

Trinity Metals Pty (Ltd)

Nyamyumba




Stormwater Report

Stormwater Management

2025/11/23



DOCUMENT APPROVAL RECORD

ACTION	FUNCTION	NAME	DATE	SIGNATURE
Prepared	Civil Engineer, (2024207886)	L. Smit	2025/11/23	
Approved	Civil Engineer, (930 513)	J.S. Davel, Pr. Eng.	2025/11/23	
Reviewed	Civil Engineer (202302621)	C.F.V. Davel Pr. Eng	2025/11/23	

DOCUMENT REVISION RECORD

DATE	REVISION	DESCRIPTION	ISSUE TO
2025/04/07	0	Based on the survey heading 1.2 of this report and current operations.	



Executive Summary

This report presents the detailed stormwater management design for the Nyamyumba Mine, one of six tin operations within Trinity Metals' Rutongo concession in Rulindo District, Northern Province, Rwanda. The mine is located on steep, highly erodible slopes underlain by nitic clays derived from shale and dolerite, where uncontrolled runoff has already formed deep gullies and undermined informal road crossings and mine infrastructure.

The hydrological assessment delineated a total contributing catchment of approximately 1.142 km², with about 23% draining to the western side and the balance to the east. A 1:50-year, 15-minute design storm was adopted and analysed using the Rational Method, resulting in a total peak discharge of 38.07 m³/s and a Western sub-catchment peak of 9.53 m³/s. These flows form the basis for the hydraulic design of all channels, sumps and stilling basins.

The Western stormwater system is configured as a network of branched diversion channels (the Western Middle Channel, West Masonry Channel and Main Channel 2) that intercept hillside and road runoff and convey it to a consolidated Western main channel. The main channel comprises four concrete-inverted, gabion-lined reaches with three sumps that act as energy dissipaters and sediment traps. Because of the steep gradients and wide sections, design discharges in the main channel are high; however, the large channel width keeps the flow subcritical under design conditions. If the channel is narrowed or obstructed, the flow could readily become supercritical, with a rapid increase in hydraulic forces acting on the gabion side slopes and bed. The final sump is positioned and sized to keep stormwater on the western side of the valley and to avoid uncontrolled transfer towards the Eastern drainage system.

The Eastern Channel is the primary diversion for runoff from the larger eastern sub-catchment. It is approximately 560 m long, with a 5 m wide Hyson-cell and concrete-lined invert and stepped gabion side walls and is conservatively sized to pass the full 38.07 m³/s peak flow. Hydraulic analysis using Manning's equation shows that, on the steep 1:8 reaches, the flow is highly supercritical with a Froude number of about 3.40. A simple hydraulic jump would produce conjugate depths in excess of 3 m, which is impractical, so a series of USBR Type III stilling basins has been introduced at intervals of roughly 110 m. These basins, with flattened 1:200 floors, baffle blocks and end sills, were sized using USBR design guidance to force controlled hydraulic jumps, reduce velocities and protect the Hyson-cell and gabion linings from erosion.

The report concludes with recommendations for extending masonry channels along roads, rationalising informal drainage into the engineered system, benching vulnerable slopes, and implementing a structured maintenance and QA/QC regime for earthworks, concrete and gabion construction in line with SANRAL, LODA and relevant SANS standards. Supporting hydrology, hydraulic calculations, design drawings, bridge sizing and Bills of Quantities are compiled in Appendices A to F.



Contents

1	INTRODUCTION	1
1.1	ABBREVIATIONS & DEFINITIONS	1
1.2	INFORMATION USED	1
1.3	BACKGROUND	2
1.4	PROJECT LOCALITY	2
1.5	EXISTING DRAINAGE AND INFRASTRUCTURE	3
1.6	GEOLOGICAL AND GEOTECHNICAL SETTING	4
1.7	DESIGN STANDARDS & CRITERIA	5
2	CATCHMENT SUMMARY	5
2.1	CATCHMENT AREA & CHARACTERISTICS	5
2.2	DESIGN PEAK FLOWS	7
2.3	HYDRAULIC DESIGN METHODOLOGY AND STANDARDS	8
3	WESTERN CHANNEL DESIGN	9
3.1	OVERVIEW	9
3.2	WESTERN MIDDLE CHANNEL	10
3.3	WEST MASONRY CHANNEL	12
3.4	WESTERN MAIN CHANNELS	14
3.5	SUMPS	16
3.6	BRIDGE CONSTRUCTION	17
4	EASTERN CHANNEL	18
4.1	OVERVIEW	18
4.2	EASTERN CHANNEL GEOMETRY AND CONSTRUCTION	19
4.3	STILLING BASINS	21
5	RECOMMENDATIONS	23
6	QUALITY ASSURANCE AND QUALITY CONTROL (QA/QC)	23
6.1	SURVEY AND SETTING-OUT	24
6.2	EARTHWORKS AND FOUNDATIONS	24
6.3	GABIONS AND ROCK PROTECTION	24
6.4	CONCRETE AND HYSON CELLS	25
6.5	CHANNEL GEOMETRY AND SLOPE CONTROL	25
6.6	DOCUMENTATION AND CONTRACTOR RESPONSIBILITIES	25
7	MAINTENANCE	26
8	BILL OF QUATITIES	26
9	CONCLUSION	27



APPENDIX A:	FLOOD HYDROLOGY REPORT	A
APPENDIX B:	WESTERN CHANNEL HYDRAULIC CALCULATIONS.....	B
APPENDIX C:	EASTERN CHANNEL HYDRAULIC CALCULATIONS.....	C
APPENDIX D:	DESIGN DRAWINGS.....	D
APPENDIX E:	BILL OF QUANTITIES (BOQ)	E

List of Figures

Figure 1-1: Topographical overview of Nyamyumba – Google Earth (Airbus 2025).....	3
Figure 1-2: Bridge crossings (yellow circle) and eroded stormwater paths (red lines), LiDAR image 2022.....	4
Figure 2-1: Division of main catchment included in this report.....	6
Figure 2-2: Western Catchment excluded.....	7
Figure 3-1: Western Channel overview	10
Figure 3-2: Western Channel plan (from drawing DTL 002).....	11
Figure 3-3: Western Channel cross-section (from drawing DTL 002)	11
Figure 3-4: West Masonry Channel typical section	13
Figure 3-5: West masonry channel decant.....	14
Figure 3-6: Main channel – Typical Section.....	16
Figure 4-1: Eastern Channel general arrangement	18
Figure 4-2: Typical cross-section of eastern channel	19
Figure 4-3: Typical stilling basin plan and section	22

List of Tables

Table 2-1: Summary of design peak flows.....	8
Table 3-1: Summary of branched channel's.....	12
Table 3-2: Summary of western bottom channel.....	13
Table 3-3: Summary of Main Channel 01	15
Table 3-4: Summary of western sumps	17
Table 4-1: Eastern channel hydraulic parameters.....	20



List of Drawings

- ETS TM NMB SWC GA 001a
- ETS TM NMB SWC GA 00b
- ETS TM NMB SWC DTL 002
- ETS TM NMB SWC CSL 003



1 INTRODUCTION

1.1 ABBREVIATIONS & DEFINITIONS

Commercial

CEO	Chief Executive Officer
CQA	Construction Quality Assurance
ETS	Engineered Tailings Solutions (Pty)Ltd
GISTM	Global Industry Standard on Tailings Management
QC	Quality Control
RoM	Run-of-Mine
SWM	Storm Water management
WPS	Environmental Consulting Company/ Laboratory

Survey & Coordinates:

GPS	Global Position System
mamsl	meters above mean sea level
NGL	Natural Ground Level
WGS84	World Geodetic System 1984

Soil

PSD	Particle Size Distribution
OMC	Optimum Moisture Content

1.2 INFORMATION USED

- LIDAR Survey March 2022 (WGS 84 Datum). Contour correction on the 01st of July 2025.
- Airbus Survey September 2024 (WGS 84 Datum).
- Flood Hydrology Calculations (April 2025), provided in Appendix A.

All calculations have been developed using industry-standard methods and checked against the SANRAL Drainage Manual and Rwanda's LODA road drainage guideline for road and slope drainage.



1.3 BACKGROUND

Nyamyumba forms part of Trinity Metals' Rutongo mining complex, a long-standing tin mining operation in Rwanda. The Rutongo concession covers approximately 9 600 ha and comprises six underground tin mines, of which Nyamyumba is one. The mine is located on steep, dissected slopes with deeply weathered soil mantles and narrow valleys.

In recent wet seasons, intense rainfall events have generated rapid runoff that concentrates in informal gullies and along access roads. The absence of engineered diversion trenches, energy dissipators and adequately sized culverts has led to:

- Deep erosion gullies cutting into unconsolidated soils;
- Undermining of informal bridge crossings and culverts;
- Localised flooding and sediment deposition near plant areas and portals; and
- Increased risk to workers and equipment during heavy storms.

The objective of this stormwater design is therefore to provide a coherent, engineered system that safely intercepts and conveys the design storm, while minimising erosion, protecting infrastructure and allowing for future expansion of the mine.

1.4 PROJECT LOCALITY

Nyamyumba Mine lies approximately 26 km north of Kigali in the Rulindo District, Northern Province, Rwanda. The mine is accessed via regional road infrastructure and is situated on the western slopes of a narrow valley draining toward downstream agricultural lands and watercourses.

Figure 1-1 illustrates the topographical setting and the relative positions of the plant and settling dams based on Airbus 2025 imagery.





Figure 1-1: Topographical overview of Nyamyumba – Google Earth (Airbus 2025)

1.5 EXISTING DRAINAGE AND INFRASTRUCTURE

Currently, Nyamyumba lacks a formal, continuous stormwater drainage network. Runoff from the steep hillsides follows:

- Natural gullies formed along preferential flow paths; and
- Ad-hoc trenches and wheel ruts produced by vehicle movements.

In the western area, several rudimentary bridge or culvert crossings exist along mine roads and footpaths. These often comprise timber logs or small diameter pipes that allow traffic across eroded channels but provide limited hydraulic capacity. A key access road near the processing area is serviced by a concrete pipe culvert that has been observed to overflow during large events.

Figure 1-2 shows the location of these bridge crossings in relation to uncontrolled stormwater paths and the plant area, using 2022 LiDAR imagery. Critical mine infrastructure – including underground portals, shafts, plant structures and worker facilities – lies close to valley bottoms and is vulnerable to overtopping and erosion in the absence of an engineered system.





Figure 1-2: Bridge crossings (yellow circle) and eroded stormwater paths (red lines), LiDAR image 2022. Critical infrastructure in the area (mine entrances (tunnel/shafts), processing plant equipment, and worker facilities situated near valley bottoms) are unprotected. The current culvert/bridges is undersized, which has led to overtopping and wash-away in past storms. A new minimum bridge span and vertical clearance will be recommended in this report.

1.6 GEOLOGICAL AND GEOTECHNICAL SETTING

Nyamumba is hosted within the broader Rutongo tin field, where mineralisation is associated with quartz veins in metasedimentary and intrusive rocks. Regional geological mapping and environmental investigations in the Rulindo area indicate:

- Deep lateritic and nitic soil profiles developed on weathered shale and dolerite;
- Medium to high plasticity clays at depth, with variable Ferricrete and saprolite horizons;
- High infiltration into deeper clay-rich horizons, promoting perched water tables; and
- Susceptibility to slope failure and gully erosion on steep concave slopes when flows are concentrated.

These conditions have two key implications for stormwater design:



- **Erosion risk** – Concentrated, high-velocity flows can rapidly incise unprotected ground, leading to deep gullies and undermining of access roads and platforms.
- **Stability and foundation conditions** – While bedrock is often shallow near ridgelines and in stream thalwegs, localised pockets of softer material and colluvial deposits occur. Channels, sumps and stilling basins must be founded on competent material or on compacted subgrade designed to resist scour and settlement.

The proposed design therefore relies heavily on lined channels (gabions, Hyson cells and concrete) and controlled energy dissipation through sumps and stilling basins.

1.7 DESIGN STANDARDS & CRITERIA

The hydrological and hydraulic design aligns with recognised standards and best practice, including:

- **SANRAL Drainage Manual** (current edition), used for the selection of design return periods, Rational Method parameters, freeboard requirements and culvert/bridge hydraulics;
- **Rwanda LODA road and drainage guidelines**, used particularly for road-side channel detailing and open-drain configurations;
- **SANS 1200 DA/DB/LC and related parts**, providing standards for earthworks, concrete works and lining construction; and
- **SANS 10160 and SANS 10100**, providing guidance on structural loading and concrete design to be used by the bridge structural engineer.
- **USBR “Hydraulic Design of Stilling Basins and Energy Dissipators”** – for selection and sizing of Type III stilling basins.

2 CATCHMENT SUMMARY

2.1 CATCHMENT AREA & CHARACTERISTICS

The contributing catchment for Nyamyumba’s stormwater system covers approximately 1.142 km² of steep mountainous terrain. The topography drives extremely fast runoff response – the time of concentration is estimated at only ~2 minutes due to short slope lengths and steep grades. Consequently, the site experiences flash flood conditions during intense cloudbursts. *Appendix A: Flood Hydrology Report* illustrates the delineated main catchment and flow directions based on the Airbus survey data (catchment boundaries were refined in QGIS using the 2024 survey).

Noteworthy, is that the LiDAR survey covered a smaller area compared to the Airbus survey, including only a portion of the western compartment.



The western portion of the mine captured roughly 0.263 km² (23%) toward the planned western diversion channel, while the remaining area (~0.879 km²) drains eastward toward the eastern channel system as detailed in Figure 2-1 below.

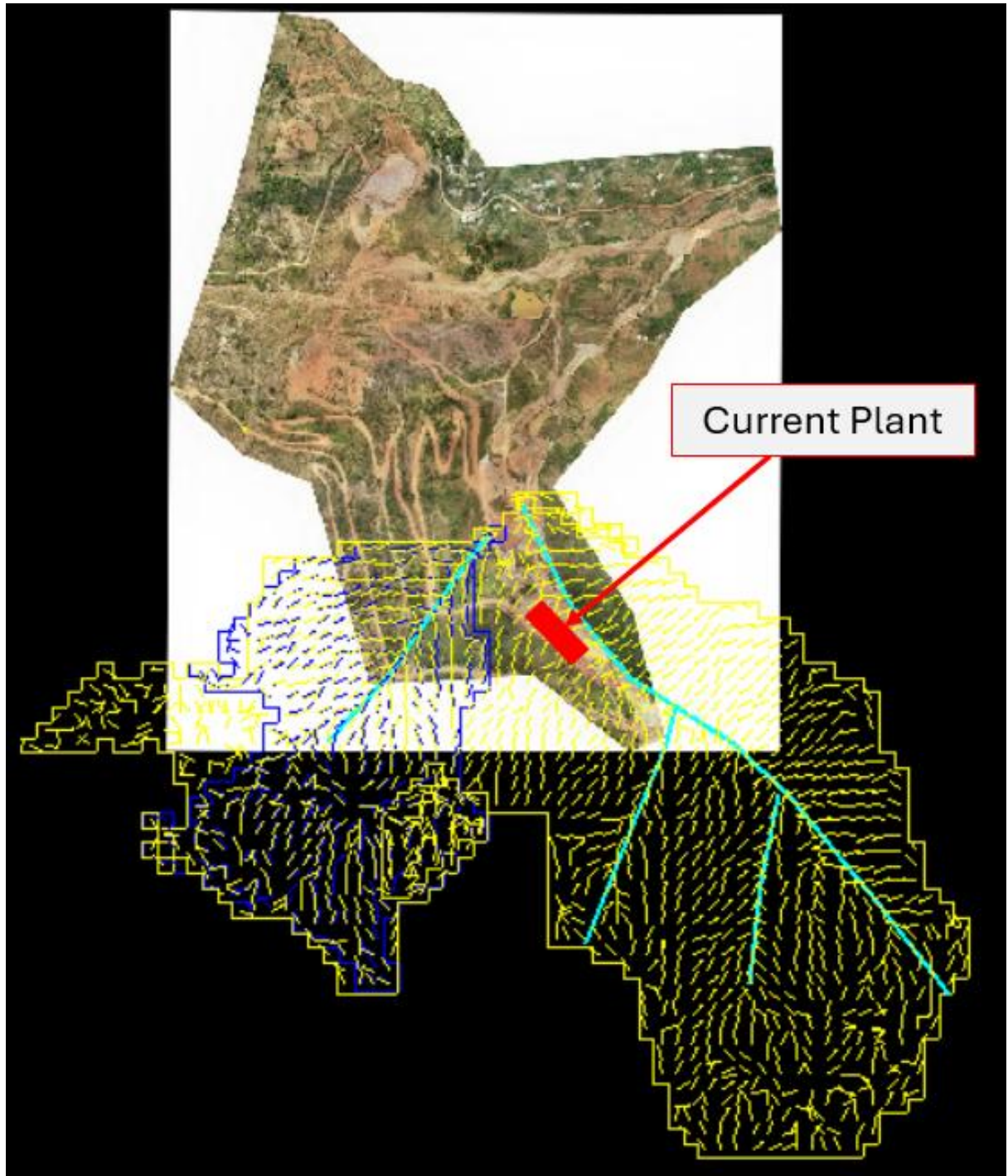


Figure 2-1: Division of main catchment included in this report

Due to limited data points, no definite stormwater for the protection of the plant area was designed. The area excluded in this report is outlined in Figure 2-2.



