TWEEFONTEIN GAUGING WEIR - PRELIMINARY DESIGN REPORT

October 2021

PREPARED BY:

Department Water and Sanitation
Directorate: Hydrological Services
Private Bag X313
PRETORIA
0001

CONTACT PERSONS

Mrs AA Coetzee
Tel No: 012 336 6938

Mr F de Bondt
Tel No: 012 336 8447

TITLE	**:**	***Tweefontein Gauging Weir: Preliminary Design Report***
Project Team	**:**	*Department of Water and Sanitation: Directorate Surface- and Groundwater Information*
Key Words	**:**	*Measurement, Gauging Structure, Design, Rating*

Compiled by	:	F.H. de Bondt	[signature]	29 October 2021
		Initials & Surname	Signature	Date
Reviewed by	:	A.A. Coetzee	[signature]	29 October 2021
		Initials & Surname	Signature	Date
Approved by	:	P. Wessels	[signature]	29 October 2021
		Initials & Surname	Signature	Date

EXECUTIVE SUMMARY

The purpose of this report is to describe the design methodology that was followed in the design of a new gauging structure in the Vals River, on the farm Tweefontein, about 12 km upstream of Bothaville in the Free State.

The Chief Directorate: Water Information Management (CD: WIM) of the Department of Water and Sanitation (DWS) initiated a study for the Review, Evaluation and Optimisation of the South African National Water Resources Monitoring Network, which gave recommendations regarding the existing surface and groundwater monitoring sites for all the Water Management Areas (WMA). Two of the river monitoring sites in the Vaal WMA that require changes are stations C6H001 (Vals River @ Roodewal) and C6H006 (Vals River @ Tweefontein). Station C6H001 requires a serious upgrade or needs to be replaced with a completely new structure, while the upgrading of station C6H006 needs to be investigated in conjunction with station C6H001.

The option that was given to replace station C6H001 with the upgrading of station C6H006, was chosen mainly due to it providing the possibility of adjusting the inaccurate flow record of station C6H001 (Vals River @ Roodewal). This will provide several years of usable flow data.

The new Tweefontein gauging structure will be used to supply information on the magnitude of flows in the lower reach of the Vals River. This information, in combination with data gathered at station C6H009 (Vals River @ Lindley), in the upper reaches of the Vals River, will assist operators of the Bloemhof Dam to synchronise releases with natural flow events in the Vals- and Vaal River and thus optimise the use of stored water from the dam, while also ensuring the safety of downstream users, property and animals during these flood events.

The gauging structure, therefore, needs to be equipped with real-time platforms adhering to requirements/standards set by the Department of Water and Sanitation (DWS).

The impact of the new gauging structure on natural flow conditions at the site was critically analysed. The impact on existing water rights was also looked at. Based on the results of these hydraulic analyses, a Crump gauging weir was designed to gauge the run-off. The existing water rights of the farmer on the right bank, the environmental impact and the hydraulic constraints experienced at the site determined the design gauging capacity. Measures to combat negative impacts such as the increase in erosion potential caused by the structure are proposed.

A complete set of engineering drawings for the new gauging structure is included in the addenda.

LIST OF FIGURES

Page No

LIST OF TABLES

Page No

TABLE OF CONTENTS

Page No

ADDENDA

TWEEFONTEIN GAUGING WEIR - PRELIMINARY DESIGN REPORT

1. INTRODUCTION

The Chief Directorate: Water Information Management (CD: WIM) of the Department of Water and Sanitation (DWS) initiated a study for the Review, Evaluation and Optimisation of the South African National Water Resources Monitoring Network (AECOM SA (Pty) Ltd, 2016).

Under the study, a Scientific Review has been completed, which gave recommendations regarding the existing surface and groundwater monitoring sites for all the Water Management Areas (WMA). The main objectives of the study were to review the existing monitoring networks against the prioritised National Monitoring Objectives in terms of:

- Existing sites meeting the identified objectives;
- Redundancies in the existing monitoring network;
- Gaps in the spatial coverage with regards to meeting important monitoring objectives; and
- Possible physical constraints associated with existing and potential new monitoring sites.

Two of the river monitoring sites in the Vaal WMA that require changes are stations C6H001 (Vals River @ Roodewal) and C6H006 (Vals River @ Tweefontein). Station C6H001 is a sharp-crested weir located on a bend, which makes the flow measurements very inaccurate, whereas the downstream station C6H006 is a cableway designed to measure flood flows. Station C6H001 requires a serious upgrade or needs to be replaced with a completely new structure. Another possibility given was to replace station C6H001 with the upgrading of station C6H006.

It was decided that station C6H001 would be replaced with the upgrading of station C6H006. This meant that the new gauging station could then be run together with station C6H001 until a correlation has been calculated between the measurements at the two stations. These correlations would then be used to adjust the inaccurate flow record of station C6H001, resulting in a more accurate flow record, which stretches from 1913 up until the current day.

The objective was to either refurbish the current cableway system, to replace it with a completely new gauging weir, or to construct a new gauging weir and then to run the two gauging points in tandem. Taking into account the environmental impact, and the hydraulic constraints of the site, the latter option was chosen. This will enable low flows, up to 210 m^3/s to be measured accurately at the weir, with higher flood flows being measured at the downstream cableway.

The new gauging structure is to be designed and constructed in the Vals River, close to the existing station C6H006, on the farm Tweefontein, located about 12 km upstream of Bothaville in the Free State. The new Tweefontein gauging structure will be used to supply information on the magnitude of flows in the lower reach of the Vals River. This information, in combination with data gathered at station C6H009 (Vals River @ Lindley), in the upper reaches of the Vals River, will assist operators of the Bloemhof Dam to synchronise releases with natural flow events in the Vals- and Vaal River and thus optimise the use of stored water from the dam, while also ensuring the safety of downstream users, property and animals during these flood events.

The scope of this conceptual design includes the design of the gauging weir and associated infrastructure only. The location of the new gauging structure in relation to stations C6H001, C6H009 and the Bloemhof Dam is shown in **Figure 1**.

Figure 1: Location of existing and new gauging structures in the Vals River drainage area upstream of Bloemhof Dam.

2. GENERAL DESIGN CRITERIA FOR GAUGING STRUCTURES

2.1 DESIGN PROCEDURE

The general procedure for designing a gauging weir can be summarised into eight basic steps. The steps that were set out by Van Heerden, et al. (1985) in the TR126 Manual are as follows:

i. Determining the structural/design capacity.
ii. Selection of the most suitable site.
iii. Calculating the control curve of the natural river section downstream of the selected site.
iv. Selection of gauging structure type.
v. Selecting the number of notches, notch lengths and step heights.
vi. Determine the low notch elevation.
vii. Preliminary calibration of the design weir.

2.2 CRITERIA FOR A PROPER GAUGING STRUCTURE SITE

In the selection process of a gauging site, particular attention should be paid to the following points (WMO, 1980):

- An adequate straight length of the channel with uniform cross-section and gradual slope.
- A steep approach channel should be avoided, if possible.
- Good foundation conditions across the width of the channel.
- Flow in the stream should be confined to a well-defined channel with stable banks.
- Impact of any increase in the upstream water level as the result of the construction of a measuring structure on the surrounding environment.
- Conditions downstream that may cause variable backwater effects, such as tidal influences, flow in downstream tributaries, dams or any other controlling features.
- The removal of rocks or boulders that may influence the measurement of discharge from the approach channel.
- Access to the site, even during flood events, is of prime importance.

