



**FLOODLINE ASSESSMENT FOR THE PROPOSED ACACIA VILLAS
DEVELOPMENT LOCATED IN MIDRAND, IN THE GAUTENG PROVINCE OF
SOUTH AFRICA.**

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Project No.: AC-ENV-02/04

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Site Coordinates: Lat: -25.958655°S, Long: 28.090008°E

Location: Acacia Villas Luxury Residential Rentals, Gauteng Province

Date: 09 December 2024

Report Approved by:



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Hydrologist

Project Director:



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Engineering Geologist

This report is provided solely for the purposes set out in it and may not, in whole or in part, be used for any other purpose without Altra Watech's prior written consent.

LIST OF ACRONYMS

ALOS	Advanced Land Observing Satellite (ALOS)
DSM	Digital Simulation Model
MAP	Mean Annual Precipitation
RM	Rational Method
SAWS	South African Weather Station
SDF	Standard Design Flood
WR2012	2012 South African Water Resources Study

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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 floodline assessment for the proposed Acacia Villas development located in Midrand, in the Gauteng Province of South Africa (Figure 1.1). The study site has an existing development which is bounded by a wall adjacent to an unnamed tributary Jukskei River. This tributary poses a risk of flooding the existing development, therefore, a floodline assessment study is required to evaluate the flood risk of the tributary to the site. This aims to ensure that the development complies with the Spatial Planning Management Act 16 of 2013 (SPLUMA) governing housing development in South Africa and the City of Johannesburg Land Use Scheme bye-laws (City of Johannesburg., 2018).



Figure 1.1: Study locality and the surrounding properties.

2 SCOPE OF WORK

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

1. Baseline Hydrology:

- Catchment delineation and physiographic setting,
- Hydroclimatic characterisation through the calculation of the design rainfall and
- Deriving drainage characteristics and calculating the peak flow volumes (1:100year return period event).

2. Floodline Modelling:

- Catchment geometry data preparation using topographical data;
- Flood line modelling using 1D HEC-RAS hydraulic software (US Army Corps of Engineers, 2023).

3. 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

The study followed the following methodology to meet the objectives of the study as outlined in the scope of work.

3.1 Desktop Study and Information Sourcing

Applicable guidelines relating to floodline assessment and the proposed developmental activities were evaluated and applied in the context of this study. The study also assessed additional reports relating to the context of the study to extract essential information to guide the study.

Hydrometeorological data representing the study site were collected and analysed to formulate a baseline understanding of local hydroclimatic regimes. 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 for the study area were obtained from various sources, including the South African Water Resources Study WR2012 database (Bailey and Pitman, 2015), South African Atlas of Agrohydrology and Climatology (Schulze, 1997) and the Daily Rainfall Data Extraction Utility (Lynch, 2004). These sources provided means to estimate the long-term Mean Annual Precipitation (MAP) of the study site and the design rainfall used to determine peak flows of a catchment that drains towards the site.

A 30 m Digital Simulation Model (DSM) data derived from Advanced Land Observing Satellite (ALOS) Japanese Aerospace Exploration Agency (JAXA) (Tadono et al., 2014) and a 5 m contour data were used to delineate the overall catchment draining to the study site. Delineation results were also used to derive physical characteristics of the catchment that affect the calculation of peak flows and floods. These characteristics included the catchment area, river network and slopes. Due to the large spatial variability of the topographic survey data (5 m contour), a series of the points were geocoded into a *.kml from 3D topographic data using Google Earth Pro. These points were interpolated by Inverse Distance Weighing (IDW) to estimate representative topography.

3.3 Peak Flow Calculations

The peak flow discharge volumes for the 1:50 and 1:100-year return period events were calculated for the delineated drainage area routing runoff through an unnamed tributary adjacent to Acacia Villa. These flows were routed in a 1-dimensional hydraulic model to simulate the modelled river section's 1:50 and 1:100-year flood events. The appropriate methodology for calculating peak flow volume depends mainly on the size of the contributing catchment and the level of hydrological data available for a particular catchment. While using at least three methods is expected, this study adopted the methodology to calculate the peak discharge values associated with a small catchment – the Rational Method (RM) explained in the South African Drainage Manual (SANRAL, 2013). This method is based on the calibrated runoff coefficient (c), which uses understanding the factors affecting hydrological response.

