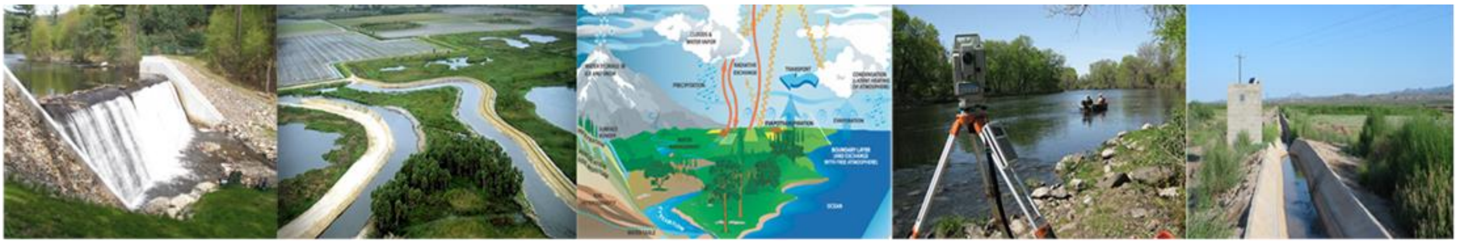
Hydrological Assessment for the Tweefontein Gauging Weir

Report

Version – Final

16 March 2023

Client Reference: Tweefontein Weir – Hydrological Assessment



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DOCUMENT VERIFICATION

TITLE: Tweefontein Gauging Weir - Hydrological Assessment	
Report Number	**23- 0102**
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SPECIALIST DECLARATION:

Altra Watech (Pty) Ltd has objectively undertaken this assessment, even if this results in views and findings that are not favourable to the client. Altra Watech has the expertise required to undertake specialist hydrological assessment studies, including flood risks, and this report presents the results objectively. The report's author is a hydrologist with an MSc degree in Hydrology with 8 years of experience in various hydrology, water resources assessment, planning, and management studies. He is registered with the South African Council of Natural Scientific Professions under Hydrological Sciences Category.

Verification	**Name**	**Signature**	**Date**
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Authorised	Sbongiseni Mazibuko (Hydrologist) ***Pr. Sci. Nat***		16 March 2023

LIST OF ACRONYMS

ALOS	Advanced Land Observing Satellite (ALOS)
EA	Environmental Authorisation
EIA	Environmental Impact Assessment
DFFE	Department of Forestry, Fisheries and the Environment
DSM	Digital Simulation Model
DWS	Department of Water and Sanitation
GIS	Geographic Information System
IWULA	Integrated Water Use License Application
NEMA	National Environmental Management Act (Act No. 107 of 1998)
NWA	National Water Act (Act No. 36 of 1998)
MAE	Mean Annual Evaporation
MAP	Mean Annual Precipitation
RM	Rational Method
SDF	Standard Design Flood
WMA	Water Management Area
WR2012	2012 South African Water Resources Study
WULA	Water Use License Application
WUL	Water Use License

EXECUTIVE SUMMARY

NSVT Consultants cc appointed Altra Watech (Pty) Ltd to undertake a hydrological assessment for the construction of the Tweefontein gauging weir (C6H006) located on the Vals River in Bothaville Farm, upstream of Bothaville, in the Free State Province of South Africa. The new weir structure aims to improve the water flow quantity monitoring of the Vals River (generated from quaternary C61A to C61J) and manage the inflows into the Bloemhof Dam.

The weir construction will modify the riverbanks and flow patterns and other surface water-related receptors sensitive to the changes in the landscape. Therefore, a hydrological assessment study was conducted to evaluate the potential risk of flooding and other surface water receptor associated with constructing the Tweefontein gauging weir. Results from this study are in support of the Water Use License Application (WULA) of the National Water Act (NWA 36 of 1998) and the Environmental Impact Assessment (EIA) Regulations of 2014 process of the National Environmental Management Act (NEMA 107 of 1998).

Located in the Middle Vaal reaches of the larger Vaal River Water Management Area (WMA), the 7 234 km^2 catchment receives stream flow generated from quaternary catchments C60A to C60J from steep Drakensberg mountains and flows to the relatively undulating and flat topography towards the weir site. Characterised by wet summers and dry winters, records from the 2012 South African Water Resources Study (WR2012) indicated that the Mean Annual Precipitation (MAP) and Mean Annual Evaporation (MAE) for the study area ranges between 513 mm to 625 mm and 1 450 mm to 1 652 mm, respectively (Bailey & Pitman, 2015).

The maximum (peak) flow volumes for the 1:100-yr return event for the delineated area draining the Vals River to the weir site were calculated using the Unit Hydrograph Method and were estimated at **1 185 m^3/s –** which was within a similar magnitude as the stage-discharge flow volumes shown in the preliminary study (DWS, 2021). These flows were routed in a 1-dimensional steady flow hydraulic model in HEC-RAS (US Army Corps of Engineers, 2016) to simulate the floodlines for the area. Floodline simulation results show that the Tweefontein weir will contain the calculated peak flow volumes for the 1:100-yr recurrence as per the width of the design dimension of the weir.

Surface water impact assessment for the receptor of water-related features was identified and quantified and the mitigation measures were drawn for the impact. Results show soil erosion due to the demolition of the existing weir, improper waste handling, removal of vegetation cover, ineffective stormwater plan, topsoil, a stockpile of building material, and potential oil spills on site can affect surface water quality in downstream areas. Also, the Vals River poses a threat of flooding the infrastructure.

It is recommended that the clearing of vegetation cover, removal of topsoil and construction footprint be kept minimal, and the development, implementation, and maintenance of the construction site stormwater management measures to reduce soil erosion. Heavy machinery movement should also be kept small to minimise soil compaction, which increases runoff generated on-site. All waste generated on-site, oil spill traps be contained and discharged off-site to reduce their impact on contributing to the deteriorating water quality in the downstream areas during the entire construction period. A cofferdam should be able to contain the peak flow volumes during the rainy days, while it is recommended that the existing weir be demolished during the dry season to reduce siltation and flooding potential.

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1 INTRODUCTION

1.1 Background

NSVT Consultants cc appointed Altra Watech (Pty) Ltd to undertake a hydrological assessment for constructing Tweefontein gauging weir located on the Bothaville Farm, upstream of Bothaville, in the Free State Province of South Africa. The Chief Directorate: Water Information Management of the Department of Water and Sanitation (DWS) recommended constructing the weir structure (C6H006) to improve the water flow quantity monitoring of the Vals River in conjunction with the inflow management of the Bloemhof Dam. Flows recorded in the weir are generated from quaternary C61A to C61J of the Vaal Water Management Area (WMA).

The construction of the weir will involve the modification of the riverbanks and flow patterns as well as other receptors that are sensitive to the changes in the landscape. A hydrological assessment study is required to evaluate the flood risk and potential surface water-related impacts associated with the construction phase. Results from this specialist study aim to support the Water Use License Application (WULA) of the National Water Act (NWA 36 of 1998) and the Environmental Impact Assessment (EIA) Regulations of 2014 process of the National Environmental Management Act (NEMA 107 of 1998).

