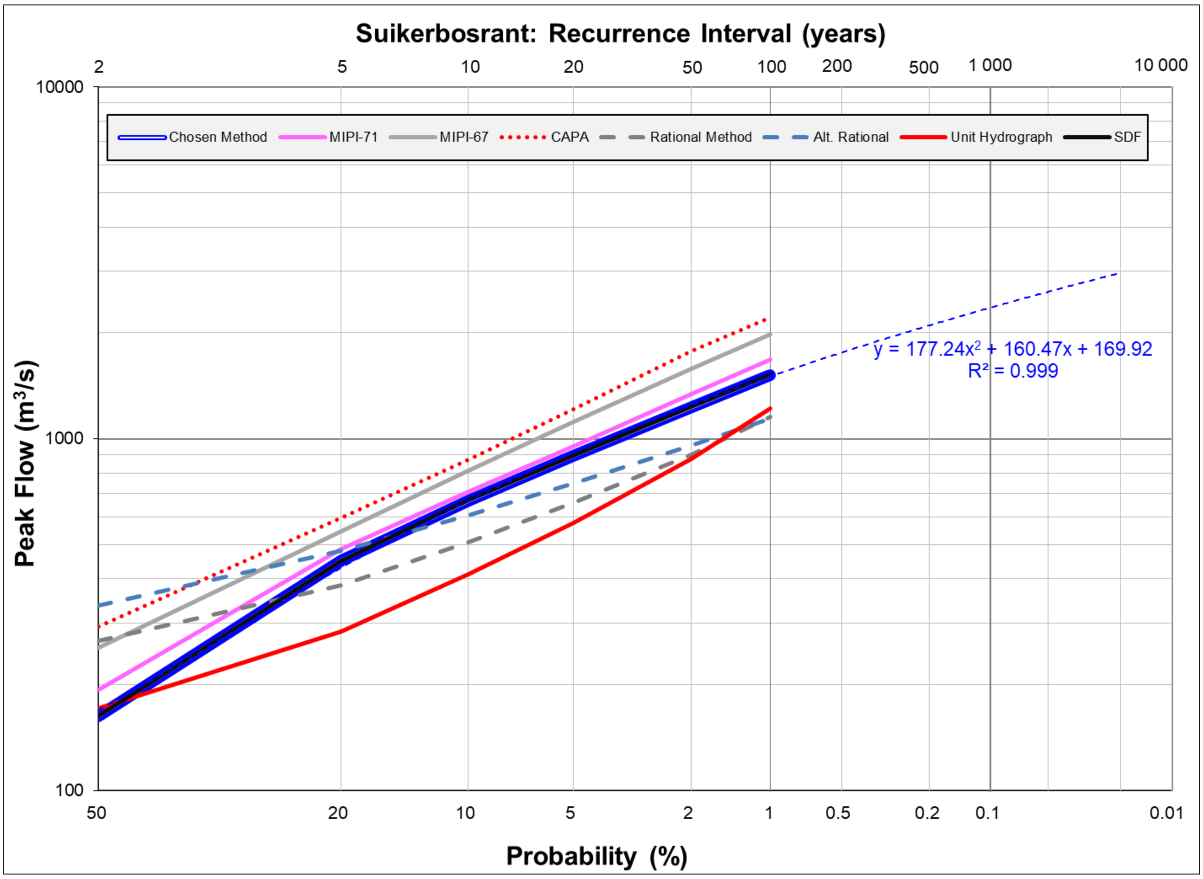

Figure 5-8: Statistical distribution of the calculated peak flow volumes

5.5 Floodlines Determination

Floodlines simulations were undertaken using HEC-RAS software, where several cross-sections were created throughout the river channel profile upstream and downstream of the proposed sludge line river locality. The right and left banks of the cross-sections were assigned to Manning's n-values based on the 2022 LULC shape file and land cover delineation done along the Vaal River. The hydraulic characteristics of the catchment and geometric setting for the modelled section are summarised in Table 5-6.

Table 5-6: Hydraulic characteristics of the modelled catchment

Catchment	Area (km^2)	Longest River (km)	Ave. Slope (m/m)	Time of Concentration (hrs)	Manning's n		
					L. Bank	Channel	R. Bank
Vaal	-	-	-	-	0.08–0.035	0.035	0.08–0.035
Suikerbosrant	3 499	176.3	0.00093	52			

6 FLOODLINE MODELLING

6.1 Topographic Data and River Geometry

HEC-RAS was used to undertake 1D hydraulic modelling along the Vaal River segment adjacent to the proposed development to determine the extent of the floodlines corresponding to the 1:100-year peak flow volume based on the water releases from the Vaal Dam. Hydraulic modelling was based on a 5 m contour obtained from the office of the Chief Surveyor General. These data did not provide realistic topographic conditions that exist; interpolated point data was used, using the best topographic data retrieved from Google Earth Pro.

The geometries of the modelled river sections of the Vaal and Suikerbosrant are presented in Figure 6-1 and 6-2. The figures show the profiles of the cross-sections in the proposed construction site's upstream and downstream reaches (for the Vaal) as well as the adjacent (for Suikerbosrant). The derived topographic setting of the study shows that the area is relatively flat and the settings of the river geometry are inconsistent when comparing similar cross-sections derived from freely available 30 m (ALOS) DSM, 5 m contour data.