3.3.1 Rational Method

The Rational Method is one of the best-known and widely used for determining peak discharge values of small to medium catchments (100 km² or less). The peak flow equation is based on a runoff coefficient (c), average rainfall intensity, and the effective area of the catchment. Calibration of the runoff coefficients for the drainage area was guided by understanding the effective runoff-generating processes and land cover attributes derived from the visual assessment of Google Earth images.

3.4 Floodline Modelling

Hydraulic parameters and the channel geometry of the modelled river section were derived from the combination of Google Earth satellite imagery and terrain analysis. Cross-sections and flow paths were prepared using RAS Mapper software and provided input into the HECRAS (US Army Corps of Engineers, 2023) flood model. Visual assessment of the 2024 satellite imagery retrieved through Google Earth Pro was used to interpret the riparian zones to estimate Manning's n coefficients. (Chow, 1959). Flood lines were generated for 1:5- and 1:100-year return events using the corresponding peak flow volume values and were mapped using QGIS. Design rainfall depths are one the important inputs into the Rational Method. Design rainfall depths for the study sites' catchments were obtained from the Design Rainfall Estimation Program (Smithers and Schulze, 2003). This information is presented in.

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.

4 DESKTOP ASSESSMENT

The following sub-sections present the dataset and information obtained during the desktop phase of the hydrological assessment study.

4.1 Data Used

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

- **30m ALOS DSM data** – for drainage areas delineation,
- **5m contour data** – for river geometry data used to route flood waters,
- **WR2012 dataset** – defining hydrological regimes of the study site,
- **HEC-RAS** – Hydraulic simulation of floodlines,
- **QGIS** – Editing spatial data and mapping, and
- **Google Earth Pro** – geocoding of topographic points.

4.2 Applicable Legislation and Guidelines

This study was conducted in accordance or with consideration of the following legislation and regulation:

4.2.1 *Spatial Planning and Land Use Management*

The Spatial Planning and Land Use Management Act 16 of 2013 (SPLUMA) (Gazette, 2013) provides for development principles which, amongst others, account for spatial sustainability and resilience through minimising environmental impacts that could be attributed to the development of infrastructure in areas that have risk.

4.2.2 *City of Johannesburg Land Use Scheme*

The City of Johannesburg Land Use Scheme (City of Johannesburg., 2018) regulations stipulate that “no development shall be permitted within the area which is subject to flooding by a 1:100 year flood or within the riparian zone and a buffer area of thirty (30) metres from the edge of the riparian zone or river bank where this is clearly identifiable, whichever is the greater”. The combination of these regulations was used to guide the outcomes of the study in terms of drawing conclusions.

5 HYDROLOGICAL ASSESSMENT

5.1 Physiographic Setting

Figure 5.1 shows the drainage patterns of the discharging flow into the study site. The figure shows that the headwater reaches are draining water from the hilly zones, and a stormwater drainage network collects the natural drainage from a predominantly urbanised area. There is a small patch of undeveloped areas with a dam on the river channel. The urbanised nature of the area suggests that the stormwater drainage system collects a larger proportion of storm runoff and is routed out of the catchment.



Figure 5.1: Study site drainage boundary, patterns and land cover.

The headwater reaches are at 1 573 meters above mean sea level (mamsl) while the outlet of the modelled river is at 1 485 mamsl. The topographic setting of the study site is graphically represented in Figure 5.3. The entire modelled section is dense vegetation, and the instream impoundment (small dam) was assigned to unique Manning's n value. The initial boundary conditions used in the hydraulic model setup were based on the calculated average slope for the entire segment of the modelled river section.