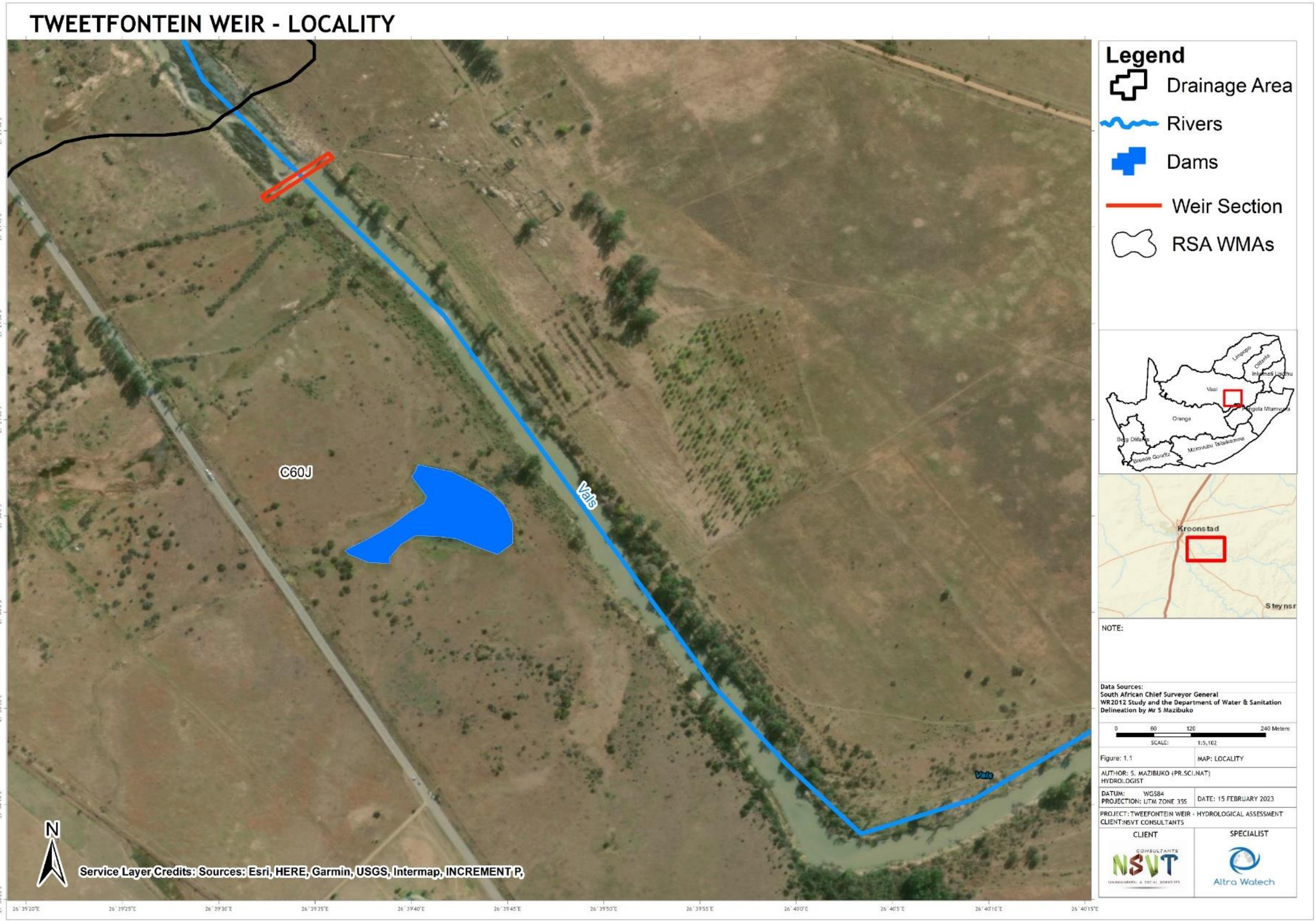


Figure 1.1: Study locality

2 SCOPE OF WORK

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

1. Desktop study and Information Sourcing:
    - Relevant data and information collection.
    - Establishing the construction and operational philosophy of the new gauging structure; and
    - Review existing literature and the applicable regulations and guidelines concerning environmental regulations and water use licensing for constructing the new gauging structure.
2. Baseline Hydrology.
    - Catchment delineation and physiographic setting,
    - A general preview of previous meteorological (climate, temperature, rainfall and evaporation) and hydrological analysis (Mean Annual Precipitation (MAP) and Mean Annual Evaporation (MAE) will be verified and updated where required, and
    - Deriving drainage characteristics and calculating the peak flow volumes (1:100-year return period event).
3. Floodline Modelling.
    - Catchment geometry data preparation using topographical data;
    - Flood line modelling using 1D HEC-RAS hydraulic software (US Army Corps of Engineers, 2016).
4. Surface Water Impact Assessment:
    - Identify, evaluate and quantify water impact elements related to the weir construction, and
    - Derive mitigation measures.
5. 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 national and regional legislation, regulation and guidelines relating to environmental impact assessment and water use licensing for the activities related to the construction of the new weir 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 and the 2020 land use/land cover database from the Department of Forestry, Fisheries and the Environment (DFFE) were 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 as a result of the construction.

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), Mean Annual Evaporation (MAE), and Mean Annual Runoff (MAR) of the study site as well as 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) were used to delineate the overall catchment draining to the construction site and to derive catchment physical characteristics that affect the calculation of the peak flows and flood routing. These characteristics included catchment area, river network, slopes, and hydraulic parameters of the modelled river sections.

3.3 Peak Flow Calculations

The peak flow discharge volume for the 1:100-year return period event was calculated for the delineated drainage area. The design rainfall depths are essential for calculating the peak flow volume methods widely used in South Africa. The computed peak flow volumes were then routed in a hydraulic model to simulate the 1:100-year flood event for the modelled river. The appropriate methodology for calculating peak flow volume depends mainly on the size of the contributing catchment and the level of hydrological data available (e.g., gauged peak flow values and design rainfall data) for a particular catchment. While using at least three methods is common, this study adopted the methodology to calculate the peak discharge values associated with the large catchments. The South African Drainage Manual (SANRAL, 2013) explains the Standard Design Flood (SDF) and the Unit Hydrograph Methods in detail.

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 km^2 or less). The peak flow equation is based on a runoff coefficient, 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.

3.3.2 Standard Design Flood Method

The SDF method was developed by Alexander (2002) to provide a uniform approach to flood calculations. This 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 the calculation of the 1:100-year peak discharge value are the catchment area, length of the longest river course, catchment height difference, annual maximum rainfall, and the average days on which the thunder was heard. This method was chosen because of the size of the catchment.

3.3.3 Unit Hydrograph Method

The Unit Hydrograph Method is primarily based on the regional analysis of the area's historical observed stream flow data. This method generally provides reliable results for medium-sized rural catchments with a size ranging from 15 to 5 000 km^2. However, some natural variability in the hydrological occurrences is lost through the broad regional divisions and the averaged form of the hydrograph.

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 of the 30 m ALOS DSM. River cross-sections and flow paths were prepared using RAS Mapper software and provided input into the HEC-RAS (US Army Corps of Engineers, 2016) flood model. Interpretation of the riverbank's visual assessment and the preliminary report findings (DWS, 2021) was used to estimate Manning's n coefficients (Chow, 1959) for riverbanks and river lines for the modelled river section of the study site. Flood lines were generated for 1:200-year return events using the corresponding peak flow volume values and were mapped.

3.5 Surface Water Impact Assessment

Potential sensitive receptors related to the surface hydrology surrounding the gauging weir location were identified and described for the sensitivity assessment. This assessment was undertaken using the impact assessment methodology guidelines provided regarding the NEMA EIA regulations, 2014. In doing so, the calculated significance of each identified potential impact is utilised to guide the relevant competent authorities and other stakeholders in the decision process associated with either authorising the activity to go ahead or not. This decision is based on the impacts, the potential to mitigate their adverse effects on the receiving environment or the irreversibility of the potential impacts. Environmental Impact Assessments (EIA) are conducted to analyse and predict the nature, extent, duration, magnitude and likelihood of the significant environmental effects due to the specific activity in question.

An impact assessment on the local and regional hydrology resulting from the activity in question was undertaken using the impact assessment methodology guideline derived from the EIA Regulations of the NEMA (Act No. 107 of 1998). The assessment of the identified potential impacts on the activities of the gauging station was addressed in a standard manner so that a wide range of impacts is comparable. The impacts, in this case, are generally classified as follows:

- ***Direct impacts*** are impacts caused directly by the activity and generally occur at the same time and the place of the activity. These impacts are usually associated with the operation or maintenance of activity and are generally obvious and quantifiable.
- ***Indirect impacts*** of an activity are indirect or induced changes that may occur as a result of the activity. These types of impacts include all the potential impacts that do not manifest immediately when the activity is undertaken or that occur at a different place as a result of the activity.

- ***Cumulative impacts***, in relation to an activity, means the past, current and reasonably foreseeable future impact of an activity, considered together with the impact of activities associated with that activity, that in itself may not be significant but may become significant when added to the existing and reasonably foreseeable impacts eventuating from similar or diverse activities.

A risk-based approach was employed in undertaking the impact assessment and the ranking. This approach makes use of a typical risk matrix in the 5 x 5 configuration (Figure 3.1), which considers likelihood and consequence in the analysis of the potential impact risk.

Reporting Matrix		1	2	3	4	5
		Insignificant	Minor	Moderate	Major	Catastrophic
5	Almost certain					
4	Likely					
3	Moderate					
2	Unlikely					
1	Rare					

Figure 3.1: Risk-based reporting matrix

3.5.1 Risk-Based Approach - Mitigation Measures

The *likelihood* of an impact occurring was determined by assessing the frequency of the identified activity, the frequency of the impact, the extent to which the activity is regulated and the ability to detect the occurrence of the impact, according to the criteria in Table 3.1. The *consequence* was determined by assessing the spatial scale, duration, and severity (see Table 3.2, and the *significance* was then determined and assigned either a low, medium or high.

Table 3.1: Likelihood components of the impact assessment

1. FREQUENCY OF THE ACTIVITY	
DESCRIPTION	**RATING**
Annually or less	1
6-monthly	2
Monthly	3
Weekly	4
Daily	5
2. FREQUENCY OF THE IMPACT	
DESCRIPTION	**RATING**
Almost never / almost impossible / >20%	1
Very seldom / highly unlikely / >40%	2
Infrequent / unlikely / seldom / >60%	3
Often / regularly / likely / possible / >80%	4
Daily / highly likely / definitely / >100%	5
3. REGULATION	
No guidelines, standards, or legislation	3
Covered by guidelines, standards, or legislation	1
4. DETECTION	
DESCRIPTION	**RATING**
Immediately	1
Without much effort	2
Needs some effort	3
With major effort	4
Remote or difficult to detect	5

Table 3.2: Consequences components of the impact assessment

1. SPATIAL SCALE	
DESCRIPTION	**RATING**
Area-specific (at impact site)	1
Entire site (entire project area)	2
Local (5 km of site)	3
Regional / neighbouring areas (5 – 50 km of site)	4
National	5
2. DURATION	
DESCRIPTION	**RATING**
One day to one month (immediate)	1
One month to one year (Short term)	2
One year to 10 years (medium term)	3
Life of the activity (long term)	4
Beyond life of the activity (permanent)	5
3. SEVERITY	

DESCRIPTION	RATING
Insignificant / non-harmful	1
Small / potentially harmful	2
Significant / slightly harmful	3
Great / harmful	4
Disastrous / extremely harmful / within a regulated sensitive area	5

The components of the identified impacts are evaluated using the computation presented in Table 3.3.

Table 3.3: Matrix calculation

DESCRIPTION	CALCULATION
Consequence	= Severity + Spatial Scale + Duration
Likelihood	= Frequency of Activity + Frequency of Incident + Legal Issues + Detection
Significance\Risk	= Consequence X Likelihood
Priority factor	= (Public response + Cumulative impact + loss of resource) / 3
Prioritised risk	= Significance x Priority factor

3.5.2 Impact Mitigation Actions

After the *likelihood*, *consequence* and *significance* determinations, impact mitigation actions are proposed. Per the NEMA EIA Regulations, 2014, mitigation means "*to anticipate and prevent negative impacts and risks, then to minimise them, rehabilitate or repair impacts to the extent feasible*." Under this condition, impact mitigation actions, which strive to align with the impact management outcomes identified, impact specifically for constructing the weir.

3.5.3 Risk-Based Approach – After Impact Mitigation Action Determination

After mitigation measures were established, the likelihood and consequence were re-assessed in terms of the criteria presented in Table 3.1 and Table 3.2, with the consideration of the proposed impact mitigation actions. Through this process, the analysis of the potential impact risk following the impact mitigation action plan's implementation was determined. The significance was re-assessed to determine whether the mitigation measures and action plans proposed serve to lessen the importance of the identified impact.