Once a suitable gauging site has been selected, a detailed survey of the site, along with a survey of the river channels upstream and downstream should be conducted. During the survey, it is important to note and photograph vegetation (river and flood banks), foundation material (gauging site), upstream and downstream conditions (islands, scour, etc.) and the estimated roughness parameters at the different cross-sections. This will enable the design engineer to perform a proper hydraulic and structural design without having personally visited the site (Van Heerden, et al., 1985).

2.3 DESIGN CRITERIA FOR A GAUGING STRUCTURE INSTALLATION

A complete gauging installation consists of three main components (BSI, 1986; ISO, 1980):

- an approach channel,
- a downstream channel and
- the gauging structure.

The condition of each of these three components affects the overall accuracy of the measurements that will be achieved at the installation.

Installation requirements include features such as concrete finish, channel roughness, the cross-sectional shape of the channel, channel slope and the influence of control devices upstream or downstream of a gauging structure. The distribution and direction of velocity in the approach channel have an important influence on the performance of a structure. After the construction of a gauging structure, any change in condition that could influence the discharge characteristics must be prevented.

2.3.1 Approach channel

Flow in the approach channel shall be smooth, free of disturbances and shall have a velocity distribution as normal as possible over the cross-sectional area. This can only be attained with a long straight approach channel free of projections at either the side or the bottom.

In artificial channels with a uniform cross-section, an approach channel with a straight length of at least 5 times the channel width is required. In natural streams, a reasonably uniform approach channel with an even longer straight length is required to ensure a relatively regular velocity distribution. If discharge upstream of a gauging structure enters the approach channel through a bend or if the flow is discharged into the channel through a conduit of smaller cross-section, or at an angle, a substantially longer straight length of channel will be required upstream of the structure.

The slope of the approach channel should not be too steep. As long as the Froude number (Fr) in the natural channel before the construction of the structure is less than 0.5 for the highest discharge to be gauged accurately, the slope of the channel is still acceptable (Ackers, et al.,1978; WMO, 1980). The Froude number in the channel at the point of stage measurement must be less than 0.4 for the design discharge, with the gauging structure in place (Van Heerden, et al., 1986).

2.3.2 Downstream channel

Conditions in the channel downstream of the structure determine tailwater levels. An accurate survey of the downstream channel is therefore required by the designer to determine a stage-discharge relation for the unobstructed channel at the site of the proposed structure. This is done using a backwater calculation. The results of these calculations are used for the hydraulic design of the measuring structure. This includes the determination of the type of structure to be used; the maximum and minimum discharge to be gauged accurately, the minimum crest level and shape of the proposed structure.

If a measuring structure has been designed to operate in modular flow conditions, the impact of the channel downstream of the structure on gauging accuracy is of little importance. However, a downstream gauge should be provided to measure tailwater levels to determine when submerged flow occurs. It is impractical to design structures high enough to avoid submergence at high discharges. Structures designed to operate in both modular and submerged flow conditions require additional instrumentation to monitor tailwater levels continuously.

If scour downstream of a structure is likely, measures to prevent scour damage need to be provided.

2.3.3 Gauging structure

The structure must be solid, watertight and capable of withstanding flood flow conditions. A structure should be constructed on a stable foundation and the crest of the structure should be placed perpendicular to the direction of flow in the stream. The profile of the crest of the structure should be designed in such a way that a small change in discharge will cause a measurable change in the stage. The structure should act as a control over a wide range of discharges without excessively raising the water level upstream of the structure. The design capacity of a gauging structure should as far as feasible be able to accurately measure flows that contribute up to 80% of the flow volume in the river.

During the construction of a structure, care should be taken that the surfaces over which water flows are smooth, especially near the weir crest. The structures should also be built to close tolerances. Flank walls should be parallel and vertical and should extend upstream past the stage measuring position. Flank walls direct the flow towards the weir crest and should therefore be given a smooth surface finish to limit the formation of eddies.

3. HYDRAULIC DESIGN OF GAUGING STRUCTURES

3.1 GENERAL INFORMATION

A survey of the river reach where the gauging structure is to be constructed was performed by the surveyors of the Free State Regional Office, Department of Water and Sanitation (DWS).

Surveyed cross-sections were used in the hydraulic analyses of the river reach for the pre-gauging structure scenario. The HEC-RAS River Analysis System (V5.0.7 March 2019) was utilised to perform backwater calculations for the surveyed reach of the Vals River.

These results formed the basis for further hydraulic analysis at the sites identified as possible gauging sites. Specialist software (Calibrate V2009.1) developed by the Directorate Hydrological Services in DWA were used to analyse the performance of the alternative structure layouts for various flow conditions in the river reach. Only the structure layouts that performed the best at each site will be discussed in further detail in the report.

3.2 TWEEFONTEIN GAUGING STRUCTURE

3.2.1 Hydraulic Design

Taking the criteria for a proper gauging structure (Chapter 2) into consideration, two possible gauging sites were identified. Due to the following factors, the preferred option was to either replace or refurbish and repurpose the existing weir at the upstream end of the surveyed reach:

- An adequate straight length approach channel.
- Approach channel with flat slope.
- Good foundation conditions.
- Stabilised banks, due to the presence of the existing structure.
- Lower cumulative environmental footprint.
- The bridge is possibly far enough downstream of the existing weir not to cause any variable backwater effects.
- Site access is good and available on both banks.
- Being able to use the existing structure as a cofferdam during the construction phase.

The average width of the natural river channel at the chosen site, just downstream of the existing weir, is about 42 m. To comply with the minimum length of pool requirements (see 2.2.1), a pool length of at least 210 m is required. The upstream pool length is sufficient, as the proposed site is approximately 1 300 m (see Figure 2).

Tailwater levels for the existing weir, which is located about 2.3 km upstream of the cableway (C6H006), were calculated using the HEC-RAS River Analysis System (V5.0.7, March 2019). As multiple control points were identified throughout the river reach between the existing weir and the cableway, subcritical flow conditions could be assumed to calculate the tailwater levels downstream of the existing weir.

The backwater analysis was done for the pre-gauging structure conditions, from the cableway (C6H006) up to the existing upstream weir, for flow rates between 20 m³/s and 1030 m³/s, with 1030 m³/s being the maximum flow measured at the cableway and 20 m³/s the lowest flow that can be measured accurately at the cableway. Chezy k values were estimated from photographs, aerial imagery and comments taken during the site visit. The Chezy k values had to be converted to Manning n values for each iteration of the backwater analysis. For the downstream boundary condition, the cableway's discharge rating table was used as input. Debris blockage at the bridge was simulated by doing the backwater analysis for scenarios where the openings between bridge piers were fully open, 25% blocked, 50% blocked, 75% blocked and 100% blocked. The backwater analysis, therefore, determined the influence of the flow rate, reach geometry, channel roughness, as well as that of debris blocking the bridge on the tailwater levels of the existing upstream weir. These results formed the basis for further hydraulic analysis.

The stage and energy levels at the cross-section immediately downstream of the existing weir are given in Addendum A for the different discharges and bridge blockage percentages. Table 1 gives the maximum stage and energy levels downstream of the existing weir, which occurred when the bridge openings were fully (100%) blocked, with Figure 5 depicting these results visually. Figure 3 shows the longitudinal section of the river reach, with the stage and energy elevations for a flow rate of 200 m³/s, and for the scenario where the bridge at cross-section 39 is fully open. Figure 4 shows the stage and energy elevations for a flow rate of 200 m³/s, and for the scenario where the bridge is fully blocked.

A sensitivity analysis was done by increasing and decreasing the Chezy k value by 20%. Addendum B summarises the difference in energy elevation and the Froude number that was calculated with the backwater analysis overall cross-sections for a flow rate of 80 m³/s.

