A. FEROX DANA BAY STORMWATER UPGRADE REPORT

PROCUREMNT PLAN NUMBER
TDR245/2021/2022

REF NO.: 10082001

22 NOVEMBER 2021

Compiled for:

Mossel Bay Local Municipality
101 Marsh Street
Mossel Bay
6500

Contact Person: Solly Beyi
Tel.: +27(0)44 606 5277
Email: sbeyi@mosselbay.gov.za

Compiled by:

V3 CONSULTING ENGINEERS

Contact Person: Mfundo Nkosi
Unit 1B, 4 Mascador Street, Mossel Bay, 6506
PO Box 730, Mossel Bay, 6500
South Africa
Email: mosselbaai@v3consulting.co.za
Tel.: +27 (0) 44 691 2305

V3 CONSULTING ENGINEERS

CLIENT	MOSSEL BAY LOCAL MUNICIPALITY
CONTRACT NO:	TDR245/2021/2022
PROJECT DESCRIPTION	A. FEROX DANA BAY STORMWATER UPGRADE REPORT
REPORT DESCRIPTION	CONCEPT AND DESIGN VIABILITY FOR STORMWATER UPGRADE AT A. FEROX, DANA BAY

Revision	0			
Date	22/11/2021			
Author(s)	M. NKOSI			
Approver(s)	D. JACOBS			

Approver's signature

Date 22 NOVEMBER 2021

Figure 1: Location A. Ferox Street and Nerina Road, Dana Bay.

Executive Summary

This report details the hydrological and hydraulic analysis of the A. Ferox watercourse, erf 7284 in Dana Bay. Hydrological analysis for a 20-year return flood revealed high energy and velocity runoff entering the watercourse. Site investigation confirmed the damage sustained by the watercourse was supported by collected data. Poor maintenance was observed to be a challenge affecting the performance of the channel.

The current state of the watercourse shows two failed gabion structures, eroding embankment threating the stability of the slope and property adjacent to it, silt build-up and vegetation overgrowth. The watercourse is not in working condition should a flood event arise.

The causes of failure of the watercourse as a stormwater management system are explained in the report together with results of the hydrological analysis.

Design recommendations include an energy breaker to manage the high energy and velocity of the runoff, a step spillway, stilling basin and bio-conveyance channel. Prescribed regular maintenance is also recommended.

The detailed design specifications and calculations are included in the Appendix.

Contents

Executive Summary 4

Contents 5

1. Introduction 6

2. Background 7

2.1 Failed Gabion Structure 7

2.2 Eroding Embankment 8

2.3 Active Slope Threat to Property 9

2.4 Lack of Maintenance 10

3. Causes of Failure of Structure 11

3.1 Under Designed System 11

3.2 Lack of Maintenance 11

4. Results of Hydrological and Hydraulic Analysis 12

5. Design Recommendations 13

5.1 Energy Breaker 13

5.2 Step Spillway 13

5.3 Stilling Basin 13

5.4 Bio-conveyance Channel 13

5.5 Maintenance 13

6. Conclusion 15

7. References 16

Appendix .... **Error! Bookmark not defined.**

Appendix A: Preliminary Concept Drawings 17

Appendix B: Calculations 18

1. Introduction

The Mossel Bay Local Municipality appointed V3 Consulting Engineers (Pty) Ltd (under contract number 7796933) to provide professional services for the Phase 2 A Ferox Watercourse Stormwater Upgrade.

V3 Consulting Engineers (Pty) Ltd has provided civil services for the analysis and design of the upgrades of the A. Ferox stormwater watercourse. This report includes a hydrological analysis of the Dana Bay catchment for the 20-year return flood. A ground survey was also carried out demarcating the affected properties adjacent to the watercourse, the stormwater culvert from A. Ferox Street and the elevation fall to the Nerina Road culvert. The site investigation revealed a failed gabion weir structure as indicated in the images of the channel.

The analysis revealed a high velocity and volume discharge into the watercourse with the energy to further erode the embankments of the channel and was the cause of the gabion structure failure. Therefore, based on the above analysis, a hydraulic design was carried out to manage stormwater runoff velocity and volume.

The recommended stormwater management systems are a stepped spillway as an energy dissipation structure to reduce flow velocity and a stilling basin with an outlet weir sill to manage volume. These are designed to ensure the protection of the watercourse embankments and private property situated on the eroding banks. These measures will also minimise the impact on the downstream flows.

