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**public works**  
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Public Works  
REPUBLIC OF SOUTH AFRICA

## **BEIT BRIDGE DEVELOPMENT OF MASTER PLAN REF: 17/1/4/1/6022/10**

### **CIVIL ENGINEERING STATUS QUO**

FINAL REPORT  
REVISION 00

**March 2023**

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# 1 INTRODUCTION

## 1.1 BACKGROUND

Beit Bridge Border Post is the port of entry and a customs and immigration post between Zimbabwe and South Africa situated in the Musina Local Municipality in South Africa.

The project is initiated by the client of the National Department of Public Works which is the Border Control Operating Coordinating Committee (BCOCC). The National Department of Public Works (DPW) appointed Delta Built Environment Consultants (Delta BEC) to develop and compile a Master Plan for the Beit Bridge Port of Entry. The approved Master Plan will be cost-effective, provide the required facilities for tenants and ensure world class cross-border operations.

The project entails the preparation of a comprehensive master plan for Beit Bridge Port of Entry. The master planning is undertaken to provide better planning of the port of entry to address land use and transportation effects of the border post. The master plan will seek to achieve the promotion of the government's objectives of economic development, good governance and rising living standards and prosperity by providing and managing the accommodation, infrastructure needs of national departments, by leading the national Expanded Public Works Programme and transformation of the construction and property industries.

The objectives of the Master Plan are:

- The master plan will be based on an area of between 120 hectares and is undertaken to provide better planning of the port of entry to address land use and transportation effects of the border post.
- The Master Plan will therefore serve as a blueprint informing the structuring of the port of entry environment which includes the operational flow and dynamics, the placement and positioning of buildings, facilities and infrastructure as well as the alignment of roads.

The project will be executed through implementation of three project phases comprising of twelve main tasks:

- Phase One : Inception and Status Quo analysis
- Phase Two : Preparation of Spatial Development Concept
- Phase Three: Master Plan Finalisation

The tasks to be executed during implementation of the above project phases include the following:

- Task One: Inception and Status Quo Analysis
- Task Two: Preparation of Spatial Development Concept
- Task Three: Master Plan Finalisation

- Task Four: Land Surveying and Orthophoto Mapping
- Task Five: Environmental Screening and Impact Assessment
- Task Six: Civil Engineering Investigation
- Task Seven: Electrical Engineering Investigation
- Task Eight: Geotechnical Investigation
- Task Nine: Conveyancing
- Task Ten: Heritage Assessment(HIA)
- Task Eleven: Traffic Impact Assessment
- Task Twelve: Urban Design

## 1.2 PURPOSE OF REPORT

The purpose of this report pertains to the analysis and review of the current civil engineering Status Quo of the border post as well as the surrounding area. This report will contextualise the current civil engineering status quo of the border post as well as provide an overview of the most salient civil engineering considerations influencing the conceptualisation of a new master plan.

## 1.3 STRUCTURE OF REPORT

The report comprises the following sections:

- Section 2: Description of the site
- Section 3: Infrastructure and bulk services
- Section 4: Floodline
- Section 5: Demand
- Section 6: Conclusion

## 2 APPROACH AND METHODOLOGY

The methodology that will be adopted during the civil engineering status quo assessment is outlined below:

- Firstly, analyse and review the current civil engineering operations at the border post.
- Secondly, contextualise the current civil engineering operations of the border post in terms of capacity and demand.
- Thirdly, provide an overview of the most salient civil engineering considerations influencing the conceptualisation of a new master plan.