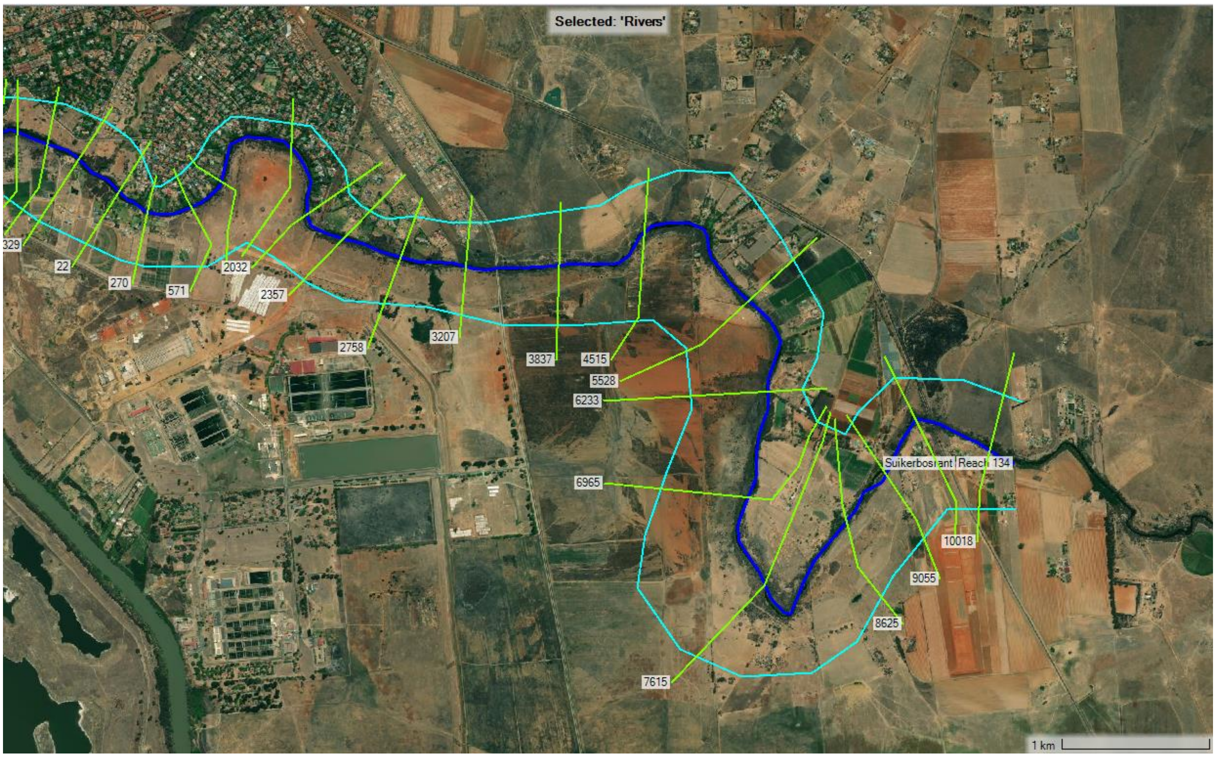

Figure 6-1: Modelled river section geometry used in the simulation of the floodlines

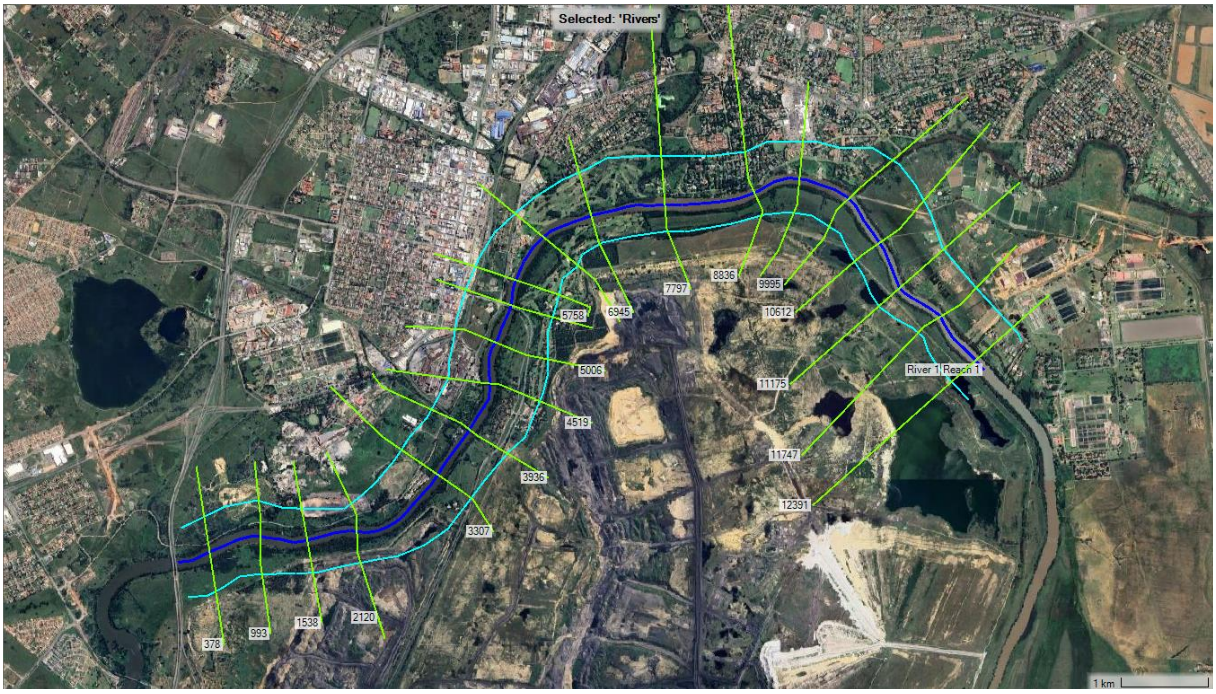

Figure 6-2: Vaal River geometry used in HEC-RAS

6.2 Floodlines Results

The resulting floodlines are given in Figures 6-3 and 6-4. Results for the Suikerbosrant show that 1:50 and 1:100-yr floodlines are not encroaching on the Sludge ring area. However, floodwater encroaches a larger area due to the backwater effect near the confluence with the Vaal River. Along the Vaal River, results show that areas of the proposed sludge pipeline will likely be inundated with the medium flood water releases from the Vaal Dam. While these results show a high area of inundation, there are issues that could be attributed to the lack of high-resolution data, which could represent the river geometry and the inactive flow areas in the model. Using high-resolution survey data can improve the modelling results by developing a 2D framework incorporating riparian embankment features, ineffective flow areas, additional tributary inflows, and inline structures such as bridges.