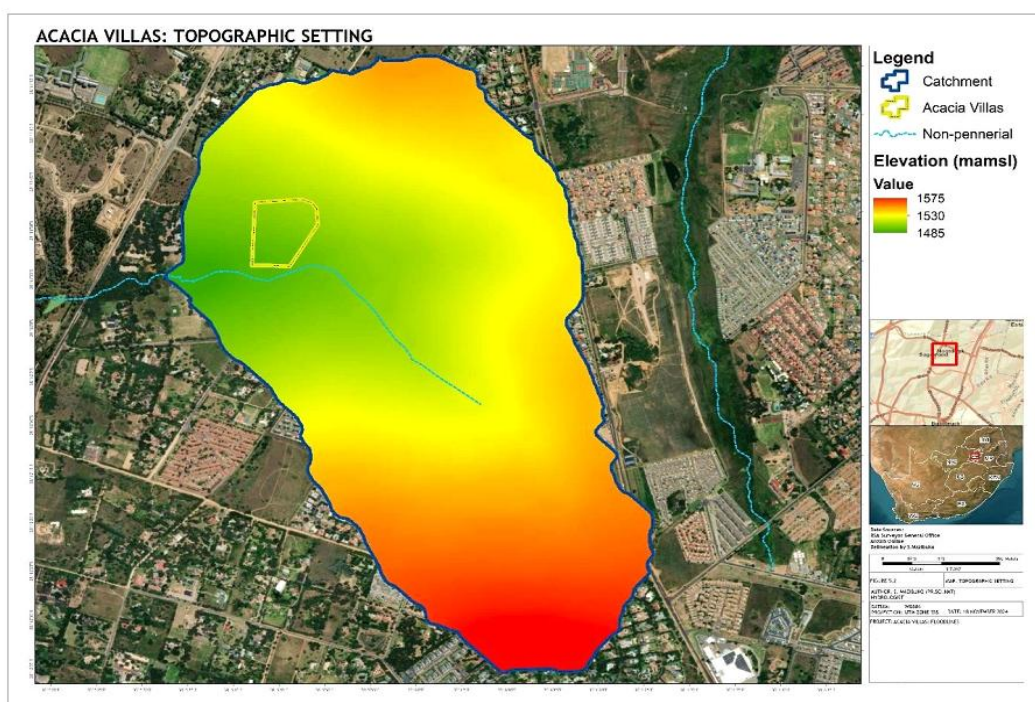


Figure 5.2: Topographic setting of the drainage area.

5.2 Baseline Hydrology and Hydrometeorology

The study area is typically characterised by temperate climatic conditions (Cwb) KoppenGeiger (Kotték, 2006) which is generally characterised by dry, cold winters and wet periodic summers. Long-term-average temperature records for a station located in Midrand indicate that the coldest month (July) experiences a minimum of 6°C while hot summers record the maximum temperature of 27°C. These variations of temperature recordings are shown in Figure 5.3.

The study site falls within quaternary catchment A21C of the upper Crocodile River, which forms part of the Limpopo WMA.. Catchment average-based rainfall records from the 90-year record South African Water Resources Study (WR2012) (Bailey & Pitman, 2015) indicate that the mine area experiences a Mean Annual Precipitation (MAP) of 670 mm while the Mean Annual Evaporation (MAE) – based on Symons Pan (S-Pan) – for the study area is 1 472 mm. The statistical distribution of monthly rainfall and evaporation is presented in Figure 5.4, indicating these variables' high seasonality. The figure shows that the average rainfall (90% of the events) for the wettest months (December and January) will likely be at most 39 mm, while extreme rainfall events (10% of the events) will likely not exceed 236 mm.