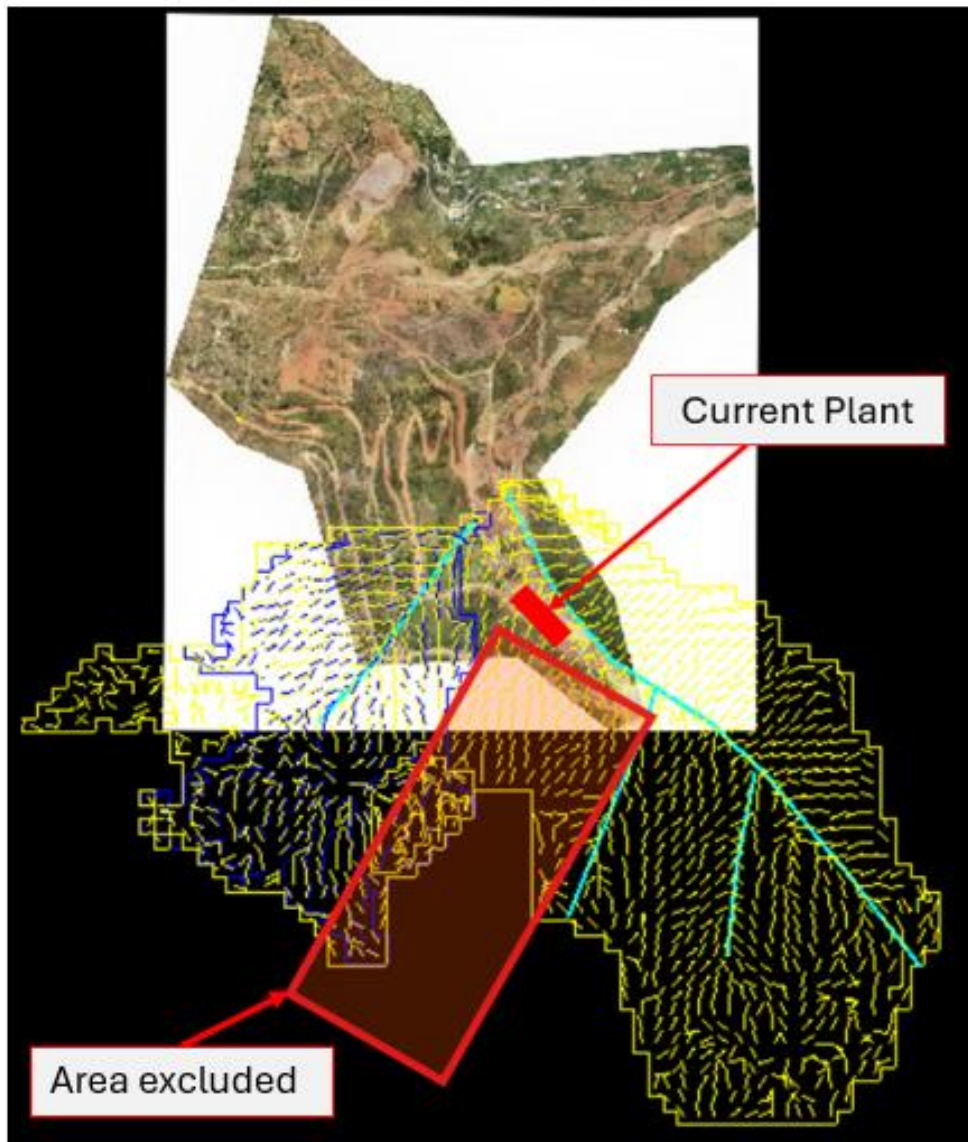


Figure 2-2: Western Catchment excluded

A portion of the eastern drainage currently crosses the plant area before entering the proposed Eastern Channel alignment. Due to limited survey data in these zones, dedicated plant-protection works are deferred to a future Phase 2 study once updated LiDAR data become available.

2.2 DESIGN PEAK FLOWS

Hydrological modelling was performed using the Rational Method, appropriate for small, steep catchments with short concentration times. A design rainfall intensity corresponding to a 1:50 year return period 15-minute storm (the critical short duration) was applied.

For Nyamyumba, this intensity was derived from regional IDF curves and equates to approximately 120 mm/hr (30 mm in 15 min). With a conservative runoff coefficient $C \approx 1.0$. Assuming most rainfall becomes runoff due to steep, saturated ground.



Table 2-1: Summary of design peak flows

Catchment	Area (km ²)	Q _{peak} (m ³ /s)	Return period & Duration	Method
Total Catchment	1.142	38.07	1:50 year	Rational
Western sub-catchment	0.263	9.53	15-minutes	Area proportional

These peak flows are used as design discharges for the Western and Eastern hydraulic systems. In reality, some attenuation will occur as flow passes through the Western system before joining the Eastern Channel; however, the Eastern Channel is conservatively sized for the full 38.07 m³/s to provide safety against uncertainty and catchment expansion.

Appendix A: Flood Hydrology Report contains the full hydrological calculations, including rainfall data, runoff coefficients, and the application of the Rational Method.

2.3 HYDRAULIC DESIGN METHODOLOGY AND STANDARDS

Hydraulic sizing of channels and structures is based on steady, uniform open-channel flow assumptions and uses Manning’s equation in the form:

$$Q = \frac{1}{n} AR^{2/3} S^{1/2}$$

where Q is discharge (m³/s), n is Manning’s roughness coefficient, A is the flow area (m²), R is hydraulic radius (m) and S is the channel bed slope (m/m). For each channel reach, the design flow from Table 2-2 is assigned, a trial normal depth is chosen, and Manning’s equation is solved iteratively to obtain consistent depth, velocity and Froude number.

Typical roughness values adopted are:

- n ≈ 0.020 for gabion-lined channels and sumps;
- n ≈ 0.015–0.017 for smooth concrete and Hyson-cell lined inverts; and
- slightly higher values where bends or rough transitions are present, as indicated in the detailed calculations.

Design checks ensure that:

- Flow depths remain below channel wall crests with suitable freeboard under the 1:50-year event;



- Velocities remain within the erosion resistance capacity of the respective linings; and
- Froude numbers and conjugate depths are compatible with the locations and dimensions of sumps and stilling basins.

Hydraulic standards and criteria are consistent with the SANRAL Drainage Manual, LODA guidance and relevant SANS standards referenced in Section 1.7.

3 WESTERN CHANNEL DESIGN

3.1 OVERVIEW

The Western stormwater system is arranged to intercept runoff from the western sub-catchment as high on the slope as practicable and to convey it in a controlled manner to the downstream western valley without allowing uncontrolled cross-flow toward the east. To achieve this, the system comprises:

Branched channels:

- Western Middle Channel – an upper gabion-lined cut-off trench;
- West Masonry Channel – a roadside masonry drain; and
- Main Channel 2 – a short link connecting the upper channels into the main system.

These branches collect hillside runoff, road runoff and local surface flows and concentrate them into a single flow path.

Western main channels:

- Main Channels 1, 3 and 4 – a continuous gabion-and-concrete channel running downslope toward the lower valley.

Three sumps:

- Strategically located to dissipate energy, trap sediment and provide controlled hydraulic transitions between steeper and flatter reaches.

Figure 3-1, provides an overview of the Western Channel arrangement, extracted from the latest general arrangement drawings ETS TM NMB GA 001b.



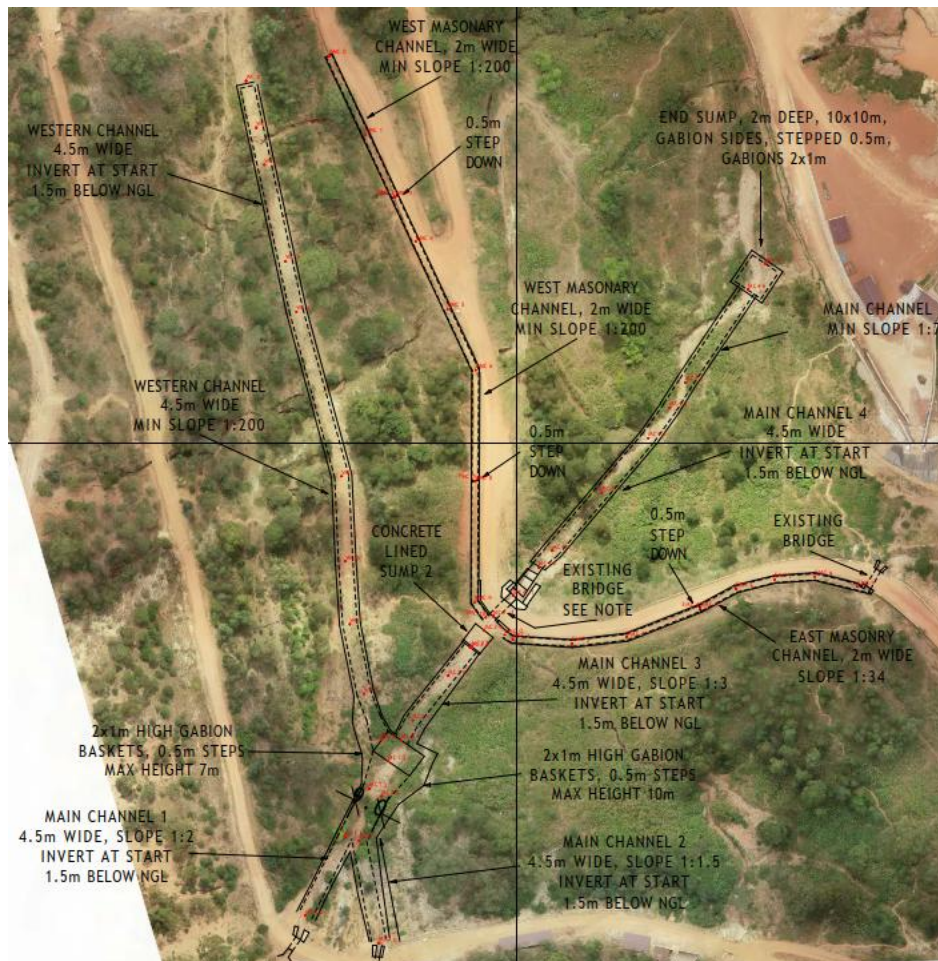


Figure 3-1: Western Channel overview

The Western main channel terminates in a final sump at the downstream edge of the system. This sump is deliberately located on the western side of the valley so that outflow continues along existing western drainage paths, preventing water from spilling over into the Eastern Channel alignment and thereby reducing erosion risk on the eastern slopes.

A detailed plan, long-section and typical cross-sections are provided in *Appendix D – Detailed Drawings* (drawings GA 001a, GA 001b, CLS 003 and DTL 002) with design calculations in *Appendix B – Western Channel Hydraulic Calculations*.

3.2 WESTERN MIDDLE CHANNEL

The Western Middle Channel is a gabion-lined cut-off trench positioned high on the western slope. Its invert is typically excavated about 1.5 m below NGL, founded on compacted residual soil with local rock exposures. The base width is 4.5 m and side walls consist of 2.0 × 1.0 m gabion baskets, stacked to provide a minimum lining height of about 2.0 m above the design water surface. Near Sump 1 the longitudinal slope flattens to around 1:200 to reduce velocities and facilitate the transition into the sump.



Figure 3-2 , from drawing DTL 002, shows a typical section and the arrangement of gabion steps near the sump.

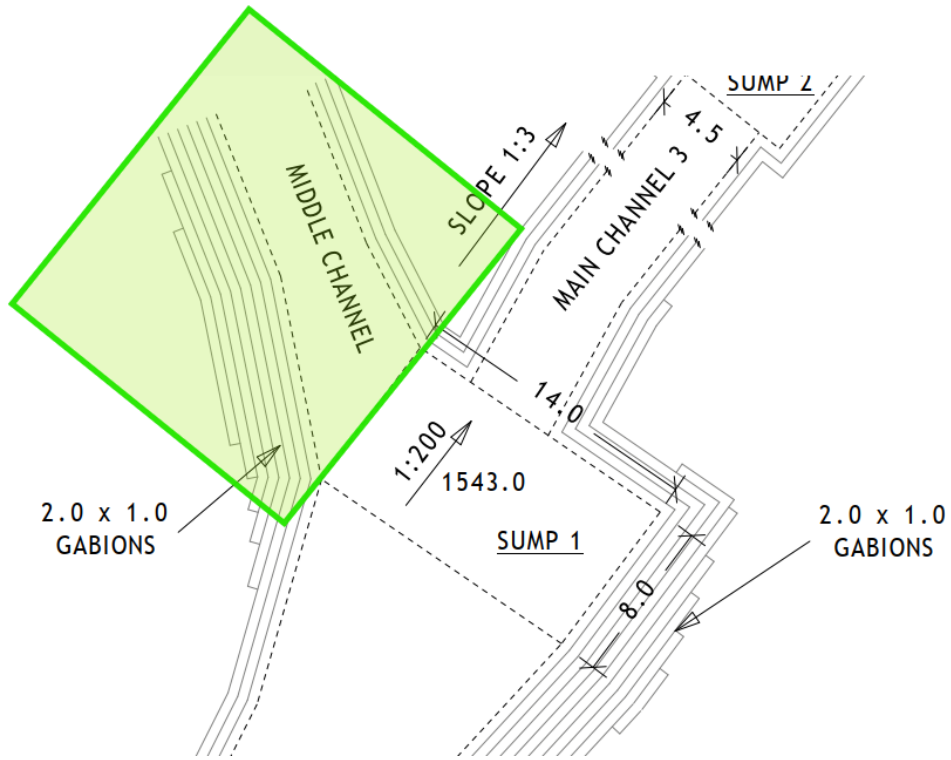


Figure 3-2: Western Channel plan (from drawing DTL 002)

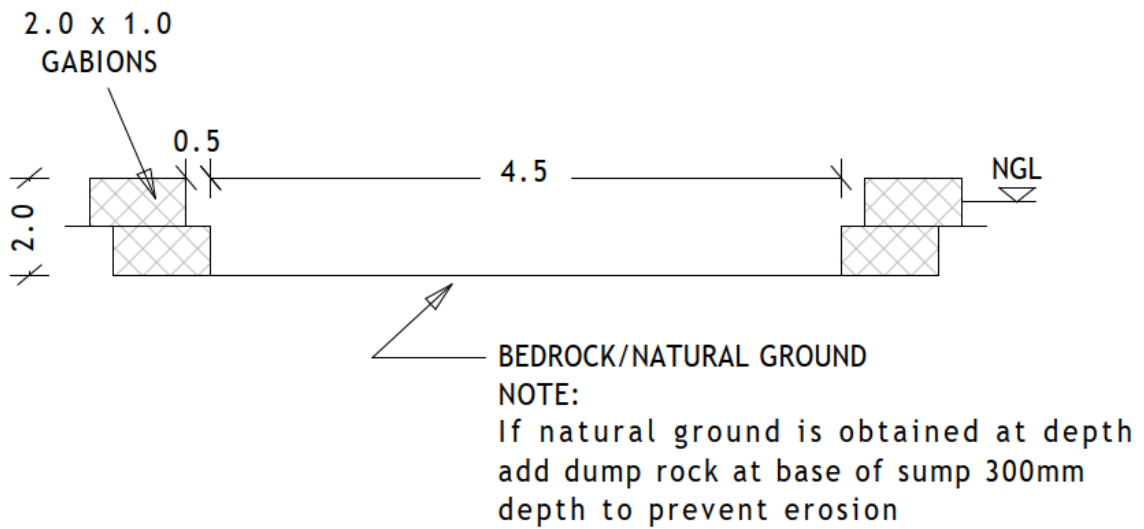


Figure 3-3: Western Channel cross-section (from drawing DTL 002)

A summary of the hydraulic parameters for the Western Channel is given in Table 3-1.



Table 3-1: Summary of branched channel's

Parameter	Western Middle Channel
Size Required (Rectangular Channel)	
Channel Width (B)	4.50
Flow Depth (y)	0.80
Flow Available	
Flow rate (Q), m ³ /s	10.54
Slope of channel's bottom surface (1:slope)	200
Mannings roughness coefficient (n-value)	0.02
Wetted Perimeter (P), m	6.10
Additional Parameters	
Flow Velocity (v), m/s	2.65
Froude Number (Fr)	0.80
Flow Regime	0.94
Flow Regime	Subcritical

The table shows that, for the design discharge, the channel operates with moderate velocities and a Froude number comfortably below unity. This confirms a subcritical regime with good hydraulic stability, and it demonstrates that the chosen 4.5 m base width is effective in keeping depths and velocities within the capacity of the gabion lining.

3.3 WEST MASONRY CHANNEL

The West Masonry Channel runs alongside the main access road and intercepts both road runoff and hillside flows. It typically has a 2.0 m wide reinforced concrete base with 220 mm thick masonry side walls founded on compacted subgrade. Where the longitudinal slope exceeds about 1:20, 0.5 m drop steps are introduced to control velocities and form short stilling pools. The typical overall slope lies between 1:8 and 1:34, depending on local topography.

The typical cross-section, including base thickness and wall depth, is illustrated in Figure 3-4.



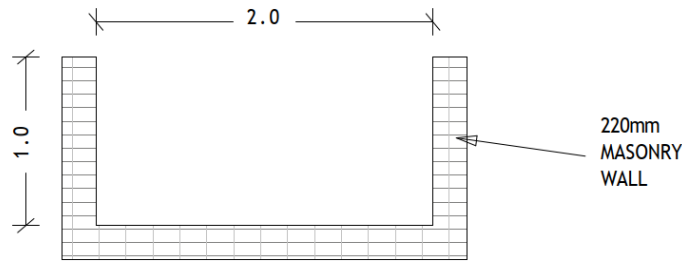


Figure 3-4: West Masonry Channel typical section

The channel is deliberately located adjacent to existing roads so that local Rwandan masonry skills can be used effectively in construction and maintenance. Similar masonry channels could later be extended along additional mine roadways to capture and safely convey road runoff into the main Western system.

Because the Western Middle Channel above this roadside trench takes the majority of the sub-catchment runoff, the West Masonry Channel is designed for approximately half of the Western Middle Channel's design peak flow, representing local accumulation and overflow from the upper channel and road runoff. For this smaller channel, supercritical conditions become more likely, and an energy dissipation step is included accordingly.

The key hydraulic parameters are summarised in Table 3-2.

Table 3-2: Summary of western bottom channel

Parameter	West Masonry Channel
Size Required (Rectangular Channel)	
Channel Width (B)	2.00
Flow Depth (y)	0.80
Flow Available	
Flow rate (Q), m ³ /s	5.48
Slope of channel's bottom surface (1:slope)	100
Mannings roughness coefficient (n-value)	0.02
Wetted Perimeter (P), m	3.60
Additional Parameters	
Flow Velocity (v), m/s	2.98
Froude Number (Fr)	1.06
Flow Regime	Supercritical



The table confirms that the narrower 2.0 m wide channel carries the design flow at a higher velocity and with a Froude number slightly greater than one. This borderline supercritical regime is acceptable provided that the channel geometry includes a 0.5 m drop step, which creates a local hydraulic jump with a calculated conjugate depth of approximately 0.87 m. This jump reduces energy before flow enters Sump 2.

The West Masonry Channel discharges into the concrete-lined Sump 2 just upstream of the second existing bridge, as shown in Figure 3-5 modified from ETS TM NBM SWC GA 001b. From there, flow is combined with that from the Western Middle Channel and conveyed into the Western main channel.