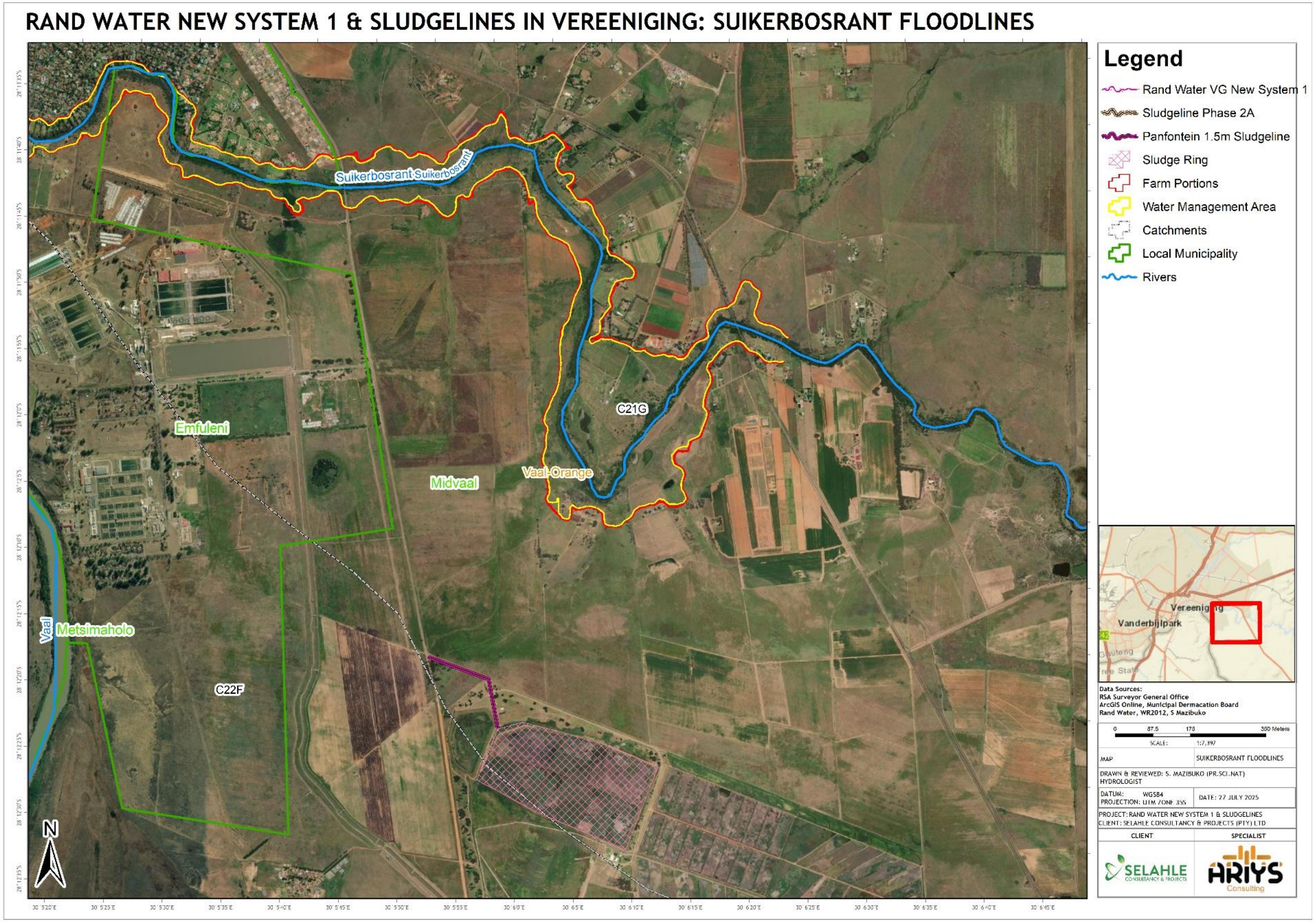

Figure 6-3: Simulated Suikerbosrant floodlines

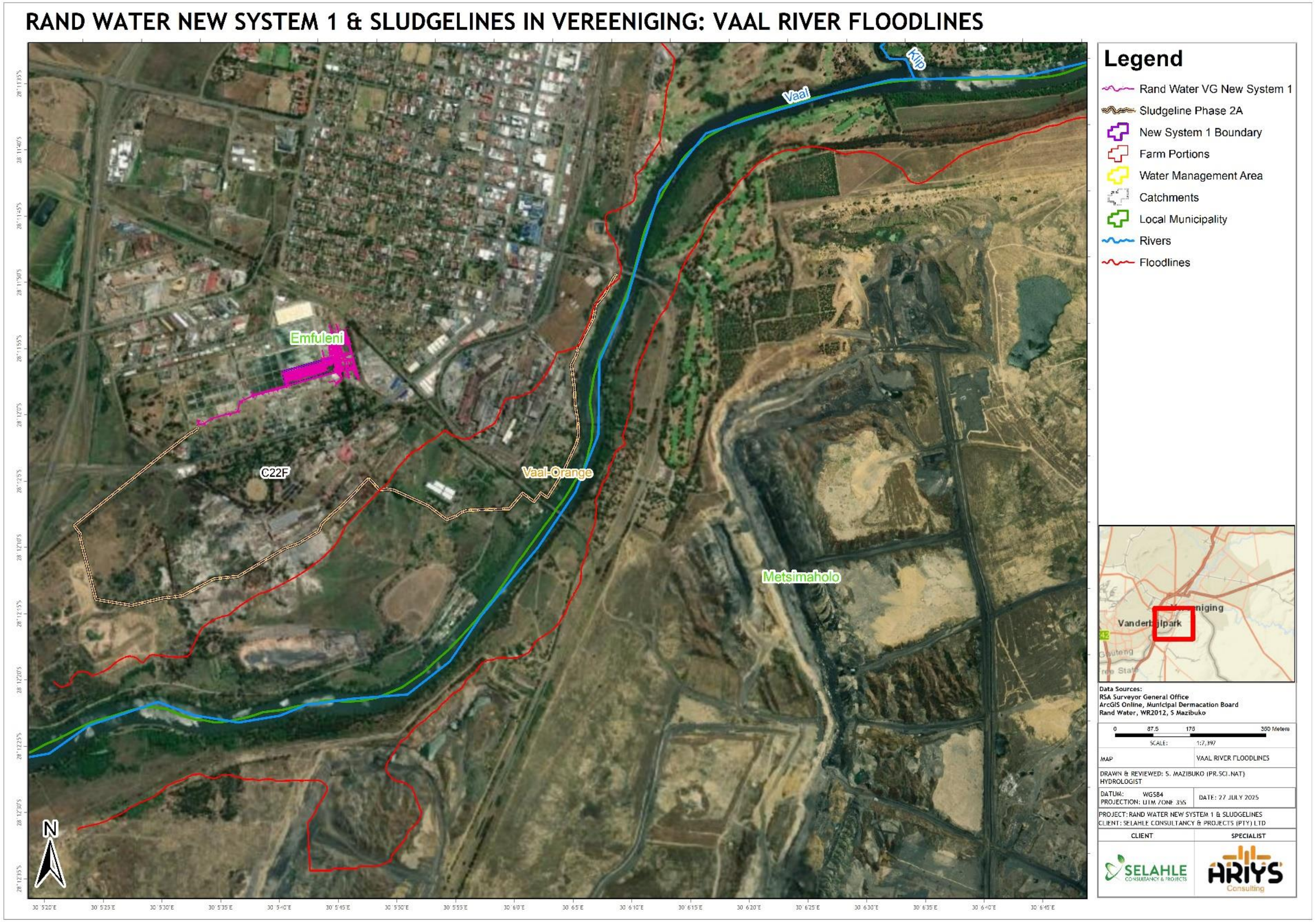

Figure 6-4: Vaal River simulated floodlines

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

- The peak flood volumes of 1 800 m^3/s from the Vaal Dam releases were used to simulate the resulting floodlines for the proposed area. These volumes are based on the dam operations for medium to small flooding events.

- Peak flow volumes derived from the Standard Design Flood method were selected to route the Suikerbosrant flood waters in the hydraulic model. These estimated the peak of 1 233 m^3/s for 1:50-yr and 1 519 m^3/s for 1:100-yr events.

- Results show that both floodlines from Suikerbosrant do not inundate the sludge ring and its associated sludge line in Panfontein. On the contrary, floodline simulation results – based on the 1 800 m^3/s flood releases from the dam – show that the Vaal River is likely to inundate the 7 km Sludgelines with the exception of the south-western cover, which is out of the flood zone.
- Using 5 m contour data, geometric data for the Vaal River was developed to route the flood waters. Results show that most of the proposed sludge line area will likely be flooded. However, there is a representation of the river and riparian profile in the hydraulic model, which resulted in uncertainty associated with the river's wetted perimeter.