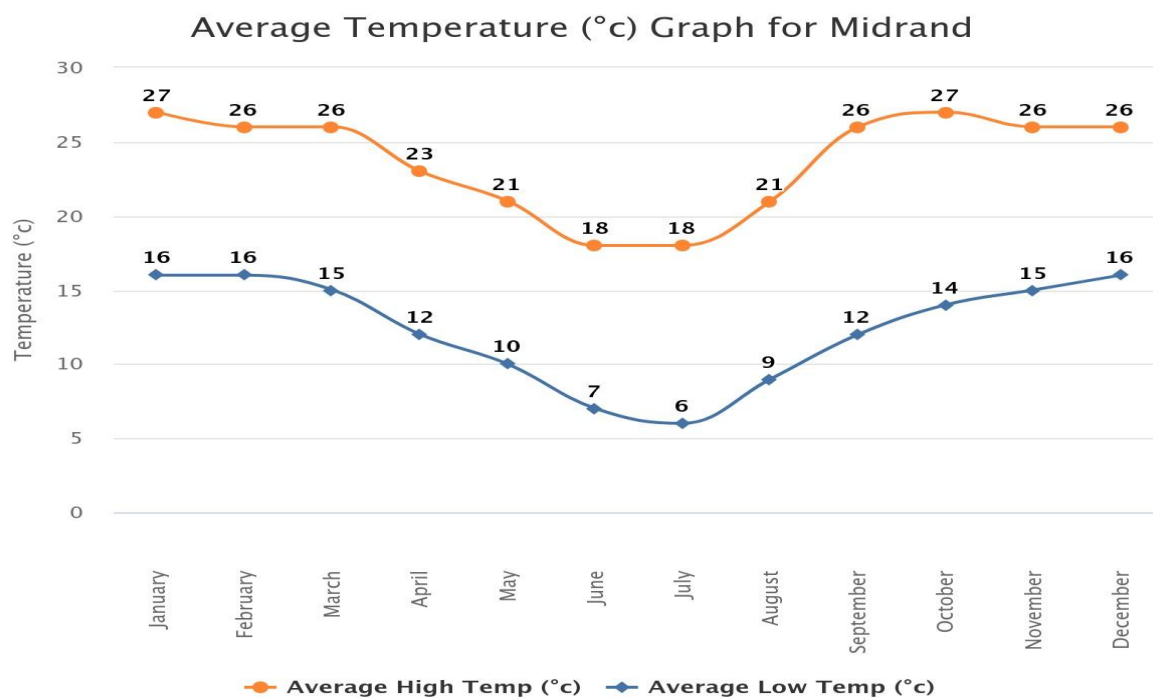


Figure 5.3: Average minimum and maximum temperatures for Midrand station.

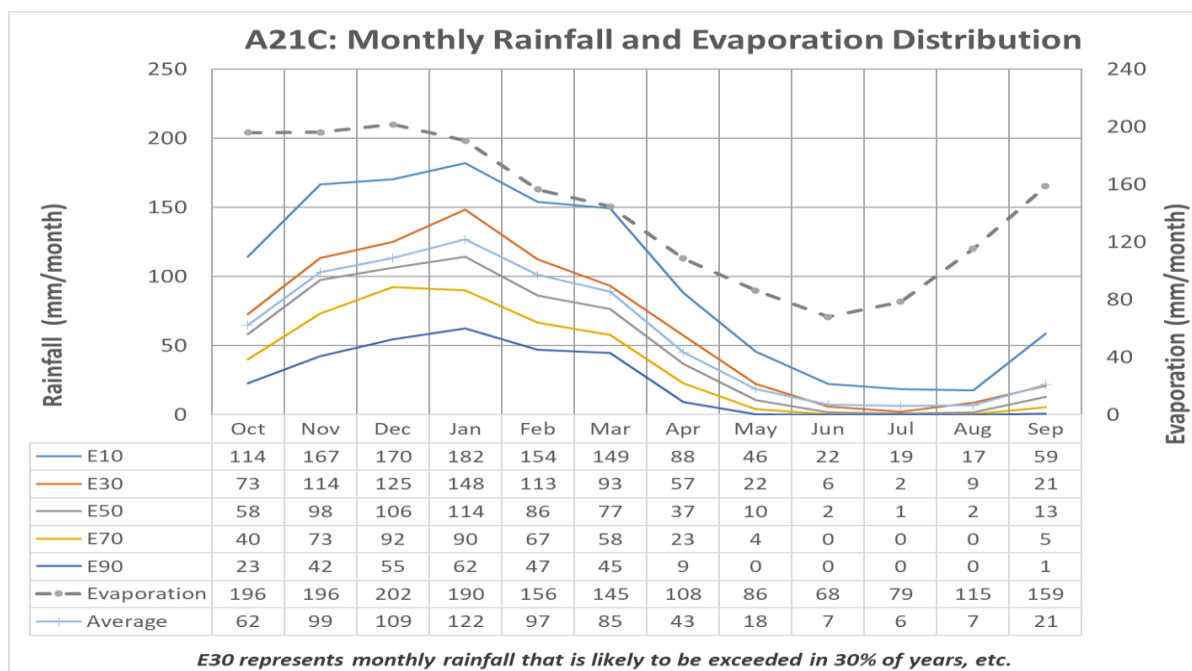


Figure 5.4: Seasonal distribution of rainfall and evaporation (modified from Bailey and Pitman, 2015).