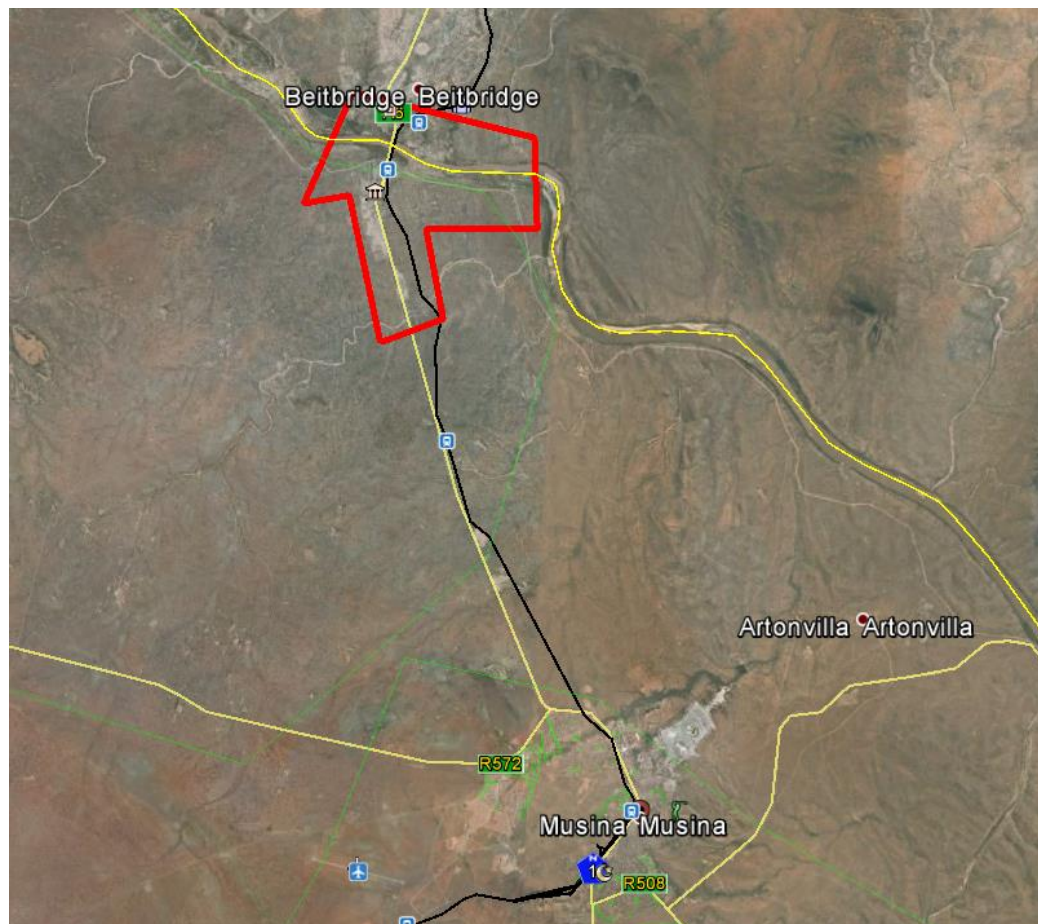


### 3 SITE LOCATION

The Beit Bridge Border Post is the main point of entry into South Africa from Zimbabwe. The Border Post is classified as a National Key Point and is operated by the Department of Public Works. The Beit Bridge Border Post is situated within the Musina Local Municipality in Limpopo Province. The Beit Bridge Border Post can be accessed by the N1 National Road which runs in a south to north direction. The N1 connects the central parts of South Africa with Zimbabwe and also further north.

The Beit Bridge Border Post is situated approximately 15km north of Musina and just south of the Limpopo River. The Beit Bridge Border Post is the busiest of the country's point of entries in South Africa.

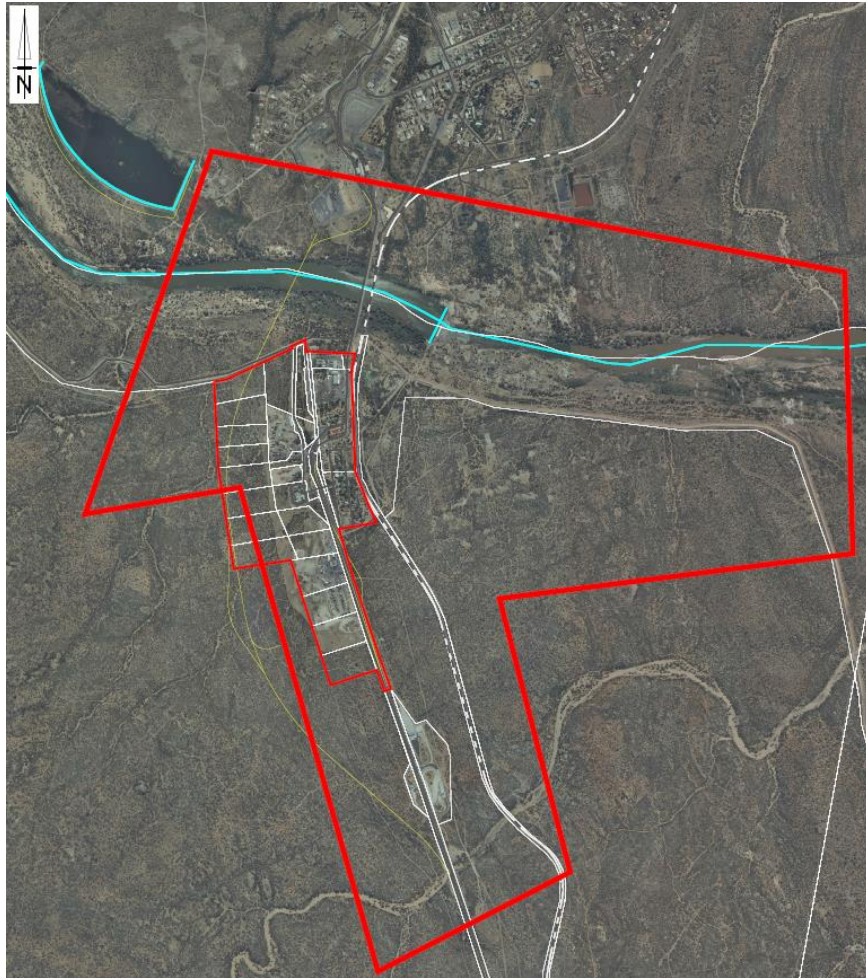
The locality plan is indicated in **Figure 3-1**.



**Figure 3-1** Locality Plan

A study area of approximately 1088 Ha has been delineated as a larger area of interest. The area which will be focussed on in more detail and be known as the Master Plan area will be delineated in the following phase. The larger study area is indicated in **Figure 3-2**.





**Figure 3-2 Larger Study Area**

## 4 INFRASTRUCTURE AND BULK SERVICES

### 4.1 WATER SUPPLY

The Beit Bridge area has a private water reticulation network, which is independent from the Musina Municipality. The 2ML capacity reservoir on site is fed through a 160mm diameter galvanised pipeline from the Limpopo River through river pumps. As-built drawing (drawing number unknown) reference WCS number 045232 sourced from Virtual Consulting Engineers indicates another 160mm diameter galvanised/asbestos pipeline supplying the Beit Bridge Reservoir from the Zimbabwe side. The border manager would, however, like to discontinue this supply, as the quality of the water is questionable, and South Africa should have an independent water supply.

Another source of water supply is through three boreholes which are located on site at the following coordinates S 22°24'36.2" E 30°01'86.0", S 22°24'47.8" E 30°01'89.9" and S 22°24'40.1" E 30°01'87.3". The borehole water is pumped with an 11kW pump at a rate of 8l/s @98m. The pipeline is approximately 5km long and 100mm to 150mm in diameter. The information regarding the boreholes and pipeline was made available by Mr Frikkie Brand of Virtual Consulting Engineers. The water supply at the border post is mainly for the consumption of travellers and domestic purposes. The main water usage is for public ablutions for pedestrians, motorists, bus passengers and truck drivers. Residential water usage is for 29 households and one SAPS barracks. The border supplies the Shell Ultra City and Private Developers opposite the border post's top residential houses non-purified water.