7.2 Recommendations

- A detailed survey of data along the proposed construction site is required to refine and reduce the uncertainties associated with the terrain setting, which are aimed at improving the floodline simulation results.

8 REFERENCES

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9 APPENDICES

9.1 Peak Flows

Utility Programs for Drainage
Flood calculations

Sinotech

Project name:	Rand Water New System 1 and Sludgeline - Floodlines
Analysed by:	SC Mazibuko (Pr.Sci.Sci.)
Name of river:	Suikerbosrant
Description of site:	Drainage to Vaal River
Filename:	C:\Users\user\Desktop\Rand Water New System 1 and Sludgeline\Rand Water New System 1 and Sludgeline.fld
Date:	22 July 2025

Printed: 27 July 2025 Page 1

Flood Frequency Analysis: Rational Method 1

Project	= Rand Water New System 1 and Sludgeline - Floodlines
Analysed by	= SC Mazibuko (Pr.Sci.Sci.)
Name of river	= Suikerbosrant
Description of site	= Drainage to Vaal River
Date	= 7/22/2025
Area of catchment	= 3498.6 km²
Dolomitic area	= 0.0 %
Mean annual rainfall (MAR)	= 694.00 mm
Length of longest watercourse	= 176.0 km
Flow of water	= Defined water course
Height difference along 10-85 slope	= 156.0 m
Rainfall region	= Inland
Area distribution	= Rural: 85 %, Urban: 8 %, Lakes: 7 %

Catchment description - Urban area (%)

Lawns		Residential and industry		Business	
Sandy, flat (<2%)	0	Houses	40	City centre	10
Sandy, steep (>7%)	0	Flats	5	Suburban	20
Heavy soil, flat (<2%)	0	Light industry	15	Streets	5
Heavy soil, steep (>7%)	0	Heavy industry	5	Maximum flood	0

Catchment description - Rural area (%)

Surface slopes		Permeability		Vegetation	
Lakes and pans	5	Very permeable	7	Thick bush & forests	7
Flat area	80	Permeable	49	Light bush & cultivated land	45
Hilly	15	Semi-permeable	22	Grasslands	42
Steep areas	0	Impermeable	22	Bare	6

Average slope	= 0.00118 m/m
Time of concentration	= 47.62 h
Run-off factor	
Rural - C1	= 0.381
Urban - C2	= 0.658
Lakes - C3	= 0.000
Combined - C	= 0.377

The HRU, Report 2/78, Depth-Duration-Frequency diagram was used to determine the point rainfall.

Return Period (years)	Time of concentration (hours)	Point rainfall (mm)	ARF (%)	Average intensity (mm/h)	Factor Ft	Runoff coefficient (%)	Peak flow (m³/s)
1:2	47.62	62.1	71.2	0.9	0.75	29.6	266.58
1:5	47.62	84.6	71.2	1.3	0.80	31.2	382.90
1:10	47.62	107.0	71.2	1.6	0.85	32.8	509.79
1:20	47.62	132.1	71.2	2.0	0.90	34.4	660.46
1:50	47.62	171.7	71.2	2.6	0.95	36.0	899.01
1:100	47.62	211.4	71.2	3.2	1.00	37.7	1156.20

Run-off coefficient percentage includes adjustment saturation factors (Ft) for steep and impermeable catchments

Calculated using Utility Programs for Drainage 2.0.0

Utility Programs for Drainage
Flood calculations

Sinotech

Project name: Rand Water New System 1 and Sludgeline - Floodlines
Analysed by: SC Mazibuko (Pr.Sci.Sci.)
Name of river: Suikerbosrant
Description of site: Drainage to Vaal River
Filename: C:\Users\user\Desktop\Rand Water New System 1 and Sludgeline\Rand Water New System 1 and Sludgeline.fld
Date: 22 July 2025

Printed: 27 July 2025 Page 1

Flood Frequency Analysis: Rational Method 2

Project	= Rand Water New System 1 and Sludgeline - Floodlines
Analysed by	= SC Mazibuko (Pr.Sci.Sci.)
Name of river	= Suikerbosrant
Description of site	= Drainage to Vaal River
Date	= 7/22/2025
Area of catchment	= 3498.6 km²
Dolomitic area	= 0.0 %
Length of longest watercourse	= 176.0 km
Flow of water	= Defined water course
Height difference along 10-85 slope	= 156.0 m
Area distribution	= Rural: 85 %, Urban: 8 %, Lakes: 7 %

Catchment description - Urban area (%)

Lawns		Residential and industry		Business	
Sandy, flat (<2%)	0	Houses	40	City centre	10
Sandy, steep (>7%)	0	Flats	5	Suburban	20
Heavy soil, flat (<2%)	0	Light industry	15	Streets	5
Heavy soil, steep (>7%)	0	Heavy industry	5	Maximum flood	0

Catchment description - Rural area (%)

Surface slopes		Permeability		Vegetation	
Lakes and pans	5	Very permeable	7	Thick bush & forests	7
Flat area	80	Permeable	49	Light bush & cultivated land	45
Hilly	15	Semi-permeable	22	Grasslands	42
Steep areas	0	Impermeable	22	Bare	6

Days on which thunder was heard	= 70 days/year
Weather Services station number	= 439764
Weather Services station location	= VLAKFONTEIN
Mean annual precipitation (MAP)	= 684 mm

Duration	2	5	10	20	50	100	200
1 day	52	71	85	100	122	140	160
2 days	67	91	109	128	156	179	203
3 days	74	100	120	140	169	193	219
7 days	99	136	164	192	233	267	303

Linear interpolation between the calculated modified recalibrated Hershfield values and the 1-day point rainfall from TR102 was used to determine point rainfall.