3.5.4 Risk-Based Approach Visual Representation

The identified impacts before mitigation were plotted in the corresponding single square on the Risk-Based Reporting Matrix to identify ways to move the impacts from the zones of almost certain and catastrophic risk to insignificant and rare risk zones in the Risk-Based Reporting Matrix illustrated in Figure 3.1. In this way, the risks associated with each impact, with or without impact mitigation action implementation, can be visually presented and will easily show how, through the implementation of appropriate impact mitigation actions, the likelihood and consequence of identified impacts can be improved.

3.6 Assumptions and Limitations

The following constraints may have affected this hydrological assessment:

- A desktop approach was implemented to estimate Manning’s n values for the identified cross-sections used in the geometry for flood routing modelling.
- Results from the preliminary study (DWS, 2021) were assumed to be more representative as they were derived from surveyed information with higher spatial resolution compared to the ALOS DSM data used in this study.
- The initial boundary conditions used in the hydraulic model setup were obtained from the simulation of the expected water level of the weir.
- The assessment of impacts and recommendation of mitigation measures drawn were informed by site-specific issues based on the specialist’s working knowledge and experience with similar activity projects and were conducted explicitly for the project's construction phase.

4 DESKTOP ASSESSMENT

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

4.1 Applicable Legislation

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

4.1.1 National Water Act

The National Water Act, 1998 (Act No. 36 of 1998) (NWA) was developed to ensure the protection of water resources in South Africa. The NWA recognises that water resource management aims to achieve the sustainable use of water for the benefit of all users. Following the provisions of the National Water Act (No. 36 of 1998) (NWA), all “water uses “must be licensed with the Competent Authority (i.e., the Regional Department of Water and Sanitation (DWS) or the relevant Catchment Management Agency (CMA) where applicable). DWS is responsible for effective and efficient water resources management to ensure sustainable economic and social development in line with the NWA. DWS is also responsible for evaluating and issuing licenses pertaining to water use (i.e., Water Use Licenses (WULs) and/or registration of General Authorisations (GAs) where this is applicable.

A “water use” is defined in Section 21 of the NWA and among the underlined which are relevant to the study includes the following:

a) Taking water from a water resource,
b) Storing water,
c) <u>Impending or diverting the flow of water in a watercourse,</u>
d) Engaging in streamflow reduction activity contemplated in Section 36 of the NWA,
e) Engaging in a controlled activity identified as such in Section 37 (1) or declared under Section 38 (1) of the NWA,
f) Discharging waste or water containing waste into a water resource through a pipe, canal, sewer, sea outfall or other conduits,
g) Disposing of waste in a manner which may detrimentally impact a water resource,
h) Disposing of waste in a manner of water which contains waste from, or which has been heated in any industrial or power generation process,
i) <u>Altering the bed, banks, course, or characteristics of a watercourse,</u>
j) Removing, discharging, or disposing of water found underground if it is necessary for the efficient continuation of an activity or the safety of people, and
k) Using water for recreational purposes.

4.1.2 National Environmental Management Act

Section 24 of South Africa's National Environmental Management Act (Act No. 107 of 1998) (NEMA) pertains to Environmental Authorisations (EAs) and requires that the potential consequences for, or impacts of, listed, or specified activities on the environment be considered, investigate, assessed, and reported on to the competent authority. The 2014 Environmental Impact Assessment (EIA) Regulations, as amended (GNR 326) published under NEMA, prescribe the process to be followed in this study.

4.2 Desktop Tools

The summary and description of the datasets utilised in the desktop assessment are presented in Table 4.1. These data had different spatial and temporal resolutions, which suggested that the analysis derived from them should be considered.

Table 4.1: Summary of the dataset and information during the desktop study of this assessment

DATASET/TOOL	SOURCE	RELEVANCE
Hydrological Data	2012 South African Water Resources Study (WR2012)	Determine the regional hydrological characteristics of the site (e.g., Mean Annual Precipitation (MAP), Mean Annual Evaporation (MAE), Mean Annual Runoff (MAR), and the general flow direction into, through, and out of the study area.
Google Earth Pro™ Imagery	2021 Google Imagery	Survey the current and historical imagery of the study area to determine the changes in the land-use practices and thus identify potential impacts.
South African national land cover (GIS coverage)	GeoTerraImage (2015)	To conduct a comparison of what is presented in the dataset against what is currently observed on-site and thus identify potential disturbances/impacts.
Topographic Data	ALOS	30 m digital simulation data to derive slope and topographic features for the area
Preliminary Assessment Report	DWS (2021)	To evaluate the state of water quality in the study site, identify the potential impacts because of the construction of the gauging station activities.

5 HYDROLOGICAL ASSESSMENT

5.1 Physiographic Setting

Figure 5.1 shows the Vals River drainage area's topographic setting and drainage patterns considered in this study. The figure shows that the headwater reaches are draining water from the hills of the Drakensberg Mountains along the altitude above 1 800 meters above mean sea level (mamsl). The collected waters flow towards the foothills above 1 250 mamsl. The headwater reaches of the Vals River basin experience a subtropical steppe climatic zone classified as BSh (warm temperate, winter, and hot summer), according to Koppen-Geiger (Kottek et al., 2006).

Figure 5.2 presents the generalised land cover in the general Vals River drainage area considered in the study. The figure shows that grasslands, small farm dams, light bushes, and cultivated land dominate the larger drainage areas, which generally classifies the area as predominantly rural. This land use suggests the site has predominantly well-developed soils with good water-holding capacity.