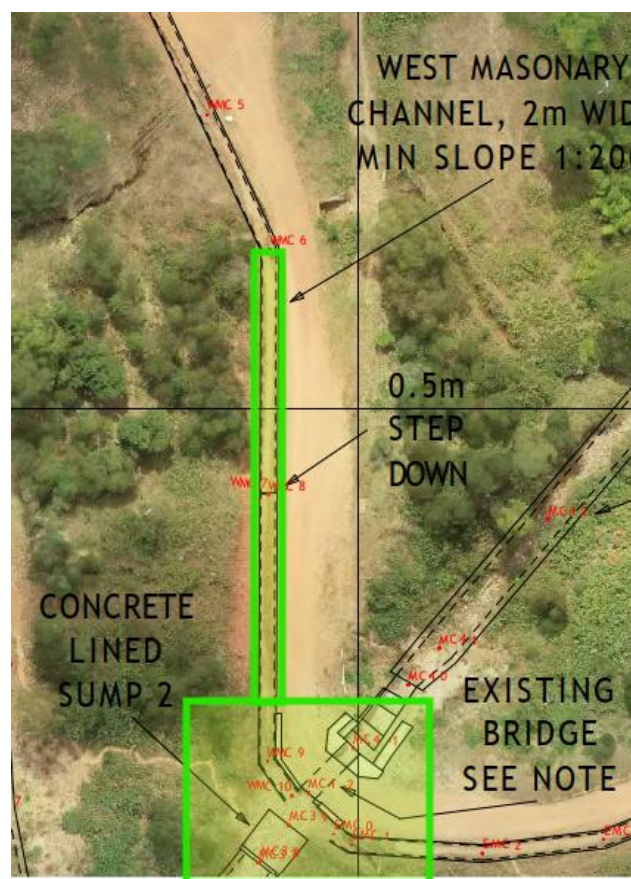


Figure 3-5: West masonry channel decant

3.4 WESTERN MAIN CHANNELS

The main channels starts at the boundary of the LiDAR survey; due to the topographical nature of the slopes the channel is divided into four sections with varying slopes as outlined in Table 3-3.



Table 3-3: Summary of Main Channel 01

Parameter	Main Channel 01	Main Channel 02	Main Channel 03	Main Channel 04
Size Required (Rectangular Channel)				
Channel Width (B)	4.50			
Flow Depth (y)	0.80			
Flow Available				
Flow rate (Q), m ³ /s	105.35	121.65	86.02	56.31
Slope of channel's bottom surface (1:slope)	2	1.5	3	7
Mannings roughness coefficient (n-value)	0.02			
Wetted Perimeter (P), m	6.10			
Additional Parameters				
Flow Velocity (v), m/s	2.65			
Froude Number (Fr)	0.94			
Flow Regime	Subcritical			

The very large theoretical flow capacities shown in the “Flow rate Q” row reflect the maximum discharge that the adopted geometry would convey at the stated slopes if the channel ran full to the design depth. In practice, the design discharge for the Western system is approximately 9.53 m³/s, so the main channels are intentionally oversized, providing ample freeboard and additional capacity for future extensions or unforeseen increases in runoff.

For hydraulic assessment of flow regime and lining performance, a consistent design depth and cross-section have been adopted across all four segments. Because the width, depth and design discharge are the same, the calculated velocity and Froude number are also common to all main channel reaches. Velocity is determined from the design discharge divided by the cross-sectional area, and the Froude number depends on this velocity and the flow depth. Variations in bed slope primarily affect the free-surface gradient and head losses rather than the chosen design flow regime.

The resulting Froude number of about 0.94 indicates near-critical but still subcritical conditions along the main channels for the design flow. This has several implications:

- The wide channel geometry keeps depths shallow and velocities moderate under design conditions, reducing erosion risk on the gabion side walls and concrete invert.



- Because the channels are designed close to the critical regime, local constrictions, debris accumulation, or unplanned narrowing could readily push the flow into the supercritical range. Under such conditions, erosive forces on the gabion lining and bed would increase significantly.
- To mitigate this risk, the design incorporates sumps for energy dissipation and recommends strict maintenance (Section 7) to keep the main channels clear of blockages and to repair any damage to the lining.

A typical cross-section of the Western main channel is shown in Figure 3-6.

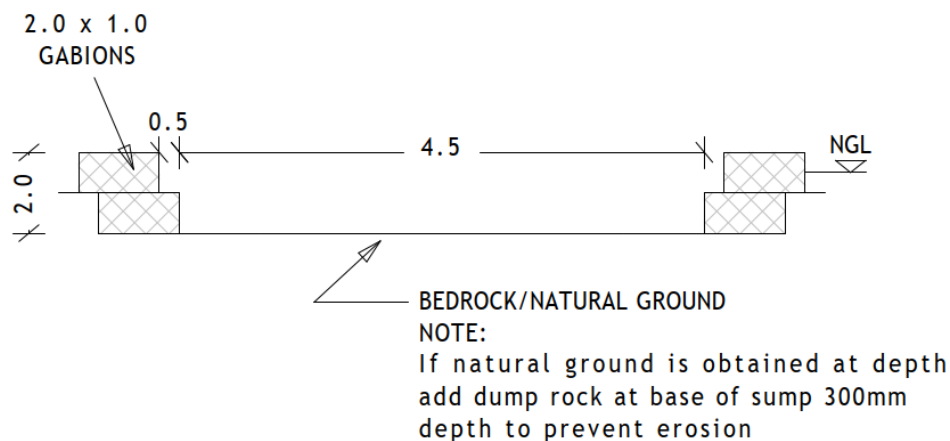


Figure 3-6: Main channel – Typical Section

Detailed calculations, including sensitivity checks on depth and roughness, are presented in Appendix B.

3.5 SUMPS

Three sumps are distributed along the Western system to perform both hydraulic and sediment management functions:

- Sump 1 – Located at the confluence of the Western Middle Channel, West Masonry Channel and Main Channel 2.
- Sump 2 – Positioned between Main Channels 3 and 4, downstream of the West Masonry Channel decant.
- Sump 3 – The final downstream sump, forming the outlet of the Western system.

All sumps are excavated into natural ground and, where necessary, shallow rock. The sides are lined with gabion walls, and the interior surfaces are sealed with 25 MPa concrete, using 19 mm stone aggregate. The base is ripped to approximately 0.5 m below the final invert and recompacted in 150 mm layers to at least 95 % Mod. AASHTO to resist scour and settlement.

A geometric summary of each sump is provided in Table 3-4.



Table 3-4: Summary of western sumps

Sump	Plan Size (m)	Minimum depth (m)	Notes
Sump 01	14 x 10	2	Junction of branched channels; main Western collection sum
Sump 02	7 x 10	2	Energy dissipator upstream of Main Channel 4
Sump 03	10 x 10	2	System outlet on western side of site

Sump 3 is intended to be operated as a small storage basin with pumped decant. Pumped water can be returned to the plant or, if required, discharged in a controlled manner toward the eastern system via a future dedicated conduit. No permanent gravity channel currently connects Sump 3 to the Eastern Channel; this is a deliberate choice to keep western runoff on the western side and thereby maintain a dry corridor between the two systems for safer mining operations.

The detailed sump geometry, including plan, section and reinforcement details, is provided on drawing ETS TM NMB SWC DTL 002 in Appendix D.

3.6 BRIDGE CONSTRUCTION

The existing bridge / culvert structure over the Western main channel is hydraulically and structurally inadequate. The upgraded crossing must provide:

- a minimum clear horizontal span of 5.5 m between inner faces of abutments; and
- a minimum vertical clearance of 1.1 m between the 1:50-year design water level and the underside of the bridge deck.

The hydraulic opening is tied into the Western main channel alignment and wall positions so that channel geometry and lining are continuous through the crossing. The replacement structure may be implemented either as:

- A single or multi-cell reinforced concrete culvert with equivalent waterway area; or
- A short span bridge with open channel beneath.

In either case, regular inspection and removal of debris will be essential to avoid blockage and afflux, particularly given the high sediment loads during intense storms.



The number of formal crossings on the Western system is intentionally limited to minimise obstructions that could increase local flow velocities, cause supercritical conditions, and trigger erosion of the gabion and concrete linings.

4 EASTERN CHANNEL

4.1 OVERVIEW

The Eastern Channel is the primary diversion for runoff generated on the eastern side of the Nyamyumba catchment. It is aligned along the eastern valley side so that flows are kept clear of mine portals, plant areas and haul roads before being discharged into a vegetated dispersion area downstream.

An overview of the Eastern Channel alignment, including chainages, bends, stilling basins and the outlet, is shown in Figure 4-1, compiled from drawings GA 001a and GA 001b.

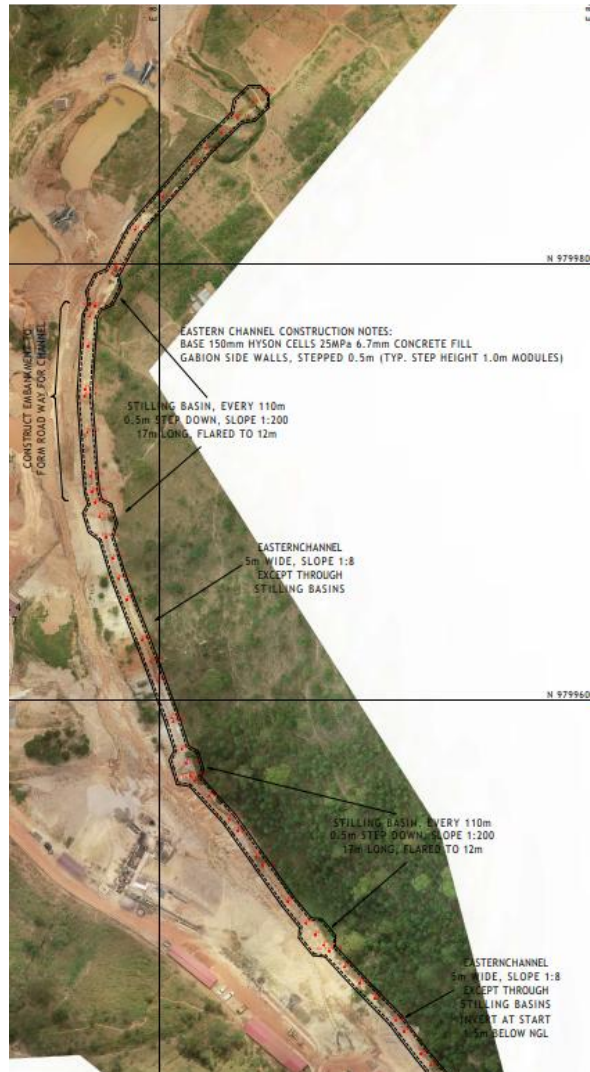


Figure 4-1: Eastern Channel general arrangement



The Eastern Channel is designed to manage the flows from the eastern sub-catchment independently of the Western system. However, for conservatism, the channel's hydraulic capacity is checked against the full 38.07 m³/s peak discharge derived from the overall hydrology.

4.2 EASTERN CHANNEL GEOMETRY AND CONSTRUCTION

The Eastern Channel is approximately 560 m long. Outside of stilling basins, the longitudinal gradient is around 1:8, while the floors of the stilling basins themselves are much flatter at about 1:200.

The typical cross-section is shown in Figure 4-2 and consist of:

- A 5.0 m wide base with 150 mm thick Hyson-cell mattress infilled with 25 MPa concrete;
- 2.0 × 1.0 m gabion walls on each side, stepped vertically in 0.5 m increments;
- channel excavated such that the invert at the upstream start is roughly 1.5 m below NGL; and
- subgrade ripped and compacted to at least 95 % Mod. AASHTO.

A representative long-section of the eastern channel is provided in Figure 4-2

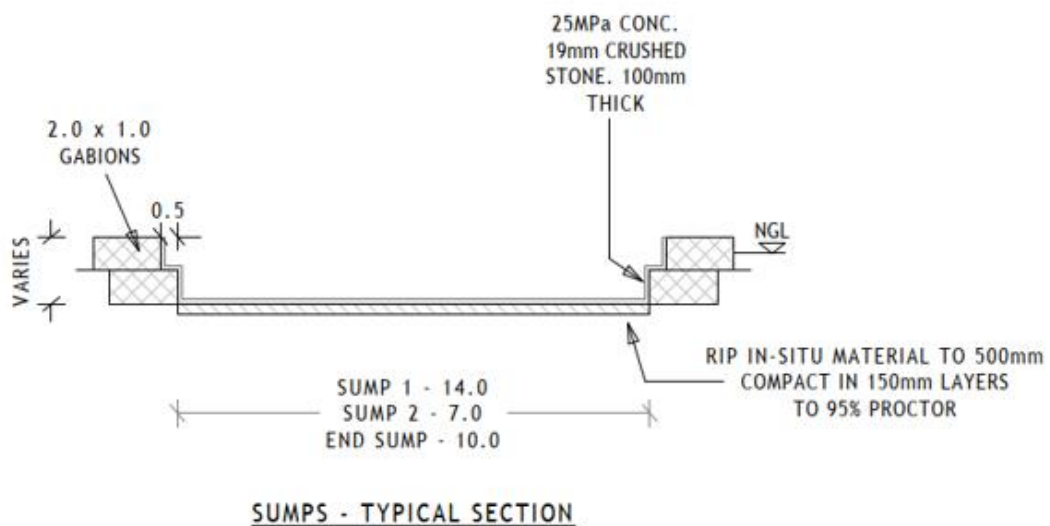


Figure 4-2: Typical cross-section of eastern channel

Table 4-1 summarises the representative hydraulic parameters for the main Eastern Channel outside the stilling basins.



Table 4-1: Eastern channel hydraulic parameters

Parameter	Eastern Channel
Size Required (Rectangular Channel)	
Channel Width (B)	5.00
Flow Depth (y)	0.80
Flow Available	
Flow rate (Q), m ³ /s	59.58
Slope of channel's bottom surface (1:slope)	8
Mannings roughness coefficient (n-value)	0.02
Wetted Perimeter (P), m	6.60
Additional Parameters	
Flow Velocity (v), m/s	9.52
Froude Number (Fr)	3.40
Flow Regime	Subcritical

The table shows that for the adopted geometry and steep slope, uniform flow in the Eastern Channel would be strongly supercritical, with a Froude number of about 3.40 and velocities approaching 10 m/s. A classical hydraulic jump formed directly in this prismatic channel would produce a conjugate depth y_2 of approximately 3.46 m, which would require very high walls and deep excavations to contain, and would still subject the invert to severe impact forces.

To avoid constructing an impractically deep jump basin and to protect the gabion and Hyson-cell lining, the design uses dedicated stilling basins at intervals along the channel (Section 4.3). These basins broaden the flow, flatten the slope, and introduce baffle blocks and end sills, thereby reducing velocity and depth requirements while providing effective energy dissipation.

The detailed derivation of the Eastern Channel's normal depth, velocity, Froude number and conjugate depths is provided in Appendix C – Eastern Channel Hydraulic Calculations.



4.3 STILLING BASINS

Given the high supercritical velocities in the Eastern Channel, the design requires robust energy dissipation structures to transition flows safely to subcritical conditions. For this purpose, USBR Type III stilling basins were selected, using the methodology and dimensionless design charts published in the USBR “Hydraulic Design of Stilling Basins and Energy Dissipators”.

Key reasons for adopting a Type III basin at Nyamyumba are:

- It is specifically intended for high Froude number inflows ($Fr \approx 2.5-4.5$), which matches the computed $Fr \approx 3.40$ in the Eastern Channel;
- The basin uses a shallow floor depression combined with an end sill and baffle blocks to produce a stable hydraulic jump without requiring excessively deep excavation; and
- It performs well in channels where the upstream invert is steep and where downstream slopes remain significant but flatter than the incoming reach.

To manage hydraulic energy and control supercritical flow a USBR Type III stilling basins are placed at intervals of roughly 110 m along the Eastern Channel. Each basin has the following principal features (see Figure 4-3 and drawing DTL 002 in Appendix D):

- A length of about 17 m;
- Width increasing from 5 m at the upstream end to approximately 12 m at the downstream end;
- Floor slope of 1:200;
- 0.5 m vertical drop between upstream and downstream inverts; and
- An end sill (~0.25 m high) and 0.4 m high baffle blocks arranged at about 135° to the flow direction.

These features are shown in Figure 4-3 (from drawing DTL 002). They promote hydraulic jumps and greatly reduce velocities entering the downstream 1:8 reaches.



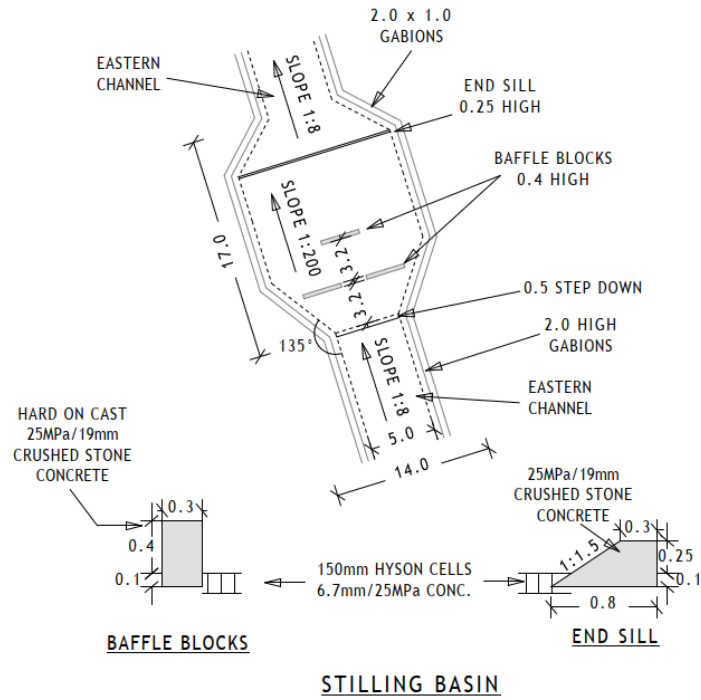


Figure 4-3: Typical stilling basin plan and section

The sizing of these basins was carried out as follows:

1. The incoming Froude number ($Fr_1 \approx 3.40$) and design discharge were taken from the Eastern Channel hydraulic analysis.
2. USBR Type III design charts were used to determine the recommended relative basin length, baffle block height and spacing, and end sill height for this Froude number.
3. Trial geometries were checked against these recommendations and iteratively refined to achieve stable jump formation within the basin length and to ensure that downstream flow is subcritical at velocities compatible with the Hyson-cell and gabion lining.
4. Structural and constructability considerations were incorporated, including appropriate thicknesses of concrete, gabion anchorage and access for maintenance.