Average slope	= 0.00118 m/m
Time of concentration	= 47.62 h
Run-off factor	
Rural - C1	= 0.381
Urban - C2	= 0.658
Lakes - C3	= 0.000
Combined - C	= 0.377

Return period (years)	Time of concentration (hours)	Point rainfall (mm)	ARF (%)	Average intensity (mm/h)	Factor Ft	Runoff coefficient (%)	Peak flow (m³/s)
1:2	47.62	66.77	83.5	1.17	0.75	29.6	336.43
1:5	47.62	90.69	83.5	1.59	0.80	31.2	482.02
1:10	47.62	108.62	83.5	1.91	0.85	32.8	607.36
1:20	47.62	127.56	83.5	2.24	0.90	34.4	748.47
1:50	47.62	155.47	83.5	2.73	0.95	36.0	955.15
1:100	47.62	178.39	83.5	3.13	1.00	37.7	1145.23

Run-off coefficient percentage includes adjustment saturation factors (Ft) for steep and impermeable catchments

Calculated using Utility Programs for Drainage 2.0.0

Utility Programs for Drainage
Flood calculations

Sinotech

Project name: Rand Water New System 1 and Sludgeline - Floodlines
Analysed by: SC Mazibuko (Pr.Sci.Sci.)
Name of river: Suikerbosrant
Description of site: Drainage to Vaal River
Filename: C:\Users\user\Desktop\Rand Water New System 1 and Sludgeline\Rand Water New System 1 and Sludgeline.fld
Date: 22 July 2025

Printed: 27 July 2025 **Page 1**

Flood frequency analysis : Standard Design Flood method

Project name	= Rand Water New System 1 and Sludgeline - Floodlines
Analysed by	= SC Mazibuko (Pr.Sci.Sci.)
Name of river	= Suikerbosrant
Description of site	= Drainage to Vaal River
Date	= 7/22/2025
Catchment characteristics:	
Area of catchment	= 3498.6 km^2
Length of longest watercourse	= 176 km
1085 height difference	= 156 m
Average slope	= 0.0012 m/m
Drainage basin characteristics:	
Drainage basin number	= 6
Mean annual daily max rain	= 51 mm
Days on which thunder was heard	= 54 days
Runoff coefficient C2	= 15 %
Runoff coefficient C100	= 60 %
Basin mean annual precipitation	= 670 mm
Basin mean annual evaporation	= 1500 mm
Basin evaporation index MAE/MAP	= 2.24

RAINFALL DATA
The rainfall data in the table below are derived from two sources. The daily rainfall is from the Department of Water Affair's publication TR102 for the representative site. The modified Hershfield equation is used for durations up to four hours. Linear interpolation is used for values between 4 hours and one day.

Weather Services station ex TR102 = 369030 @ SYLVAN
Point mean annual precipitation = 670 mm

Dur:	RP =2	5	10	20	50	100	200
.25 h	16	27	35	43	54	62	71
.50 h	21	35	45	56	70	81	92
1 h	25	43	56	69	87	100	113
2 h	30	51	67	82	103	119	134
4 h	35	59	74	84	97	108	120
1 day	51	65	74	84	97	108	120
2 days	64	85	99	113	133	149	166
3 days	74	98	116	134	160	181	204
7 days	92	121	142	164	193	217	242

Runoff coefficients C2 = 15 % C100 = 60 %

Return period (years)	Time of concentration (hours)	Point precipitation (mm)	ARF (%)	Catchment precipitation (mm)	Runoff coefficient (%)	Peak flow (m^3/s)
1:2	47.62	63.8	83.5	53.3	15.0	163.25
1:5	47.62	84.7	83.5	70.7	31.2	451.09
1:10	47.62	98.6	83.5	82.4	39.7	668.20
1:20	47.62	112.5	83.5	94.0	46.7	896.13
1:50	47.62	132.4	83.5	110.6	54.6	1233.41
1:100	47.62	148.4	83.5	123.9	60.0	1518.56

Calculated using Utility Programs for Drainage 2.0.0

Utility Programs for Drainage
Flood calculations

Sinotech

Project name: Rand Water New System 1 and Sludgeline - Floodlines
Analysed by: SC Mazibuko (Pr.Sci.Sci.)
Name of river: Suikerbosrant
Description of site: Drainage to Vaal River
Filename: C:\Users\user\Desktop\Rand Water New System 1 and Sludgeline\Rand Water New System 1 and Sludgeline.fld
Date: 22 July 2025

Printed: 27 July 2025 **Page 1**

Flood Frequency Analysis: Empirical methods

Project	= Rand Water New System 1 and Sludgeline - Floodlines
Analysed by	= SC Mazibuko (Pr.Sci.Sci.)
Name of river	= Suikerbosrant
Description of site	= Drainage to Vaal River
Date	= 7/22/2025

Area of catchment	= 3498.6 km²
Length of longest watercourse	= 176.0 km
Height difference along equal-area slope	= 156.0 m
Distance to catchment centroid	= 58.0 km
Dolomitic area	= 0.0 %
Mean annual rainfall	= 694.0 mm
Veld type	= 4 & 5A
Kovács region	= K4(K = 4.6)
Catchment parameter with regard to reaction time	= 0.01

Peak discharges by means of an empirical method developed by Midgley and Pitman

Return period (years)	KT constant	Peak flow (m³/s)
1:10	0.59	825.36
1:20	0.68	951.26
1:50	0.95	1328.96
1:100	1.20	1678.69

Calculated using Utility Programs for Drainage 2.0.0

Utility Programs for Drainage
Flood calculations

Project name: Rand Water New System 1 and Sludgeline - Floodlines
Analysed by: SC Mazibuko (Pr.Sci.Sci.)
Name of river: Suikerbosrant
Description of site: Drainage to Vaal River
Filename: C:\Users\user\Desktop\Rand Water New System 1 and Sludgeline\Rand Water New System 1 and Sludgeline.fld
Date: 22 July 2025

Printed: 27 July 2025 Page 1

Flood Frequency Analysis: Unit Hydrograph Method

Project	= Rand Water New System 1 and Sludgeline - Floodlines
Analysed by	= SC Mazibuko (Pr.Sci.Sci.)
Name of river	= Suikerbosrant
Description of site	= Drainage to Vaal River
Date	= 7/22/2025
Area of catchment	= 3498.6 km^2
Length of longest watercourse	= 176.0 km
Height difference along equal area slope	= 156.0 m
Distance to catchment centroid	= 58.0 km
Veld type	= Region 4
Duration interval	= 1 hour

Slope of longest stream	= 0.0009 m/m
Catchment index	= 342874.1
Catchment lag	= 33.078
Coefficient (Ku)	= 0.386 m^3/s - $hours/km^2$
Peak discharge of unit hydrograph (Qp)	= 40.827 m^3/s