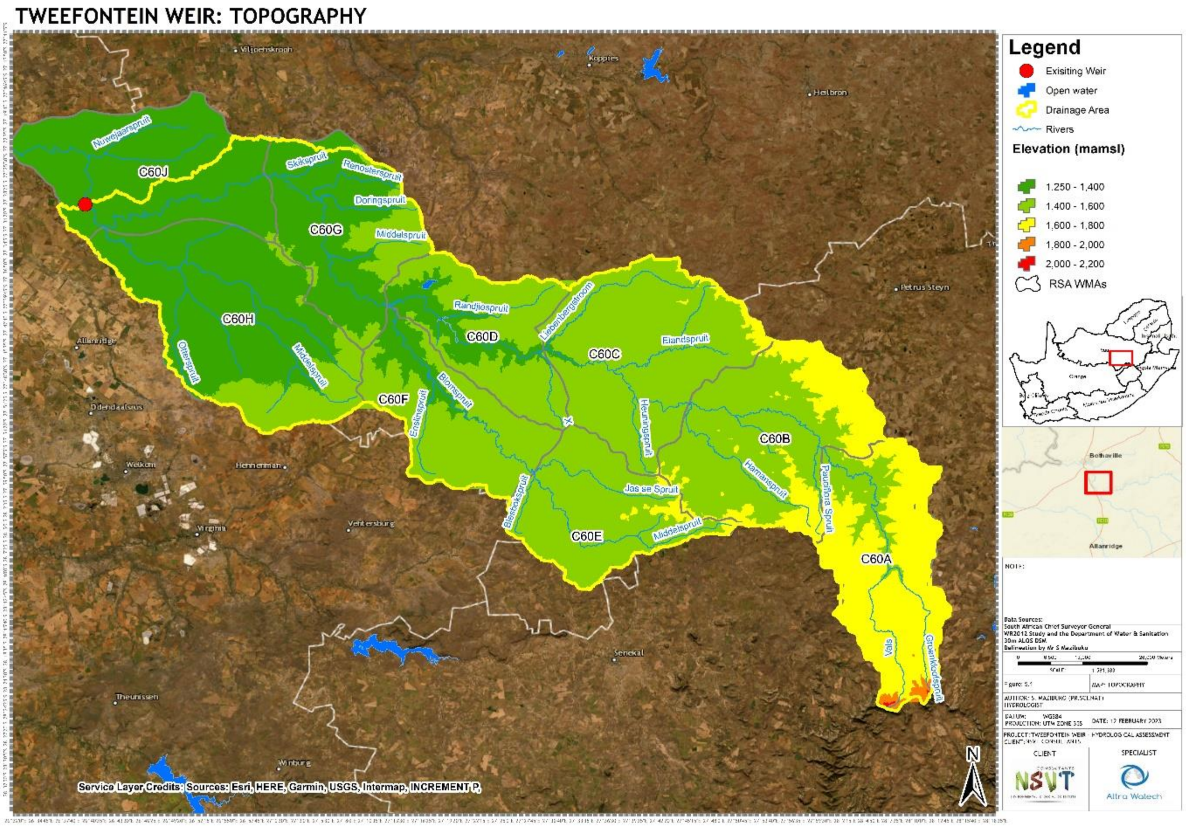


Figure 5.1: Topographic setting

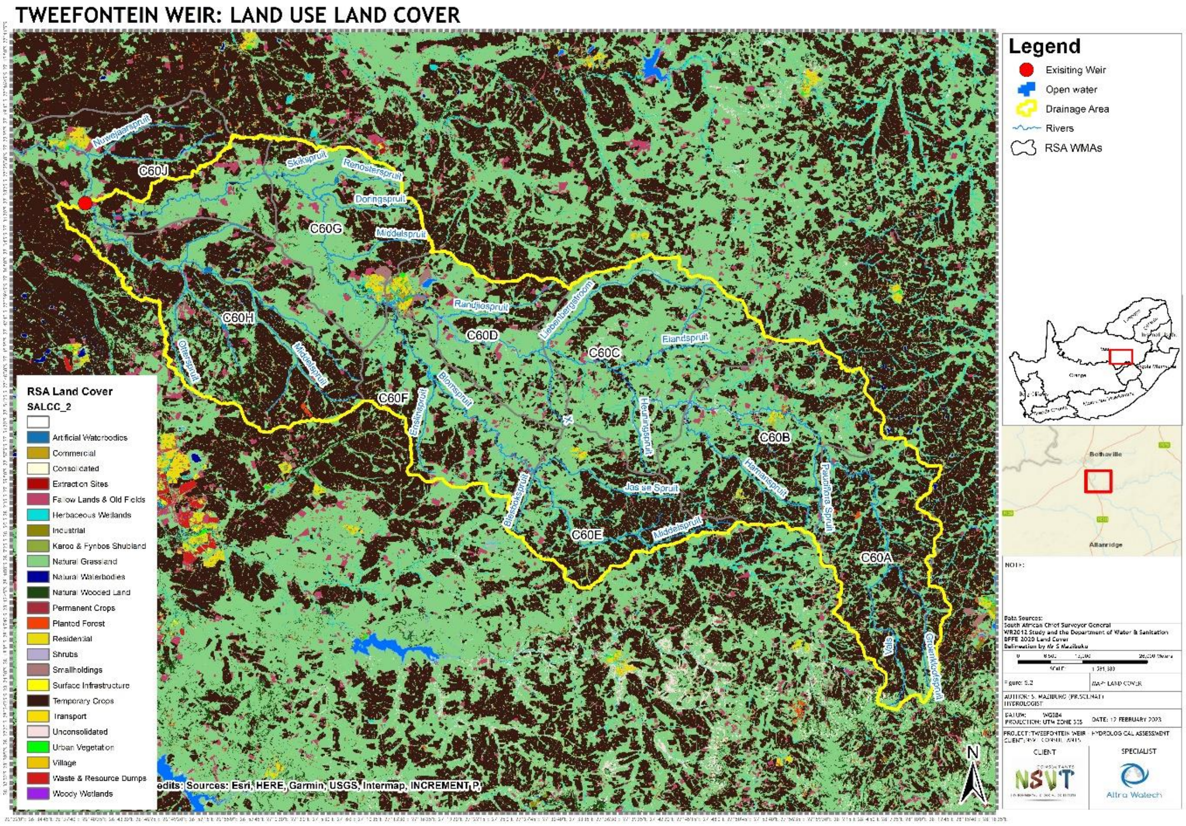


Figure 5.2: Land use and land cover

5.2 Baseline Hydrology

The study area is typically characterised by moderate to cold semi-arid climatic conditions (BSk) Koppen-Geiger (Kottek, Grieser, Beck, Rudolf, & Rubel, 2006) which vary daily and seasonal temperatures. Generally, hot summers and mild-to-cold winters are experienced in the area. December and January are the hottest months, with an average temperature of 30°C, while an average low temperature of about 6°C is experienced in June and July (WorldWeatherOnline, 2022). Figure 5.3 shows the long-term seasonal distribution of the average minimum and maximum temperatures surrounding Bothaville.

The site is nested within quaternary C60J, which drains its runoff from catchment C60A of the Vaal WMA. Rainfall records from the South African Water Resources Study (WR2012) (Bailey & Pitman, 2015) indicate that the area receives a Mean Annual Precipitation (MAP) from 513 to 625 mm. The monthly rainfall distributions (for all quaternary catchments) based on the WR2012 study (with a longer record) are presented in Figure 5.4. The MAE based on Symons Pan (S-Pan) for the study area ranges from 1 450 to 1 652 mm, and its monthly distribution is also presented in Figure 5.5.

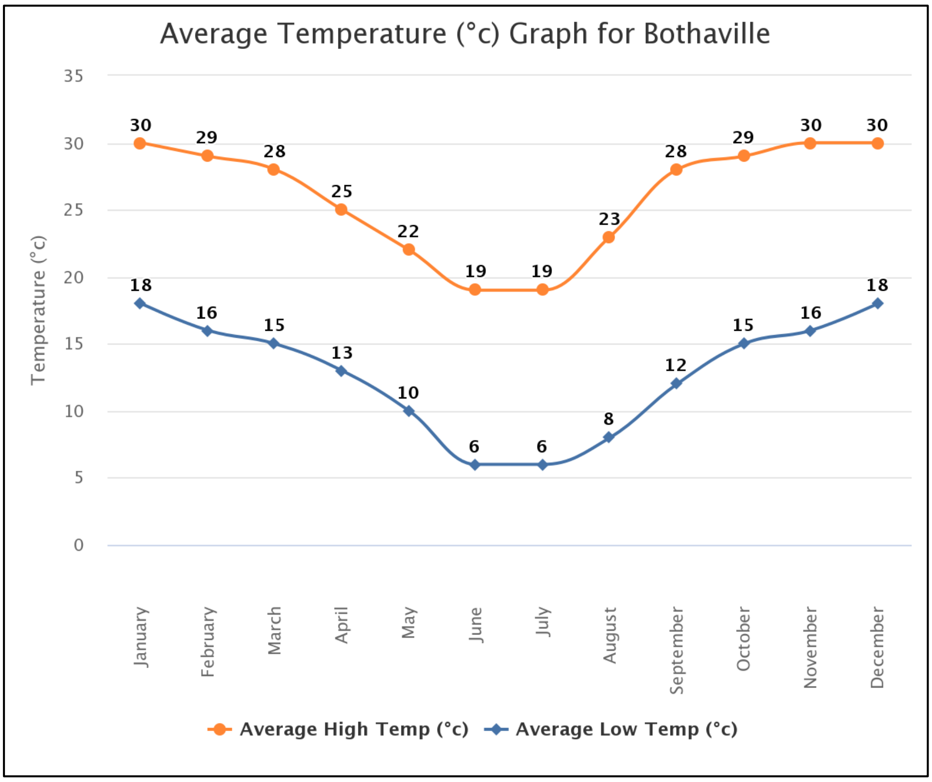
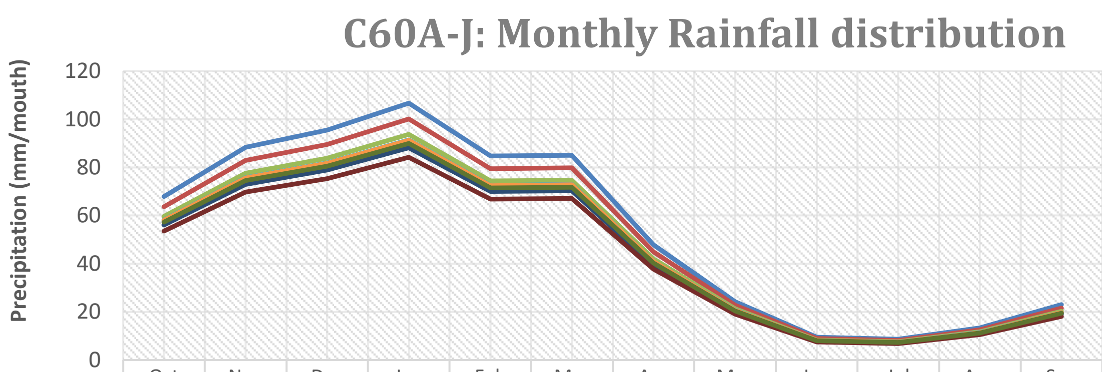
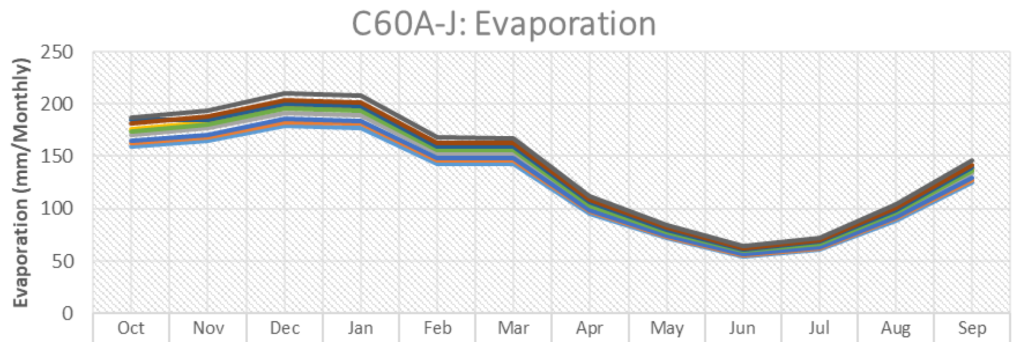


Figure 5.3: Average monthly temperature for the area (WorldWeatherOnline, 2022)



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
C60A	67.86	88.335	95.42	106.665	84.695	85.02	47.84	24.18	9.49	8.645	13.325	23.01
C60B	63.684	82.899	89.548	100.101	79.483	79.788	44.896	22.692	8.906	8.113	12.505	21.594
C60C	59.6124	77.5989	83.8228	93.7011	74.4013	74.6868	42.0256	21.2412	8.3366	7.5943	11.7055	20.2134
C60D	57.42	74.745	80.74	90.255	71.665	71.94	40.48	20.46	8.03	7.315	11.275	19.47
C60E	58.1508	75.6963	81.7676	91.4037	72.5771	72.8556	40.9952	20.7204	8.1322	7.4081	11.4185	19.7178
C60F	58.0464	75.5604	81.6208	91.2396	72.4468	72.7248	40.9216	20.6832	8.1176	7.3948	11.398	19.6824
C60G	56.0628	72.9783	78.8316	88.1217	69.9711	70.2396	39.5232	19.9764	7.8402	7.1421	11.0085	19.0098
C60H	53.5572	69.7167	75.3084	84.1833	66.8439	67.1004	37.7568	19.0836	7.4898	6.8229	10.5165	18.1602
C60J	57.2112	74.4732	80.4464	89.9268	71.4044	71.6784	40.3328	20.3856	8.0008	7.2884	11.234	19.3992

Figure 5.4: Monthly average rainfall distribution (Bailey & Pitman, 2015)



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
C60A	159.065	165.155	179.365	177.335	143.101	142.97	94.975	71.63	54.81	61.19	88.74	124.845
C60B	162.356	168.572	183.076	181.004	146.061	145.928	96.94	73.112	55.944	62.456	90.576	127.428
C60C	170.035	176.545	191.735	189.565	152.97	152.83	101.525	76.57	58.59	65.41	94.86	133.455
C60D	175.52	182.24	197.92	195.68	157.904	157.76	104.8	79.04	60.48	67.52	97.92	137.76
C60E	164.55	170.85	185.55	183.45	148.035	147.9	98.25	74.1	56.7	63.3	91.8	129.15
C60F	173.326	179.962	195.446	193.234	155.93	155.788	103.49	78.052	59.724	66.676	96.696	136.038
C60G	184.518	184.518	200.394	198.126	159.878	159.732	106.11	80.028	61.236	68.364	99.144	139.482
C60H	181.005	187.935	204.105	201.795	162.839	162.69	108.075	81.51	62.37	69.63	100.98	142.065
C60J	186.49	193.63	210.29	207.91	167.773	167.62	111.35	83.98	64.26	71.74	104.04	146.37

Figure 5.5: Monthly evaporation distribution (Bailey & Pitman, 2015)

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5.3 Floodlines Determination

Floodlines simulations were undertaken using HEC-RAS version 6.3 software, where several cross-sections were created throughout the river profile up-and-downstream site of the Tweefontein weir. Ineffective areas and hydraulic structures were not digitised and were excluded from the geometry model due to the limitation of the topographic data (i.e., flows were assumed to be continuous along the terrain).