The entire interior of each basin – including floor, baffles and end sill – is lined with 25 MPa concrete, and the transition sections upstream and downstream are lined with Hyson cells infilled with concrete. The side slopes are formed by stepped gabion walls, sealed on their inner faces with concrete to prevent water ingress and potential piping through the fill.

The design intent is that high-velocity, supercritical flow from the 1:8 channel sections enters each stilling basin, forms a controlled hydraulic jump within the widened basin, and exits at significantly



reduced velocity and in a subcritical regime. This arrangement avoids uncontrolled jumps further downstream, protects the lining, and limits the potential for scour or undermining of the structure.

5 RECOMMENDATIONS

The following strategic recommendations support the effectiveness and resilience of the Nyamyumba stormwater system:

1. **Extend masonry channels along key roads.**

Local masonry-lined side drains should be constructed along steep road sections and tied into the West Masonry Channel and Eastern Channel, reducing the risk of road-edge erosion and uncontrolled gullies.

2. **Divert runoff into engineered main channels wherever practicable.**

Informal rills and ad-hoc ditches should be rationalised so that stormwater is intercepted by the Western and Eastern main channels rather than traversing operational areas or flowing in unprotected paths.

3. **Use terracing or benching on vulnerable slopes.**

On steep western slopes above the Western Channel, small terraces should be formed to interrupt long flow paths, encourage infiltration and guide water into the cut-off channels.

4. **Introduce drop structures in masonry channels.**

Additional 0.5 m drop steps in the West Masonry and similar channels should be installed on steeper reaches to reduce velocities and form local stilling pools.

5. **Extend the Eastern system as survey data improves.**

Once updated LiDAR is available and operational layouts are fixed, the Eastern Channel can be extended or supplemented with additional controls to incorporate any remaining drainage gaps near the plant and downstream infrastructure.

6 QUALITY ASSURANCE AND QUALITY CONTROL (QA/QC)

High-quality construction is critical to the performance and longevity of the Nyamyumba stormwater system, especially given the steep topography, erosive soils and reliance on older survey data for initial design. This section outlines the key QA/QC requirements, which should be incorporated into the construction specification in accordance with SANS 1200, SANS 2001, SANS 10100 and related standards.



6.1 SURVEY AND SETTING-OUT

Accurate setting-out of channels, sumps, stilling basins and bridge works is vital for achieving the design hydraulic gradients and freeboard.

- Verify survey control points against the latest WGS84 coordinates before starting construction.
- Set out centreline, invert levels and sidewall tops at the specified chainages for all channels using a total station or GNSS survey equipment.
- Check constructed inverts and wall heights at regular intervals (e.g., every 20–25 m) and compare with design values; document all measurements.
- Where significant deviations from design levels are detected (e.g., exceeding ± 100 mm), halt construction in that section and consult the design engineer to determine whether local adjustments or revised gradients are required.

6.2 EARTHWORKS AND FOUNDATIONS

Earthworks must comply with SANS 1200 DA / DB and be executed to provide stable foundations for gabions, Hyson cells, concrete bases and bridge abutments.

- Strip topsoil, organics and loose material from channel footprints and sump areas before excavation.
- Excavate to the design invert or until competent material is encountered; avoid leaving thin lenses of soft material beneath structural elements.
- Where bedrock is not encountered at the expected depth, consider over-excavation and replacement with compacted engineered fill or concrete blinding, subject to engineer approval.
- Compact fills supporting channel walls, gabion baskets and sump bases in layers not exceeding 150–200 mm thickness, to at least 95 % Mod. AASHTO; verify compaction with in-situ density tests where practical.

6.3 GABIONS AND ROCK PROTECTION

Gabion works must meet manufacturer's specifications and relevant SANS requirements.

- Use galvanised or PVC-coated wire baskets with specified mesh aperture and wire thickness; verify supplier certificates.
- Fill gabions with hard, durable rock of appropriate size (typically 100–250 mm) free from soft or friable material.



- Place and compact rock to minimise voids and ensure a dense matrix; lids should close without excessive bulging.
- Tie baskets together with lacing wire at all edges and diaphragms to form a continuous monolithic structure.
- Ensure gabion steps and retaining walls are founded on competent material or concrete pads where indicated, with geotextile provided behind walls where seepage is expected.

6.4 CONCRETE AND HYSON CELLS

Concrete works – including stilling basins, sump linings, end sills, baffle blocks, Hyson cell infill and bridge components – must comply with SANS 2001-CC1 and SANS 10100.

- Use a concrete mix with a characteristic strength of at least 25 MPa at 28 days for all hydraulic structures, unless a higher grade is specified.
- Perform regular slump tests, cube tests and temperature monitoring to confirm compliance with mix design and curing conditions.
- Ensure adequate curing (e.g., wet covering or curing membrane) for at least seven days, particularly in stilling basin floors and Hyson-cell inverts exposed to high velocities.
- Confirm that Hyson cell panels are properly anchored, fully filled with concrete, and finished flush to minimise turbulence and snagging of debris.

6.5 CHANNEL GEOMETRY AND SLOPE CONTROL

Given the sensitivity of hydraulic performance to channel geometry, careful QA/QC is required to ensure that design widths, depths and slopes are achieved.

- Measure channel width, wall height and invert level at regular cross-sections and compare with design; tolerances should be agreed with the engineer (typically ± 50 mm in width and depth).
- Confirm that constructed slopes along each reach are close to the design values (e.g., 1:8, 1:200), particularly near transitions into sumps and stilling basins; adjust via local excavation or backfill where necessary.
- Check that all drop structures and steps are built to the specified height and that transitions are smoothly graded to avoid unintended local accelerations or ponding.

6.6 DOCUMENTATION AND CONTRACTOR RESPONSIBILITIES



- Maintain a comprehensive QA/QC file including test results (compaction, concrete strength), survey records, inspection reports and photographs.
- Record and communicate any deviations or unforeseen ground conditions to the design engineer without delay.
- Update as-built drawings to reflect final levels, channel alignments, and locations of key structures, to support future maintenance and potential Phase 2 works.

7 MAINTENANCE

The performance of the stormwater system is highly dependent on regular maintenance. Recommended activities include:

- Routine inspections before and after significant rainfall to check channels, sumps, stilling basins and the bridge for erosion, structural damage or blockages.
- Sediment removal from sumps and stilling basins when accumulated material significantly reduces effective depth or flow area.
- Vegetation management along channels and banks to maintain protective grass cover while preventing tree roots from destabilising gabions.
- Repair of gabions and concrete where baskets have broken, stones have been lost, or concrete has cracked or spalled.
- Inspection of road crossings to verify that bridge abutments, wing walls and approach embankments remain stable and free of scour.
- Record-keeping, including an inspection log and updated as-built drawings as minor changes are implemented.

These tasks should form part of the mine's routine environmental and civil maintenance programme.

8 BILL OF QUANTITIES

A detailed Bill of Quantities (BoQ) is provided in Appendix E. It is structured to provide the volume and material requirements for the construction of the western and eastern channel.

The quantities are based on the latest design drawings (Appendix D) and may be refined during detailed setting-out.



9 CONCLUSION

The stormwater management system presented in this report provides a coherent, technically robust solution for managing surface water at Nyamyumba Mine. Using a combination of hydrological analysis, open-channel hydraulics and recognised design standards, the system has been configured to:

- Safely convey the 1:50-year design storm for both the western and eastern catchments;
- Intercept and control runoff via branched channels on the western side and a dedicated Eastern Channel that bypasses critical mine infrastructure;
- Dissipate energy and control supercritical flows using sumps in the Western system and USBR Type III stilling basins in the Eastern channel;
- Maintain predominantly subcritical flow regimes in the main channels under design conditions, while recognising that local narrowing or obstruction could induce supercritical flows and therefore requires vigilant maintenance; and
- Provide sufficient structural and hydraulic capacity – especially in oversized Western main channels and lined Eastern reaches – to accommodate uncertainty in hydrology, survey and future mine development.

The report also emphasises the importance of QA/QC and maintenance. Given the erosive character of the local soils and steep slopes, the long-term success of the system will depend on:

- Constructing channels, sumps, stilling basins and bridge works in strict accordance with the specified geometry and lining details;
- Adhering to SANS-based QA/QC protocols for survey, earthworks, gabions, concrete and Hyson cells; and
- Implementing a proactive inspection and maintenance programme to manage sediment, repair damage and address any changes in site conditions.

Subject to these implementation and operational commitments, the proposed stormwater system is considered fit for purpose and capable of significantly reducing flood and erosion risks at Nyamyumba Mine, thereby supporting safe, sustainable and compliant mining operations within the broader Rutongo concession.

THE END



Appendix A: Flood Hydrology Report



Flood Hydrology Report

Nyamyumba Mine

This appendix summarises the flood hydrology assessment undertaken for the stormwater management and tailings facility design at Nyamyumba Mine. The objective is to estimate design rainfall, runoff response and peak flows associated with extreme rainfall events, and to provide input parameters for sizing interception drains, diversion channels and storage volumes. The methodology follows the same overall approach as that applied at Nyakabingo Mine, adjusted to the local catchment characteristics and rainfall regime at Nyamyumba.

1. Precipitation Depth and IDF Curves

Due to limited long-term records from automatic rain gauges in Rwanda, particularly for short-duration events, design rainfall at Nyamyumba was derived from regional Intensity–Duration–Frequency (IDF) relationships rather than from a dedicated on-site gauge record.

A literature review undertaken for the Nyakabingo flood hydrology study was re-used for Nyamyumba. This includes national drainage design guidelines, hydrological modelling case studies and, most importantly, published IDF analyses for Rwanda. The work by Wagesho & Van De Vyver (2016) and Van De Vyver et al. (2013) provides regional IDF parameters for a network of rainfall stations across the country.

The 26 rainfall stations compiled in these studies were grouped into five homogeneous rainfall regions, each with its own set of IDF parameters. Nyamyumba Mine is located in Western Province, Rubavu District, near Lake Kivu and in the vicinity of the Gisenyi and Busasamana rain gauge stations. These gauges fall within Rainfall Region 2 (Busasamana, Gisenyi, Gishyita and Kabaya). Region 2 is therefore considered most representative of the Nyamyumba site.

For Nyamyumba, the regional IDF parameters for Region 2 and a 1:50 year return period were evaluated for storm durations of 15 minutes and 24 hours. The resulting 24-hour 50-year rainfall depth from the IDF curves was increased by an overall factor of safety to account for data uncertainty and potential future intensification of extreme storms. This yields a conservative design 24-hour rainfall depth of 195 mm. The corresponding 15-minute 50-year rainfall depth used for peak-flow calculations is 30 mm.

Expressed as average rainfall intensities, the adopted design values are:

- $i_{15mn} = 30 \text{ mm} / 0.25 \text{ h} = 120 \text{ mm/h}$
- $i_{24h} = 195 \text{ mm} / 24 \text{ h} \approx 8.1 \text{ mm/h}$

A 1:50 year return period was adopted to be consistent with the Nyakabingo design criteria and with typical national guidance for critical mining and tailings infrastructure, providing a balance between safety and practicality.

2. Catchment Delineation and Classification

Topographic information for the Nyamyumba area was analysed to delineate the upstream drainage area contributing runoff towards the proposed tailings facility and associated diversion works. High-resolution digital elevation data, orthophotography and mine layout information were used to trace surface flow paths, identify watershed divides and define the boundary of the contributing catchment.

In contrast to Nyakabingo, where several sub-catchments were distinguished, the Nyamyumba facility is predominantly influenced by a single upstream catchment. This catchment is referred to as CM_1 in the calculations. The following geometric characteristics were derived from the digital elevation model and plan layout:

- Catchment area $A = 1.142 \text{ km}^2$ (approximately 114.2 ha).
- Maximum flow path length $L = 2.377 \text{ km}$.
- Average ground slope $S = 0.20 \text{ m/m}$.

The time of concentration (T_c) for CM_1 was estimated using empirical relationships that relate T_c to flow length, slope and surface roughness, consistent with the approach used for Nyakabingo. The resulting value is $T_c \approx 2$ minutes, indicating a very rapid hydrological response to short, intense storms. Because the adopted 15-minute design storm duration is substantially greater than T_c , the assumption of approximately uniform rainfall during the time of concentration required by the Rational Method is satisfied.

3. Runoff Estimation – Rational Method

Peak runoff from the Nyamyumba catchment was estimated using the Rational Method, which is widely applied to small catchments (typically less than about 15 km^2) and short-duration design storms. For Nyamyumba the standard form of the equation in SI units is:

$$Q = 0.278 \times C \times i \times A$$

where:

- Q = peak discharge (m^3/s);
- C = runoff coefficient (-);
- i = rainfall intensity corresponding to the selected storm duration and return period (mm/h);
- A = catchment area (km^2).

Given the combination of steep slopes, compacted mine workings, haul roads and exposed subsoil within the Nyamyumba catchment, a runoff coefficient of $C = 1.0$ was adopted. This

represents near-complete conversion of rainfall to runoff under extreme storm conditions and is consistent with the conservative assumption used at Nyakabingo.

Short-duration design event (15-minute, 1:50 year)

For the short-duration design event used to size diversion channels and local drainage structures:

- $A = 1.142 \text{ km}^2$;
- $C = 1.0$;
- $i = 120 \text{ mm/h}$ (30 mm in 15 minutes).

Substituting these values into the Rational Method gives:

$$Q_{15\text{min}} = 0.278 \times 1.0 \times 120 \times 1.142 \approx 38.07 \text{ m}^3/\text{s}$$

This peak discharge is used as the design flow for sizing new or upgraded diversion channels, culverts and other hydraulic structures that must safely pass rapid runoff from intense convective storms.

Long-duration design event (24-hour, 1:50 year)

For assessment of longer-lasting inflows to storage facilities (e.g. tailings impoundment, sedimentation ponds) the 24-hour design storm was also evaluated:

- $A = 1.142 \text{ km}^2$;
- $C = 1.0$;
- $i = 195 \text{ mm} / 24 \text{ h} \approx 8.1 \text{ mm/h}$.

Substituting into the Rational Method gives:

$$Q_{24\text{h}} = 0.278 \times 1.0 \times 8.125 \times 1.142 \approx 2.58 \text{ m}^3/\text{s}$$

Although the 24-hour peak discharge is much lower than the 15-minute value, it is important for checking the capacity of spillways, outlet structures and emergency discharge routes associated with storage facilities.

4. Hydrological Focus Area

The hydrological design for Nyamyumba concentrates on managing runoff from the single upstream catchment CM_1 draining towards the mine and tailings facility. The calculated peak flows for both the short-duration and 24-hour design storms are used to:

- Dimension cut-off drains and diversion channels around the facility footprint;
- Check the capacity of existing natural channels intersecting the site; and
- Confirm that spillways and emergency routes can safely convey excess flows without causing erosion or overtopping of critical infrastructure.

5. Summary Table of Input Parameters

No	Description	Quantum (Nyamyumba Catchment CM_1)
1	Catchment delineation	Single upstream catchment based on high-resolution DEM, orthophotos and mine layout.
1.1	Design rainfall and return period	1:50 year / 24-hour storm, design depth 195 mm (Region 2 IDF with factor of safety).
1.2	Short-duration design rainfall	1:50 year / 15-minute storm, design depth 30 mm.
2	Run-off calculation method	Rational Method ($Q = 0.278 \times C \times i \times A$).
2.1	Runoff coefficient C	1.0 (steep, compacted and largely impervious mine terrain).
2.2	Average slope	0.20 m/m.
2.3	Time of concentration	2 minutes.
2.4	Catchment area	1.142 km ² (≈ 114.2 ha).
2.5	Design peak discharge – 15-minute storm	38.07 m ³ /s.
2.6	Design peak discharge – 24-hour storm	2.58 m ³ /s.