Return period = 1:50 year

Storm duration (minutes)	Point rainfall (mm)	Point intensity (mm/h)	ARF (%)	Average rainfall (mm)	Runoff factor (%)	Effective rain (mm)
60	90.8	90.8	40.2	36.6	17.8	6.52
120	107.8	53.9	44.8	48.3	21.2	10.24
180	116.7	38.9	47.5	55.4	23.0	12.76
240	122.7	30.7	49.4	60.6	24.3	14.74
300	127.2	25.4	51.0	64.9	25.3	16.42
360	130.8	21.8	52.4	68.5	26.1	17.90
420	133.8	19.1	53.5	71.7	26.8	19.23
480	136.5	17.1	54.6	74.5	27.5	20.45
540	138.7	15.4	55.5	77.0	28.0	21.59
600	140.8	14.1	56.4	79.4	28.5	22.65
660	142.6	13.0	57.2	81.6	29.0	23.65
720	144.3	12.0	58.0	83.6	29.4	24.59
780	145.9	11.2	58.7	85.6	29.8	25.50
840	147.3	10.5	59.3	87.4	30.2	26.36
900	148.6	9.9	59.9	89.1	30.5	27.19
960	149.9	9.4	60.5	90.7	30.8	27.98
1020	151.1	8.9	61.1	92.3	31.2	28.75
1080	152.2	8.5	61.6	93.8	31.5	29.49
1140	153.2	8.1	62.1	95.2	31.7	30.21
1200	154.2	7.7	62.6	96.5	32.0	30.90
1260	155.2	7.4	63.1	97.9	32.3	31.58
1320	156.1	7.1	63.5	99.1	32.5	32.23
1380	157.0	6.8	63.9	100.4	32.7	32.87
1440	157.8	6.6	64.3	101.6	33.0	33.49
1500	158.7	6.3	64.7	102.7	33.2	34.10
1560	159.4	6.1	65.1	103.8	33.4	34.69
1620	160.2	5.9	65.5	104.9	33.6	35.26
1680	160.9	5.7	65.8	106.0	33.8	35.83
1740	161.6	5.6	66.2	107.0	34.0	36.38
1800	162.3	5.4	66.5	108.0	34.2	36.92
1860	163.0	5.3	66.9	108.9	34.4	37.45
1920	163.6	5.1	67.2	109.9	34.6	37.97
1980	164.2	5.0	67.5	110.8	34.7	38.48
2040	164.8	4.8	67.8	111.7	34.9	38.98
2100	165.4	4.7	68.1	112.6	35.1	39.47
2160	166.0	4.6	68.3	113.4	35.2	39.95
2220	166.5	4.5	68.6	114.3	35.4	40.42
2280	167.1	4.4	68.9	115.1	35.5	40.89
2340	167.6	4.3	69.2	115.9	35.7	41.35
2400	168.1	4.2	69.4	116.7	35.8	41.80
2460	168.6	4.1	69.7	117.5	36.0	42.24
2520	169.1	4.0	69.9	118.2	36.1	42.67
2580	169.6	3.9	70.1	119.0	36.2	43.10
2640	170.1	3.9	70.4	119.7	36.4	43.52
2700	170.6	3.8	70.6	120.4	36.5	43.94
2760	171.0	3.7	70.8	121.1	36.6	44.35
2820	171.5	3.6	71.0	121.8	36.7	44.75
2880	171.9	3.6	71.3	122.5	36.9	45.15

Return period = 1:100 year

Storm duration (minutes)	Point rainfall (mm)	Point intensity (mm/h)	ARF (%)	Average rainfall (mm)	Runoff factor (%)	Effective rain (mm)
60	111.8	111.8	40.2	45.0	20.3	9.14
120	132.6	66.3	44.8	59.4	24.0	14.28
180	143.6	47.9	47.5	68.2	26.1	17.77
240	151.0	37.7	49.4	74.6	27.5	20.52
300	156.6	31.3	51.0	79.9	28.6	22.85
360	161.0	26.8	52.4	84.3	29.5	24.90
420	164.7	23.5	53.5	88.2	30.3	26.75
480	167.9	21.0	54.6	91.7	31.0	28.45
540	170.8	19.0	55.5	94.8	31.7	30.03
600	173.3	17.3	56.4	97.7	32.2	31.51
660	175.5	16.0	57.2	100.4	32.8	32.90
720	177.6	14.8	58.0	102.9	33.2	34.22
780	179.5	13.8	58.7	105.3	33.7	35.48
840	181.3	12.9	59.3	107.5	34.1	36.68
900	182.9	12.2	59.9	109.6	34.5	37.83
960	184.5	11.5	60.5	111.6	34.9	38.94
1020	185.9	10.9	61.1	113.6	35.2	40.01
1080	187.3	10.4	61.6	115.4	35.6	41.05
1140	188.6	9.9	62.1	117.1	35.9	42.05
1200	189.8	9.5	62.6	118.8	36.2	43.02
1260	191.0	9.1	63.1	120.5	36.5	43.96
1320	192.2	8.7	63.5	122.0	36.8	44.88
1380	193.2	8.4	63.9	123.5	37.0	45.77
1440	194.3	8.1	64.3	125.0	37.3	46.63
1500	195.3	7.8	64.7	126.4	37.6	47.48
1560	196.2	7.5	65.1	127.8	37.8	48.31
1620	197.2	7.3	65.5	129.1	38.0	49.11
1680	198.0	7.1	65.8	130.4	38.3	49.90
1740	198.9	6.9	66.2	131.7	38.5	50.68
1800	199.7	6.7	66.5	132.9	38.7	51.43
1860	200.6	6.5	66.9	134.1	38.9	52.17
1920	201.3	6.3	67.2	135.2	39.1	52.90
1980	202.1	6.1	67.5	136.4	39.3	53.61
2040	202.9	6.0	67.8	137.5	39.5	54.31
2100	203.6	5.8	68.1	138.6	39.7	55.00
2160	204.3	5.7	68.3	139.6	39.9	55.67
2220	205.0	5.5	68.6	140.7	40.0	56.33
2280	205.6	5.4	68.9	141.7	40.2	56.98
2340	206.3	5.3	69.2	142.7	40.4	57.62
2400	206.9	5.2	69.4	143.6	40.6	58.25
2460	207.6	5.1	69.7	144.6	40.7	58.87
2520	208.2	5.0	69.9	145.5	40.9	59.48
2580	208.8	4.9	70.1	146.4	41.0	60.08
2640	209.4	4.8	70.4	147.3	41.2	60.67
2700	209.9	4.7	70.6	148.2	41.3	61.25
2760	210.5	4.6	70.8	149.1	41.5	61.83
2820	211.0	4.5	71.0	149.9	41.6	62.39
2880	211.6	4.4	71.3	150.8	41.8	62.95

Return period = 1:50 year

Storm duration (minutes)	Unit hydrograph peak (Qe) (m^3/s)	Peak discharge (m^3/s)
60	0.998	265.763
120	0.996	416.320
180	0.993	516.938
240	0.988	594.755
300	0.973	652.496
360	0.960	701.705
420	0.944	740.935
480	0.922	769.733
540	0.900	793.194
600	0.881	814.773
660	0.861	831.109
720	0.839	842.850
780	0.818	851.615
840	0.798	858.466
900	0.779	864.921
960	0.762	870.047
1020	0.744	873.312
1080	0.727	875.430
1140	0.711	876.530
1200	0.695	876.701
1260	0.680	876.264
1320	0.665	875.257
1380	0.651	873.715
1440	0.638	872.212
1500	0.625	870.607
1560	0.613	868.525
1620	0.602	866.104
1680	0.590	863.404
1740	0.579	860.524
1800	0.569	857.420
1860	0.559	854.302
1920	0.549	851.264
1980	0.540	848.023
2040	0.531	844.579
2100	0.522	840.931
2160	0.513	837.081
2220	0.505	833.258
2280	0.497	829.463
2340	0.489	825.535
2400	0.481	821.463
2460	0.474	817.402
2520	0.467	813.388
2580	0.460	809.246
2640	0.453	804.989
2700	0.446	800.809
2760	0.440	796.649
2820	0.434	792.399
2880	0.428	788.069