Table 1: Discharge - stage relation for the Vals River @ Tweefontein downstream of the existing weir.

Discharge (m^3/s)	Water Level (m)	Energy Level (m)	Discharge (m^3/s)	Water Level (m)	Energy Level (m)
20.00	1261.29	1261.3	300.00	1262.98	1263.07
30.00	1261.42	1261.43	350.00	1263.17	1263.28
40.00	1261.53	1261.54	400.00	1263.35	1263.47
50.00	1261.62	1261.63	450.00	1263.51	1263.64
60.00	1261.71	1261.72	500.00	1263.66	1263.81
70.00	1261.79	1261.81	600.00	1263.94	1264.11
80.00	1261.86	1261.89	700.00	1264.20	1264.39
100.00	1262.00	1262.03	800.00	1264.43	1264.65
150.00	1262.30	1262.34	900.00	1264.65	1264.88
200.00	1262.55	1262.61	1000.00	1264.86	1265.11
250.00	1262.78	1262.85	1027.00	1264.91	1265.17

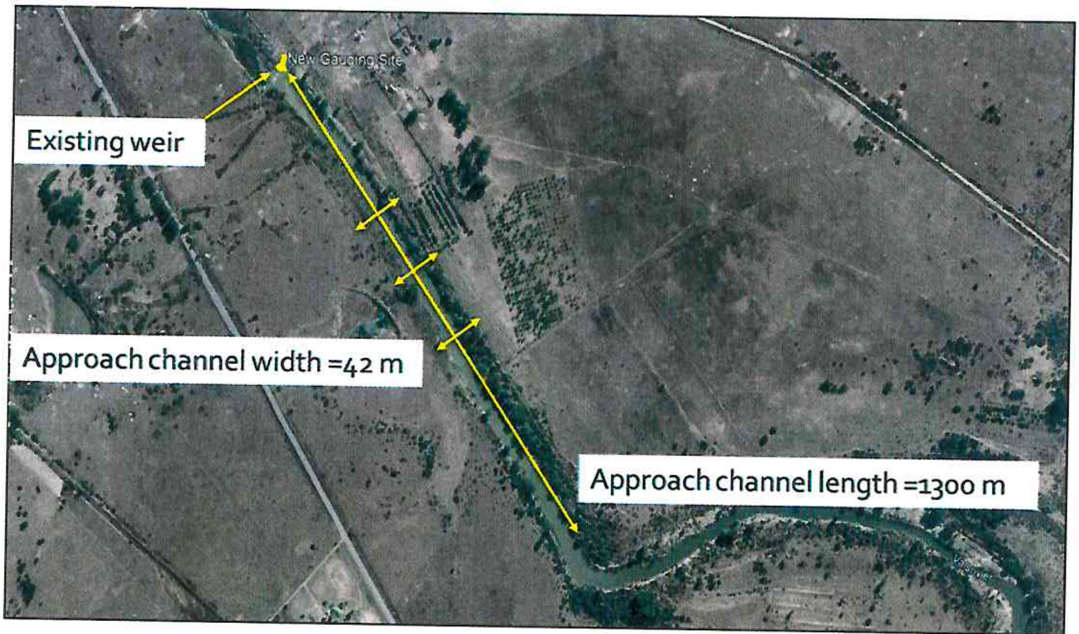


Figure 2: Approach channel upstream of the new gauging site in the Vals River @ Tweefontein.

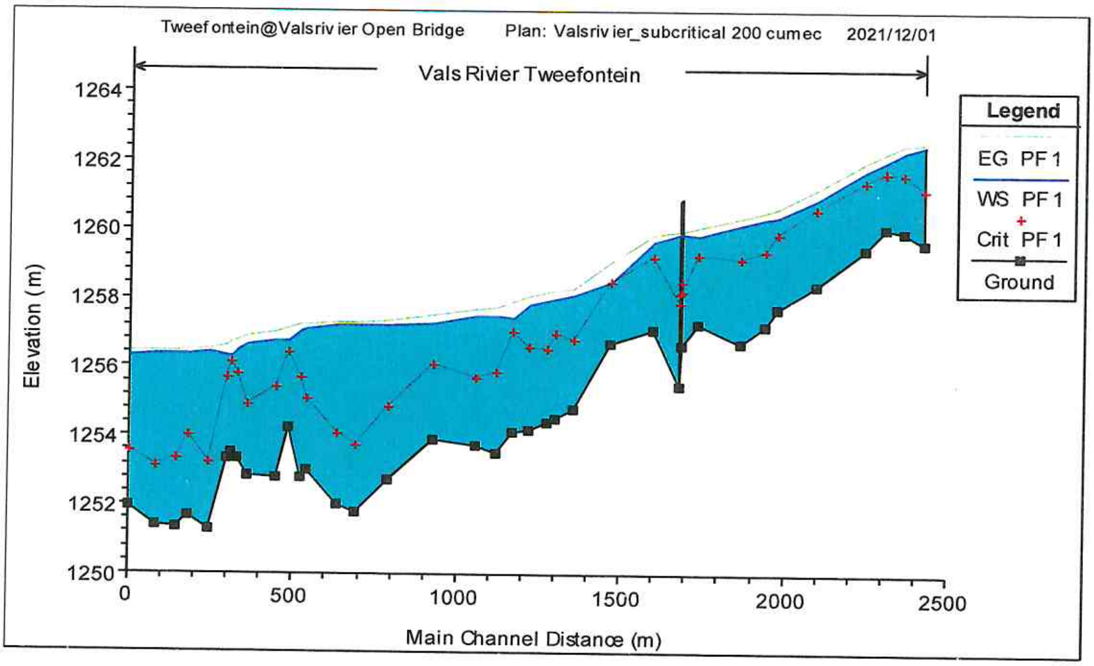


Figure 3: Longitudinal section of the river reach at Tweefontein for a flow of 200 m³/s, with the bridge openings fully open.

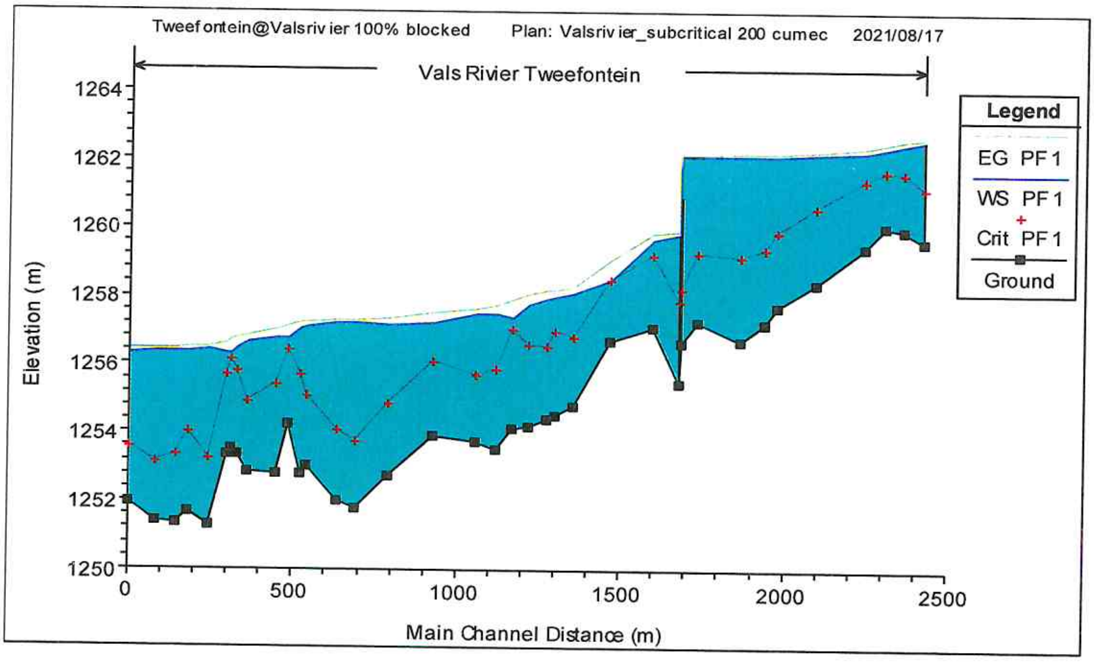


Figure 4: Longitudinal section of the river reach at Tweefontein for a flow of 200 m³/s, with the bridge openings fully blocked.