2. Background

The site investigation sought to understand the condition of the natural channel and identify areas of concern for future remedial action. The following observations were made from the site investigation of the watercourse.

2.1 Failed Gabion Structure

Two rectangular weir structures were identified on site. The Upstream Weir was found to have completely failed having been pushed to the side by the energy of the flow of the runoff. (Figure 2.) As a result, there is no control point for the upstream flow and therefore providing no protection for downstream flow and the watercourse embankments.

Figure 2: Failed upstream gabion weir structure.

The condition of the Downstream Weir indicated a partial failure due to silt build up and overgrowth of vegetation. This renders the structure semi-functional and unable to fully manage the capacity of the upstream flow. (Figure 3.)

Figure 3: Partially failed downstream gabion weir structure.

2.2 Eroding Embankment

The condition of the Eastern Bank of the channel shows undercutting of the slope due to erosion. (Figure 4.) The undercutting has compromised the stability of the slope.

Figure 4: Eastern bank of watercourse undercut by erosion.

2.3 Active Slope Threat to Property

Due to undercutting by the flow, the condition of the Eastern Bank of the channel presents a threat of active slope failure due to erosion. (Figure 5.) This poses a threat to the property of erf 7285 and residents have taken to using their own means to sure up the stability of the embankment by stacking tyres.

Figure 5: Slope erosion presents a threat to property adjacent to watercourse.

2.4 Lack of Maintenance

Evident in the condition of the watercourse and contribution to the non-functionality of the gabion weir structures is the lack of maintenance. Overgrowth of vegetation and the build-up of silt has reduced the stormwater management performance of the control structures. (Figure 6.)

Figure 6: Lack of maintenance resulting in silt build-up and vegetation overgrowth.

3. Causes of Failure of Structure

Taking the observations of the site investigation and the hydrological and hydraulic analysis in account, two main factors have been found for the failure of the system.

3.1 Under Designed System

The volume and velocity of the discharge of the flow from the A. Ferox culvert enters the watercourse at a higher energy than the gabion weir structures can manage. A concrete hydraulic control structure is recommended as best practice for energy dissipation to prevent scouring and displacement of structures due to hydraulic forces (US Bureau of Reclamation).

3.2 Lack of Maintenance

Overgrowth of vegetation and the build-up of silt has reduced the stormwater management performance of the control structures. This is due to a clear lack of regular maintenance. The gabion weir structured also suffered from not having a regular maintenance or being rehabilitated when signs of structural failure began to emerge.

4. Results of Hydrological and Hydraulic Analysis

The following are results of the hydrological study of the Dana Bay catchment (Figure 7) with respect to the runoff channelled through the A. Ferox watercourse. (Table 1.)