### 4.2 POTABLE WATER RETICULATION

Beit Bridge has a single reticulation network for both potable and fire water. The reticulation network can be summarised as follows:

- 160mm diameter uPVC pipeline
- 110mm diameter uPVC pipeline
- 90mm diameter uPVC pipeline
- 75mm diameter uPVC pipeline
- Twenty two number of gate valves varying with pipe size
- Eight number of fire hydrants
- Thirty shut-off valves

A layout of this existing water reticulation network is presented on Drawing No. P13163-SQ-03-WR-001 in Annexure A

### 4.3 SEWAGE DISPOSAL

The Beit Bridge sewage network is also independent of the Musina Municipality. The sewage drains to the waste water treatment works located on site as indicated on the as-built drawing attached in Appendix A with no known drawing number. The sewage inflow is estimated at between 300 – 400m<sup>3</sup> per day. Approximately 550m meters of the sewer drainage network, indicated in Layout Drawing No. P13163-SQ-03-SR-001 by a dashed line, drains northwards and is then pumped through a 160mm uPVC pump line to the waste water treatment works which is located east of the border post. The remaining network comprises a 150mm diameter clay pipeline network which drains to the waste water treatment works.

On-site inspection indicated that the sewage system is fully functional with no visible problems, such as overflowing manholes and no complaints from the border control manager and residents.

A layout of the sewer network is presented on Drawing No. P13163-SQ-03-SR-001 in Appendix B

### 4.4 ROADS

The border post's roads are surfaced, with the surfacing still in good condition. There are existing road signs and paint markings. The site also has demarcated parking areas for both trucks and vehicles

### 4.5 SIDEWALKS

Pedestrians have demarcated walkways constructed of paving blocks, and painted road crossings where required.

### 4.6 STORMWATER

The stormwater management at Beit Bridge is mainly surface run-off. The stormwater drawings sourced from Public Works appear to be outdated in comparison to the current layout of the border post. The layouts also indicate berms which are not visible on site. There are very few visible formal stormwater structures. There are two inlets which collect water which is transported through an underground pipeline and discharge into the natural environment as is indicated on layout P13163-SQ-03-SW-002. There are also structures such as the trapezoidal channel indicated in **Figure 3-1**, which also discharge into the natural environment.



Figure 4-1 Trapezoidal channel discharging into the natural environment



## 5 FLOOD LINE CALCULATION

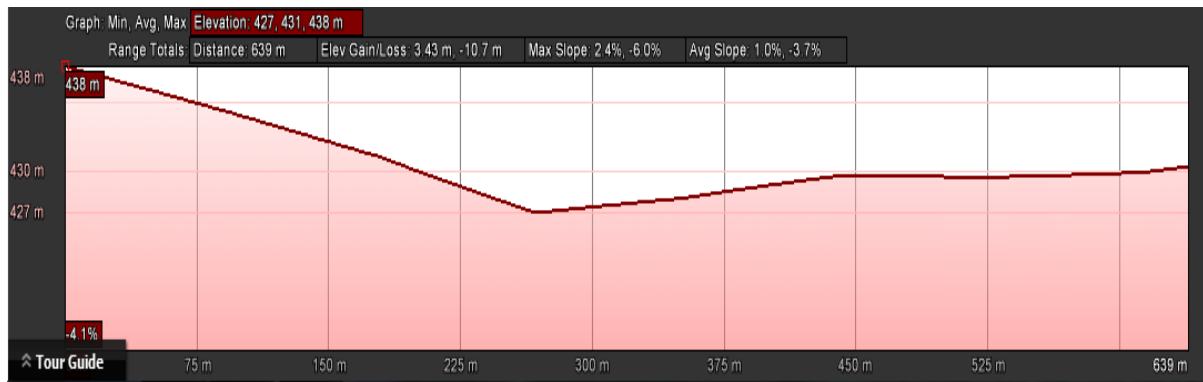
### 5.1 TOPOGRAPHY AT BEIT BRIDGE

Beit Bridge is situated at the Limpopo River with a mean elevation of 427m above sea level. Located adjacent to a river makes the border vulnerable to flooding, thus the need for the determination of the 1:100 year floodline. Legislation requires that town establishments not be placed within the 1:100 year floodline.

The topography of the area is further explained graphically in Figure 5-1 and Figure 3-2.



Figure 5-1 Layout of cross section AA (refer to Figure 2-2 for section AA)



**Figure 5-2 Typical topography at Beit Bridge**

## 5.2 DETERMINING THE 1 IN 100 YEAR FLOODLINE

The one in hundred year flood refers to a storm occurrence which will in all probability not occur at a frequency of more than once every 100 years. The description “floodline” refers to the line which can be drawn indicating the backwater (flooding) effects caused by a high water surface profile.

### 5.2.1 RAINFALL

Data for the site was obtained from the Department of Water Affairs website, which is <http://www.dwa.gov.za/hydrology/HyDataSets.aspx?Station=A7H008>. The Limpopo River forms the northern boundary of quaternary catchment A71K. The catchment area spans 202 985km<sup>2</sup>. Flow data from measuring station A7H008, which is located just south of Beit Bridge at 22.22727° Latitude and 29.99031° Longitude was used for the flood estimation. Data is available from 1992 to 2014, during this time period data is not available for 1994 and 2002.

Table 5-1 Station A7H008 Peak Annual Flow

| Date     | Flow (m <sup>3</sup> ) |
|----------|------------------------|
| 19921226 | 1723.834               |
| 19931231 | 2991.292               |
| 19950222 | 2094.356               |
| 19960129 | 3148.307               |
| 19970405 | 379.253                |
| 19980201 | 496.04                 |
| 19990122 | 653.807                |
| 20010304 | 685.451                |
| 20011207 | 408.56                 |
| 20030110 | 502.98                 |
| 20040307 | 1510.934               |
| 20050124 | 700.709                |
| 20060125 | 663.233                |
| 20070330 | 856.25                 |
| 20080110 | 922.713                |
| 20090201 | 1535.344               |
| 20100406 | 1072.788               |
| 20110109 | 1439.497               |
| 20120106 | 161.978                |
| 20130120 | 8815.039               |
| 20140313 | 1396.728               |