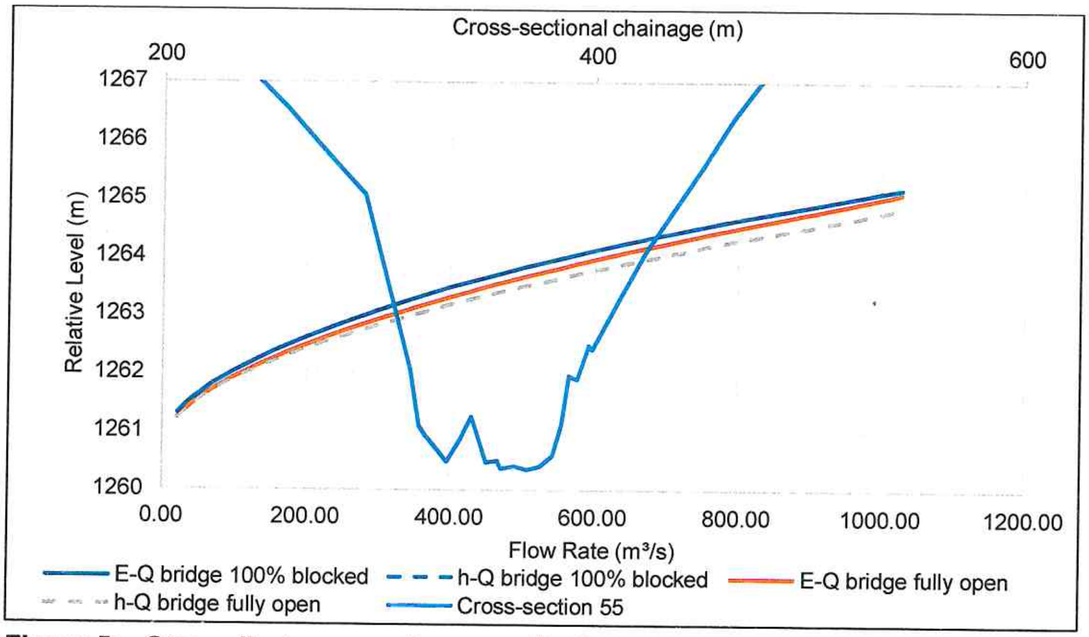


Figure 5: Stage-discharge and energy-discharge relationship for the pre-gauging structure scenario, immediately downstream of the existing weir.

After having calculated the tailwater levels at the existing structure, six alternative gauging structural layouts were designed and then analysed for the various flow conditions using specialist software (Calibrate V2009.1) developed by the Directorate Hydrological Services in DWS. The structure that performed best and was found to be most suitable to minimise upstream water levels, consisting of two 21 m horizontal Crump weir crests. The low notch was designed with a crest elevation of 1262.7 m above mean sea level. This is the same elevation as that of the existing weir and, therefore, the weir complies with legal aspects pertaining to the farmer's water extraction license.

The low notch is designed to be positioned toward the right bank of the river, mainly because the threat of vandalism to instrumentation is lower on the right bank, due to it being less accessible to the general public. The right bank was also preferred, as good rock was identified during the site visit, which meant that better foundation conditions and erosion protection for the instrumentation hut were possibly available. The second notch, which is 300 mm higher than the low notch at 1263.0 m above mean sea level is positioned toward the left bank of the river.

Water quality and water levels (stage) will be measured 2 m (H_d) and 4 m ($2H_d$) upstream of the weir crest respectively. The instrumentation (pressure transducers, etc.) will be housed inside the flank wall on the right bank of the river. This proposed gauging structure layout adheres to the design requirements set out by DWS (Van Heerden, et al., 1986) and other internationally accepted gauging structure standards (Ackers, et al., 1978; BSI, 1986). A plan layout of the proposed gauging structure is shown in Figure 6 and Addendum E.

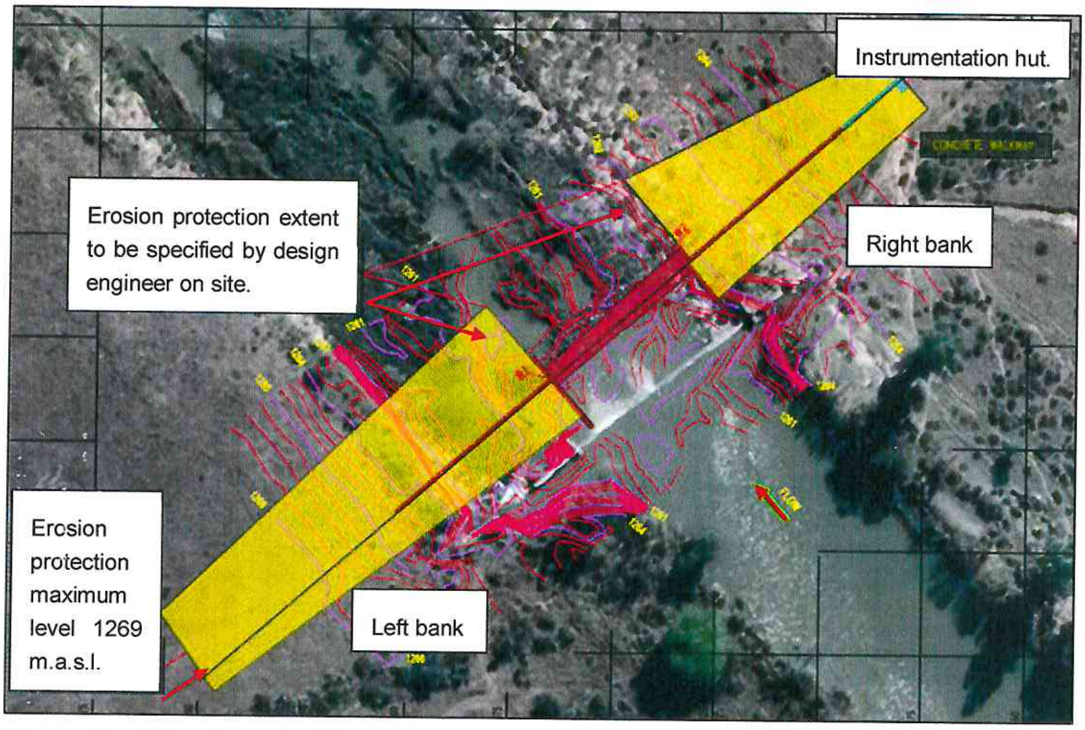


Figure 6: Plan layout of the proposed Crump gauging structure to be constructed in the Vals River @ Tweefontein.