The right and left bank river cross-sections were assigned to Manning's n-values corresponding to the grassland and bushes. This was aimed at ensuring that different land cover features and riparian vegetation types along the riverbanks are accounted for to ensure that all frictional losses are accounted for in the routing of a peak flood volume. The hydraulic characteristics of the catchment and geometric setting for the study site are summarised in Table 5.1.

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
Tweefontein	Vals	7 254	235	116	0.0012	0.045	0.035	0.050

5.4 Peak Flow Volumes

Peak volumes of the area draining to the study site were calculated using the methods presented in section 3.4 of this report. Amongst these methods, only the result for the Rational method was not considered for application due to its recommended scale of applicability. Peak flow volumes estimated from the Unit Hydrograph Method (presented in Table 5.2.) were considered conservative (**1 185 m^3/s**) and were found to be within a similar magnitude as the stage-discharge flow volumes shown in the preliminary study (DWS, 2021). A summary of the catchment attributes used in the computation of the unit hydrograph peak flow volumes for the study site is presented in Table 5.3.

Table 5.2: Summary of the peak flow calculation methods

Summary of peak flows (m^3/s)

Method	1:2	1:5	1:10	1:20	1:50	1:100
Rational	213.84	310.59	417.67	545.97	749.19	970.61
Alternative rational	311.87	463.30	603.82	760.47	988.30	1206.94
Unit hydrograph	165.19	274.14	400.77	561.19	851.87	1185.25
Standard design flood	197.52	693.59	1154.17	1675.59	2453.71	3107.35

Table 5.3: Peak flow volumes for the 1:100-yr return period using the Unit Hydrograph Method.

Utility Programs for Drainage
Flood calculations

Sinotech

Project name:	**Tweefontein Gauging Weir**
Analysed by:	**Mr Sbongiseni Mazibuko**
Name of river:	**Vals River**
Description of site:	**Upgrade of the Tweefontein Gauging Weir**
Filename:	**C:\Users\mazibukosc\My Drive\Consulting\3. Alcatech\13. Tweetfonteing Weir\ Tweetfontein Weir.fld**
Date:	**13 February 2023**

Printed: 13 February 2023 **Page 1**

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Flood Frequency Analysis: Unit Hydrograph Method

Project                                   = Tweefontein Gauging Weir
Analysed by                               = Mr Sbongiseni Mazibuko
Name of river                             = Vals River
Description of site                       = Upgrade of the Tweefontein Gauging Weir
Date                                      = 2/13/2023
Area of catchment                         = 7254.1 km²
Length of longest watercourse             = 235.0 km
Height difference along equal area slope  = 208.0 m
Distance to catchment centroid            = 118.0 km
Veld type                                 = Region 4
Duration interval                         = 30 minutes
------------------------------------------------------------------------------------------

Slope of longest stream                   = 0.0009 m/m
Catchment index                           = 932077.8
Catchment lag                             = 47.603
Coefficient (Ku)                          = 0.386 m³/s - hours/km²
Peak discharge of unit hydrograph (Qp)    = 58.822 m³/s
------------------------------------------------------------------------------------------
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6 FLOODLINES

The geometry of the modelled river section of the study (Figure 6.1) shows that the river section encroaching the weir site is relatively flat and has a long tailwater section expected to have a steady flow regime during the flooding event. While it is evident from the satellite imagery retrieved from Google Earth that the weir tailwater reach is relatively straight, the topographic data used (30 m ALOS DSM) did not adequately represent the ground conditions as shown in the expected floodwater velocity profiles in Figure 6.2.

The resulting floodlines for the 1:100-yr recurrent peak flow event are presented in Figure 6.3. Results were derived using the calculations of the Unit Hydrograph methods and show that the maximum extent of floodwaters upstream of the existing weir will reach 1 268 mamsl. The inundation water levels for upstream and downstream reaches of the existing weir are presented in Figure 6.4 and Figure 6.5, respectively. The upstream cross-section profile (from the derived river geometry) shows that the new weir can contain the 1:100-yr peak flood as the design dimension protection structure (Figure 6.6) indicates a maximum height of 1 269 mamsl.