Table 5-2 Result of flood peak estimation according to statistical methods

| Return Period | Method  |                      |                       |          |                |                            |                            |            |             |
|---------------|---------|----------------------|-----------------------|----------|----------------|----------------------------|----------------------------|------------|-------------|
|               | Log 10  | Extreme value Type 1 | General Extreme value |          | Log normal     |                            |                            | Log Gumbel | Log Pearson |
|               |         |                      | EV2                   | EV3      | Q <sub>T</sub> | Q <sub>T</sub> (Lower 95%) | Q <sub>T</sub> (Upper 95%) |            |             |
| 2             | 1573.68 | 1 268.38             | 123.49                | Infinite | 1 041.48       | 704.00                     | 1 540.74                   | 901.52     | 1006.61     |
| 5             | 3165.68 | 2 935.65             | 719.86                | Infinite | 2 207.24       | 659.67                     | 1 644.28                   | 1982.66    | 2183.64     |
| 10            | 3998.39 | 4 042.24             | 719.86                | Infinite | 3 271.25       | 613.78                     | 1 767.21                   | 3345.20    | 3342.35     |
| 20            | 4685.93 | 5 104.57             | 719.86                | Infinite | 4 513.50       | 571.08                     | 1 899.34                   | 5527.25    | 4805.51     |
| 50            | 5459.72 | 6 476.75             | 719.86                | Infinite | 6 512.22       | 521.68                     | 2 079.21                   | 10573.14   | 7316.41     |
| 100           | 5975.33 | 7 509.57             | 719.86                | Infinite | 8 364.91       | 489.52                     | 2 215.79                   | 17227.91   | 9741.08     |
| 200           | 6451.35 | 8 542.40             | 719.86                | Infinite | 10 460.30      | 461.30                     | 2 351.35                   | 28071.20   | 12716.39    |

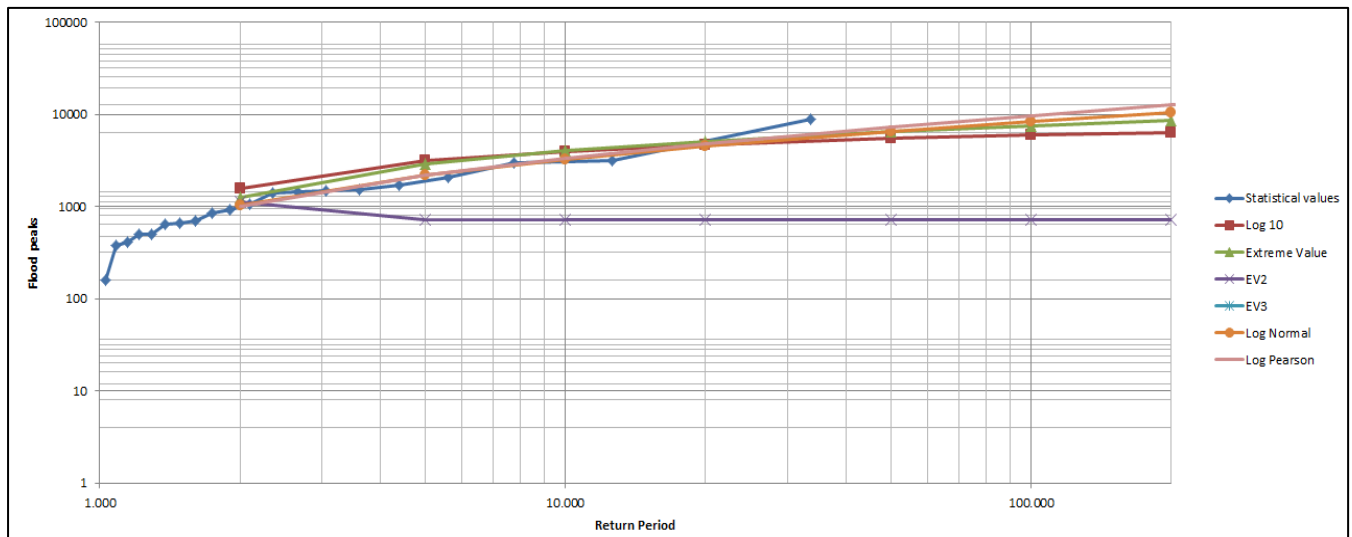


Figure 5-3 Graph comparison of statistical methods

Log Pearson provides the graph closest to the statistical values. This method is also the most widely recognised statistical method with municipalities such as the City of Tshwane Metropolitan Municipality recommending it. The results computed from Log Pearson are thus the flood peaks utilised for the computation of the floodline in HEC-RAS.

### 5.3 HEC-RAS MODELLING

Delta BEC used the HEC-RAS program developed by the US Department of Defence to determine the extent of the 1 in 100 year flood. The program determines the backwater effect caused by the increase in flow as well as the contraction and expansions and the change in elevation. The program is based on the conservation of energy principles as outlined by Bernoulli.

### 5.3.1 USER INPUT VALUES

To use the HEC-RAS program, initial user input values are needed such as:

- Profile and layout of the River (Survey)
- Location and details of bridges
- Peak flow
- Control point

#### 5.3.1.1 Survey

In order to determine both the layout as well as the profile of the River, Delta BEC appointed FJ Look Surveyors to conduct a detailed survey of Beit Bridge for the purpose of defining the floodline. The output result of the layout contours are graphically illustrated in Figure 5-4.



**Figure 5-4** Surveyors impression of Beit Bridge

A typical cross section of the River is outlined in Figure 4-3. The cross section is directly programmed into HEC-RAS in order to determine the complete layout of the River. Cross sections were spaced at 20 metre intervals, as this interval provides the best use of information and allows us to model the River as accurately as possible.