The structure as designed should be able to accurately gauge discharges greater than 2.80 m³/s, provided that the structure is constructed to close tolerances, adheres to the prescribed surface finishes and that stage measurements are executed accurately. With this crest layout, the first 6.85 m³/s of discharge in the river is confined to the low notch, which means about 5% of the total yield would be measured only through the low notch. Flows would, however, be measured over only the low notch for about 94% of the time.

The design capacity of the structure, at an energy level of 2.0 m above the low notch crest (1264.7 m.a.s.l.), is 210 m³/s and at this discharge, the structure operates under modular flow conditions with a submergence ratio of 0%. Corrections for the impact of non-modular flow conditions (submerged flow) are only applied once submergence ratios greater than 75% are experienced at a Crump weir gauging structure. Flows above the design flow are to be measured at the downstream cableway. This configuration was chosen in order to minimise and keep the water levels upstream of the gauging weir as close as possible to that of the existing weir. With the design flow of 210 m³/s, approximately 60% of the total yield would be measured over the Crump weir, whereas flow would be measured over the Crump for over 99% of the time.

The impact of the gauging weir on the water (stage) and energy levels upstream of the structure is shown in Figure 7 for different flow rates. The results of the calculations used to draw Figure 7 are shown in Table 2. The small difference in upstream energy level and stage upstream of the structure at the design discharge of 210 m³/s (0,078 m) shows that the approach velocity in the channel will be very slow. This will assist greatly in improving the gauging accuracy.

Table 2: Discharge - stage relation for the Vals River @ Tweefontein upstream of the existing weir.

Stage (m)			Energy Elevation (m)		
Discharge (m^3/s)	**Water level above low notch (m)**	**Stage elevation above M.S.L. (m)**	**Discharge (m^3/s)**	**Energy level above low notch (m)**	**Energy elevation above M.S.L. (m)**
20.00	0.520	1263.220	20.00	0.522	1263.222
30.00	0.642	1263.342	30.00	0.645	1263.345
40.00	0.749	1263.449	40.00	0.755	1263.455
50.00	0.846	1263.546	50.00	0.854	1263.554
60.00	0.936	1263.636	60.00	0.947	1263.647
70.00	1.021	1263.721	70.00	1.035	1263.735
80.00	1.101	1263.801	80.00	1.119	1263.819
100.00	1.250	1263.950	100.00	1.275	1263.975
150.00	1.580	1264.280	150.00	1.627	1264.327
200.00	1.869	1264.569	200.00	1.941	1264.641
250.00	2.078	1264.778	250.00	2.170	1264.870
300.00	2.236	1264.936	300.00	2.341	1265.041
350.00	2.373	1265.073	350.00	2.492	1265.192
400.00	2.491	1265.191	400.00	2.624	1265.324
450.00	2.598	1265.298	450.00	2.746	1265.446
500.00	2.696	1265.396	500.00	2.859	1265.559
600.00	2.872	1265.572	600.00	3.064	1265.764
700.00	3.026	1265.726	700.00	3.247	1265.947
800.00	3.165	1265.865	800.00	3.416	1266.116
900.00	3.293	1265.993	900.00	3.572	1266.272
1000.00	3.408	1266.108	1000.00	3.717	1266.417
1027.00	3.438	1266.138	1027.00	3.755	1266.455

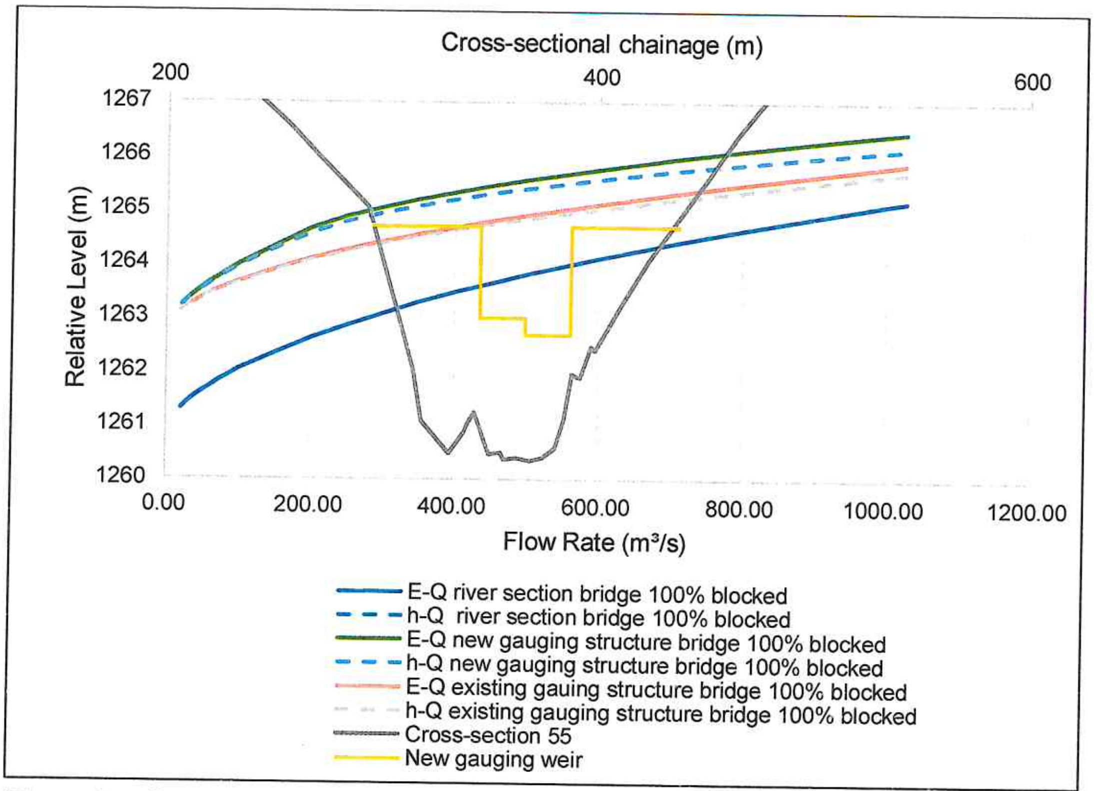


Figure 7: Stage and energy levels upstream of the Tweefontein gauging structure.

3.2.2 Structural Design

To determine if the structure, as designed during the hydraulic design phase, are safe in terms of overturning, sliding and crushing, the different structural components need to be analysed against the forces acting upon them. The method used was that of Kroon (1984) in *Swaartekrag Damstrukture*. The primary forces acting upon these different structural components are water/hydrostatic pressure, uplift pressure, sediment pressure and the self-weight of the structure. Figures 9 to 11 show the schematics of loads acting on weirs, cut-off walls and flank walls respectively. Each component needed to be checked for stability against sliding, overturning and cracking. Adjustments to the structural design are applied if the component does not adhere to the prescribed safety limit.

Two flow scenarios were considered during the stability calculations for the Tweefontein gauging weir. The first scenario was for flow occurring at the design head of 2.0 m (210 m³/s) above the low notch crest. The second scenario catered for a surcharge head of 1.5 m above the design head of 2.0 m, with downstream water levels corresponding to the design flow conditions. For each of the structural components, stability was analysed at the highest, as well as at the lowest parts of the river cross-section (see Figure 8).

Addendum C summarises the different forces acting upon each of these structural components, along with the safety factor against sliding and overtopping.

The gauging weir stability was found to be satisfactory. However, to ensure that the cut-off walls adhere to the stability limits, a downstream slope of 0.55: 1 (H: V) was added to the cross-section. To avoid confusion during construction, the same downstream slope was specified for both the left- and right bank cut-off walls. The final structure was found to be within the failure safety factors and was, therefore, assumed to be stable.