5.3 Floodlines Determination

Floodlines simulations were undertaken using HEC-RAS version 6.4 software, where several cross-sections were created throughout the river channel profile up and downstream of the Acacia Villas study site (see Appendix 1). The right and left banks of the cross-sections were assigned to Manning's n-values corresponding to the dense vegetation together with the main river. The hydraulic characteristics of the catchment and geometric setting for the modelled section are summarised in Table 5.1. The calibrated runoff coefficient values for all variables used to compute the peak discharge is 50% (0.50), which accounts for the rural (29%), urban (68%) and lakes (3%), which accounts for the wetland and small dam feature.

Table 5.1: Hydraulic characteristics of the modelled catchment

Site	River	Area (km ²)	Hydraulic Length (L)	Distance to Centroid (L _c)	Ave. Slope (m/m)	Manning's n		
						L. Bank	Channel	R. Bank
Acacia Villa	Unnamed Tributary	2.6	1.3	1.3	0.023	0.04	0.04	0.04

5.4 Peak Flow Volumes

Peak flow volumes estimated from RM (presented in Table 5.2 with a yellow and red highlight) were considered conservative (**59 m³/s** and **76 m³/s**) and were assumed to account for representative volumes, given that it is calibrated based on the known factors that affect runoff generation as per the visual assessment of the Google Earth Imagery. A summary of the catchment attributes used in the computation of the peak flow volumes using the Rational Method for the study site is presented in Table 5.3.

Table 5.2: Summary of the peak flow calculation methods

Utility Programs for Drainage Flood calculations 							
Project name:	Acacia Villa Floodline						
Analysed by:	Mr S Mazibuko (Pr.Sci.Nat.)						
Name of river:	Unnamed Jukskei Tributary						
Description of site:	Flood line determination						
Filename:	E:\Altra Watech\2024\Selkatskop Floods\Acacia Floodlines.fld						
Date:	21 November 2024						
Printed: 25 November 2024							Page 1
Summary of peak flows (m ³ /s)							
Method	1:2	1:5	1:10	1:20	1:50	1:100	1:200
Rational 1	19.50	26.92	34.53	43.46	58.99	75.86	60
Rational 2	17.32	29.67	39.41	49.72	65.18	78.69	60
Unit hydrograph	11.63	19.42	28.45	39.82	60.29	83.57	60
Standard design flood	3.560	12.50	20.81	30.20	44.23	56.01	55
Empirical			22.41	25.83	36.08	45.58	50

Table 5.3: Variables used in the Rational Method

Utility Programs for Drainage

Flood calculations

Sinotech

Project name: Acacia Villa Floodline
Analysed by: Mr S Mazibuko (Pr.Sci.Nat.)
Name of river: Unnamed Jukskei Tributary
Description of site: Flood line determination
Filename: E:\Altra Watech\2024\Selkatskop Floods\Acacia Floodlines.fld
Date: 21 November 2024

Printed: 25 November 2024

Page 1

Flood Frequency Analysis: Rational Method 1

Project = Acacia Villa Floodline
Analysed by = Mr S Mazibuko (Pr.Sci.Nat.)
Name of river = Unnamed Jukskei Tributary
Description of site = Flood line determination
Date = 21/11/2024
Area of catchment = 2.6 km²
Dolomitic area = 0.0 %
Mean annual rainfall (MAR) = 682.00 mm
Length of longest watercourse = 1.3 km
Flow of water = Defined water course
Height difference along 10-85 slope = 22.0 m
Rainfall region = Inland
Area distribution = Rural: 29 %, Urban: 68 %, Lakes: 3 %

Catchment description - Urban area (%)

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

Catchment description - Rural area (%)

Surface slopes		Permeability	Vegetation	
Lakes and pans	4	Very permeable	Thick bush & forests	2
Flat area	86	Permeable	Light bush & cultivated land	10
Hilly	10	Semi-permeable	Grasslands	78
Steep areas	0	Impermeable	Bare	10

Average slope = 0.02256 m/m

Time of concentration = 21.0 min

Run-off factor

Rural - C1 = 0.465

Urban - C2 = 0.540

Lakes - C3 = 0.000

Combined - C = 0.502

The ERU, 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 (m ³ /s)
1:2	0.35	21.8	99.6	62.1	0.50	43.5	19.50
1:5	0.35	29.7	99.4	84.4	0.55	44.1	26.92
1:10	0.35	37.6	99.2	106.7	0.60	44.8	34.53
1:20	0.35	46.4	99.1	131.5	0.67	45.8	43.46
1:50	0.35	60.3	98.8	170.5	0.83	47.9	58.99
1:100	0.35	74.2	98.5	209.2	1.00	50.2	75.86