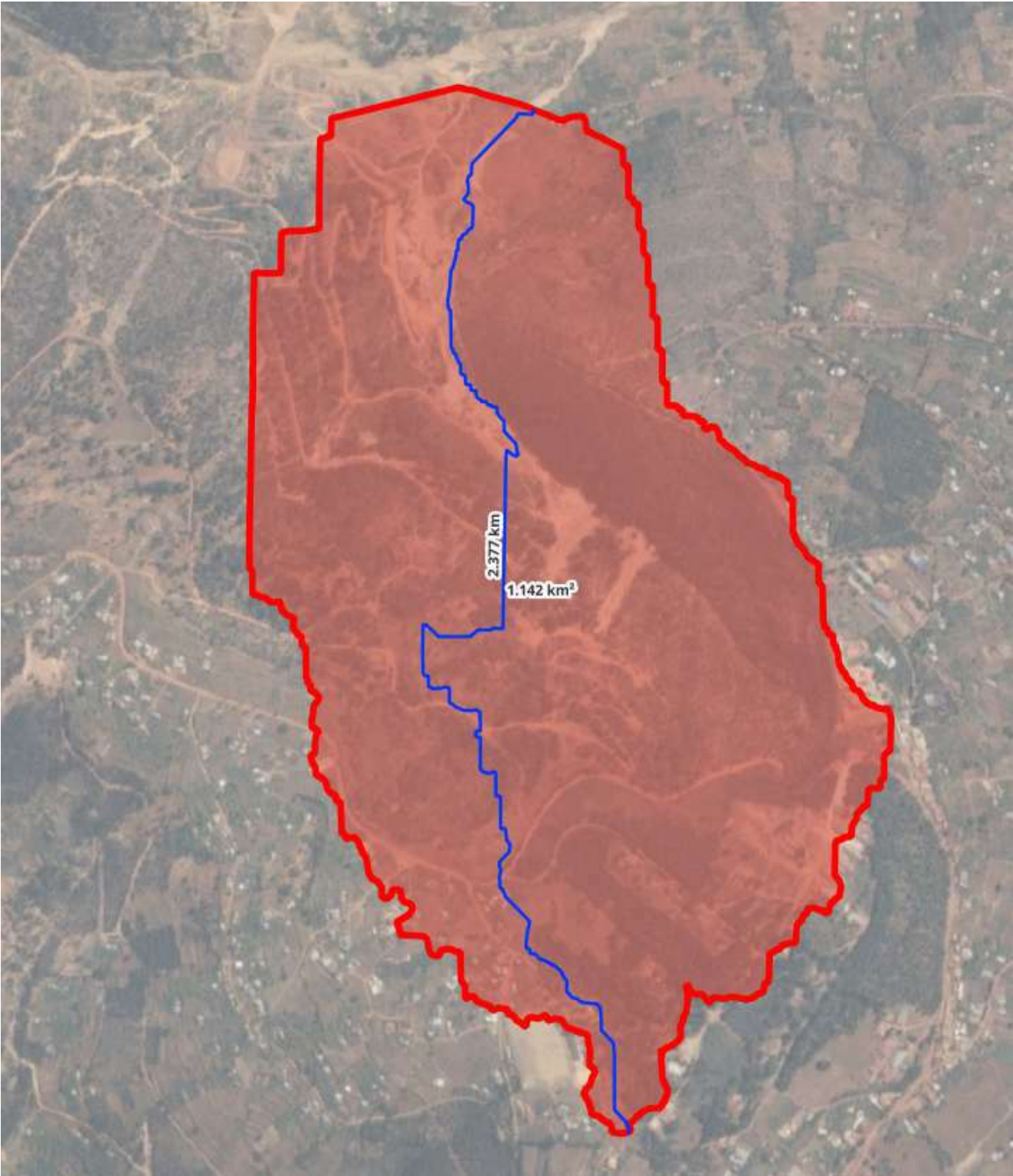
6. Nyamyumba Calculation Summary

Nyamyumba Calculation Summary									
CM Nr.	Area	Length	Slope	Time of concentration	1:50 year rainfall depth 15 minute	1:50 year rainfall depth 24 hours	Runoff coefficient t	Runoff short duration (m ³ /s)	Runoff short duration (m ³ /s)
	km ²	km	m/m	min	mm	mm		m ³ /s	m ³ /s
1	1.142	2.377	0.2	2	30	195	1	38.07	2.58

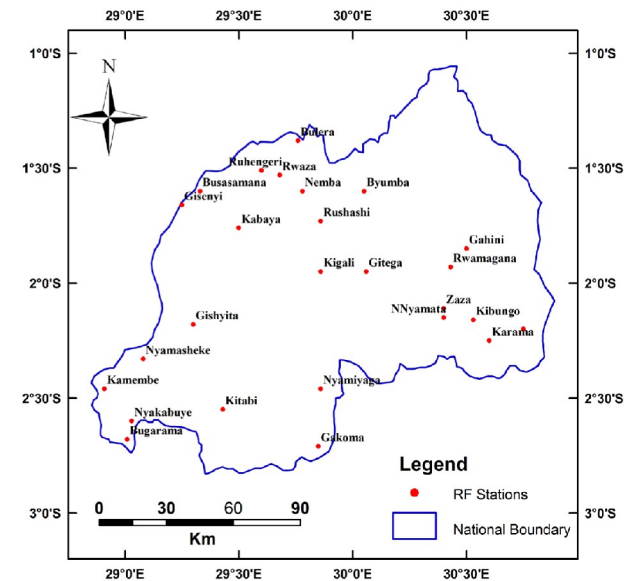
7. Notes and Assumptions

- Design rainfall depths are based on the Rwanda regional IDF relationships (Region 2) for a 1:50 year return period, with an added factor of safety applied to the 24-hour depth.
- The runoff coefficient of 1.0 is intentionally conservative and reflects the largely compacted and disturbed nature of the mine catchment under extreme storm conditions.
- The Rational Method is considered applicable given the relatively small catchment area (1.142 km²) and the short time of concentration (approximately 2 minutes).
- All results represent peak flows at the catchment outlet under fully saturated antecedent conditions.

Nyamyumba Calculation Summary									
CM Nr.	Area	Length	Slope	Time of concentration	1:50 year rainfall depth 15 minute	1:50 year rainfall depth 24 hours	Runoff coefficient	Runoff short duration (m ³ /s)	Runoff short duration (m ³ /s)
	km ²	km	m/m	min	mm	mm		m ³ /s	m ³ /s
1	1.142	2.377	0.2	2	30	195	1	38.07	2.58



S. No.	Rainfall Stations	East	South	Record Length (Years)	Elevation (m)	Mean Annual RF (mm)				
		Longitude (Degree)	Latitude (Degree)							
1	Gitega	30.06	-1.95	1969-2014	46	1474	1069.7	-0.95	1.95	-1.95
2	Kigali	29.86	-1.95	1971-2014	43	1490	1069.5	-0.95	1.95	-1.95
3	Nyamiyaga	29.86	-2.46	1957-2013	57	1800	1198.1	-1.46	2.46	-2.46
4	Gakoma	29.85	-2.71	1986-2013	28	1450	1159.2	-1.71	2.71	-2.71
5	Kitabi	29.43	-2.55	1984-2014	31	2262	1832.2	-1.55	2.55	-2.55
6	Gishyita	29.3	-2.18	1981-2014	32	1665	1539.5	-1.18	2.18	-2.18
7	Busasamana	29.33	-1.6	2001-2014	14	2055	1114.3	-0.6	1.6	-1.6
8	Gisenyi Airport	29.25	-1.66	1982-2014	33	1554	1112.1	-0.66	1.66	-1.66
9	Kabaya	29.5	-1.76	1974-2014	41	2292	1000.8	-0.76	1.76	-1.76
10	Bugarama	29.01	-2.68	1981-2014	34	900	897.3	-1.68	2.68	-2.68
11	Kamembe	28.91	-2.46	1971-2014	44	1591	1500.3	-1.46	2.46	-2.46
12	Nyakabuye	29.03	-2.6	1997-2014	18	1400	1527	-1.6	2.6	-2.6
13	Nyamasheke	29.08	-2.33	1977-2014	38	1527	1317.6	-1.33	2.33	-2.33
14	Nemba	29.78	-1.6	1987-2014	28	1686	1535.7	-0.6	1.6	-1.6
15	Rushashi	29.86	-1.73	1979-2012	32	1650	1259.5	-0.73	1.73	-1.73
16	Ruhengeri	29.6	-1.51	1952-2014	63	1860	1399.6	-0.51	1.51	-1.51
17	Rwaza	29.68	-1.53	1932-2014	83	1800	1332.2	-0.53	1.53	-1.53
18	Bulera lac	29.76	-1.38	1947-2014	68	1862	1134.7	-0.38	1.38	-1.38
19	Byumba meteo	30.05	-1.6	1996-2014	19	2235	1332.5	-0.6	1.6	-1.6
20	Gahini	30.5	-1.85	1974-2014	41	1534	1016.5	-0.85	1.85	-1.85
21	Zaza	30.41	-2.11	1945-2014	70	1515	1138.6	-1.11	2.11	-2.11
22	Nyarubuye	30.75	-2.2	1958-2013	56	1750	924.08	-1.2	2.2	-2.2
23	Kibungo	30.53	-2.16	1957-2012	56	1680	1097.15	-1.16	2.16	-2.16
24	Karama	30.6	-2.25	1965-2014	50	1347	915.66	-1.25	2.25	-2.25
25	Nyamata	30.45	-2.15	1982-2014	33	1428	1084.79	-1.15	2.15	-2.15
26	Rwamagana	30.43	-1.93	1950-2014	63	1535	1115.83	-0.93	1.93	-1.93



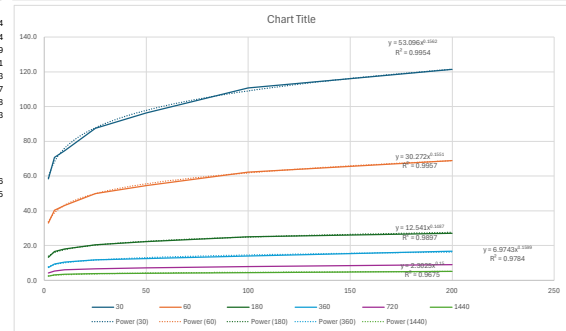
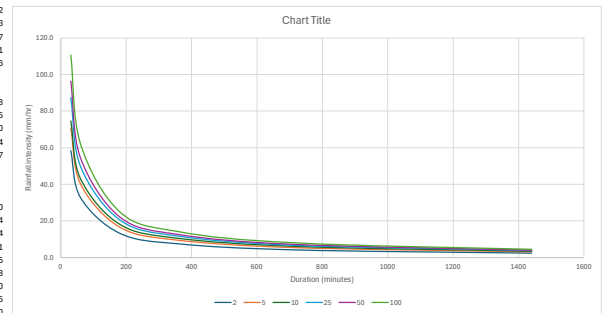
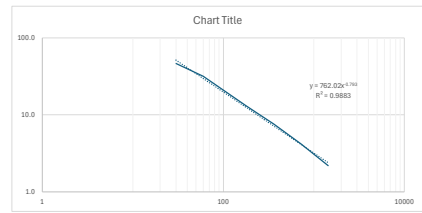
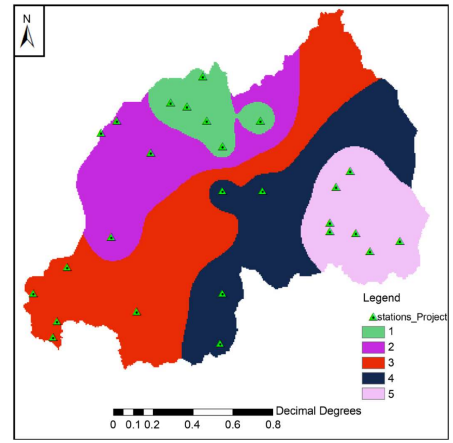
15 Rainfall Stations with IDF Parameters

S.N	Stations	Coefficients	T = 2 yrs	T = 5 yrs	T = 10 yrs	T = 25 yrs	T = 50 yrs	T = 100 yrs
1	Bugarama	α	1048.23	1650.65	1289.53	1109.04	1057.19	2169.15
		γ	6.38	17.33	11.71	4.85	2.19	15.94
		C	0.88	0.91	0.83	0.79	0.77	0.86
		SEE	1.82	0.56	2.53	2.32	2	1.55
2	Bulera	α	2250.96	2142.42	2480.84	2268.19	2846.76	2017.67
		γ	20.56	19.8	19.57	17.33	18.55	11.71
		C	0.97	0.93	0.94	0.9	0.93	0.86
		SEE	1.84	1.84	1.81	2.11	1.84	2.49
3	Busasama	α	1123.6	1373.92	1544.18	1831.31	2214.25	2532.86
		γ	0.62	2.44	3.15	3.94	6.43	8.62
		C	0.8	0.8	0.8	0.82	0.84	0.84
		SEE	0.77	0.83	0.79	0.95	0.78	1.28
4	Byumba	α	2155.87	1222.45	1078.97	1018.31	1068.94	1187.06
		γ	28.94	11.58	4.85	0.05	0.02	0.02
		C	0.95	0.85	0.82	0.8	0.79	0.8
		SEE	1.84	1.77	2.13	3.18	3.15	2.62
5	Gahini	α	366.08	2122.56	2206.1	2259.42	2460.77	2435.12
		γ	0	22.42	20.56	18.55	16.85	13.71
		C	0.68	0.91	0.92	0.91	0.92	0.91
		SEE	1.36	1.14	1.06	0.99	0.93	0.82
6	Gakoma	α	653.46	745.76	814.81	980.55	1037.34	1232.85
		γ	0.02	0.05	0.05	0.05	0.05	0.62
		C	0.78	0.76	0.76	0.77	0.76	0.77
		SEE	4.44	4.02	4.31	4.41	4.49	3.9
7	Gisenyi	α	713.11	780.93	898.91	1231.39	1322.68	2015.57
		γ	0.62	0.62	0.62	2.19	0.62	6.38
		C	0.8	0.76	0.76	0.79	0.78	0.83
		SEE	4.52	3.28	3.7	1.74	2.67	2.36
8	Gishyita	α	743.6	1045.55	841.99	923.06	958.47	1029.51
		γ	4.25	7.38	2.03	2	0.62	0.62
		C	0.8	0.83	0.78	0.78	0.77	0.77
		SEE	2.87	3.04	2.79	3.2	2.99	3
9	Gitega	α	1351.9	1200.76	2087.7	2301.76	2533.42	2153.77
		γ	13.94	7.63	13.14	10.25	9.23	4.22
		C	0.9	0.86	0.93	0.93	0.93	
		SEE	1.17	1.29	1.21	1.04	0.93	
10	Kabaya	α	2312.29	1427.51	1482.56	1571.987	2369.535	2520.63
		γ	26.03	11.85	8.32	3.94	11.86	8.61
		C	0.97	0.87	0.86	0.85	0.88	0.88
		SEE	2.48	1.74	1.28	1.94	0.91	1.18
11	Kamembe	α	1222.07	1241.79	1181.43	1387.63	1199.1	1888.25
		γ	13.94	8.61	4.61	4.85	0.62	8.22
		C	0.86	0.84	0.81	0.81	0.77	0.83
		SEE	1.5228	2.4225	2.8966	3.3448	4.1961	2.9383
12	Karama	α	3525.93	3669.83	3419.79	3510.284	3648.82	3728.63
		γ	47.83	45.31	35.89	29.36	27.42	23.03
		C	0.98	0.98	0.97	0.97	0.97	0.96
		SEE	1.69	1.63	1.39	0.95	0.81	0.68
13	Kibungo	α	3600.71	3617.14	3219.35	3564.3	3723.39	3729.97
		γ	46.59	43.12	32.25	27.41	24.18	20.54
		C	0.97	0.97	0.95	0.95	0.95	0.95
		SEE	2.67	2.48	1.97	1.73	1.55	1.39
14	Kigali	α	1040.31	1592.58	2130.82	3047.59	4010.53	5792.7
		γ	7.79	10.7	14.94	21.54	27.79	37.88
		C	0.86	0.91	0.93	0.95	0.96	0.99
		SEE	1.34	2.02	1.17	0.35	0.67	1.35
15	Kitabi	α	1526.31	2708.73	3153.95	3665.86	4547.55	4377.41
		γ	13.94	28.94	29.49	29.02	32.27	29.37
		C	0.89	0.93	0.94	0.94	0.96	0.94
		SEE	0.99	0.74	0.7	0.74	0.76	0.73

Region Stations
 Region-1 Bulera, Byumba, Nema, Ruhengeri, Rushashi and Rwaza
 Region-2 Busasamana, Gisenyi, Gashyamba and Kabaya
 Region-3 Bugarama, Kamembe, Kibabo, Nyamashaka and Nyakabuye
 Region-4 Gakoma, Gitega, Kabaya, Kigali and Nyaminyaga
 Region-5 Gahini, Karama, Kibungo, Nyarubuye, Nyamata, Rwamagana and Zaza

Fitting Distribution
 Generalized logistic
 Gamma & Pearson Type-II
 Generalized extreme value
 Generalized extreme Value
 Gamma & Pearson Type-II

Region	Parameters	T = 2 yrs	T = 5 yrs	T = 10 yrs	T = 25 yrs	T = 50 yrs	T = 100 yrs
1	α	1649.52	1737.75	1847.72	1984.65	1895	2278.12
	Y	20.56	17.33	15.92	13.14	10.09	13.67
	C	0.91	0.89	0.88	0.86	0.85	0.86
	2α	983.74	1112.82	1095.21	1375.48	1566.78	1861.69
	Y	4.85	4.85	2.2	3.15	3.15	4.85
	C	0.93	0.81	0.79	0.81	0.82	0.83
	3α	976.75	1390.01	1401.19	1590.16	1784.72	2237.46
	Y	10.62	15.94	13.85	13.7	14.56	17.33
	C	0.84	0.86	0.84	0.84	0.84	0.86
	4α	724.64	847.46	994.08	1076.6	1133.46	1983.76
Y	3.15	2.36	3.15	2.19	0.62	9.23	
C	0.79	0.78	0.78	0.77	0.76	0.83	
5α	729.58	976.1	1145.79	1389.89	1690.38	1661.38	
Y	3.09	4.85	4.85	5.62	7.29	4.84	
C	0.81	0.81	0.82	0.82	0.84	0.82	
ReturnPeriod		0.5	1	3	6	12	24
	2yr	30	60	180	360	720	1440
	5yrs	23.1	31.8	38.9	45.7	50.5	52.5
	10yrs	27.9	38.2	46.1	54.7	60	65
	25yrs	31.5	42.9	51.4	60.8	68.7	73.1
	50yrs	36.1	48.4	57.5	68.7	77.7	83.7
	100yrs	40.2	52.8	62.7	74	84.9	91.4
2yr		46.2	31.8	13.0	7.6	4.2	2.2
	1	74.68	39.74	14.62	7.78	4.14	2.20
	2	58.46	32.89	13.21	7.43	4.18	2.35
	3	56.10	31.34	12.46	6.96	3.89	2.17
	4	49.34	28.54	11.98	6.93	4.01	2.32
5	46.41	26.47	10.87	6.20	3.54	2.02	
5yr	1	84.21	45.44	17.09	9.22	4.98	2.69
	2	70.79	40.38	16.58	9.46	5.39	3.08
	3	74.59	41.10	15.98	8.80	4.85	2.67
	4	59.70	34.77	14.76	8.59	5.00	2.91
	5	62.09	35.42	14.55	8.30	4.73	2.70
10yr	1	92.63	50.33	19.14	10.40	5.65	3.07
	2	74.57	43.13	18.11	10.47	6.06	3.50
	3	80.49	44.96	17.87	9.98	5.58	3.12
	4	70.03	40.78	17.31	10.08	5.87	3.42
	5	70.45	39.90	16.21	9.18	5.20	2.95
25yr	1	101.68	56.02	21.78	12.00	6.61	3.64
	2	87.50	49.91	20.50	11.69	6.67	3.80
	3	91.34	51.03	20.28	11.33	6.33	3.54
	4	78.46	46.01	19.75	11.58	6.79	3.98
	5	85.46	48.41	19.66	11.14	6.31	3.57
50yr	1	105.21	58.37	22.94	12.73	7.06	3.92
	2	96.33	54.57	22.17	12.56	7.11	4.03
	3	102.52	57.27	22.76	12.71	7.10	3.97
	4	85.47	50.47	21.90	12.93	7.64	4.51
	5	97.10	54.24	21.56	12.04	6.73	3.76
100yr	1	122.25	67.35	26.18	14.43	7.95	4.38
	2	110.64	62.24	25.01	14.07	7.91	4.45
	3	120.07	66.15	25.72	14.17	7.81	4.30
	4	117.89	66.32	25.64	14.99	8.43	4.74
	5	102.15	57.86	23.50	13.31	7.54	4.27
Region2-3		30	60	180	360	720	1440
	0.5	1	3	6	12	24	
	2	58.5	32.9	13.2	7.4	4.2	2.4
	5	70.8	40.4	16.6	9.5	5.4	3.1
	10	74.6	43.1	18.1	10.5	6.1	3.5
	25	87.5	49.9	20.5	11.7	6.7	3.8
	50	96.3	54.6	22.2	12.6	7.1	4.0
	100	110.6	62.2	25.0	14.1	7.9	4.5
	200	121.47	68.85	27.05	16.80	8.96	5.10
		0.5	1	3	6	12	24
2	29.2	32.9	39.6	44.6	50.2	56.4	
5	35.4	40.4	49.7	56.8	64.7	73.9	
10	37.3	43.1	54.3	62.8	72.7	84.1	
25	43.7	49.9	61.5	70.1	80.0	91.3	
50	48.2	54.6	66.5	75.3	85.3	96.7	
100	55.3	62.2	75.0	84.4	95.0	106.8	
200	60.7	68.8	81.1	100.8	107.5	122.3	
	53.093	30.27	12	7.5	4	2.3026	
	0.1562	0.1551	0.1534	0.1522	0.1522	0.15	