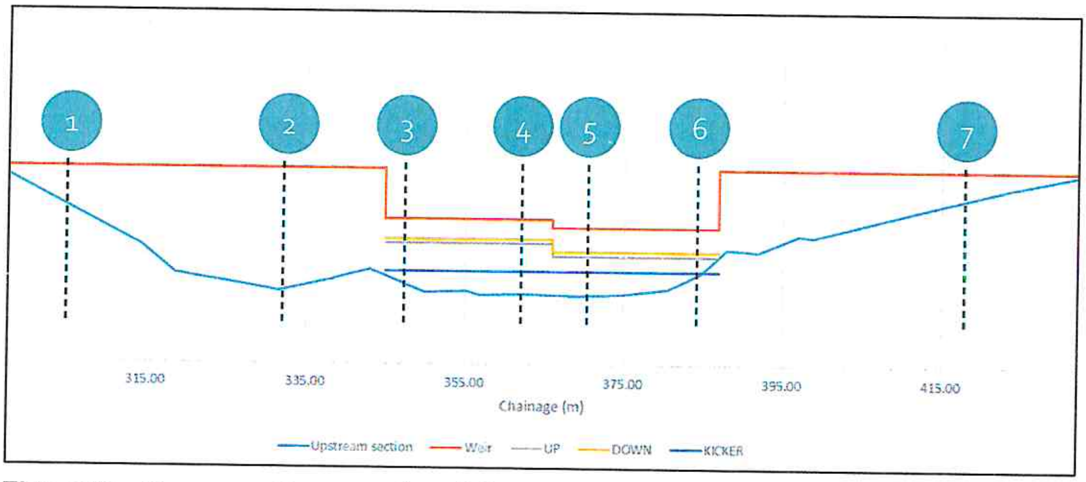


Figure 8: Cross sections analysed for stability at each of the different structural components.

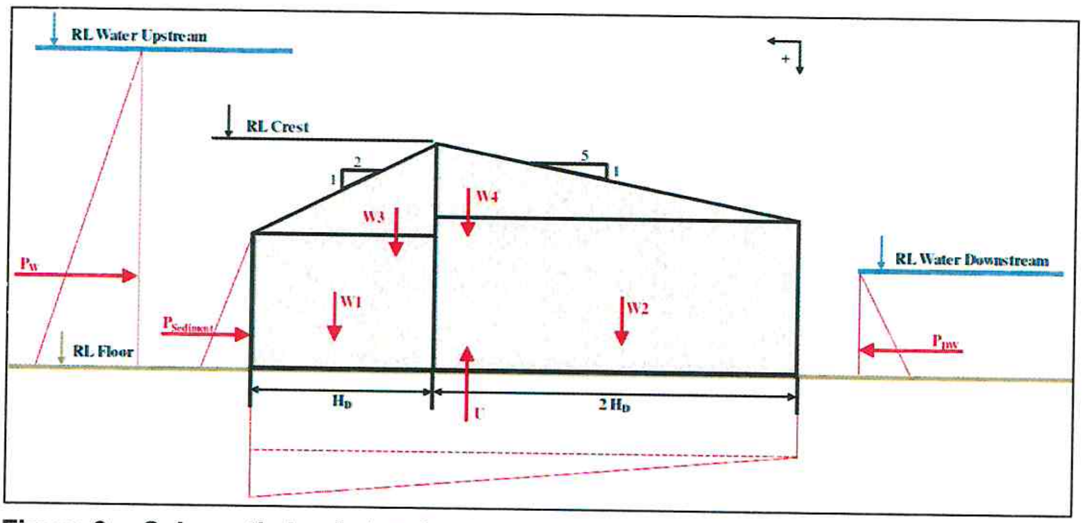


Figure 9: Schematic loads involved in stability calculations for weirs.

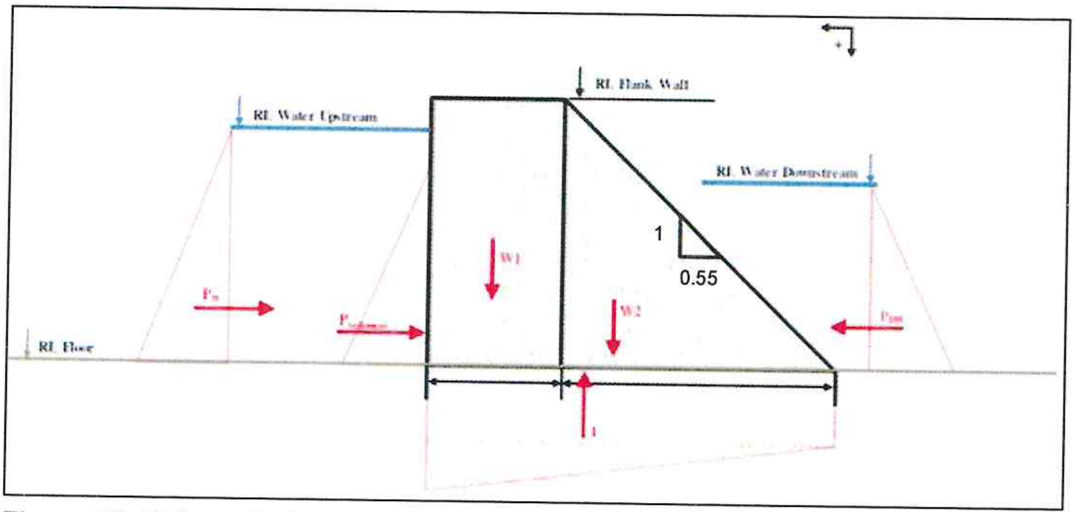


Figure 10: Schematic loads involved in stability calculations for cut-off walls.

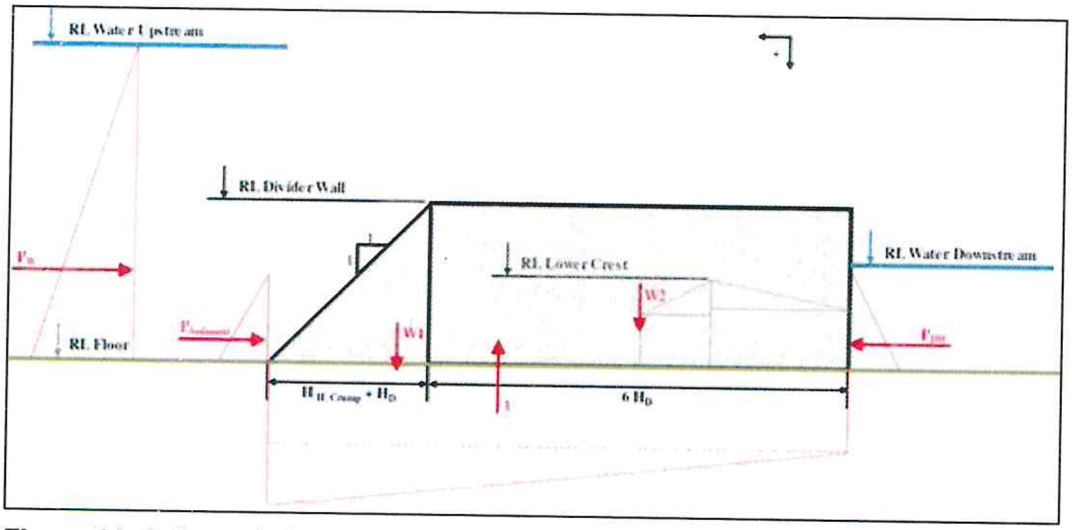


Figure 11: Schematic loads involved in stability calculations for flank walls.