Return period = 1:100 year

Storm duration (minutes)	Unit hydrograph peak (Qe) (m³/s)	Peak discharge (m³/s)
60	0.998	372.338
120	0.996	580.509
180	0.993	719.858
240	0.988	827.765
300	0.973	907.888
360	0.960	976.235
420	0.944	1030.763
480	0.922	1070.819
540	0.900	1103.480
600	0.881	1133.545
660	0.861	1156.331
720	0.839	1172.732
780	0.818	1185.003
840	0.798	1194.614
900	0.779	1203.678
960	0.762	1210.894
1020	0.744	1215.521
1080	0.727	1218.552
1140	0.711	1220.167
1200	0.695	1220.486
1260	0.680	1219.960
1320	0.665	1218.637
1380	0.651	1216.568
1440	0.638	1214.553
1500	0.625	1212.393
1560	0.613	1209.567
1620	0.602	1206.268
1680	0.590	1202.578
1740	0.579	1198.636
1800	0.569	1194.380
1860	0.559	1190.102
1920	0.549	1185.935
1980	0.540	1181.482
2040	0.531	1176.744
2100	0.522	1171.722
2160	0.513	1166.416
2220	0.505	1161.146
2280	0.497	1155.913
2340	0.489	1150.493
2400	0.481	1144.872
2460	0.474	1139.264
2520	0.467	1133.720
2580	0.460	1127.995
2640	0.453	1122.110
2700	0.446	1116.331
2760	0.440	1110.578
2820	0.434	1104.697
2880	0.428	1098.705

Return period	Storm duration (minutes)	Peak discharge (m³/s)
1:2 year	1260	171.58
1:5 year	1200	283.23
1:10 year	1200	413.00
1:20 year	1200	577.65
1:50 year	1200	876.70
1:100 year	1200	1220.49

Calculated using Utility Programs for Drainage 2.0.0

9.2 Design Rainfall Estimation

Design Rainfall in South Africa: Ver 3 (July 2012)

User selection has the following criteria:
Coordinates: Latitude: 26 degrees 35 minutes; Longitude: 28 degreess 26 minutes
Durations requested: 5 m, 10 m, 15 m, 30 m, 45 m, 1 h, 1.5 h, 2 h, 4 h, 6 h, 8 h, 10 h, 12 h, 16 h, 20 h, 24 h, 1 d, 2 d, 3 d, 4 d, 5 d, 6 d, 7 d
Return Periods requested: 2 yr, 5 yr, 10 yr, 20 yr, 50 yr, 100 yr
Block Size requested: 0 minutes

Data extracted from Daily Rainfall Estimate Database File
The six closest stations are listed