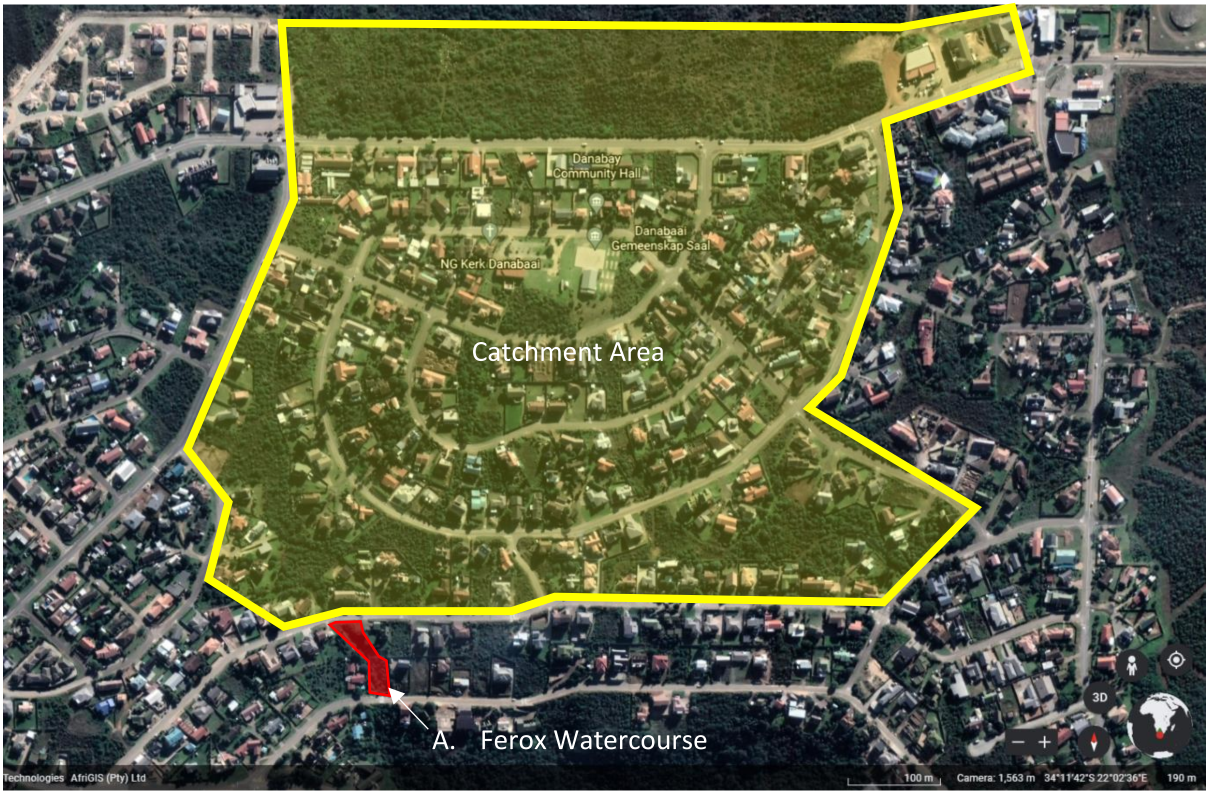

Figure 7: Danabay catchment area and A. Ferox watercourse.

Analysis	Result	Comments
Catchment Size	**447 000 m^2**	
Longest Watercourse	**635 m**	
Height Difference	**60.64 m**	
Pre-development Peak Flow	**1.494 m^3/s**	
Pre-development Peak Velocity	**3 m/s**	
Pre-development Peak Volume	**1494 l/s**	
Post-development Peak Flow	**2.36 m^3/s**	Peak flow is markedly higher due to hardening of the catchment area.
Post-development Peak Velocity	**4.69 m/s**	
Post-development Peak Volume	**2360 l/s**	The volume of runoff being channelled indicates high silt deposits being conveyed.

Table 1: Hydrological Analysis of Dana Bay Catchment Area for 20-year Return Flood.

5. Design Recommendations

5.1 Energy Breaker

To break the energy of the runoff entering the watercourse from the A. Ferox culvert, a 2m deep stilling basin is recommended. The stilling basin will allow for water to fall on itself creating a stilling effect and then slowly discharging it through the toe drains. Refer to Appendix A for the design specification.

5.2 Step Spillway

The energy breaker at entry will not be enough to manage all the energy of the runoff. Thus, further energy management and dissipation is needed. A stepped spillway will convey the runoff effectively whilst reducing the energy and velocity of the runoff. The advantage of the step spillway structure is that it reduces the scale of further dissipation structures that are needed downstream. The calculations yielded a 10-step concrete spillway with sidewalls to prevent scouring. Refer to Appendix A for design specifications.

5.3 Stilling Basin

A final control structure is needed to transmission the flow from supercritical to subcritical. A stilling basin will produce a hydraulic jump and slowly discharge the controlled flow over the sill into the bio-conveyance channel. The sill is reduced in size because of the efficacy of the step spillway that reduced energy before entering the stilling basin. This is another advantage of the stepped spillway. Refer to Appendix A for specifications of design.

5.4 Bio-conveyance Channel

The downstream section between and the stilling basin and the outlet culvert on Nerina Road is a natural channel. Therefore, to promote groundwater regeneration and stormwater infiltration and reduction of peak discharge, a natural channel will be retained. This will protect the milkwood tree found in the middle of the channel. Stone pitched walls will be used to define the channel and protect the embankment from erosion and potential slope failure.

5.5 Maintenance

Critical to the functioning and lifespan of the whole channel is maintenance. The system has been designed with maintenance in mind. The design allows for conveyance of silt to prevent build-up and, therefore, reduce clogging and blockages. However, regular debris removal will need to take place together with cutting and removal of vegetation and overgrowth.