3.2.3 Erosion Protection

The exact extent of solid rock on the banks of the site selected for the construction of the Tweefontein gauging weir is not yet known. From a visual inspection, the right banks seem to have solid rock, however, the extent of rock on the left bank is not yet known. Therefore, rip-rap protection needed to be included in the design of the gauging structure.

The difference between upstream and downstream energy levels, increases the erosion potential of the water flowing past the structure across the floodplain, by increasing the flow velocity in this area potentially to a maximum of close to 3.8 m/s. To combat the erosion potential of this swiftly flowing water, it is very important to anchor the cut-off wall in solid rock up to the crest level of the wall.

Additional erosion protection will also be required against and on top of the riverbanks and the floodplain, as shown in Figure 4, to prevent or minimise erosion damage around these areas. The relationship used for sizing rip-rap is based on tractive force theory and was derived for straight channels under uniform flow. However, a factor has been included to account for the turbulent flow conditions typically present in rivers (Van Vuuren, et al., 2013). The methods used for rip-rap calculation, as given in the SANRAL Road Drainage Manual Version 1 were used to design the rip-rap for the river banks. The table in Addendum D shows the detailed calculations performed for the design of the rip-rap.

The rip-rap for the banks at the Tweefontein gauging structure was sized for a flow rate of 3000 m^3/s. Rip-rap sizes are specified to range between 350 mm and 450 mm for a safety factor ranging between 2.5 and 3.0. The extent of the erosion protection will be specified by the design engineer on site, once the in-situ conditions are better known.

3.2.4 Rating of the gauging weir structure

The stage-discharge relationship (rating) of the gauging structures can only be established once the construction of the weir structures is completed. A complete and detailed as-built survey of the structure, the upstream river section in line with the stage measurement equipment and the riverbanks is required to establish a rating.

Please note that these ratings are not stable over time. Variable channel conditions upstream of a structure, such as a sediment build-up, could seriously influence the rating of a structure. This will necessitate the regular survey of a structure to correct the rating if necessary. Changes downstream of structures could also necessitate that corrections for submergence need to be applied in the future. If required, additional stage recording instrumentation to monitor downstream water levels will have to be installed. These readings should then be used to correct for submergence.

In general, is it advised to check the rating of a structure at least once every five years or after a drought or major flood event at the structure or if any changes have been made to the structure.

4. MISCELLANEOUS DESIGN ASPECTS

4.1 GEOTECHNICAL

No detailed geotechnical investigation, such as drilling of core holes to determine the depth of excavation required etc., was carried out at the gauging site. Sites were selected to suit the hydraulic gauging requirements but also by observing rock foundation conditions in the river channel.

4.2 STRUCTURAL

All gauging structure components such as Crump sections, dividing/flank walls and cut-off walls were analysed to ensure stability. Critical forces (upstream and downstream water and sediment pressure, uplift) have been considered.

4.3 FOUNDATION PREPARATION

Sound rock has to be completely exposed and all organic material and debris removed before placement of concrete commences, to ensure proper rock/concrete contact.

4.4 CONCRETE SPECIFICATION

- Crump weir sections: Grade 25/19
- Dividing/flank walls: Grade 25/19
- Cut-off walls: Grade 25/19
- Instrumentation hut: Grade 25/19
- Instrumentation hut base: Grade 15/19
- Conduit pipe protection: Grade 15/19

Note: Rubble masonry concrete (RMC) may be used for the construction of the base of instrumentation huts. RMC may also be utilised in the construction of cut-off walls, provided that the finishing of the top of these walls adheres to the standards specified in the design drawings. If RMC is to be used for cut-off walls, the dimensions of these walls need to be verified to ensure structural stability.

4.5 INSTRUMENTATION

All instrumentation (gauge plates, pressure transducers, data loggers, rain gauges, real-time platforms, instrumentation housing etc.) should comply with the standards and specifications as set by the Directorate: Hydrological Services in DWS.

Gauge plates need to be installed at the gauging structure at the position specified in the design drawings. Gauge plates are required to assist officials to enable correct settings for the electronic equipment and to take manual control readings to detect incorrect stage readings or failure of the electronic equipment. Provision has been made for the installation of water quality monitoring instrumentation. This instrumentation could be installed whenever required.

Due to the extreme level of vandalism experienced at gauging stations only reinforced concrete instrumentation huts as specified in the design drawings will be constructed to house data loggers and communication equipment at the sites.

4.6 Design Drawings

Copies of the design drawings of the Tweefontein Gauging Weir is included in the addenda as follow:

- Addendum E: Engineering drawings – Tweefontein Gauging Structure

5. SERVITUDES

Servitudes need to be registered on the affected properties. These servitudes are necessary to allow DWS officials to collect data and maintain the gauging structures and the immediate surrounding areas in future. No provision has been made for the registration of temporary servitudes during the construction phase of the structures.

If required, permanent servitudes to grant access to the gauging stations from the nearest public road should also be registered. Before registration of these servitudes, the access routes need to be negotiated with landowners and the necessary inputs from officials in Hydrological Services.

6. REFERENCES

Ackers, P., White, W.R., Perkins, J.A., Harrison, A.J.M. (1978): 'Weirs and Flumes for Flow Measurement', John Wiley & Sons, Chichester.

AECOM SA (Pty) Ltd. (2016): 'Review, Evaluation and Optimisation of the South African Water Resources Monitoring Network: Scientific Review Report', Pretoria: Department of Water and Sanitation.

BSI 3680: Part 4b (1986): 'Measurement of Liquid Flow in Open Channels – Triangular Profile Weirs', BSI, London.

Kroon, J., 1984. *Swaartekrag damstrukture,* Pretoria: University of Pretoria.

van Heerden, J. J., van der Spuy, D. & le Roux, P. J., 1985. *Manual for the planning, design and operation of river gauging stations,* Pretoria: Department of Water Affairs.

van Vuuren, S. J. et al., 2013. Revetments: Riprap protection. In: E. Kruger, ed. *Drainage manual.* Pretoria: SANRAL, pp. 8.44-8.45.

Wessels, P. & Rooseboom, A., 2009. Flow-gauging structures in South African Rivers Part 2: Calibration. *Water SA,* 35(1), pp. 11-19.

ADDENDA:

ADDENDUM A: Stage and Energy Levels - Downstream of Existing Weir

ADDENDUM B: Sensitivity Analysis – Chezy k Roughness Parameter

ADDENDUM C: Stability Analysis

ADDENDUM D: Rip-rap Design

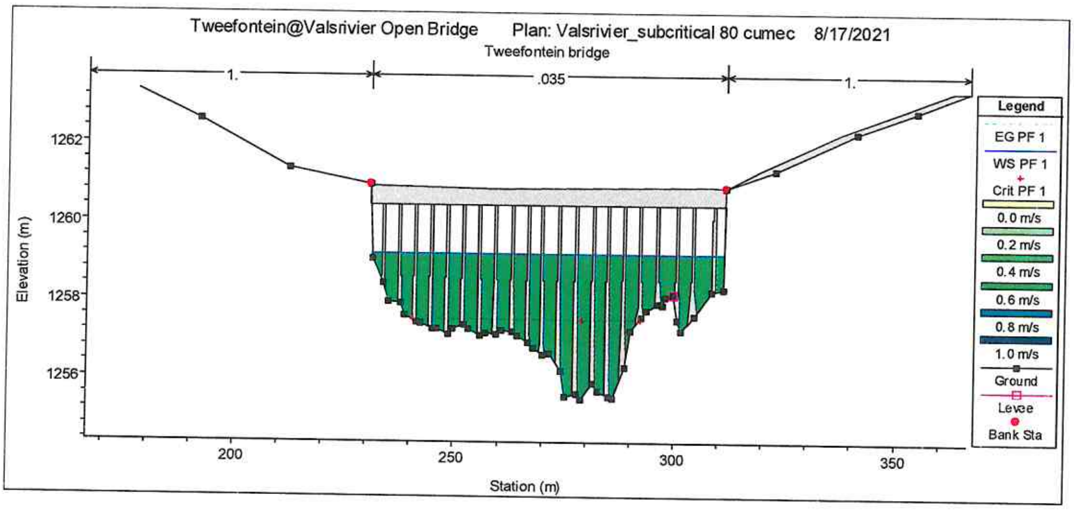
ADDENDUM E: Engineering drawings – Tweefontein Gauging Structure