Station Name	SAWS Number	Distance (km)	Record (Years)	Latitude (°)	Latitude (')	Longitude (°)	Longitude (')	MAP (mm)	Altitude (m)	Duration (m/h/d)	Return Period (years) 2	2L	2U	5	5L	5U	10	10L	10U	20	20L	20U	50	50L	50U	100	100L	100U
KRAAL (SAR)	0439755_W	5.1	62	26	33	28	24	665	1580	1 d	57.4	57.1	57.7	79.3	78.9	79.7	95.9	95.4	96.3	113.5	112.5	114.4	139.2	137.2	140.7	160.7	157.7	163.4
										2 d	70.5	70.0	71.0	97.8	97.1	98.2	118.8	117.3	120.0	141.7	138.5	144.4	175.7	169.2	181.5	204.9	194.5	214.3
										3 d	76.7	76.4	77.1	105.7	105.3	106.2	128.0	127.1	128.6	152.1	150.3	153.6	187.7	184.1	190.5	218.0	211.8	223.0
										4 d	82.5	82.2	82.9	112.6	112.1	113.2	135.6	134.6	136.2	160.2	158.5	161.7	196.3	192.6	199.3	227.0	220.7	232.1
										5 d	88.6	88.2	89.1	120.6	120.0	121.0	144.4	143.3	145.1	169.6	168.0	171.2	206.1	202.4	209.2	236.6	230.3	241.8
										6 d	94.4	93.9	95.1	128.1	127.5	128.8	153.2	151.0	154.7	179.3	175.4	182.6	216.8	208.8	223.4	247.8	234.9	259.1
										7 d	98.5	98.1	98.9	133.3	132.7	134.0	159.0	157.2	160.5	185.8	182.5	188.5	223.9	216.7	229.5	255.0	244.1	264.3
RIETFONTEIN	0440035_W	10.8	41	26	35	28	32	686	1645	1 d	51.5	51.2	51.7	71.1	70.7	71.4	85.9	85.5	86.3	101.7	100.8	102.5	124.7	122.9	126.1	144.0	141.3	146.4
										2 d	63.7	63.2	64.1	88.3	87.7	88.7	107.3	105.9	108.4	128.0	125.1	130.4	158.7	152.8	163.9	185.0	175.7	193.5
										3 d	71.6	71.3	71.9	98.7	98.3	99.1	119.5	118.6	120.1	142.0	140.3	143.4	175.2	171.9	177.8	203.5	197.7	208.2
										4 d	78.8	78.5	79.2	107.6	107.1	108.1	129.6	128.6	130.2	153.1	151.4	154.5	187.6	184.0	190.4	216.9	210.8	221.7
										5 d	85.7	85.3	86.2	116.6	116.0	117.0	139.6	138.6	140.3	164.0	162.4	165.5	199.3	195.7	202.3	228.8	222.7	233.8
										6 d	91.7	91.3	92.4	124.5	123.9	125.1	148.8	146.7	150.3	174.2	170.4	177.4	210.7	202.8	217.1	240.8	228.2	251.7
										7 d	96.1	95.6	96.5	130.0	129.4	130.7	155.1	153.3	156.6	181.2	178.0	183.9	218.4	211.3	223.8	248.8	238.1	257.8
HEIDELBERG I	0476630_W	14.1	92	26	30	28	20	726	1560	1 d	53.8	53.5	54.0	74.3	73.9	74.6	89.8	89.3	90.2	106.3	105.4	107.1	130.3	128.5	131.8	150.5	147.7	153.1
										2 d	66.8	66.3	67.2	92.6	92.0	93.1	112.6	111.1	113.7	134.2	131.2	136.8	166.5	160.3	171.9	194.1	184.3	203.0
										3 d	75.6	75.3	76.0	104.2	103.8	104.7	126.2	125.3	126.8	149.9	148.2	151.5	185.1	181.5	187.8	215.0	208.9	219.9
										4 d	83.1	82.8	83.5	113.5	112.9	114.0	136.6	135.6	137.2	161.4	159.7	162.9	197.8	194.0	200.7	228.6	222.3	233.8
										5 d	90.1	89.7	90.6	122.5	121.9	123.0	146.8	145.7	147.5	172.4	170.7	174.0	209.5	205.7	212.6	240.5	234.1	245.8
										6 d	95.9	95.5	96.6	130.2	129.6	130.9	155.7	153.5	157.2	182.2	178.2	185.6	220.4	212.2	227.1	251.9	238.7	263.3
										7 d	102.2	101.7	102.6	138.3	137.7	139.0	165.0	163.1	166.5	192.8	189.3	195.6	232.3	224.8	238.1	264.6	253.2	274.2
HEIDELBERG-PS	0476660_W	14.1	61	26	29	28	21	712	1560	1 d	50.3	50.1	50.6	69.5	69.2	69.8	84.0	83.6	84.4	99.5	98.6	100.3	122.0	120.2	123.4	140.9	138.2	143.3
										2 d	61.2	60.8	61.6	84.9	84.4	85.3	103.2	101.8	104.2	123.1	120.3	125.4	152.6	147.0	157.6	178.0	168.9	186.2
										3 d	70.0	69.7	70.3	96.4	96.0	96.9	116.8	115.9	117.3	138.7	137.1	140.1	171.2	167.9	173.8	198.9	193.2	203.4
										4 d	76.4	76.1	76.8	104.3	103.8	104.8	125.6	124.6	126.1	148.4	146.8	149.7	181.8	178.3	184.5	210.2	204.3	214.9
										5 d	82.8	82.4	83.2	112.6	112.1	113.1	134.9	133.9	135.6	158.5	156.9	159.9	192.6	189.0	195.4	221.1	215.2	225.9
										6 d	88.1	87.7	88.8	119.7	119.1	120.3	143.0	141.0	144.5	167.5	163.8	170.5	202.5	195.0	208.7	231.5	219.4	242.0
										7 d	93.1	92.7	93.5	126.0	125.4	126.6	150.3	148.6	151.7	175.6	172.4	178.1	211.6	204.8	216.9	241.0	230.7	249.8
VLAKFONTEIN	0439764_W	16.2	78	26	44	28	26	684	1555	1 d	50.1	49.9	50.4	69.2	68.9	69.6	83.7	83.3	84.1	99.1	98.2	99.8	121.5	119.8	122.9	140.3	137.7	142.7
										2 d	62.6	62.2	63.1	86.9	86.3	87.3	105.6	104.2	106.6	125.9	123.0	128.3	156.1	150.3	161.2	182.0	172.8	190.4
										3 d	71.2	70.8	71.5	98.0	97.6	98.5	118.8	117.9	119.3	141.1	139.4	142.5	174.1	170.8	176.7	202.3	196.5	206.8
										4 d	78.1	77.8	78.5	106.6	106.1	107.1	128.3	127.4	128.9	151.6	150.0	153.0	185.8	182.3	188.6	214.8	208.9	219.6
										5 d	84.2	83.9	84.7	114.6	114.0	115.0	137.3	136.2	137.9	161.2	159.7	162.7	195.9	192.3	198.8	224.9	218.9	229.8
										6 d	89.7	89.3	90.4	121.9	121.3	122.5	145.7	143.6	147.1	170.5	166.8	173.7	206.2	198.5	212.5	235.7	223.4	246.4
										7 d	96.8	96.4	97.2	131.0	130.4	131.7	156.3	154.5	157.8	182.6	179.3	185.3	220.0	212.9	225.5	250.7	239.9	259.8
BALFOUR (MAG)	0440129_W	17.7	95	26	39	28	35	688	1615	1 d	53.3	53.0	53.5	73.6	73.2	73.9	89.0	88.5	89.4	105.3	104.4	106.1	129.1	127.3	130.6	149.1	146.3	151.6
										2 d	64.3	63.8	64.7	89.1	88.5	89.5	108.3	106.9	109.4	129.2	126.2	131.6	160.2	154.2	165.4	186.8	177.3	195.4
										3 d	72.3	71.9	72.6	99.6	99.2	100.0	120.6	119.7	121.2	143.2	141.5	144.7	176.8	173.4	179.4	205.4	199.5	210.0
										4 d	78.4	78.0	78.7	107.0	106.5	107.5	128.8	127.9	129.4	152.2	150.5	153.6	186.5	182.9	189.3	215.6	209.6	220.4
										5 d	84.6	84.2	85.1	115.1	114.6	115.6	137.9	136.9	138.5	162.0	160.4	163.5	196.8	193.2	199.7	225.9	219.9	230.9
										6 d	88.8	88.4	89.4	120.6	120.0	121.1	144.1	142.0	145.5	168.7	165.0	171.8	204.0	196.4	210.2	233.1	221.0	243.7
										7 d	93.4	92.9	93.8	126.4	125.8	127.0	150.7	149.0	152.2	176.1	172.9	178.7	212.2	205.4	217.5	241.7	231.3	250.5

Gridded values of all points within the specified block

Latitude (°)	Latitude (')	Longitude (°)	Longitude (')	MAP (mm)	Altitude (m)	Duration (m/h/d)	Return Period (years) 2U	5U	10U	20U	50U	100U
26	35	28	26	683	1660	5 m	10.8	14.9	18.0	21.4	26.3	30.6
						10 m	15.7	21.6	26.1	31.0	38.2	44.3
						15 m	19.5	26.9	32.5	38.6	47.5	55.1
						30 m	24.7	34.1	41.3	49.0	60.3	70.0
						45 m	28.4	39.3	47.5	56.4	69.4	80.6
						1 h	31.4	43.4	52.5	62.3	76.7	89.0
						1.5 h	36.2	49.9	60.4	71.7	88.2	102.4
						2 h	39.9	55.2	66.7	79.2	97.4	113.1
						4 h	47.3	65.3	78.9	93.7	115.3	133.9
						6 h	52.2	72.1	87.1	103.4	127.3	147.8
						8 h	56.0	77.3	93.4	110.9	136.5	158.5
						10 h	59.1	81.6	98.6	117.1	144.1	167.3
						12 h	61.8	85.3	103.1	122.4	150.7	174.9
						16 h	66.2	91.5	110.6	131.3	161.6	187.6
						20 h	69.9	96.6	116.8	138.6	170.6	198.1
						24 h	73.1	101.0	122.0	144.9	178.3	207.1
						1 d	63.3	87.5	105.7	125.6	154.5	179.4
						2 d	76.4	105.5	127.5	151.4	186.3	216.4
						3 d	85.2	117.7	142.3	169.0	207.9	241.5
						4 d	93.8	129.5	156.5	185.9	228.7	265.6
						5 d	101.0	139.4	168.6	200.1	246.3	286.0
						6 d	107.2	148.1	179.1	212.6	261.6	303.8
						7 d	112.9	155.9	188.4	223.7	275.3	319.7