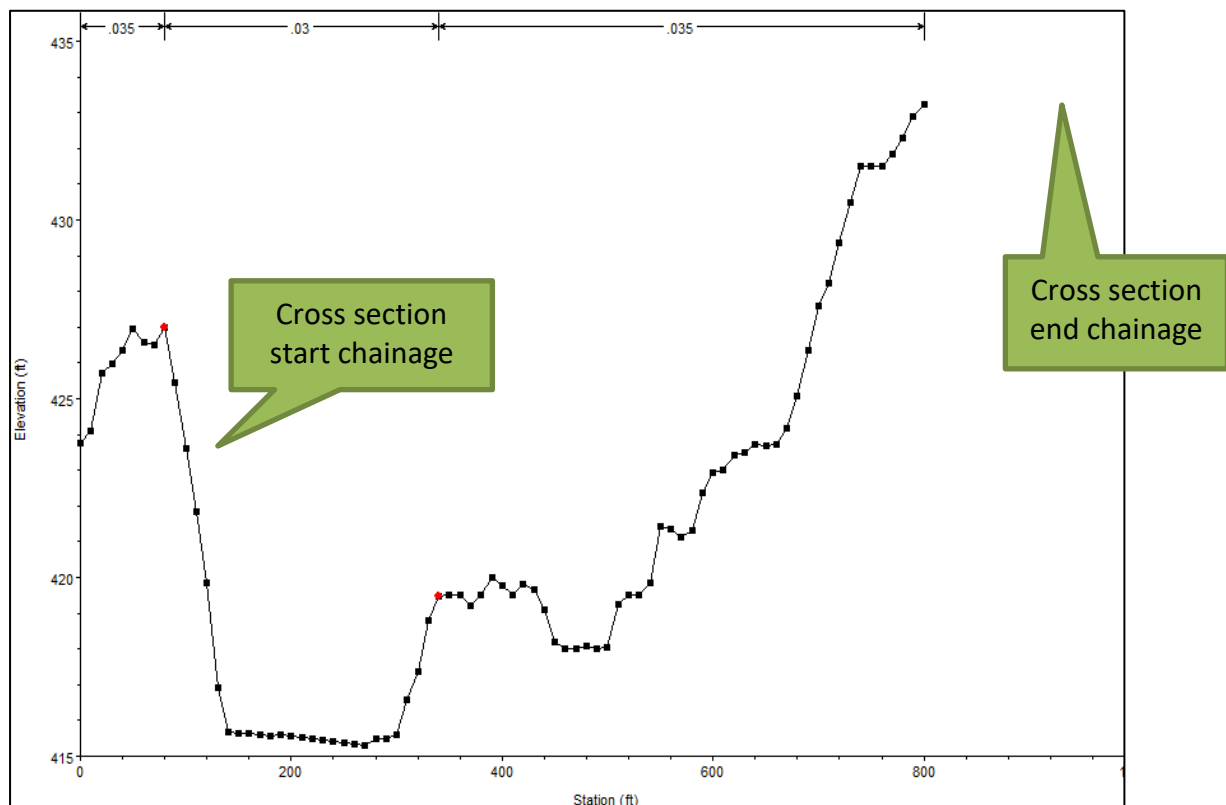


Figure 5-5 River Typical Cross Section

### 5.3.1.2 Control point

The control point refers to a section of the River where a known water surface profile can be calculated/measured. This point will serve as the calibration point from where all surface profiles will be calculated. For the purpose of this study the control point identified to best serve the modelling of the River is the Department of Water Affairs and Forestry measuring station A7H008. This point is selected as flows for it are available. The assumption made by Delta BEC was that the section of the River will enter the critical flow regime, and as such will have a defined water surface profile that can be used in all subsequent calculations.

The Super-critical flow is downstream while sub-critical flow, is located upstream. During the 1 in 100 year flood, the flow would be super critical and the downstream conditions would thus control the flow.