Appendix B: Western Channel Hydraulic Calculations



Used (Catchment 01)		
Catchment Area		
1:50 year rainfall depth 15 minutes		mm
Tc	2	min
Watercourse length		m
Runoff short duration	9.53	m ³ /s
Capacity Required		

Free Surface Flow (West Middle Channel)

Manning Equation

$$Q = \frac{A^{5/3} S^{1/2}}{n P^{2/3}}$$

Step Spacing	
Step Count	
Total Drop	
Baffle Dimensions (USBR Guide)	
h _b =	0.04
t _b =	0.15
s _b =	0.74
h _{still} =	0.07

Size Required		
b =	4.50	m
y =	0.80	m
z =	-	1:___
T =	4.50	m

Flow Available		
Q =	10.54	m ³ /s
A =	3.60	m ²
S =	0.01	1/slope
n =	0.02	used ks = 30
P =	6.10	m
R =	0.590164	

Sequent Depth (y ₂) for Hydraulic Jump	
y ₂	0.74

Safety Factor	
A (needed)	4.68 m ²
New H =	1.50 m
A (Achieved)	6.75 m ²

Additional Parameters	
v =	2.65 m/s
Flow depth =	0.80 m
Fr =	0.94

Fr-value	
Subcritical Flow	<1
Supercritical Flow	>1
Critical Flow	1

T = 4.50 m

Free Surface Flow (Bottom Channel)

Manning Equation

$$Q = \frac{A^{5/3} S^{1/2}}{n P^{2/3}}$$

Step Spacing	
Step Count	
Total Drop	
Baffle Dimensions (USBR)	
h _b =	0.05
t _b =	0.17
s _b =	0.87
h _{still} =	0.09

Size Required		
b =	2.00	m
y =	0.80	m
z =	-	1:___
T =	2.00	m

Flow Available		
Q =	5.48	m ³ /s
A =	1.60	m ²
S =	0.01	1/slope
n =	0.02	used ks = 30
P =	3.60	m
R =	0.44	

Sequent Depth (y ₂) for	
y ₂	0.87

Safety Factor	
A (needed)	2.08 m ²
New H =	1.50 m
A (Achieved)	3.00 m ²

Additional Parameters	
v =	2.98 m/s
Flow depth =	0.80 m
Fr =	1.06

Fr-value	
Subcritical Flow	<1
Supercritical Flow	>1
Critical Flow	1

T = 2.00 m

Free Surface Flow (West Main Channel 01)

Manning Equation

$$Q = \frac{A^{5/3} S^{1/2}}{n P^{2/3}}$$

Step Spacing	
Step Count	
Total Drop	
Baffle Dimensions (USBR)	
h _b =	0.04
t _b =	0.15
s _b =	0.74
h _{still} =	0.07

Size Required		
b =	4.50	m
y =	0.80	m
z =	-	1:___
T =	4.50	m

Flow Available		
Q =	105.35	m ³ /s
A =	3.60	m ²
S =	0.50	1/slope
n =	0.02	used ks = 30
P =	6.10	m
R =	0.590164	

Sequent Depth (y ₂) for	
y ₂	0.74

Safety Factor	
A (needed)	4.68 m ²
New H =	1.50 m
A (Achieved)	6.75 m ²

Additional Parameters	
v =	2.65 m/s
Flow depth =	0.80 m
Fr =	0.94

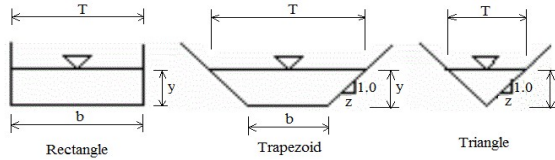
Fr-value	
Subcritical Flow	<1
Supercritical Flow	>1
Critical Flow	1

T = 4.50 m

Free Surface Flow (West Main Channel 02)

Manning Equation

$$Q = \frac{A^{5/3} S^{1/2}}{n P^{2/3}}$$



Step Spacing	
Step Count	
Total Drop	
Baffle Dimensions (USBR)	
h _b =	0.04
t _b =	0.15
s _b =	0.74
h _{still} =	0.07

Size Required		
b =	4.50	m
y =	0.80	m
z =	-	1:___
T =	4.50	m

Flow Available		
Q =	121.65	m ³ /s
A =	3.60	m ²
S =	0.67	1/slope
n =	0.02	used ks = 30
P =	6.10	m
R =	0.590164	

Sequent Depth (y ₂) for	
y ₂	0.74

USBR Basin Lengths	
L _{basin}	3.71
Type	II

Safety Factor		
A (needed)	4.68	m ²
New H =	1.50	m
A (Achieved)	6.75	m ²

Additional Parameters		
v =	2.65	m/s
Flow depth =	0.80	m
Fr =	0.94	

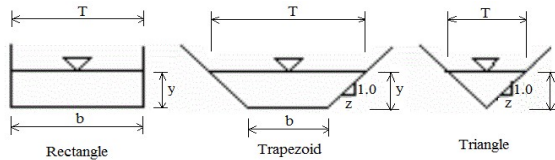
Fr-value	
Subcritical Flow	<1
Supercritical Flow	>1
Critical Flow	1

T = 4.50 m

Free Surface Flow (West Main Channel 03)

Manning Equation

$$Q = \frac{A^{5/3} S^{1/2}}{n P^{2/3}}$$



Step Spacing	
Step Count	
Total Drop	
Baffle Dimensions (USBR)	
h _b =	0.04
t _b =	0.15
s _b =	0.74
h _{still} =	0.07

Size Required		
b =	4.50	m
y =	0.80	m
z =	-	1:___
T =	4.50	m

Flow Available		
Q =	86.02	m ³ /s
A =	3.60	m ²
S =	0.33	1/slope
n =	0.02	used ks = 30
P =	6.10	m
R =	0.590164	

Sequent Depth (y ₂) for	
y ₂	0.74

USBR Basin Lengths	
L _{basin}	3.71
Type	II

Safety Factor		
A (needed)	4.68	m ²
New H =	1.50	m
A (Achieved)	6.75	m ²

Additional Parameters		
v =	2.65	m/s
Flow depth =	0.80	m
Fr =	0.94	

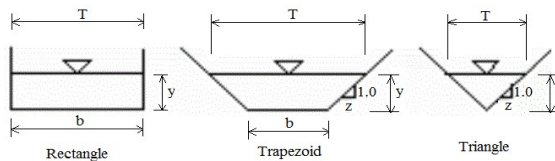
Fr-value	
Subcritical Flow	<1
Supercritical Flow	>1
Critical Flow	1

T = 4.50 m

Free Surface Flow (West Main Channel 04)

Manning Equation

$$Q = \frac{A^{5/3} S^{1/2}}{n P^{2/3}}$$



Step Spacing	
Step Count	
Total Drop	
Baffle Dimensions (USBR)	
h _b =	0.04
t _b =	0.15
s _b =	0.74
h _{still} =	0.07

Size Required		
b =	4.50	m
y =	0.80	m
z =	-	1:___
T =	4.50	m

Flow Available		
Q =	56.31	m ³ /s
A =	3.60	m ²
S =	0.14	1/slope
n =	0.02	used ks = 30
P =	6.10	m
R =	0.590164	

Sequent Depth (y ₂) for	
y ₂	0.74

USBR Basin Lengths	
L _{basin}	3.71
Type	II

Safety Factor		
A (needed)	4.68	m ²
New H =	1.50	m
A (Achieved)	6.75	m ²

Additional Parameters		
v =	2.65	m/s
Flow depth =	0.80	m
Fr =	0.94	

Fr-value	
Subcritical Flow	<1
Supercritical Flow	>1
Critical Flow	1

T = 4.50 m

Appendix C: Eastern Channel Hydraulic Calculations

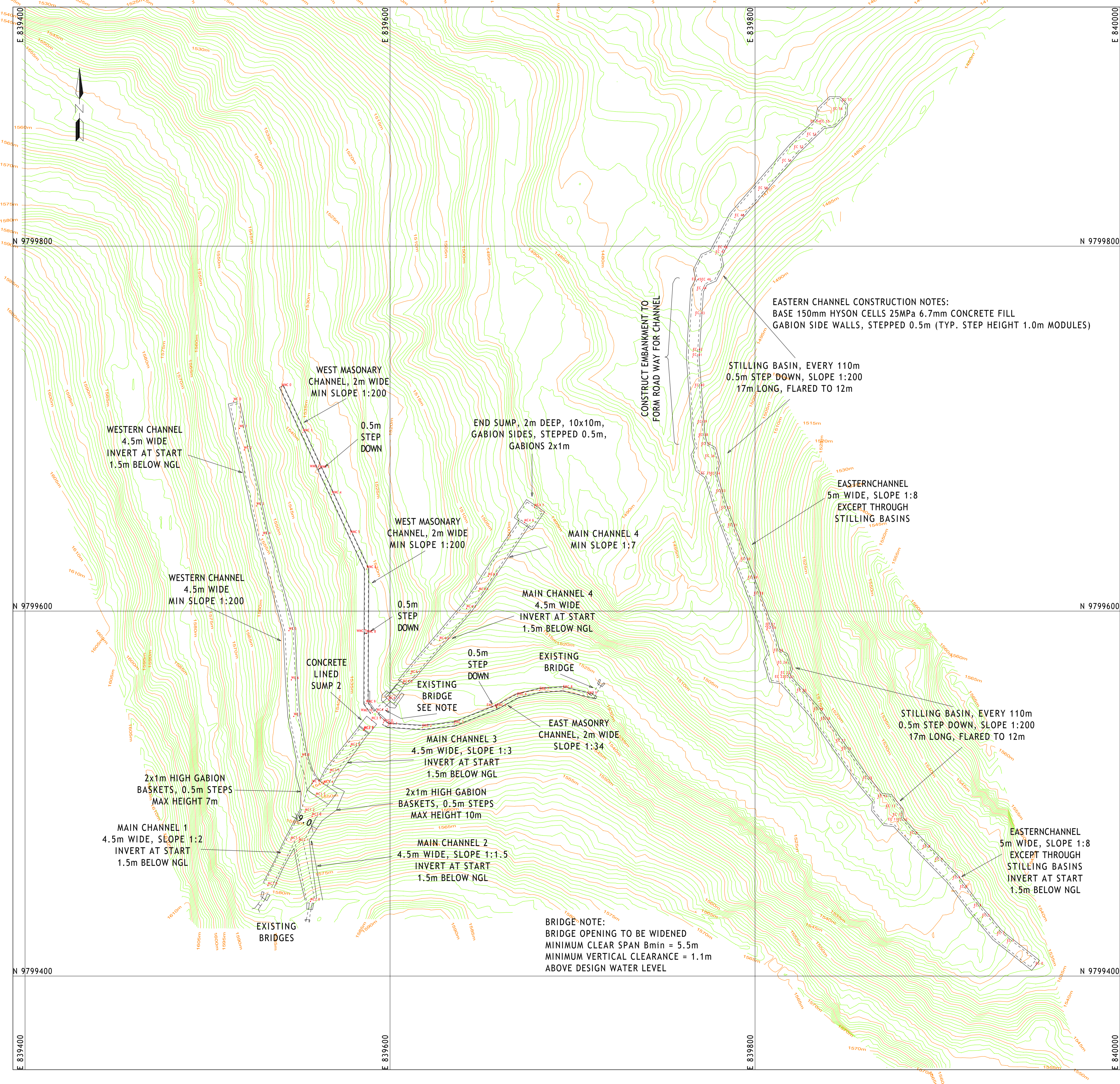


Used (Catchment 01)		
Catchment Area	1142	
1:50 year rainfall depth 24 hours	195	mm
Tc	2	min
Watercourse length	2337	m
Runoff short duration	38.07	m³/s
Capacity Required		

Free Surface Flow (Eastern Channel)																																																							
<p>Manning Equation</p> $Q = \frac{A^{5/3} S^{1/2}}{n P^{2/3}}$																																																							
		<table border="1" style="width: 100%;"> <thead> <tr> <th colspan="2">Step Spacing</th> </tr> </thead> <tbody> <tr> <td>Step Count</td> <td></td> </tr> <tr> <td>Total Drop</td> <td></td> </tr> <tr> <th colspan="2">Baffle Dimensions (USBR)</th> </tr> <tr> <td>h_b=</td> <td>2.00</td> </tr> <tr> <td>t_b=</td> <td>0.69</td> </tr> <tr> <td>s_b=</td> <td>3.46</td> </tr> <tr> <td>h_{still}=</td> <td>0.35</td> </tr> </tbody> </table>	Step Spacing		Step Count		Total Drop		Baffle Dimensions (USBR)		h _b =	2.00	t _b =	0.69	s _b =	3.46	h _{still} =	0.35																																					
Step Spacing																																																							
Step Count																																																							
Total Drop																																																							
Baffle Dimensions (USBR)																																																							
h _b =	2.00																																																						
t _b =	0.69																																																						
s _b =	3.46																																																						
h _{still} =	0.35																																																						
<table border="1" style="width: 100%;"> <thead> <tr> <th colspan="3">Size Required</th> </tr> </thead> <tbody> <tr> <td>b =</td> <td>5.00</td> <td>m</td> </tr> <tr> <td>y =</td> <td>0.80</td> <td>m</td> </tr> <tr> <td>z =</td> <td>-</td> <td>1:___</td> </tr> <tr> <td>T =</td> <td>5.00</td> <td>m</td> </tr> </tbody> </table>	Size Required			b =	5.00	m	y =	0.80	m	z =	-	1:___	T =	5.00	m	<table border="1" style="width: 100%;"> <thead> <tr> <th colspan="4">Flow Available</th> </tr> </thead> <tbody> <tr> <td>Q =</td> <td>59.58</td> <td>m³/s</td> <td></td> </tr> <tr> <td>A =</td> <td>4.00</td> <td>m²</td> <td></td> </tr> <tr> <td>S =</td> <td>0.13</td> <td>1/slope</td> <td>8</td> </tr> <tr> <td>n =</td> <td>0.02</td> <td></td> <td>used ks = 30</td> </tr> <tr> <td>P =</td> <td>6.60</td> <td>m</td> <td></td> </tr> <tr> <td>R =</td> <td>0.606061</td> <td></td> <td></td> </tr> </tbody> </table>	Flow Available				Q =	59.58	m ³ /s		A =	4.00	m ²		S =	0.13	1/slope	8	n =	0.02		used ks = 30	P =	6.60	m		R =	0.606061			<table border="1" style="width: 100%;"> <thead> <tr> <th colspan="2">Sequent Depth (y₂) for</th> </tr> </thead> <tbody> <tr> <td>y₂</td> <td>3.46</td> </tr> </tbody> </table> <table border="1" style="width: 100%;"> <thead> <tr> <th colspan="2">USBR Basin Lengths</th> </tr> </thead> <tbody> <tr> <td>L_{basin}</td> <td>17.32</td> </tr> <tr> <td>Type</td> <td>II</td> </tr> </tbody> </table>	Sequent Depth (y ₂) for		y ₂	3.46	USBR Basin Lengths		L _{basin}	17.32	Type	II
Size Required																																																							
b =	5.00	m																																																					
y =	0.80	m																																																					
z =	-	1:___																																																					
T =	5.00	m																																																					
Flow Available																																																							
Q =	59.58	m ³ /s																																																					
A =	4.00	m ²																																																					
S =	0.13	1/slope	8																																																				
n =	0.02		used ks = 30																																																				
P =	6.60	m																																																					
R =	0.606061																																																						
Sequent Depth (y ₂) for																																																							
y ₂	3.46																																																						
USBR Basin Lengths																																																							
L _{basin}	17.32																																																						
Type	II																																																						
<table border="1" style="width: 100%;"> <thead> <tr> <th colspan="3">Safety Factor</th> </tr> </thead> <tbody> <tr> <td>A (needed)</td> <td>5.20</td> <td>m²</td> </tr> <tr> <td>New H =</td> <td>1.50</td> <td>m</td> </tr> <tr> <td>A (Achieved)</td> <td>7.50</td> <td>m²</td> </tr> </tbody> </table>	Safety Factor			A (needed)	5.20	m ²	New H =	1.50	m	A (Achieved)	7.50	m ²	<table border="1" style="width: 100%;"> <thead> <tr> <th colspan="3">Additional Parameters</th> </tr> </thead> <tbody> <tr> <td>v =</td> <td>9.52</td> <td>m/s</td> </tr> <tr> <td>Flow depth =</td> <td>0.80</td> <td>m</td> </tr> <tr> <td>Fr =</td> <td>3.40</td> <td></td> </tr> </tbody> </table>	Additional Parameters			v =	9.52	m/s	Flow depth =	0.80	m	Fr =	3.40		<table border="1" style="width: 100%;"> <thead> <tr> <th colspan="2">Fr-value</th> </tr> </thead> <tbody> <tr> <td>Subcritical Flow</td> <td><1</td> </tr> <tr> <td>Supercritical Flow</td> <td>>1</td> </tr> <tr> <td>Critical Flow</td> <td>1</td> </tr> </tbody> </table>	Fr-value		Subcritical Flow	<1	Supercritical Flow	>1	Critical Flow	1																					
Safety Factor																																																							
A (needed)	5.20	m ²																																																					
New H =	1.50	m																																																					
A (Achieved)	7.50	m ²																																																					
Additional Parameters																																																							
v =	9.52	m/s																																																					
Flow depth =	0.80	m																																																					
Fr =	3.40																																																						
Fr-value																																																							
Subcritical Flow	<1																																																						
Supercritical Flow	>1																																																						
Critical Flow	1																																																						
T = 5.00 m																																																							