6. Conclusion

The report detailed the hydrological and hydraulic analysis of the A. Ferox watercourse in Dana Bay. Hydrological analysis for a 20-year return flood showed high energy and velocity runoff entering the watercourse supporting the structural and slope damage observed in the site investigation. Poor maintenance was observed to be a contributing factor of the failure of the stormwater management system.

The current state of the watercourse shows two failed gabion structures, eroding embankment threating the stability of the slope and property on it, silt build-up and vegetation overgrowth. The watercourse is not in working condition should a high flood event arise.

The causes of failure of the watercourse as a stormwater management system is the design capacity of the upstream gabion structure not being sufficient to manage the high energy of the runoff entering the system, and a lack of maintenance over time.

Results of the hydrological analysis have been provided. Design recommendations include an energy breaker to manage the energy and velocity of the runoff, a stepped spillway, stilling basin and bio-conveyance channel. Prescribed regular maintenance is also recommended.

The detailed design specifications and calculations are included in the Appendix.

V3 CONSULTING ENGINEERS

Unit 1B, 4 Mascador Street, Voorbaai,
Mossel Bay, 6506
PO Box 730, Mossel Bay, 6500
South Africa
Tel: +27 (0) 44 691 2305

Enquiries	:	MFUNDO NKOSI
Our ref.	:	10082001
Your ref.	:	
File ref.	:	10082001/02/06
Date	:	19 MAY 2022

10082001: A. Ferox Storm Water Upgrades – Alternative Designs

1. Introduction

This report details the alternative designs considered for the A. Ferox storm water channel in Dana Bay, Mossel Bay. The Mossel Bay Local Municipality appointed V3 Consulting Engineers (Pty) Ltd (under contract number 7796933) to provide professional services for the Phase 2 A Ferox Watercourse Stormwater Upgrade.

V3 Consulting Engineers (Pty) Ltd has provided civil services for the analysis and design of the upgrades of the A. Ferox stormwater watercourse.

2. Current Design Rational

A hydrological analysis of the Dana Bay catchment for the 20-year return flood was conducted. A ground survey was also carried out demarcating the affected properties adjacent to the watercourse, the culvert area, and the elevation fall to the Nerina Road culvert. The site investigation revealed a failed gabion weir structure as indicated in the images of the channel.

High velocity and volume discharge into the watercourse were determined by the analysis. The energy of the flow erodes the embankments of the channel and was the cause of the gabion structure failure. Therefore, based on the above analysis, a hydraulic design was carried out to manage stormwater runoff velocity and volume.

The recommended stormwater management systems are: (1) a stepped spillway as an energy dissipation structure to reduce flow velocity, and (2) a stilling basin with an outlet weir sill to manage volume. These are designed to ensure the protection of the watercourse embankments and private property situated on the eroding embankments. These measures will also minimise the impact on the downstream flows and manage capacity for future urban development. Figure 1 shows the Stepped Spillway Design and Stilling Basin.