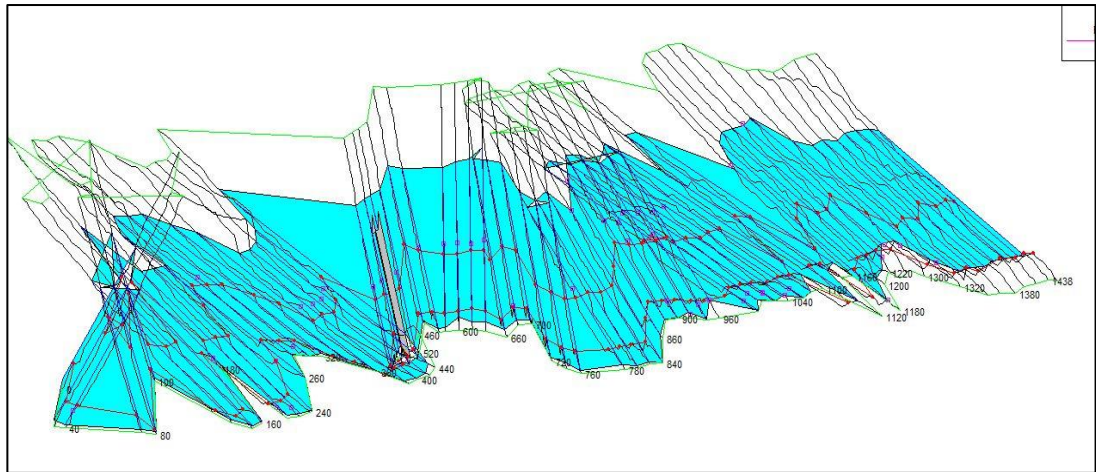


Figure 5-6 HEC-RAS output results

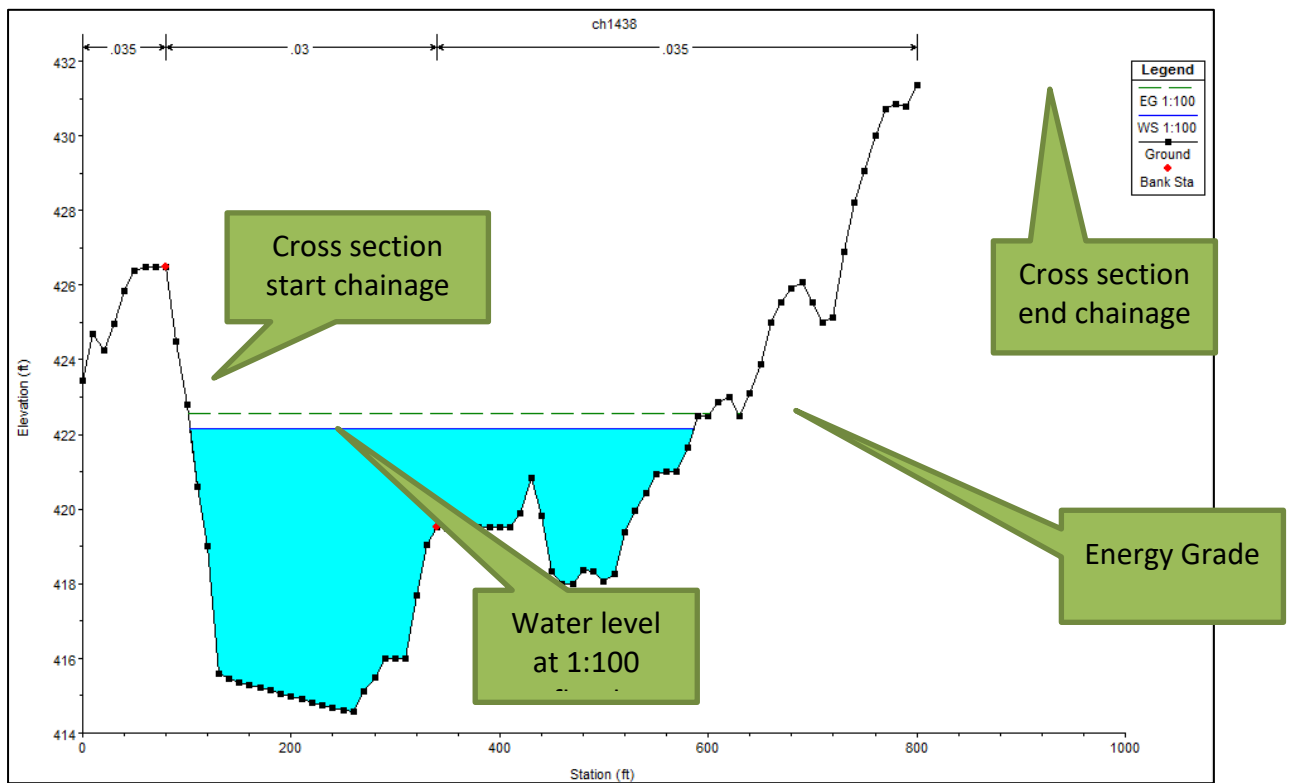


Figure 5-7 HEC-RAS output results – cross section view

## 5.4 CONCLUSION

The extent of the 1:100 year floodline has been statistically determined. Beit Bridge is located in quaternary catchment A71K. The Department of Water Affairs has measuring stations at various points across the country. Measuring station A7H008 is located just south of the Beit Bridge within quaternary catchment A71K. This measuring station was utilised as a control point for the determination of this floodline.

## **6 CURRENT TRAFFIC PROCEDURES AND SHORT COMINGS**

### **6.1 CAPACITY OF TWO-LANE BRIDGE CROSSING**

The capacity of the narrow single carriageway two-lane bridge that crosses the Limpopo River is limited by the upstream and downstream traffic flow and control conditions. The current average daily demand of about 1,000 vehicles is only a small proportion of the potential capacity if the bottlenecks upstream and downstream of the bridge are eliminated. The current average daily demand of 5,000 vehicles per day on the N1 between Beit Bridge and Musina is a good indication of the capacity of a single carriageway two-lane road without any upstream and downstream bottlenecks (i.e. theoretical maximum throughput of the bridge).