Run-off coefficient percentage includes adjustment saturation factors (Ft) for flat and permeable catchments

Calculated using Utility Programs for Drainage 2.0.0

6 FLOODLINES

The geometry of the modelled river section is presented in Figure 6.1 and shows the profiles of the cross-sections in the upstream and the downstream reach. The derived topographic setting of the study shows that the area is relatively flat and its setting is not consistent with the freely available 30 m (ALOS) DSM. Also, the 5 m (contour) topographic data were also not deemed adequate to be representative of the area for setting up of the hydraulic model in HECRAS. To overcome this challenge, a Digital Simulation Model (DSM) was developed to route the flood in HEC-RAS using the terrain data derived from interpolating topographic points from Google Earth Pro. This proved to better reflect the topographic setting of the area.

The resulting floodlines for the 1:50 and 1:100-yr recurrent peak flow events are presented in Figure 6.2. Results were derived using the calculations of the Rational Method and show that the maximum extent of both floodwaters volumes of 59 m³/s (1:50-yr) and 76 m³/s (1:100-yr) encroach the property by roughly 35m from the southern boundary. Water level and longitudinal profile of the maximal flood water along the modelled river section are given in Appendix 9.3.

Flood modelling results, generally, indication that the infrastructure might be at risk from flooding based on the estimated peak flow volumes. This could also be worsened by the anticipated changes in the rainfall intensities induced by climate change which were not accounted in the study.