Appendix D: Design Drawings





SETTING OUT COORDS - EASTERN CHANNEL

EC 0	839953.814	9799405.835	1528.020
EC 1	839938.129	9799418.244	1525.520
EC 2	839932.764	9799422.488	1524.633
EC 3	839924.623	9799432.172	1523.020
EC 4	839920.020	9799437.647	1522.117
EC 5	839912.379	9799447.806	1520.520
EC 6	839908.462	9799453.013	1519.726
EC 7	839898.814	9799462.890	1518.020
EC 8	839891.926	9799469.942	1516.784
EC 9	839885.053	9799477.318	1515.520
EC 10	839878.236	9799484.634	1514.270
EC 11	839878.202	9799484.670	1513.769
EC 12	839875.623	9799487.439	1513.750
EC 13	839871.788	9799492.078	1513.720
EC 14	839867.328	9799497.473	1513.685
EC 15	839859.107	9799507.426	1512.060
EC 16	839847.564	9799523.648	1509.560
EC 17	839844.451	9799528.023	1508.889
EC 18	839835.984	9799539.951	1507.060
EC 19	839832.263	9799545.191	1506.275
EC 20	839822.950	9799555.471	1504.560
EC 21	839816.235	9799562.881	1503.310
EC 22	839816.201	9799562.917	1502.804
EC 23	839814.179	9799565.150	1502.789
EC 24	839812.426	9799570.723	1502.760
EC 25	839810.325	9799577.400	1502.725
EC 26	839806.422	9799589.802	1501.100
EC 27	839805.852	9799591.610	1500.871
EC 28	839799.489	9799608.696	1498.600
EC 29	839796.245	9799617.404	1497.440
EC 30	839792.397	9799627.423	1496.100
EC 31	839785.226	9799646.093	1493.600
EC 32	839781.572	9799655.607	1492.316
EC 33	839778.707	9799664.818	1491.100
EC 34	839775.737	9799674.366	1489.850
EC 35	839775.722	9799674.414	1489.350
EC 36	839772.766	9799683.916	1489.300
EC 37	839770.686	9799690.600	1489.265
EC 38	839769.158	9799695.514	1488.586
EC 39	839768.610	9799702.778	1487.640
EC 40	839767.108	9799722.722	1485.140
EC 41	839765.856	9799739.327	1483.036
EC 42	839766.054	9799742.314	1482.640
EC 43	839767.374	9799762.270	1480.140
EC 44	839768.278	9799775.950	1478.361
EC 45	839770.684	9799780.617	1477.640
EC 46	839770.707	9799780.662	1477.140
EC 47	839778.472	9799795.729	1477.055
EC 48	839779.842	9799798.387	1476.680
EC 49	839789.003	9799815.806	1474.180
EC 50	839801.909	9799830.706	1471.680
EC 51	839815.003	9799845.823	1469.180
EC 52	839821.475	9799853.296	1467.931
EC 53	839828.566	9799860.210	1466.680
EC 54	839835.726	9799867.191	1465.430
EC 55	839835.762	9799867.226	1464.930
EC 56	839842.886	9799874.172	1464.880
EC 57	839847.913	9799879.072	1464.845

SETTING OUT COORDS - MAIN CHANNEL 1

MC1 0	839533.077	9799449.654	1576.520
MC1 1	839545.706	9799474.666	1557.922
MC1 2	839553.467	9799490.038	1549.580
MC1 3	839559.405	9799498.716	1543.000

SETTING OUT COORDS - MAIN CHANNEL 3

MC3 4	839563.660	9799505.364	1542.961
MC3 5	839567.196	9799511.741	1540.589
MC3 6	839578.482	9799525.885	1534.702
MC3 7	839585.579	9799534.781	1531.000
MC3 8	839585.891	9799535.172	1530.000
MC3 9	839589.945	9799540.253	1529.968

SETTING OUT COORDS - MAIN CHANNEL 4

MC4 -2	839592.784	9799544.862	1528.250
MC4 -1	839599.233	9799551.346	1528.204
MC4 0	839607.117	9799560.385	1523.426
MC4 1	839611.481	9799565.702	1520.685
MC4 2	839627.194	9799584.169	1512.160
MC4 3	839641.955	9799601.518	1507.030
MC4 4	839648.711	9799611.012	1504.150
MC4 5	839653.832	9799619.137	1501.978
MC4 6	839673.623	9799648.651	1497.236
MC4 7	839679.192	9799656.957	1497.186

SETTING OUT COORDS - WESTERN CHANNEL

WC 0	839514.288	9799715.050	1554.130
WC 1	839517.530	9799700.193	1552.410
WC 2	839520.106	9799688.387	1552.290
WC 3	839526.800	9799657.706	1551.580
WC 4	839530.311	9799641.614	1551.497
WC 5	839544.614	9799589.318	1551.226
WC 6	839545.911	9799562.367	1551.091
WC 7	839547.246	9799542.354	1550.990
WC 8	839551.705	9799520.243	1550.877
WC 9	839557.363	9799505.649	1542.977

SETTING OUT COORDS - WEST MASONRY CHANNEL

WMC 0	839540.596	9799722.879	1538.315
WMC 1	839552.229	9799697.950	1534.810
WMC 2	839561.428	9799678.238	1533.100
WMC 3	839561.534	9799678.011	1532.551
WMC 4	839568.090	9799663.962	1531.150
WMC 5	839578.188	9799642.323	1529.950
WMC 6	839587.158	9799623.103	1529.350
WMC 7	839587.006	9799587.981	1529.174
WMC 8	839587.005	9799587.731	1528.674
WMC 9	839586.839	9799549.413	1528.482
WMC 10	839590.358	9799544.470	1528.452

SETTING OUT COORDS - EAST MASONRY CHANNEL

EMC 0	839596.397	9799538.942	1529.870
EMC 1	839598.940	9799537.408	1529.790
EMC 2	839617.742	9799536.194	1529.246
EMC 3	839635.186	9799538.149	1528.738
EMC 4	839658.240	9799547.312	1528.013
EMC 5	839658.527	9799547.426	1527.563
EMC 6	839669.751	9799553.481	1527.183
EMC 7	839682.015	9799556.547	1526.801
EMC 8	839694.839	9799557.421	1526.412
EMC 9	839708.200	9799554.191	1526.000

tailings solutions

Koos Davel
813 Richmond St.
Wingate Park, Pretoria.
Tel. 082 067 2347
koos@tailings.solutions

Client:

TRINITY METALS

Title:
**NYAMYUMBA MINE
STORMWATER CONTROL
GENERAL ARRANGEMENT**

Date: Nov. 2025	Surveyed:
Scale: 1:1000 (A1)	Designed: LS
Reference No.:	Drawn: RAS
Drawing No.: ETS TM NMB SWC GA 001a	



EASTERN CHANNEL CONSTRUCTION NOTES:
 BASE 150mm HYSON CELLS 25MPa 6.7mm CONCRETE FILL
 GABION SIDE WALLS, STEPPED 0.5m (TYP. STEP HEIGHT 1.0m MODULES)

STILLING BASIN, EVERY 110m
 0.5m STEP DOWN, SLOPE 1:200
 17m LONG, FLARED TO 12m

EASTERN CHANNEL
 5m WIDE, SLOPE 1:8
 EXCEPT THROUGH
 STILLING BASINS

STILLING-BASIN, EVERY 110m
 0.5m STEP DOWN, SLOPE 1:200
 17m LONG, FLARED TO 12m

EASTERN CHANNEL
 5m WIDE, SLOPE 1:8
 EXCEPT THROUGH
 STILLING BASINS
 INVERT AT START
 1.5m BELOW NGL

BRIDGE NOTE:
 BRIDGE OPENING TO BE WIDENED
 MINIMUM CLEAR SPAN Bmin = 5.5m
 MINIMUM VERTICAL CLEARANCE = 1.1m
 ABOVE DESIGN WATER LEVEL

SETTING OUT COORDS - EASTERN CHANNEL

EC 0	839953.814	9799405.835	1528.020
EC 1	839938.129	9799418.244	1525.520
EC 2	839932.764	9799422.488	1524.633
EC 3	839924.623	9799432.172	1523.020
EC 4	839920.020	9799437.647	1522.117
EC 5	839912.379	9799447.806	1520.520
EC 6	839908.462	9799453.013	1519.726
EC 7	839898.814	9799462.890	1518.020
EC 8	839891.926	9799469.942	1516.784
EC 9	839885.053	9799477.318	1515.520
EC 10	839878.236	9799484.634	1514.270
EC 11	839878.202	9799484.630	1513.769
EC 12	839875.623	9799487.439	1513.750
EC 13	839871.788	9799492.078	1513.720
EC 14	839867.328	9799497.473	1513.685
EC 15	839859.107	9799507.426	1512.060
EC 16	839847.564	9799523.648	1509.560
EC 17	839844.451	9799528.023	1508.889
EC 18	839835.984	9799539.951	1507.060
EC 19	839832.263	9799545.191	1506.275
EC 20	839822.950	9799555.471	1504.560
EC 21	839816.235	9799562.881	1503.310
EC 22	839816.201	9799562.917	1502.804
EC 23	839814.179	9799565.150	1502.789
EC 24	839812.426	9799570.723	1502.760
EC 25	839810.325	9799577.400	1502.725
EC 26	839806.422	9799589.802	1501.100
EC 27	839805.852	9799591.610	1500.871
EC 28	839799.489	9799608.696	1498.600
EC 29	839796.245	9799617.404	1497.440
EC 30	839792.397	9799627.423	1496.100
EC 31	839785.226	9799646.093	1493.600
EC 32	839781.572	9799655.607	1492.316
EC 33	839778.707	9799664.818	1491.100
EC 34	839775.737	9799674.366	1489.850
EC 35	839775.722	9799674.414	1489.350
EC 36	839772.766	9799683.916	1489.300
EC 37	839770.686	9799690.600	1489.265
EC 38	839769.158	9799695.514	1488.586
EC 39	839768.610	9799702.778	1487.640
EC 40	839767.108	9799722.722	1485.140
EC 41	839765.856	9799739.327	1483.036
EC 42	839766.054	9799742.314	1482.640
EC 43	839767.374	9799762.270	1480.140
EC 44	839768.278	9799775.950	1478.361
EC 45	839770.684	9799780.617	1477.640
EC 46	839770.707	9799780.662	1477.140
EC 47	839778.472	9799795.729	1477.055
EC 48	839779.842	9799798.387	1476.680
EC 49	839789.003	9799815.806	1474.180
EC 50	839801.909	9799830.706	1471.680
EC 51	839815.003	9799845.823	1469.180
EC 52	839821.475	9799853.296	1467.931
EC 53	839828.566	9799860.210	1466.680
EC 54	839835.726	9799867.191	1465.430
EC 55	839835.762	9799867.226	1464.930
EC 56	839842.886	9799874.172	1464.880
EC 57	839847.913	9799879.072	1464.845

SETTING OUT COORDS - MAIN CHANNEL 1

MC1 0	839533.077	9799449.654	1576.520
MC1 1	839545.706	9799474.666	1557.922
MC1 2	839553.467	9799490.038	1549.580
MC1 3	839559.405	9799498.716	1543.000

SETTING OUT COORDS - MAIN CHANNEL 3

MC3 4	839563.660	9799505.364	1542.961
MC3 5	839567.196	9799511.741	1540.589
MC3 6	839578.482	9799525.885	1534.702
MC3 7	839585.579	9799534.781	1531.000
MC3 8	839585.891	9799535.172	1530.000
MC3 9	839589.945	9799540.253	1529.968

SETTING OUT COORDS - MAIN CHANNEL 4

MC4 -2	839592.784	9799544.862	1528.250
MC4 -1	839599.233	9799551.346	1528.204
MC4 0	839607.117	9799560.385	1523.426
MC4 1	839611.481	9799565.702	1520.685
MC4 2	839627.194	9799584.169	1517.160
MC4 3	839641.955	9799601.518	1512.030
MC4 4	839648.711	9799611.012	1504.150
MC4 5	839653.832	9799619.137	1501.978
MC4 6	839673.623	9799648.651	1497.236
MC4 7	839679.192	9799656.957	1497.186

SETTING OUT COORDS - WESTERN CHANNEL

WC 0	839514.288	9799715.050	1554.130
WC 1	839517.530	9799700.193	1552.410
WC 2	839520.106	9799688.387	1552.290
WC 3	839526.800	9799657.706	1551.580
WC 4	839530.311	9799641.614	1551.497
WC 5	839544.614	9799589.318	1551.226
WC 6	839545.911	9799562.367	1551.091
WC 7	839547.246	9799542.354	1550.990
WC 8	839551.705	9799520.243	1550.877
WC 9	839557.363	9799505.649	1542.977

SETTING OUT COORDS - WEST MASONRY CHANNEL

WMC 0	839540.596	9799722.879	1538.315
WMC 1	839552.229	9799697.950	1534.810
WMC 2	839561.428	9799678.238	1533.100
WMC 3	839561.534	9799678.011	1532.551
WMC 4	839568.090	9799663.962	1531.150
WMC 5	839578.188	9799642.323	1529.950
WMC 6	839587.158	9799623.103	1529.350
WMC 7	839587.006	9799587.981	1529.174
WMC 8	839587.005	9799587.731	1528.674
WMC 9	839586.839	9799549.413	1528.482
WMC 10	839590.358	9799544.470	1528.452

SETTING OUT COORDS - EAST MASONRY CHANNEL

EMC 0	839596.397	9799538.942	1529.870
EMC 1	839598.940	9799537.408	1529.790
EMC 2	839617.742	9799536.194	1529.246
EMC 3	839635.186	9799538.149	1528.738
EMC 4	839658.240	9799547.312	1528.013
EMC 5	839658.527	9799547.426	1527.563
EMC 6	839669.751	9799553.481	1527.183
EMC 7	839682.015	9799556.547	1526.801
EMC 8	839694.839	9799557.421	1526.412
EMC 9	839708.200	9799554.191	1526.000