### **6.2 OPERATIONAL LIMITATIONS AND BOTTLENECKS**

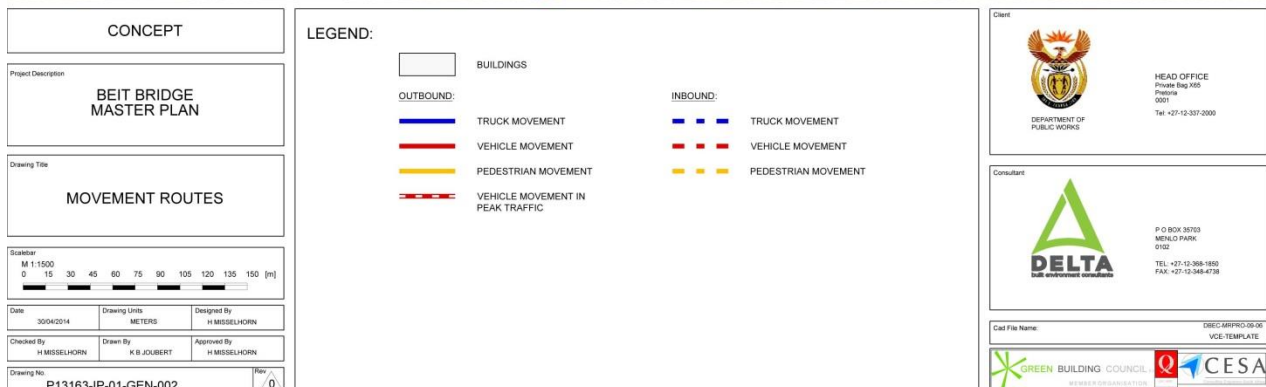
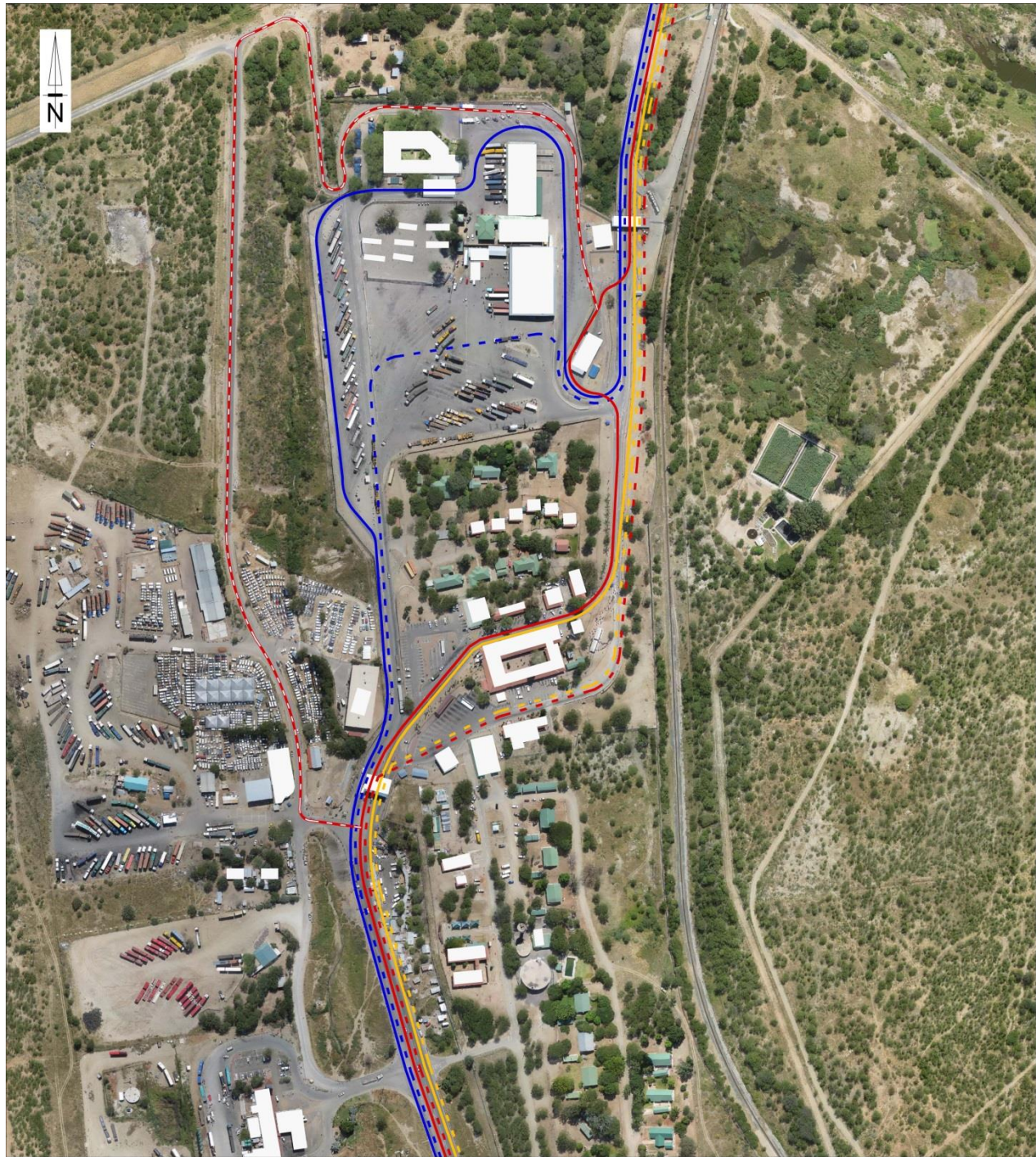
#### **6.2.1 TRAVEL ROUTES**

The following drawing indicates the route that different modes use through the border post.

All traffic was divided into:

- Heavy vehicles
- Light vehicles
- Pedestrians





**Figure 6—1: Traffic Flow**



Various issues were observed and raised during the site visit. The issues discussed below make reference to activity zones which is visible in Figure 6—2.



Figure 6—2: Port Operations (Zones)

### 6.2.2 PEDESTRIANS

- ❖ Currently there is no clear physical division between in- and outbound pedestrian movements which creates confusion and friction at the arrival – departures building (Zones 6 & 7). It furthermore enhances opportunities for loitering, theft and unlawful activities.

### 6.2.3 PUBLIC TRANSPORTATION

- ❖ Busses usually arrive during the evenings in groups of up to 5. They stop in tandem in front of the arrivals building (Zone 7) to off-load passengers for processing. This scenario results in spillbacks into the road since there are not adequate parking spaces. After off-loading they are inspected and then proceed to the collection (parking) area (Zone 8).
- ❖ The existing parking layout does not allow through circulation of vehicles; all parked vehicles must reverse before they can proceed. As a

consequence, busses with trailers avoid parking in this area and rather park in the road next to this area blocking both the road and parking spaces.

- ❖ The taxi drop-and-go facility outside the port at the South Gate (Zone 1) is unofficially being utilised as a taxi rank and holding area. Informal trading and restaurants are congesting the area and results in taxis picking-up or dropping off passengers in the road. It also obstructs pedestrian movements, resulting in pedestrians walking in the roadways.

#### **6.2.4 PARKING**

- ❖ There is not sufficient allocated parking for private staff vehicles on site resulting in the use of public parking spaces by staff. Shortages in covered parking spaces for staff were also reported.
- ❖ A shortage in reserved parking areas for official vehicles close to or near operational buildings results in vehicles being parked in undesignated areas.
- ❖ The parking area for light vehicles in front of the arrivals building (Zone 7) is not properly designed and has insufficient manoeuvring space. This area is also saturated at peak times and arriving vehicles sometimes have to park in the road.
- ❖ The parking area for departures (Zone 6) provides a limited amount of prime shaded parking close to the departures building. As a result, vehicles that attempt to use these bays have to reverse to find alternative parking if these bays are full, and in doing so, they block the outgoing vehicles.

#### **6.2.5 RAIL**

- ❖ There is no rail platform close to the port, making train inspections difficult. A requirement for lifting equipment to inspect containers was also raised.

#### **6.2.6 HEAVY VEHICLE CIRCULATION**

- ❖ A steady queue of about 40 heavy vehicles entering the port from Musina was observed in the mornings, which reduced to about 15 heavy vehicles during the afternoons. Trucks are prohibited from using the access point close to the port gate (Zone 1) and have to use the access at the Ultra City to gain access to the truck parks in the area.
- ❖ The parking area provided for the outbound trucks (25 bays) were hardly utilised and about 10 parked trucks were observed.
- ❖ Truck parking, circulation and manoeuvring at the inspection building (Zone 2) is problematic. The area is not well designed; there is only one

through lane which serves both the pre-cleared trucks and trucks that still have to be inspected. Trucks waiting to be inspected have to park downstream (about 12 parking bays) of the docking bays (about 12 utilised during the site visit) then travel upstream to reverse into a docking bay in a single lane one-way system. The required circulation reduces the throughput of this area resulting in unnecessary delays for especially the pre-cleared trucks.