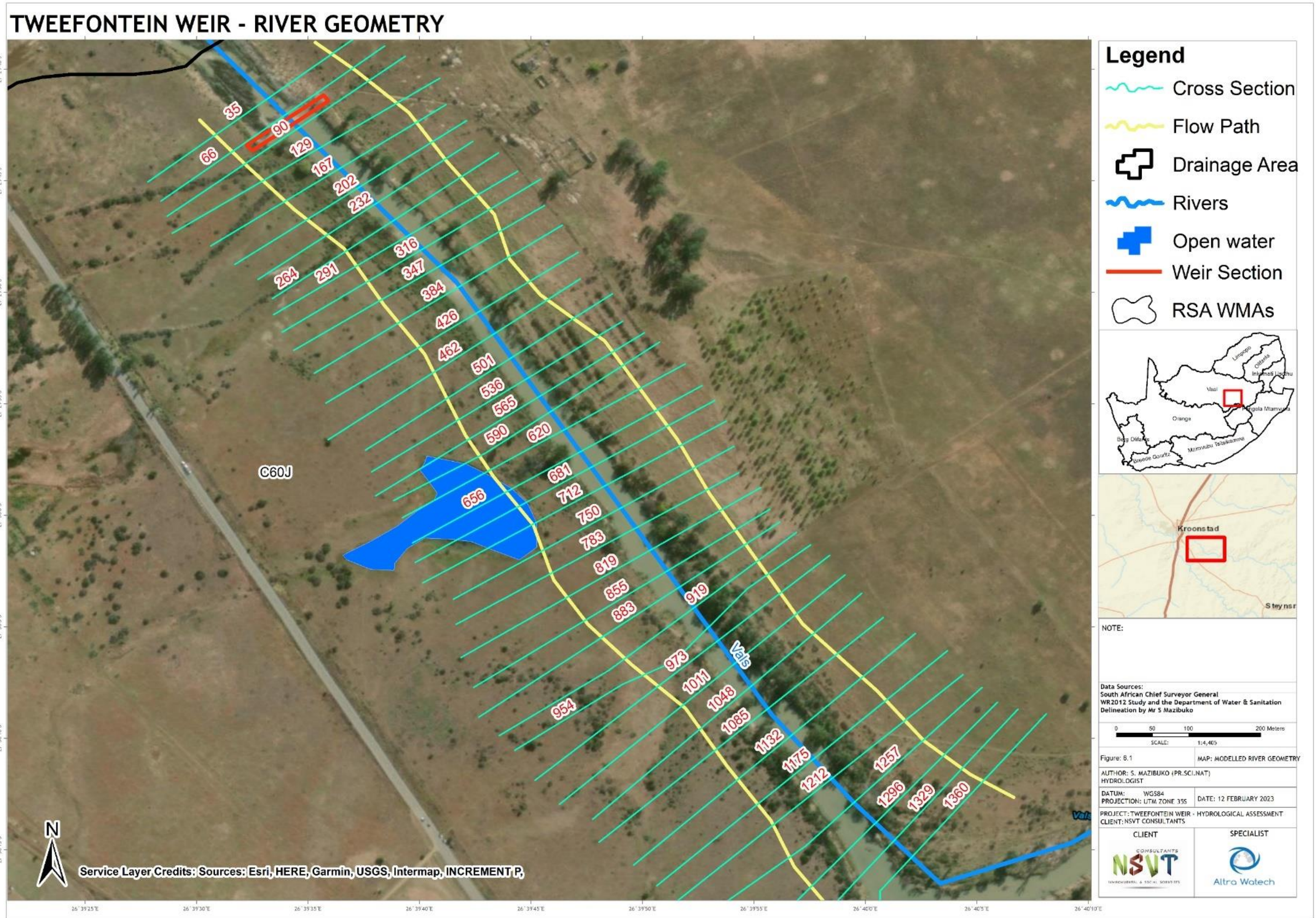

Figure 6.1: Modelled river section geometry

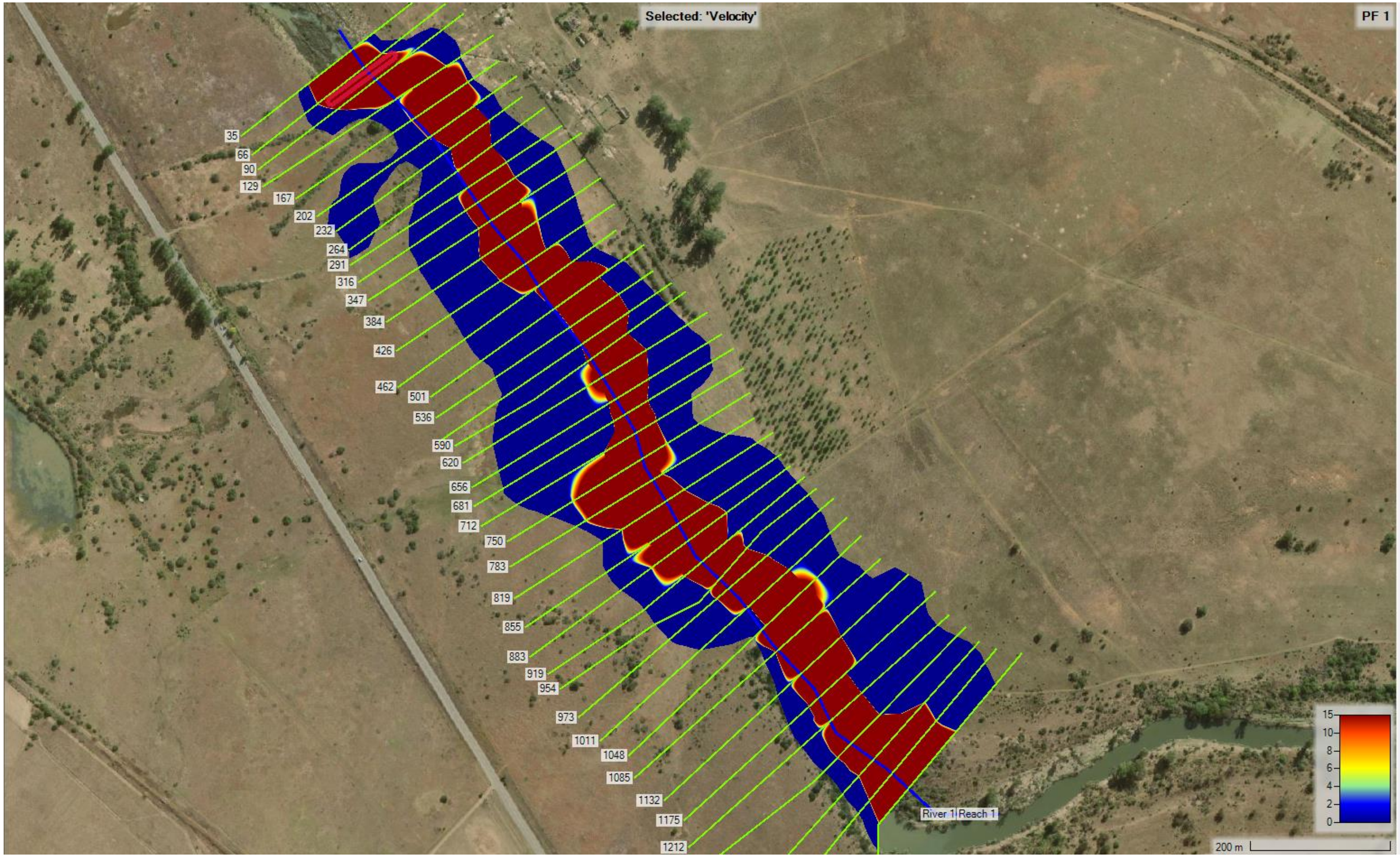

Figure 6.2: Velocity profiles of the modelled Vals River section

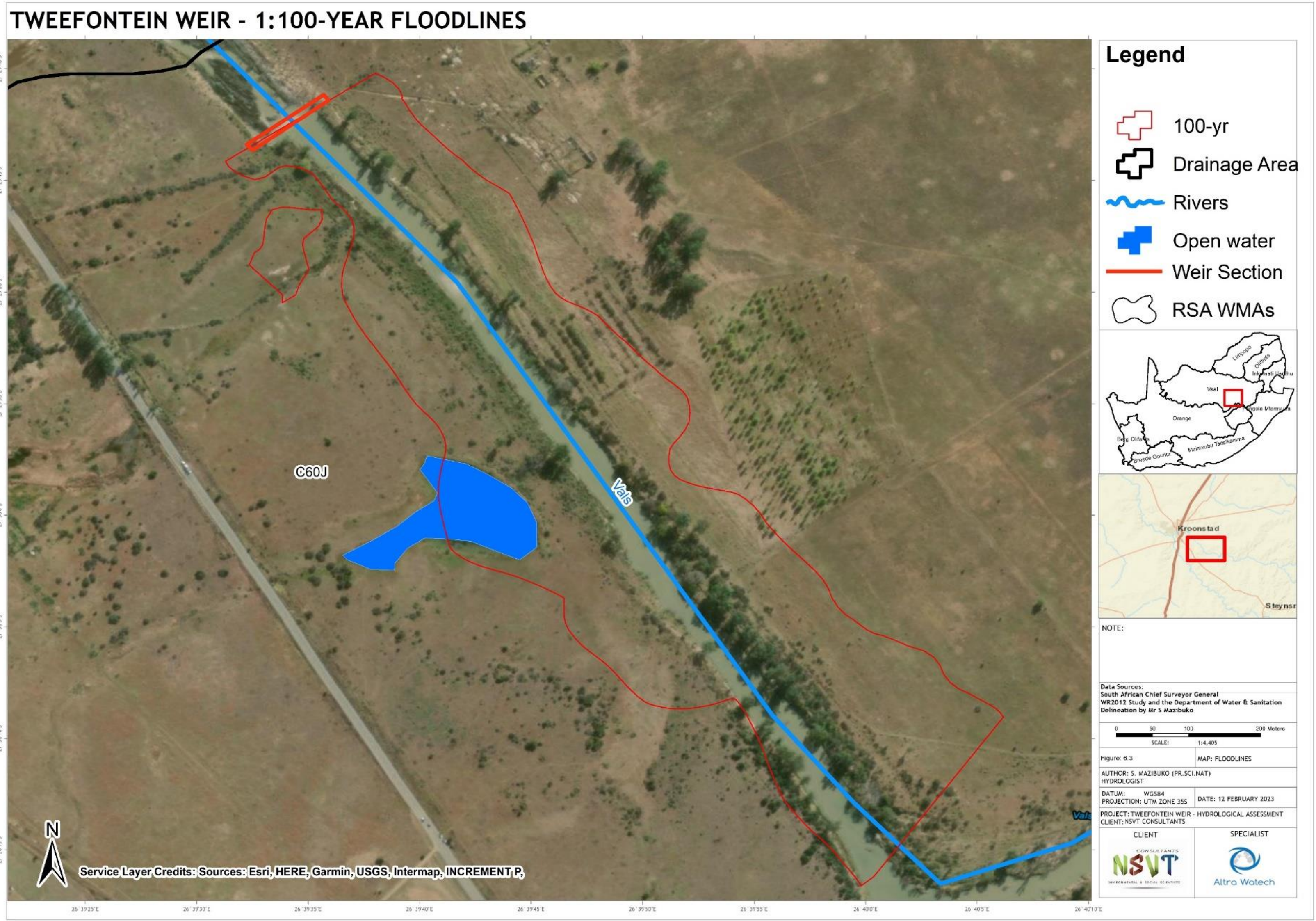

Figure 6.3: Simulation results of the 1:100-yr flood lines of the Vals River

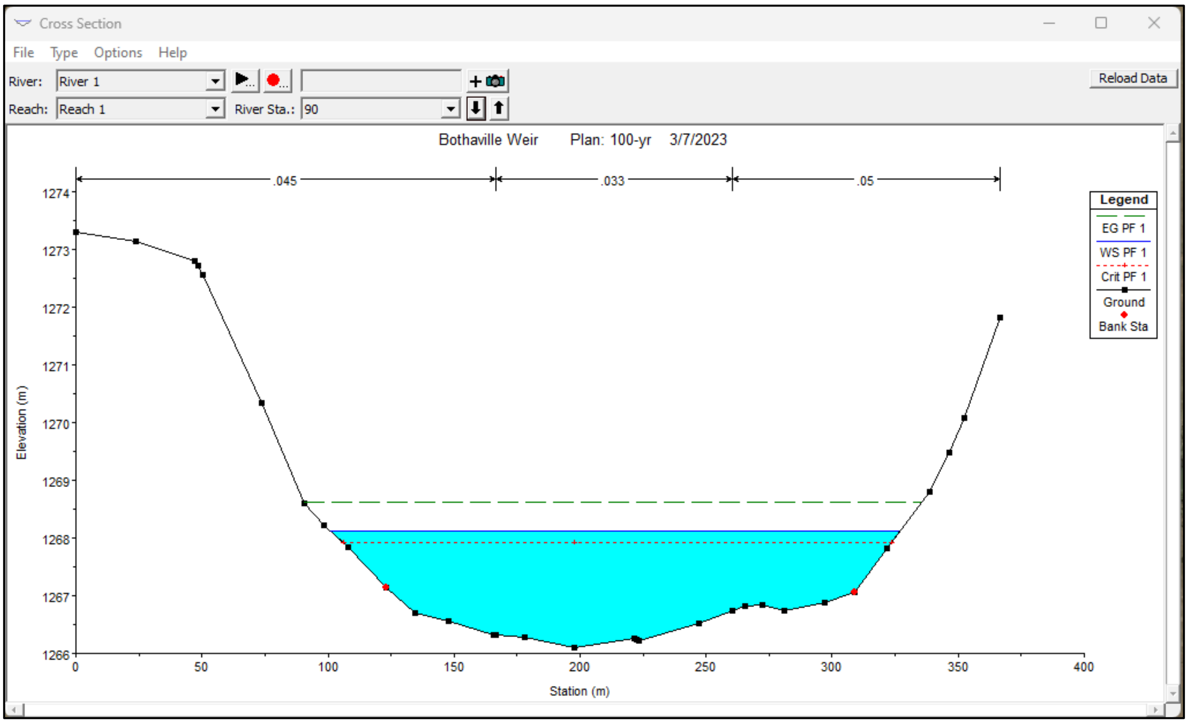

Figure 6.4: River cross-section and 1:100-yr inundation profile upstream of the existing weir