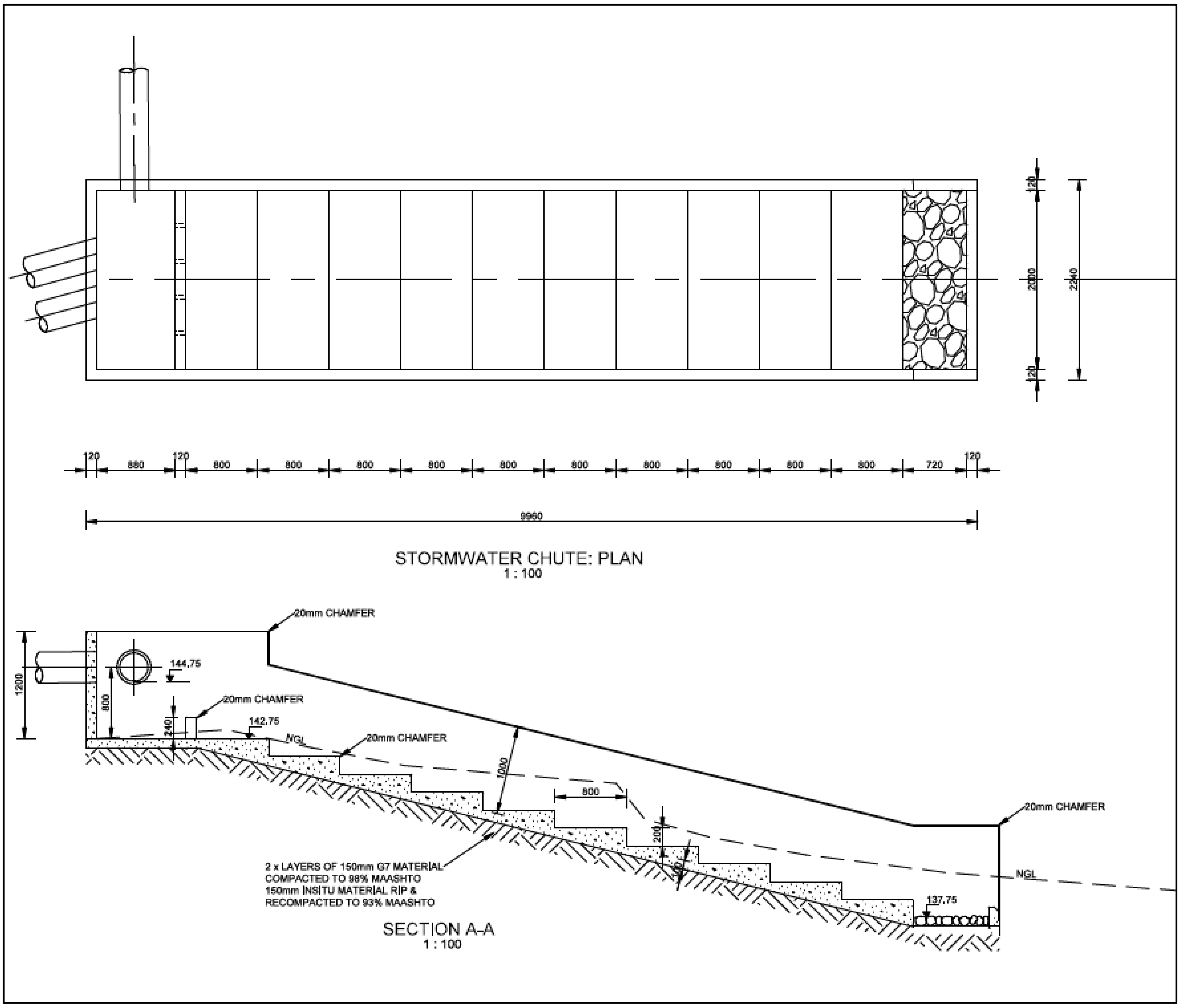

Figure 1: A. Ferox Stepped Spillway Design and Stilling Basin

The design optimizes the use of the area by only occupying 400m^2 of a total 1316m^2 of the culvert. Therefore, the design protects natural vegetation and ensures that approximately 70% of the natural culvert is protected.

It must also be noted, due to the high flow velocity and elevation, damage such as cavitation and embankment undercutting are common occurrences. Therefore, design guidelines recommend the use of a concrete structure to withstand damage due to high flow velocities. *US Bureau of Reclamation (1987).*

3. Alternative Designs Considered

A storm water management system that uses as much local materials and incorporated as much of the natural features and flora of the culvert was considered. These methodologies are in line with the Water Research Commission's South African Guidelines for Sustainable Drainage Systems.

3.1 Dual System Infiltration Trench

A Dual System Infiltration Trench has two functions: (1) Catches and infiltrates surface runoff and (2) reduces flow volumes. Figure 2 shows a general design of a Dual System Infiltration Trench.