- ❖ A requirement for U-turn facilities for trucks was also raised. The curved road alignment through the system also reduces the throughput.
- ❖ No major truck delays were observed on the inbound side (Zone 3). However, the road markings and parking bay striping is faded which makes it difficult to park in an organised fashion. This area appears to be underutilised.

### 6.3 ROAD NETWORK PLANNING

The planning for a proposed road network plan for the study area is briefly discussed in this chapter. This network plan was prepared by Civil Concepts in support of a township application that was applied for at the Musina Local Municipality.



Figure 6—3: Civil Concepts Network Plan

This plan includes a new alignment for the N1 to the west of the existing border facilities with a new bridge crossing of the Limpopo River, as well as two east-west linkages to connect the land to the west of the township / port with the land to the east of the township / port. During a meeting with SANRAL on 27 May 2014 they indicated that they are not opposed to any of the proposals as long as the status of the N1 is protected as a long distance mobility route.

However, the road network plan for the area, and the proposed new township, can only be finalised in conjunction with the compilation of the Master Plan for the border post.

It should be noted that the current capacity of the bridge is efficient to cater for a demand much larger than what the current traffic requires. It is understood that the bottleneck is not caused by the capacity of the bridge, but rather the operational aspects of the border post. It is thus projected that an extra bridge will thus not be required in the near future.

From the interviews with the BCOCC line departments it was also mentioned that the proposed road will cause a split in the operations as it is too far from the current operations.

## 7 DEMAND FOR INFRASTRUCTURE AND BULK SERVICES

### 7.1 CIVIL INFRASTRUCTURE

#### 7.1.1 WATER DEMAND

The bulk water demand for Beit Bridge was determined utilising the forecasted areas for each of the options, namely BCOCC guidelines, option 1 common one country facility and option 2 juxtaposed facility. *The Guidelines for Human Settlement Planning and Design*, and the *City of Tshwane Metropolitan Municipality Guidelines for the Construction of Water and Sanitation Systems* were used as guidelines for the determination of the demands. A reservoir with the storage capacity of 26.111 MI will be required in the year 2044 should the BCOCC guidelines be utilised, should the common one country facility option be utilised a reservoir with a storage capacity of 39.166 MI will be required, and should option 2 – the juxtaposed facility be utilised the reservoir should have a capacity of 24.517 MI.

The parameters utilised are shown in Table 7-1, and a summary of the storage requirements in Table 7-2. For detailed calculations please refer to Annexure E.

Table 7-1: Design parameters

| Design parameter  | Value                         |
|---|-------------------------------|
| Average Annual Daily Demand (AADD) for Government facilities/offices    | 0.6 kl/100m <sup>2</sup> /day |
| Daily peak factor   | 1.7                           |
| Fire Risk Category  | Moderate                      |
| Fire flow at any one hydrant under the condition of domestic peak flows | 25 l/s                        |

Table 7-2: Water storage capacity requirements (MI)

| Option                               | 2014  | 2024  | 2044  |
|--------------------------------------|-------|-------|-------|
| BCOCC Guidelines                     | 2.216 | 2.851 | 4.108 |
| Option 1 Common One Country Facility | 2.604 | 3.556 | 5.442 |
| Option 2 Juxtaposed Facilities       | 2.142 | 2.581 | 3.945 |

#### 7.1.2 POTABLE WATER RETICULATION

Beit Bridge has a single reticulation network for both potable and fire water. The reticulation network can be summarised as follows:

- 160mm diameter uPVC pipeline
- 110mm diameter uPVC pipeline
- 90mm diameter uPVC pipeline
- 75mm diameter uPVC pipeline

- Twenty two number of gate valves varying with pipe size
- Eight number of fire hydrants
- Thirty shut-off valves

### 7.1.3 SEWER DEMAND

The sewage outflow for Beit Bridge was determined utilising the forecasted areas for each of the options, namely BCOCC guidelines, option 1 common one country facility and option 2 juxtaposed facility. *The Guidelines for Human Settlement Planning and Design*, and the *City of Tshwane Metropolitan Municipality Guidelines for the Construction of Water and Sanitation Systems* were used as guidelines for the determination of the sewage outflow. The sewage outflow in the year 2044 is calculated to be 26.111l/s should the BCOCC guidelines be utilised, 39.166 l/s should the option 1 common one country facility be utilised and 24.517 l/s should the option 2 juxtaposed facility be utilised.

The design parameters utilised are shown in Table 5-3, and a summary of the sewage outflow in Table 5-4. For detailed calculations please refer to Appendix F

Table 7-3: Design parameters

| Design parameter  | Value                         |
|---|-------------------------------|
| <b>Average Annual Daily Demand (AADD) for Government facilities/offices</b> | 0.6 kl/100m <sup>2</sup> /day |
| <b>Daily peak factor</b>  | 2.5                           |
| <b>Stormwater infiltration</b>  | 15%                           |

Table 7-4: Sewage Outflow (l/s)

| Option                                      | 2014  | 2024   | 2044   |
|---|-------|--------|--------|
| <b>BCOCC Guidelines</b>                     | 7.593 | 13.807 | 26.111 |
| <b>Option 1 Common One Country Facility</b> | 11.39 | 20.711 | 39.166 |
| <b>Option 2 Juxtaposed Facilities</b>       | 6.868 | 11.166 | 24.517 |

## 8 CONCLUSION

Beit Bridge is self-sustained with its own water treatment plant, reservoir and waste water treatment works independent from the Musina Municipality. The status quo of the water, sewer, stormwater reticulation networks and roads has been discussed, and layouts presented. The services are sufficient for the current demand, with no major problems being identified during the site visit.



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## APPENDIX A: SITE LAYOUT PLAN

## APPENDIX B: WATER QUALITY TEST RESULTS