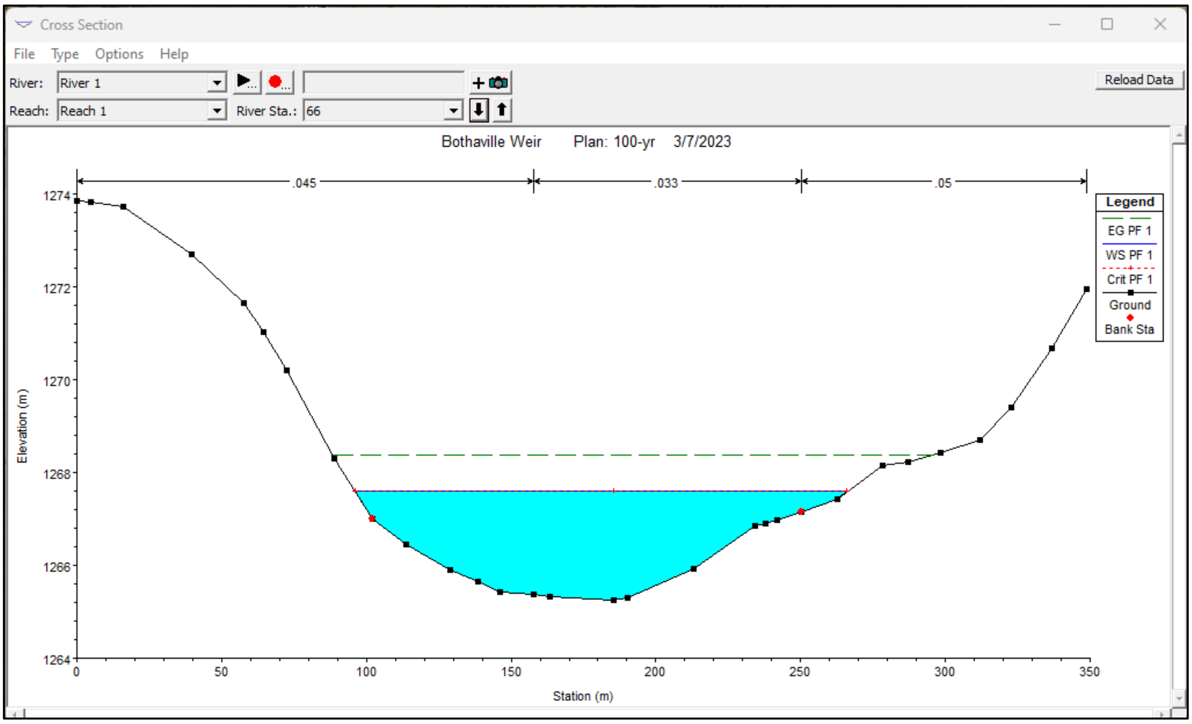

Figure 6.5: River cross-section and 1:100-yr inundation profile downstream of the existing weir

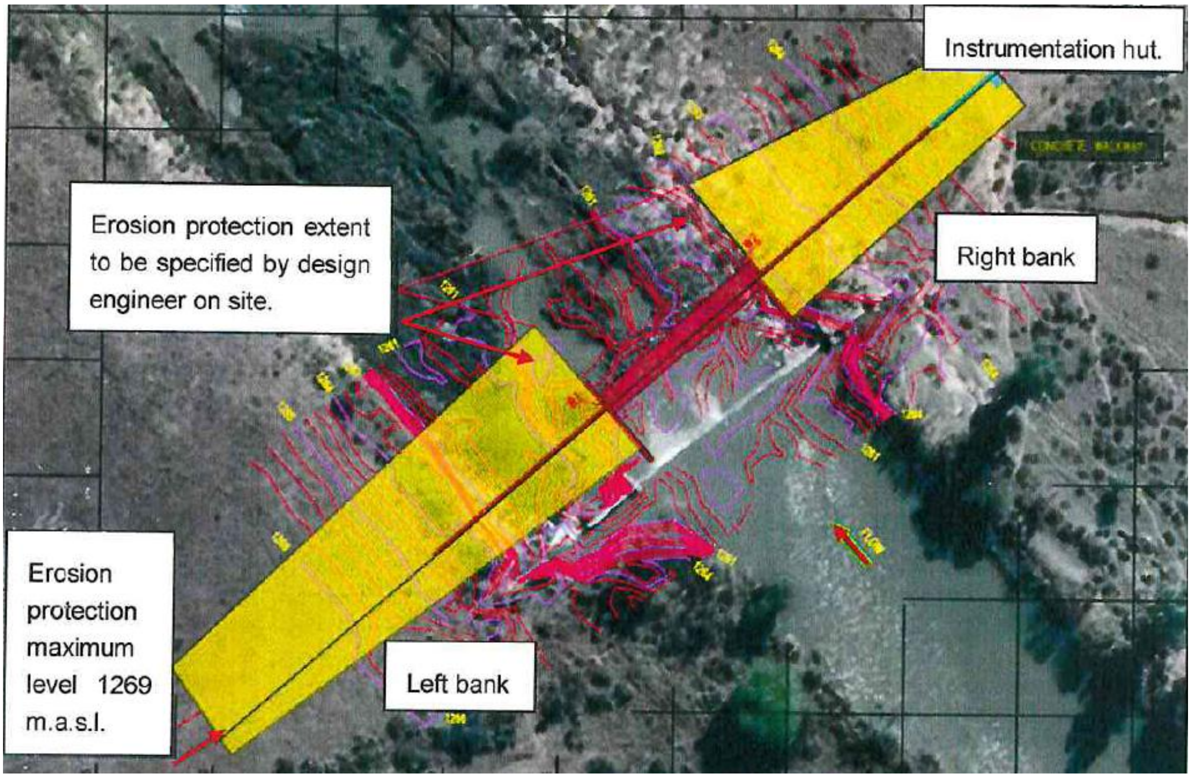

Figure 6.6: Design dimension layout of the Tweefontein gauge station (DWS, 2021)

7 SURFACE WATER IMPACT ASSESSMENT

The impact assessment on the sensitive features relating to surface water within and surrounding the area of the gauging station site was identified and quantified and mitigation measures were drawn for the infrastructure's construction, operation and decommissioning phases. The following potential impacts were identified.

7.1 Construction

Table 7.1 lists a summary of the identified potential impacts associated with constructing the Tweefontein gauging weir. Flooding and increased sediments are amongst the elements identified to have a high influence on the identified activities for the project.

Table 7.1: Identified impacts during the construction phase.

Aspects Assessment - Construction Phase						
No.	**Phase**	**Activity**	**Aspect (cause)**	**Potential Impact (effect on environment)**	**Specialist Study**	**Ability to influence**
1	Construction	Removal of topsoil and vegetation	Surface water siltation	Siltation of the Vals River	Surface Water	Medium
2	Construction	Heavy machinery and vehicle movement	Soil surface compaction	Increased surface water runoff	Soil, Land Use and Land Capability	High
3	Construction	Hydrocarbon, fuel or chemical handling and spillage	Surface water pollution	Pollution of surface water due to spillages, seepages or leaks and improper waste handling, storage and disposal.	Surface Water	Medium
4	Construction	Flooding of the Vals River	Peak flow volumes	Peak floods cause damage to the infrastructure and loss of life	Surface Water	High
5	Construction	Demolition of the existing weir	Erosion and sedimentation on the river	Increased erosion and contamination of water resources downstream	Surface Water	High
6	Construction	On-site waste	Deterioration of water quality	Deterioration of water quality downstream	Surface Water	Medium
7	Construction	Ineffective stormwater management	Increased Erosion	Siltation of the Vals River	Surface Water	Medium

The identified potential receptors (given in the above tables) related to surface water features were quantified as per the methodology provided in section 3.6. Results relating to the impacts (likelihood, consequence, and significance) are presented in Table 7.2. Erosion due to the demolition of the existing weir, improper waste handling, removal of vegetation cover, ineffective stormwater plan, topsoil and the stockpile of building material, together with the potential oil spills on site, have the ability to affect surface water quality in the downstream areas. Flooding during peak flow events is likely to pose risks to the infrastructure and loss of life and was given a medium rating.

Mitigation measures were again evaluated to note the potential changes that could mitigate the identified impacts and their results are presented in Table 7.3. Mitigation measures of the impacts identified show significant improvement in the rating, suggesting that the construction can be conducted in a manner that will not be detrimental to the environment.

Table 7.2: Surface water impact assessment for constructing the weir *before* mitigation measures.

Impact Assessment			Likelihood									Consequence							Significance	Significance
No.	Activity	Potential Impact	Freq. of activity	Rate	Freq. of impact	Rate	Legal Issues	Rate	Detection	Rate	Likelihood	Spacial scale	Rate	Duration	Rate	Severity	Rate	Consequence		
1	Removal of topsoil and vegetation	Siltation of the Vals River	Monthly	3	Infrequent / unlikely / seldom / >60%	3	Covered by guidelines, standards or legislation	1	Immediately	1	3	Whole site (entire project area)	2	One month to one year (Short term)	2	Insignificant / non-harmful	1	2	2	Medium
2	Heavy machinery and vehicle movement	Increased surface water runoff	Daily	5	Often / regularly / likely / possible / >80%	4	Covered by guidelines, standards or legislation	1	Immediately	1	5	Whole site (entire project area)	2	One day to one month (immediate)	1	Insignificant / non-harmful	1	2	2	Medium
3	Hydrocarbon, fuel or chemical handling and spillage	Pollution of surface water due to spillages, seepages, or leaks and improper waste handling, storage and disposal.	Weekly	4	Infrequent / unlikely / seldom / >60%	3	Covered by guidelines, standards or legislation	1	Immediately	1	4	Local (within 5km)	3	One month to one year (Short term)	2	Small / potentially harmful	2	3	2	Medium
4	Flooding of the Vals River	Peak floods cause damage to the infrastructure and loss of life	Annually or less	1	Very seldom / highly unlikely / >40%	2	Covered by guidelines, standards or legislation	1	Immediately	1	2	Whole site (entire project area)	2	One month to one year (Short term)	2	Great / harmful	4	4	2	Medium
5	Demolition of the existing weir	Increased erosion and contamination of water resources downstream	Weekly	4	Infrequent / unlikely / seldom / >60%	3	Covered by guidelines, standards or legislation	1	Immediately	1	4	Local (within 5km)	3	One day to one month (immediate)	1	Insignificant / non-harmful	1	3	2	Medium
6	On-site waste	Deterioration of water quality downstream	Daily	5	Infrequent / unlikely / seldom / >60%	3	Covered by guidelines, standards or legislation	1	Without much effort	2	5	Local (within 5km)	3	One day to one month (immediate)	1	Insignificant / non-harmful	1	3	2	Medium
7	Ineffective stormwater management	Siltation of the Vals River	Monthly	3	Infrequent / unlikely / seldom / >60%	3	Covered by guidelines, standards or legislation	1	Immediately	1	3	Whole site (entire project area)	2	One day to one month (immediate)	1	Insignificant / non-harmful	1	2	2	Medium

Table 7.3: Surface water impact assessment for constructing the weir *after* mitigation measures.