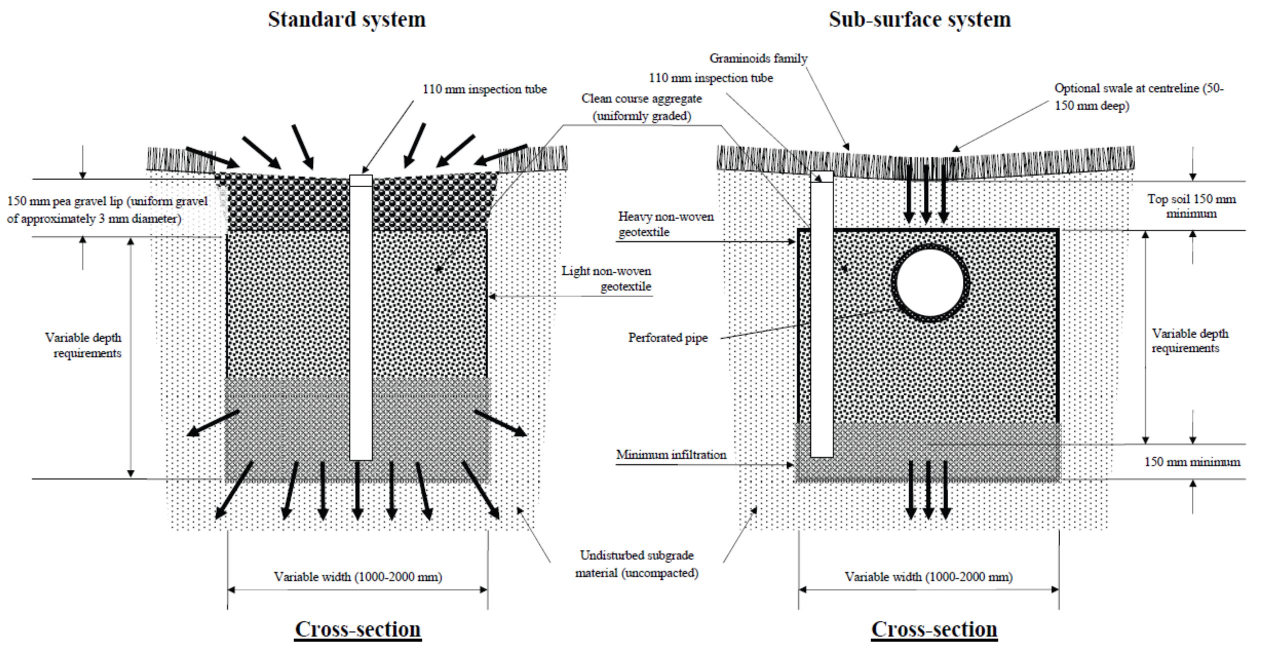

Figure C6: General design for dual system infiltration trenches
[after SEMCOG (2008)]

Figure 2: General Design for Dual System Infiltration Trenches

The Dual System Infiltration Trench has limitations in managing high velocity flows. To manage higher velocities larger trench depth and area are required therefore increasing the area of the disturbed surface for construction. Infiltration trenches also require a high degree of regular maintenance. One of the functions of failure of the existing A. Ferox culvert was a lack of maintenance.

Due to these factors this design consideration was eliminated.

3.2 Bio-Conveyance Channel

A bio-conveyance channel uses natural flora and terrain to manage storm water runoff. Some bio-conveyance designs include swales, berms, and retention ponds.

A configuration using one, or a combination, of these conveyance features was considered. The limitations of a bio-conveyance channel are that it can manage large volumes but fails to adequately manage high velocity discharge.

The outlet discharging into the A. Ferox culvert has seen pre-development flows increase from 3m/s to 4.69m/s post-development. Therefore, the flow velocity increase renders a bio-conveyance channel design solution less favourable. The design solution also does not provide a sufficiently adequate remedy for embankment erosion and silt build-up over time. Hence, this solution will require a rigorous maintenance regime which comes with cost implications and a higher potential of channel failure. Figure 3 shows a typical bio-conveyance channel design.