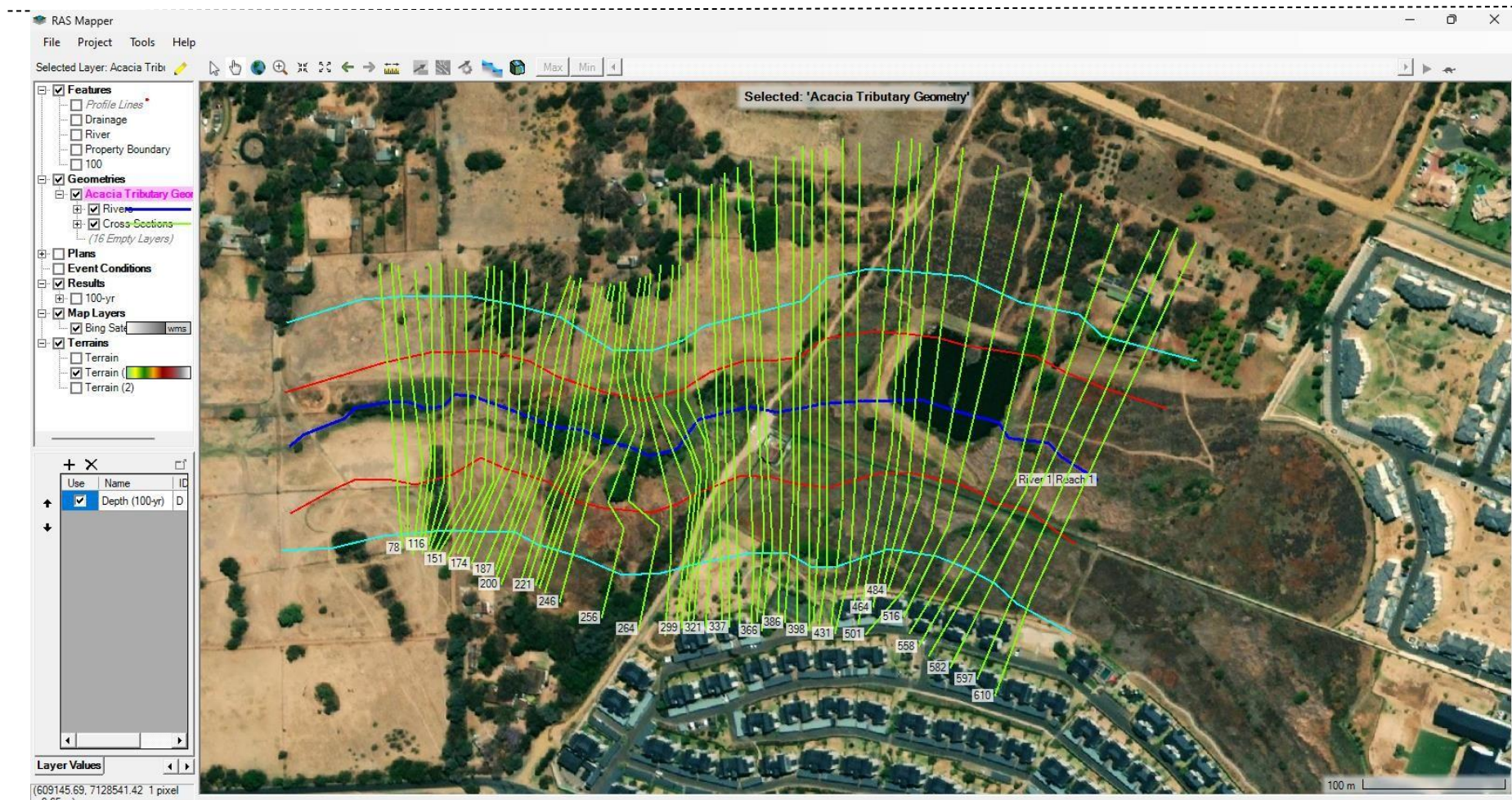


Figure 6.1: Modelled river section geometry used in the simulation of the floodlines.



Figure 6.2: Modelled river section geometry used in the simulation of the floodlines.

7 CONCLUSIONS

7.1 Conclusions and Recommendations

The following findings and recommendations were derived from the study:

- The study site is characterized by urban area dominated by housing and undeveloped area on a relatively gentle slope which routes its natural runoff to the a swampy flat riparian area which was modelled in this study.
- Google Earth-derived topographic data were interpolated to create river geometry for which the flood was routed in HEC-RAS due to disparities in the 30m ALOS DSM and 5m contour data. This is attributed to the spatial scale of the DSM data and the fact that these data do not capture the changes to the ground infrastructure developments, thus introducing uncertainties in the flood routing simulations.
- The maximum (peak) flow volumes for the 1:50 and 1:100-yr return events were calculated using the Rational Method and were estimated to have a peak volumes of 59 m³/s and 76 m³/s.
- Floodline simulation results show that the calculated peak flow volumes for both floodlines encroach the southern part of the property in question and this could pose a flood threat to the infrastructure.
- It is recommended that a high-resolution survey data be conducted as a means of using a more representative topographic data for routing flood waters in a hydraulic model with improved confidence. An alternative recommendation is to construct a flood protection structure or explore an alternative of canalising the stream in the areas upstream of the property.

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9 APPENDICES

9.1 Peak Flows - Rational Method 2

Utility Programs for Drainage Flood calculations



Sinotech

Project name: Acacia Villa Floodline
 Analysed by: Mr S Mazibuko (Pr.Sci.Nat.)
 Name of river: Unnamed Jukskei Tributary
 Description of site: Flood line determination
 Filename: E:\Altra Watech\2024\Selkatskop Floods\Acacia Floodlines.fld
 Date: 21 November 2024

Printed: 25 November 2024

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Flood Frequency Analysis: Rational Method 2

Project = Acacia Villa Floodline
 Analysed by = Mr S Mazibuko (Pr.Sci.Nat.)
 Name of river = Unnamed Jukskei Tributary
 Description of site = Flood line determination
 Date = 21/11/2024
 Area of catchment = 2.6 km²
 Dolomitic area = 0.0 %
 Length of longest watercourse = 1.3 km
 Flow of water = Defined water course
 Height difference along 10-85 slope = 22.0 m
 Area distribution = Rural: 29 %, Urban: 68 %, Lakes: 3 %

Catchment description - Urban area (%)

Lawns		Residential and industry	Business	
Sandy, flat (<2%)	0	Houses	80	City centre
Sandy, steep (>7%)	0	Flats	20	Suburban
Heavy soil, flat (<2%)	0	Light industry	0	Streets
Heavy soil, steep (>7%)	0	Heavy industry	0	Maximum flood

Catchment description - Rural area (%)

Surface slopes		Permeability		Vegetation	
Lakes and pans	4	Very permeable	8	Thick bush & forests	2
Flat area	86	Permeable	15	Light bush & cultivated land	10
Hilly	10	Semi-permeable	40	Grasslands	78
Steep areas	0	Impermeable	37	Bare	10

Days on which thunder was heard = 60 days/year

Weather Services station number = 476067

Weather Services station location = JOHANNESBURG (RIEPEN)

Mean annual precipitation (MAP) = 685 mm

Duration 2 5 10 20 50 100 200

1 day 54 72 86 100 121 139 158

2 days 67 90 108 126 153 175 198

3 days 76 101 121 141 169 193 218

7 days 100 132 155 179 212 238 266

The modified recalibrated Hershfield relationship was used to determine point rainfall.