ADDENDUM A:

STAGE AND ENERGY LEVELS - Downstream of Existing Weir

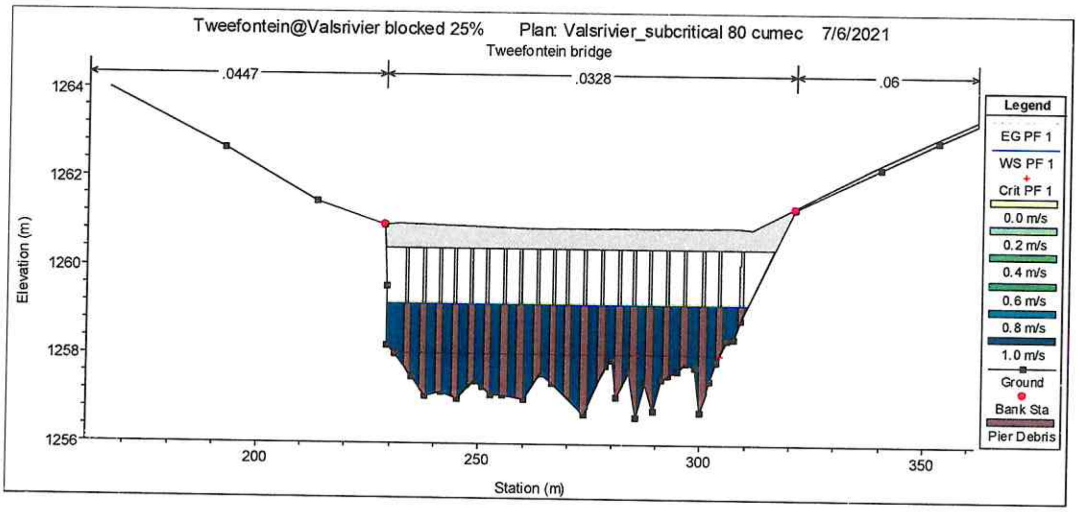
ADDENDUM A: STAGE AND ENERGY LEVELS DOWNSTREAM OF EXISTING TWEEFONTEIN WEIR

BRIDGE OPENING 0% BLOCKED



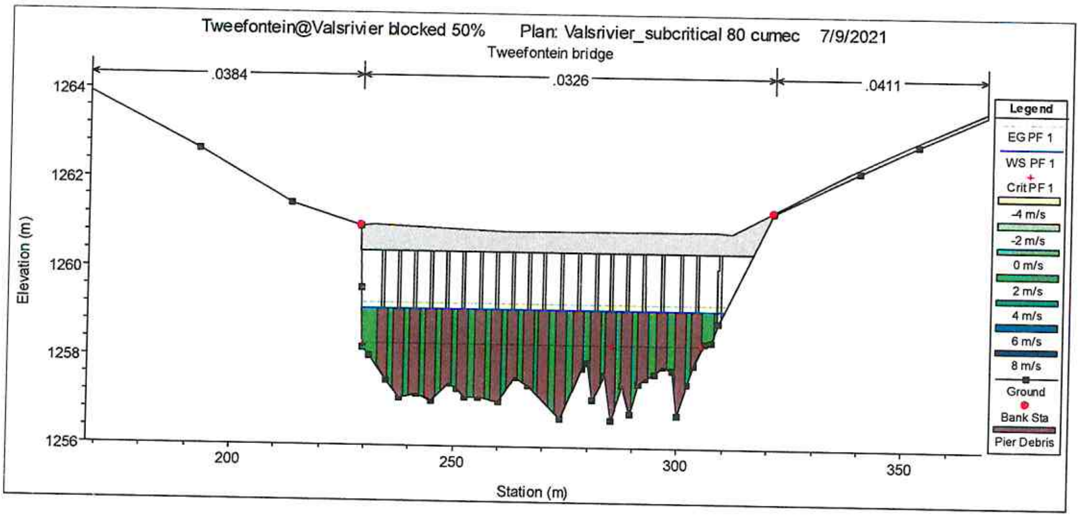
Discharge (m^3/s)	Water Level (m)	Energy Level (m)	Discharge (m^3/s)	Water Level (m)	Energy Level (m)
20.00	1261.21	1261.21	300.00	1262.82	1262.93
30.00	1261.33	1261.34	350.00	1263.00	1263.12
40.00	1261.45	1261.46	400.00	1263.17	1263.31
50.00	1261.54	1261.55	450.00	1263.33	1263.49
60.00	1261.62	1261.64	500.00	1263.48	1263.65
70.00	1261.70	1261.72	600.00	1263.77	1263.96
80.00	1261.77	1261.79	700.00	1264.03	1264.24
100.00	1261.90	1261.93	800.00	1264.28	1264.51
150.00	1262.18	1262.23	900.00	1264.51	1264.76
200.00	1262.42	1262.49	1000.00	1264.76	1265.02
250.00	1262.63	1262.72	1027.00	1264.83	1265.10

Bridge openings 25% blocked



Discharge (m^3/s)	Water Level (m)	Energy Level (m)	Discharge (m^3/s)	Water Level (m)	Energy Level (m)
20.00	1261.21	1261.21	300.00	1262.82	1262.93
30.00	1261.33	1261.34	350.00	1263.00	1263.12
40.00	1261.45	1261.46	400.00	1263.17	1263.31
50.00	1261.54	1261.55	450.00	1263.33	1263.49
60.00	1261.62	1261.64	500.00	1263.48	1263.65
70.00	1261.70	1261.72	600.00	1263.77	1263.96
80.00	1261.77	1261.79	700.00	1264.03	1264.25
100.00	1261.90	1261.93	800.00	1264.28	1264.51
150.00	1262.18	1262.23	900.00	1264.51	1264.77
200.00	1262.41	1262.49	1000.00	1264.76	1265.02
250.00	1262.63	1262.71	1027.00		

BRIDGE OPENINGS 50% BLOCKED



Discharge (m^3/s)	Water Level (m)	Energy Level (m)	Discharge (m^3/s)	Water Level (m)	Energy Level (m)
20.00	1261.21	1261.21	300.00	1262.82	1262.93
30.00	1261.33	1261.34	350.00	1263.00	1263.12
40.00	1261.45	1261.46	400.00	1263.17	1263.31
50.00	1261.54	1261.55	450.00	1263.34	1263.49
60.00	1261.62	1261.64	500.00	1263.51	1263.67
70.00	1261.70	1261.72	600.00	1263.79	1263.98
80.00	1261.77	1261.79	700.00	1264.05	1264.26
100.00	1261.90	1261.93	800.00	1264.30	1264.53
150.00	1262.18	1262.23	900.00	1264.52	1264.77
200.00	1262.42	1262.49	1000.00	1264.76	1265.03
250.00	1262.63	1262.71	1027.00		