Mitigation Assessment				Likelihood									Consequence							Significance	
No.	Activity	Potential Impact	Mitigation Measures	Freq. of activity	Rate	Freq. of impact	Rate	Legal Issues	Rate	Detection	Rate	Likelihood	Spacial scale	Rate	Duration	Rate	Severity	Rate	Consequence		
1	Removal of topsoil and vegetation	Siltation of the Vals River	• Retain maximum surface vegetation cover. • Restrict vegetation clearance as far as possible. • Restrict vegetation clearance to a minimum footprint area.	Monthly	3	Almost never / almost impossible / >20%	1	Covered by guidelines, standards or legislation	1	Immediately	1	3	Area specific (at impact site)	1	One day to one month (immediate)	1	Insignificant / non-harmful	1	1	1	Low
2	Heavy machinery and vehicle movement	Increased surface water runoff	• Implementing anti-erosion measures such as constructing berms to reduce the water velocity. • Stormwater runoff shall be considered and its flow control on the construction site	Monthly	3	Almost never / almost impossible / >20%	1	Covered by guidelines, standards or legislation	1	Immediately	1	3	Area specific (at impact site)	1	One day to one month (immediate)	1	Insignificant / non-harmful	1	1	1	Low
3	Hydrocarbon, fuel or chemical handling and spillage	Pollution of surface water due to spillages, seepages or leaks and improper waste handling, storage and disposal.	• All hazardous substances must be stored and handled on impervious substrates and bunded areas that are able to contain potential spillage. • Waste handling and storage facilities must be located away from surface water resources and drainage lines. • All vehicles and equipment must be kept in good working order and regularly serviced.	6 monthly	2	Almost never / almost impossible / >20%	1	Covered by guidelines, standards or legislation	1	Immediately	1	2	Area specific (at impact site)	1	One day to one month (immediate)	1	Insignificant / non-harmful	1	1	1	Low
4	Flooding of the Vals River	Peak floods cause damage to the infrastructure and loss of life	• Construction of a cofferdam capable of containing peak flow water.	Annually or less	1	Almost never / almost impossible / >20%	1	Covered by guidelines, standards or legislation	1	Immediately	1	1	Whole site (entire project area)	2	One month to one year (Short term)	2	Significant / slightly harmful	3	3	2	Medium

5	Demolition of the existing weir	Increased erosion and contamination of water resources downstream	• Keep the construction footprint small and use minimal road access. • Excavation must be limited to small portions and be done during the low-flow periods.	Monthly	3	Almost never / almost impossible / >20%	1	Covered by guidelines, standards or legislation	1	Immediately	1		3		Whole site (entire project area)	2	One day to one month (immediate)	1	Insignificant / non-harmful	1	2	1	Low
6	On-site waste	Deterioration of water quality downstream	• Waste generated on-site should be contained and taken out of site	Annually or less	1	Almost never / almost impossible / >20%	1	Covered by guidelines, standards or legislation	1	Immediately	1		1		Area specific (at impact site)	1	One day to one month (immediate)	1	Insignificant / non-harmful	1	1	1	Low
7	Ineffective stormwater management	Siltation of the Vals River	• Stormwater runoff shall be considered and its flow control on the construction site. • The excavated area must not be left open for a period longer than four weeks. • Proper on-site stormwater management measures must be put in place. • No surface water ponding must be allowed on site.	Annually or less	1	Very seldom / highly unlikely / >40%	2	Covered by guidelines, standards or legislation	1	Immediately	1		2		Area specific (at impact site)	1	One day to one month (immediate)	1	Insignificant / non-harmful	1	1	1	Low

Risk-based matrix for this assessment before and after the mitigation measures are presented in Figure 7.1. The mitigation measured derived for the identified activities indicates the significance; as a result, impact likelihood and consequence reduced to the range of rare and unlikely with relatively minor impacts.

Without Mitigation		1 Insignificant	2 Minor	3 Moderate	4 Major	5 Catastrophic
5	Almost certain	0	1	1	0	0
4	Likely	0	0	2	0	0
3	Moderate	0	2	0	0	0
2	Unlikely	0	0	0	1	0
1	Rare	0	0	0	0	0
After Mitigation		1 Insignificant	2 Minor	3 Moderate	4 Major	5 Catastrophic
5	Almost certain	0	0	0	0	0
4	Likely	0	0	0	0	0
3	Moderate	2	1	0	0	0
2	Unlikely	2	0	0	0	0
1	Rare	1	0	1	0	0

Figure 7.1: Risk-based mitigation matrix before and after mitigation measures.

The suggested implementation tools and their support for all identified impacts are given in the prioritisation list in Table 7.4. The table indicates that while all identified impacts showed a medium effect, after the derived mitigation measures, the impact of the identified activities scored low except for flooding. It was assumed that if all mitigation measures were adhered to per the recommended implementation, their likelihood and consequence elements reduced their significance. Priority during the construction should be given to ensuring that pollution is prevented, increased siltation to the water resource, and the prevention of flooding.

Table 7.4: Prioritisation table of the derived mitigation measures

Prioritisation																
No.	**Aspect**	**Potential Impact**	**Specialist Studies**	**Mitigation Measures**	**Significance before Mitigation**	**Significance After Mitigation**		**Public Response**	**Rate**	**Cumulative Impact**	**Rate**	**Loss of resource**	**Rate**		**Prioritisation**	
1	Surface water siltation	Siltation of the Vals River	Surface Water	• Retain maximum surface vegetation cover. • Restrict vegetation clearance as far as possible. • Restrict vegetation clearance to a minimum footprint area.	Medium	Low		Low	1	Low	1	Low	1		1	Low
2	Soil surface compaction	Increased surface water runoff	Soil, Land Use and Land Capability	• Implementing anti-erosion measures such as constructing berms to reduce the water velocity. • Stormwater runoff shall be considered and its flow control on the construction site	Medium	Low		Low	1	Low	1	Low	1		1	Low
3	Surface water pollution	Pollution of surface water due to spillages, seepages or leaks and improper waste handling, storage and disposal.	Surface Water	• All hazardous substances must be stored and handled on impervious substrates and bunded areas that are able to contain potential spillage. • Waste handling and storage facilities must be located away from surface water resources and drainage lines. • All vehicles and equipment must be kept in good working order and regularly serviced.	Medium	Low		Low	1	Medium	3	Low	1		3	Medium
4	Peak flow volumes	Peak floods cause damage to the infrastructure and loss of life	Surface Water	• Construction of a cofferdam capable of containing peak flow water.	Medium	Medium		Medium	3	Medium	3	Low	1		3	Medium
5	Erosion and sedimentation on the river	Increased erosion and contamination of water resources downstream	Surface Water	• Keep the construction footprint small and use minimal road access. • Excavation must be limited to small portions during the low-flow periods.	Medium	Low		Low	1	Low	1	Medium	3		3	Medium
6	Deterioration of water quality	Deterioration of water quality downstream	Surface Water	• Waste generated on-site should be contained and taken out of site	Medium	Low		Low	1	Low	1	Low	1		1	Low
7	Increased Erosion	Siltation of the Vals River	Surface Water	• Stormwater runoff shall be considered and its flow control on the construction site. • The excavated area must not be left open for a period longer than four weeks. • Proper on-site stormwater management measures must be put in place. • No surface water ponding must be allowed on site.	Medium	Low		Low	1	Low	1	Low	1		1	Low

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

The following findings and recommendations were derived from the study:

- The drainage area of the construction site of the Tweefontein gauging weir on the Vals River was delineated using a 30 m ALOS DSM data and the computed Mean Annual Precipitation (MAP), Annual Evaporation (MAE) and natural Mean Annual Runoff (MAR) from the WR2012 study were estimated at 577 mm and 1 830 mm, respectively. These values represent the overall drainage from quaternary catchment C60A to C60J.
- Steep headwater reaches followed by undulating hills and flatlands towards the catchment outlet are characterised by predominantly grasslands and agricultural land.
- Riverline derived from the DSM data were used to create river geometry for which the flood was routed. Disparities in the delineated river lines to those observed from the satellite imagery were observed. This is attributed to the spatial scale of the 30 m ALOS DSM data and the fact that these data do not capture the changes to the ground infrastructure developments, thus introducing uncertainties in the flood simulations.
- The maximum (peak) flow volumes for the 1:100-yr return event were calculated using the Unit Hydrograph Method and were estimated to have a peak volume of **1 185 m^3/s**. This flow volume value was routed on the 1-D hydraulic model to evaluate the potential risk the Vals River poses on the new weir. Floodline simulation results show that the calculated peak flow volumes for the 1:100-yr recurrence will be contained within the weir as per the width of the weir structure.
- Surface water impact assessment for the receptor of water-related features was identified and quantified and the mitigation measures were drawn for the impact. Results show soil erosion due to the demolition of the existing weir, improper waste handling, removal of vegetation cover, ineffective stormwater plan, topsoil and the stockpile of building material, and potential oil spills on site, can affect surface water quality in downstream areas. Also, the Vals River poses a threat of flooding the infrastructure.

8.2 Recommendations

The following recommendations were made for the construction phase of the project:

- Development, implementation, and maintenance of the construction site stormwater management measures as well as prevention of ponding surfaces to reduce erosion on site.

- All waste generated on-site is contained and discharged off-site to reduce the potential of contamination on site.
- It is recommended that clearing vegetation cover, removal of topsoil and construction footprint be kept minimal to reduce soil erosion. Heavy machinery movement should also be kept small to minimise soil compaction, which increases runoff generated on-site.
- It is also recommended that any spillages of oil and hydrocarbons on-site be contained and cleaned to reduce their impact on contributing to the deteriorating water quality in the downstream areas during the entire construction period.
- A cofferdam should be able to contain the peak flow volumes during the rainy days, while it is recommended that the existing weir be demolished during the dry season to reduce siltation and flooding potential.

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