Average slope = 0.02256 m/m

Time of concentration = 21.0 min

Run-off factor

Rural - C1 = 0.465

Urban - C2 = 0.540

Lakes - C3 = 0.000

Combined - C = 0.502

Return period (years)	Time of concentration (hours)	Point rainfall (mm)	ARF (%)	Average intensity (mm/h)	Factor Ft	Runoff coefficient (%)	Peak flow (m ³ /s)
1:2	0.35	19.28	100.0	55.18	0.50	43.5	17.32
1:5	0.35	32.53	100.0	93.09	0.55	44.1	29.67
1:10	0.35	42.55	100.0	121.77	0.60	44.8	39.41
1:20	0.35	52.57	100.0	150.45	0.67	45.8	49.72
1:50	0.35	65.82	100.0	188.36	0.83	47.9	65.18
1:100	0.35	75.84	100.0	217.03	1.00	50.2	78.69

Run-off coefficient percentage includes adjustment saturation factors (Ft) for flat and permeable catchments

Calculated using Utility Programs for Drainage 2.0.0

9.2 Peak Flows - Standard Design Flood Method

Utility Programs for Drainage Flood calculations



Sinotech

Project name: Acacia Villa Floodline
Analysed by: Mr S Mazibuko (Pr.Sci.Nat.)
Name of river: Unnamed Jukskei Tributary
Description of site: Flood line determination
Filename: E:\Altra Watech\2024\Selkatskop Floods\Acacia Floodlines.fld
Date: 21 November 2024

Printed: 25 November 2024

Page 1

Flood frequency analysis : Standard Design Flood method

Project name = Acacia Villa Floodline
Analysed by = Mr S Mazibuko (Pr.Sci.Nat.)
Name of river = Unnamed Jukskei Tributary
Description of site = Flood line determination
Date = 21/11/2024
Catchment characteristics:
Area of catchment = 2.6 km²
Length of longest watercourse = 1.3 km
1085 height difference = 22 m
Average slope = 0.0226 m/m
Drainage basin characteristics:
Drainage basin number = 1
Mean annual daily max rain = 56 mm
Days on which thunder was heard = 30 days
Runoff coefficient C2 = 10 %
Runoff coefficient C100 = 40 %
Basin mean annual precipitation = 550 mm
Basin mean annual evaporation = 1800 mm
Basin evaporation index MAE/MAP = 3.27

RAINFALL DATA

The rainfall data in the table below are derived from two sources. The daily rainfall is from the Department of Water Affairs'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 = 546204 @ STRUAN

Point mean annual precipitation = 550 mm

Dur:	RP =2	5	10	20	50	100	200
.25 h	15	25	33	41	51	59	67
.50 h	20	33	43	53	67	77	87
1 h	24	41	53	66	82	95	107
2 h	29	48	63	78	98	113	127
4 h	33	56	73	90	113	130	148
1 day	56	80	99	119	150	177	206
2 days	71	105	132	161	205	243	286
3 days	80	117	146	177	224	263	308
7 days	102	154	196	242	310	369	435

CAUTION. The time of concentration is less than one hour.

Runoff coefficients C2 = 10 % C100 = 40 %

Return period (years)	Time of concentration (hours)	Point precipitation (mm)	ARF (%)	Catchment precipitation (mm)	Runoff coefficient (%)	Peak flow (m ³ /s)
1:2	0.35	17.2	100.0	17.2	10.0	3.560
1:5	0.35	29.0	100.0	29.0	20.8	12.50
1:10	0.35	38.0	100.0	38.0	26.5	20.81
1:20	0.35	46.9	100.0	46.9	31.1	30.20
1:50	0.35	58.8	100.0	58.8	36.4	44.23
1:100	0.35	67.7	100.0	67.7	40.0	56.01

Calculated using Utility Programs for Drainage 2.0.0

9.3 Surface Water Profiles