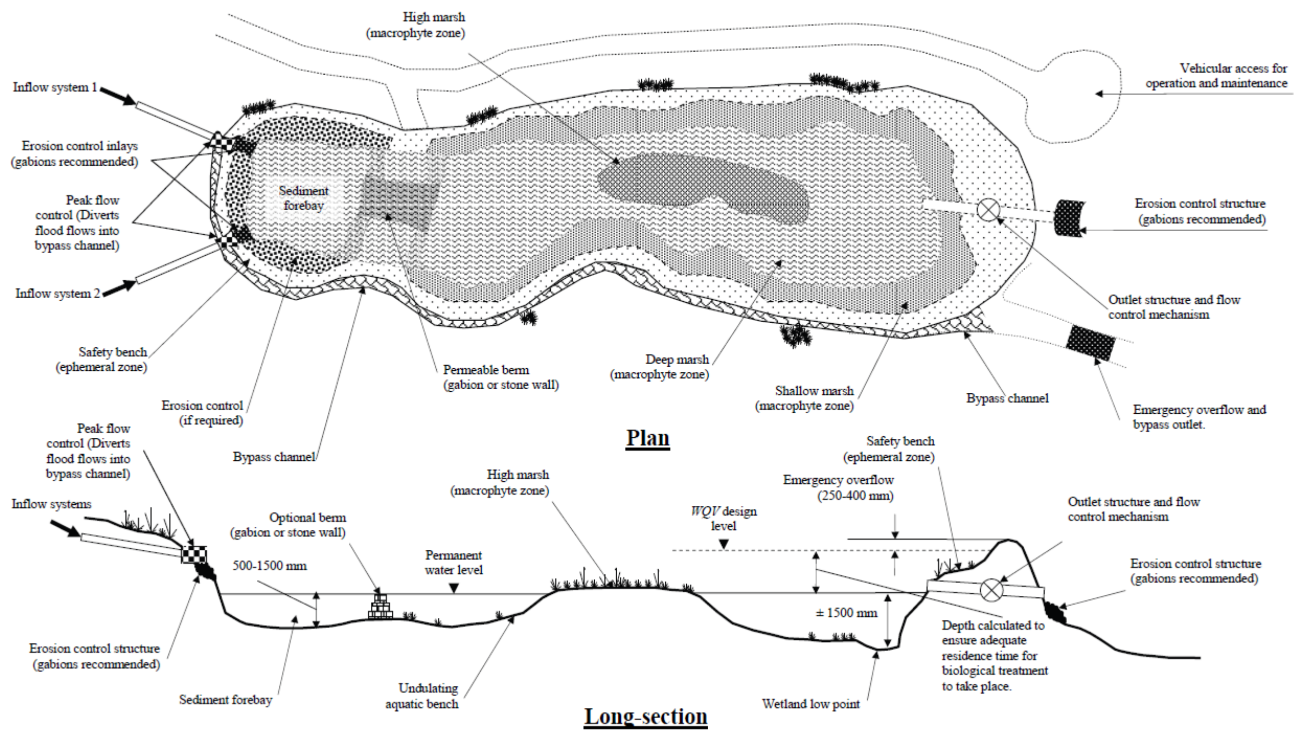

Figure C11: General design for constructed wetlands
[after Wilson *et al.,* (2004); Woods-Ballard *et al.,* (2007) & others]

Figure 3: General design for constructed wetlands

3.3 Rehabilitation of Existing Gabion Weirs

The reason for the failure of the existing gabion weirs is due to their lack of ability to manage high velocity and volumes of flows. Silt build-up over time and lack of routine maintenance was also the cause of displacement of the weirs. Hence this design consideration was ruled out. See Figure 4.

Figure 4: Failed displaced weir structure, A. Ferox.

4. Conclusion

It is resolved that from the high flow velocity and volumes, due to the consistent increase of hard surfaces from urban development, a stepped spillway and stilling basin is required to ensure effective long-term storm water management, embankment protection, and minimal impact to the channel's flora.

If there are any questions, please feel free to contact the undersigned.

Yours faithfully

Mfundo Nkosi
Civil Engineer, Infrastructure
Mossel Bay
V3 CONSULTING ENGINEERS (PTY)LTD.

7. References

- Armitage, N. et al, 2013. “Alternative Technology for Stormwater Management”. The South African Guidelines for Sustainable Drainage Systems. Water Research Commission. University of Cape Town.

- Brown, L.K., 2009. “Energy Dissipation Design”. Columbia County Stormwater Management Design Manual.

- Chadwick, A., et al, 2013. “Hydraulics in Civil and Environmental Engineering”. CRC Press; 5th edition.

- Frizell, K.W. et al, 1978 – 2015. “Guidelines for Hydraulic Design of Stepped Spillways”. U.S. Department of the Interior Bureau of Reclamation Technical Service Center Hydraulic Investigations and Laboratory Services Denver, Colorado.

- Philp, L., et al, 2006. “Hydraulic Design of Energy Dissipators for Culverts and Channels”. Hydraulic Engineering Circular No. 14, Third Edition. U.S. Department of Transportation, Federal Highway Administration.