SETTING OUT COORDS - MAIN CHANNEL 2

MC2 0	839556.405	9799440.951	1580.205
MC2 1	839550.172	9799473.528	1557.922
MC2 2	839557.299	9799487.644	1549.647

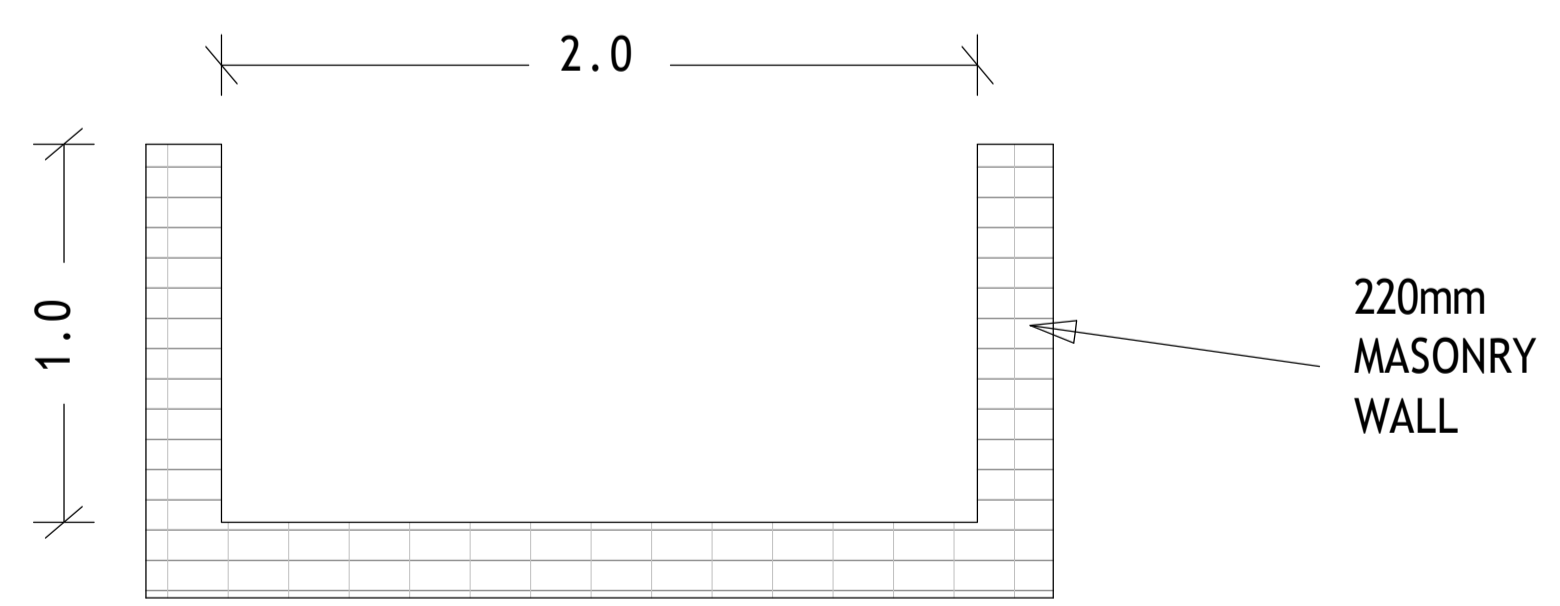
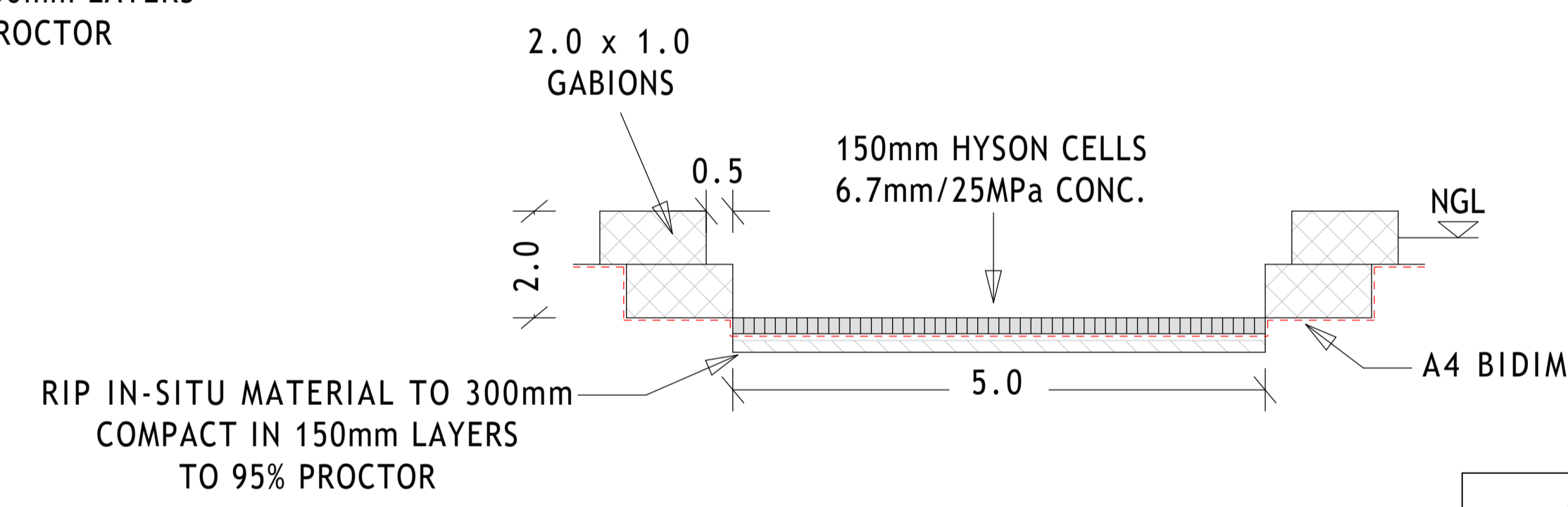
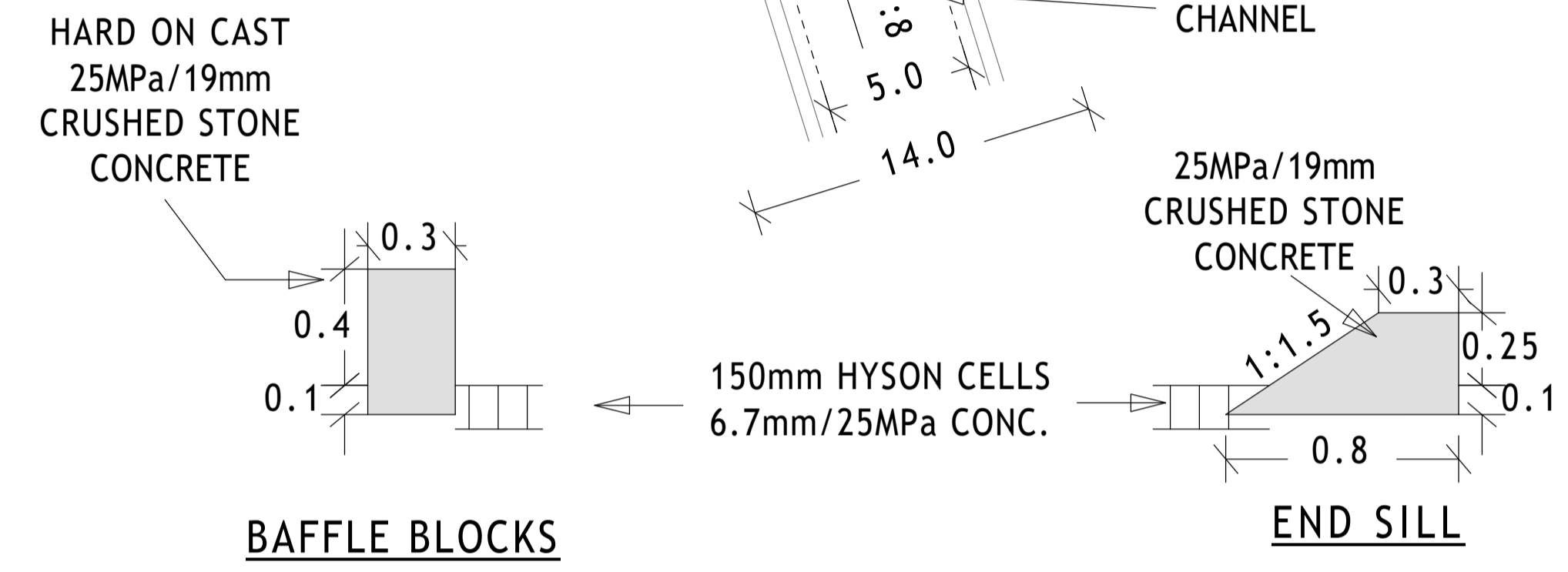
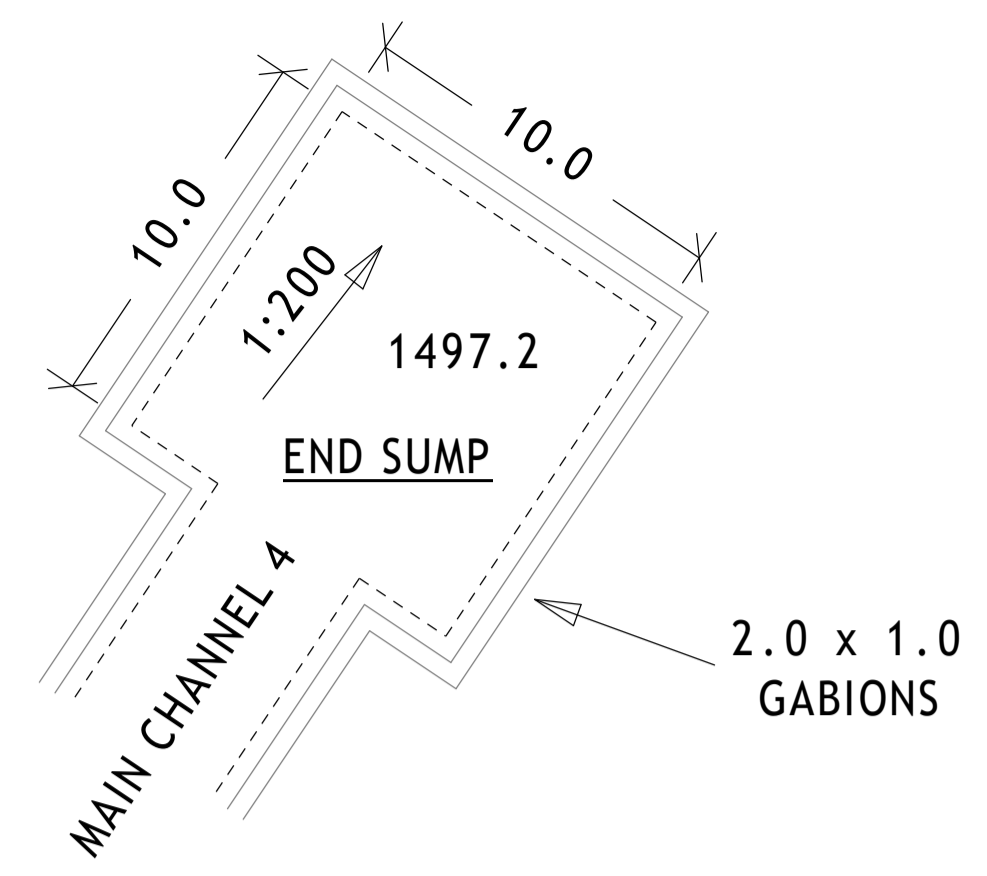
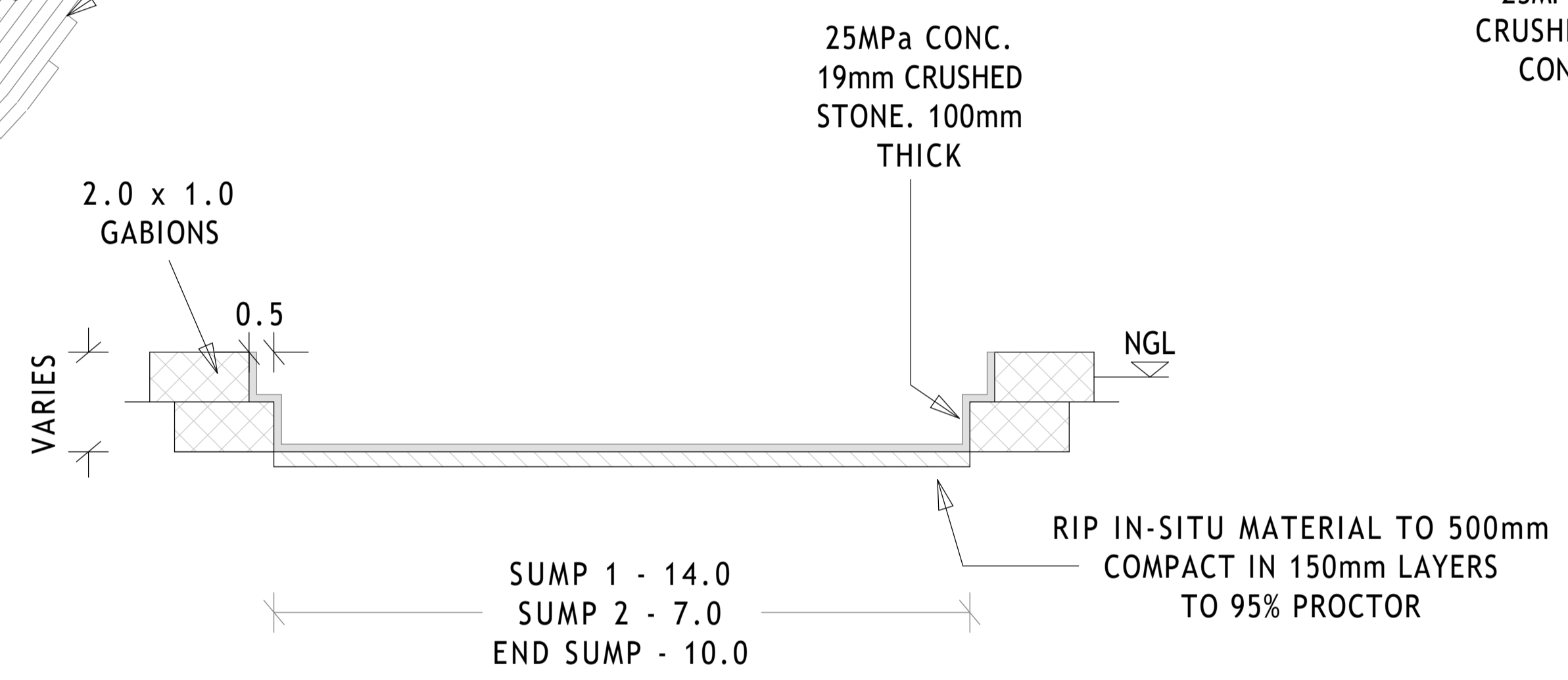
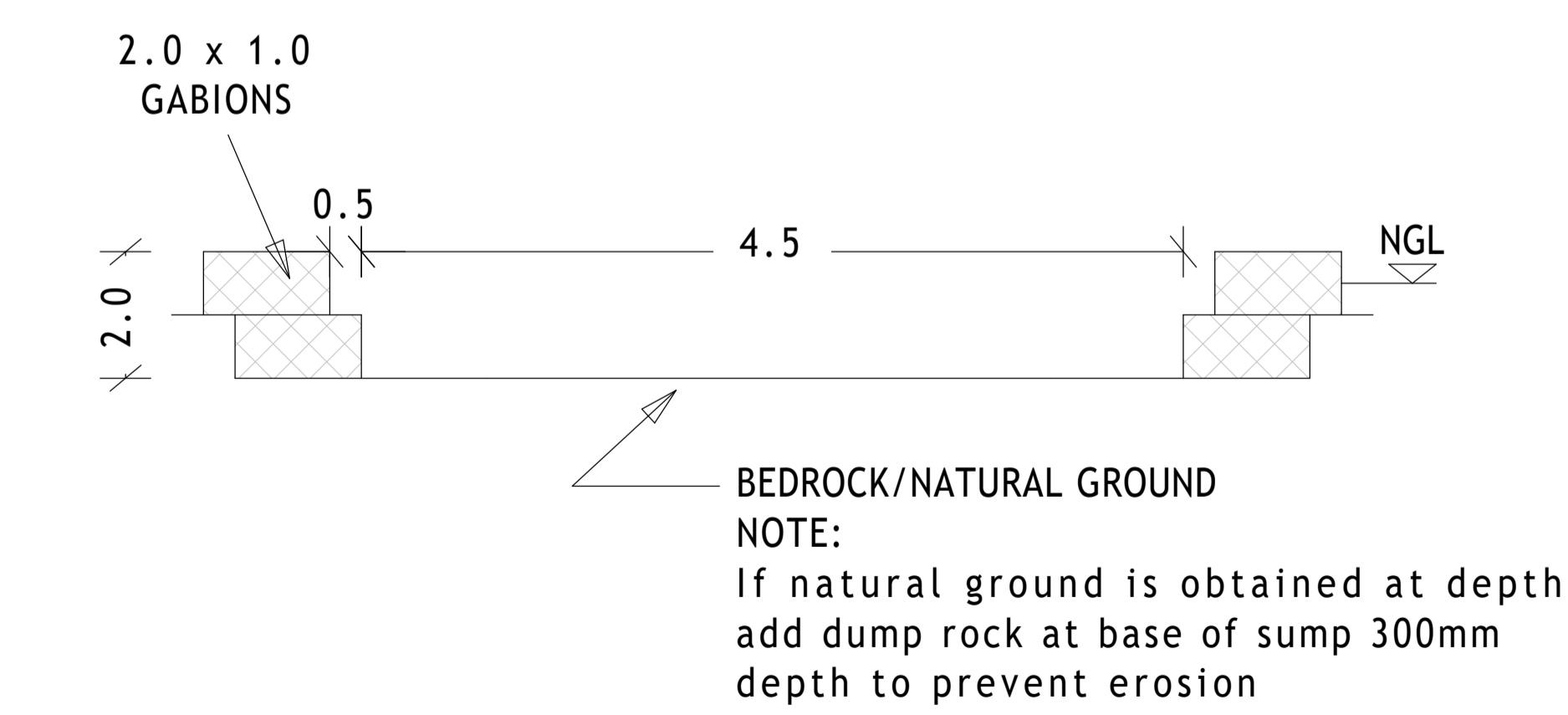
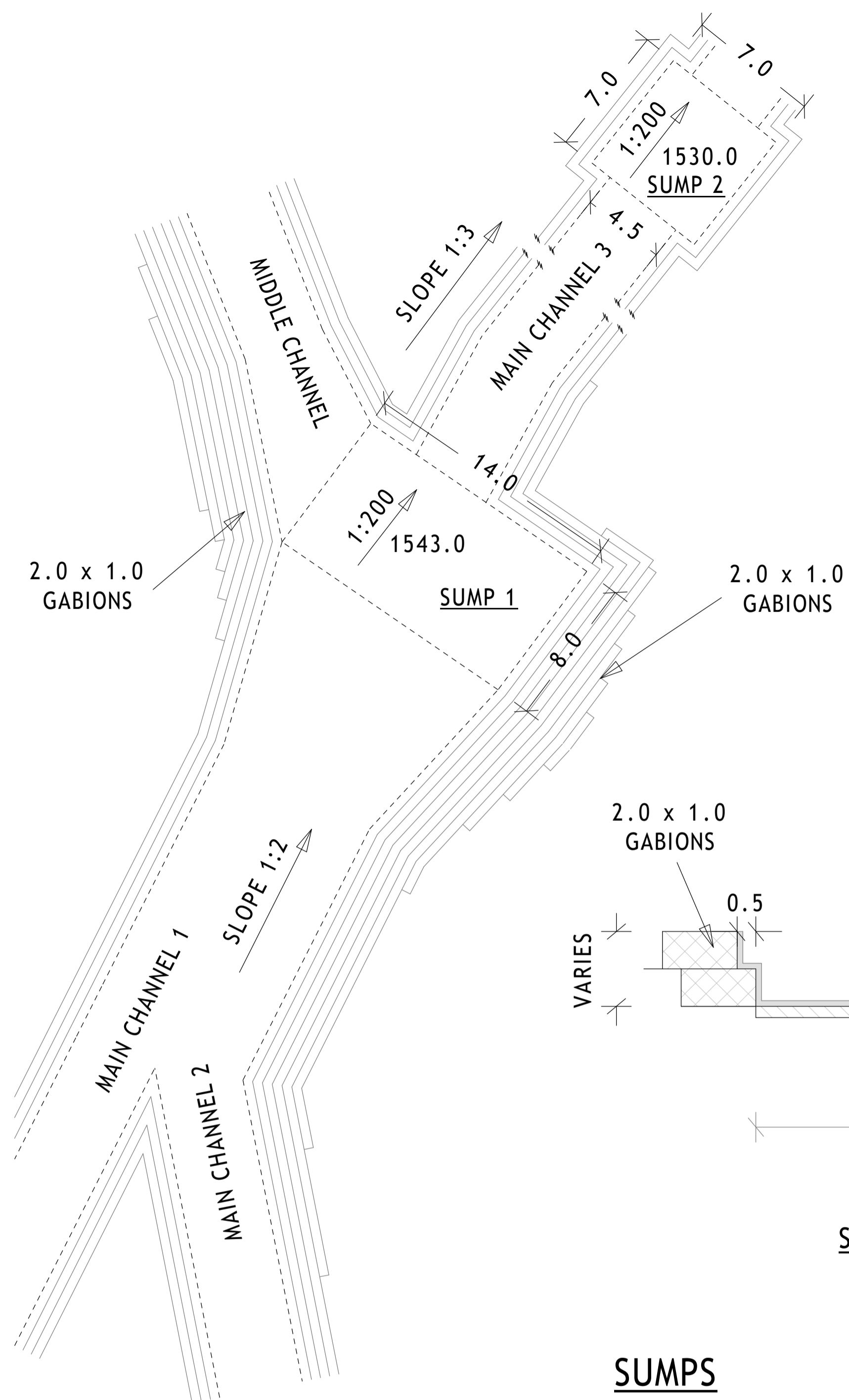
tailings solutions
 Koos Davel
 813 Richmond St.
 Wingate Park, Pretoria.
 Tel. 082 067 2347
 koos@tailings.solutions

Client:

TRINITY METALS

Title:
 NYAMYUMBA MINE
 STORMWATER CONTROL
 GENERAL ARRANGEMENT

Date: Nov.2025	Surveyed:
Scale: 1:1000 (A1)	Designed: LS
Reference No.:	Drawn: RAS
Drawing No.:	ETS TM NMB SWC GA 001a



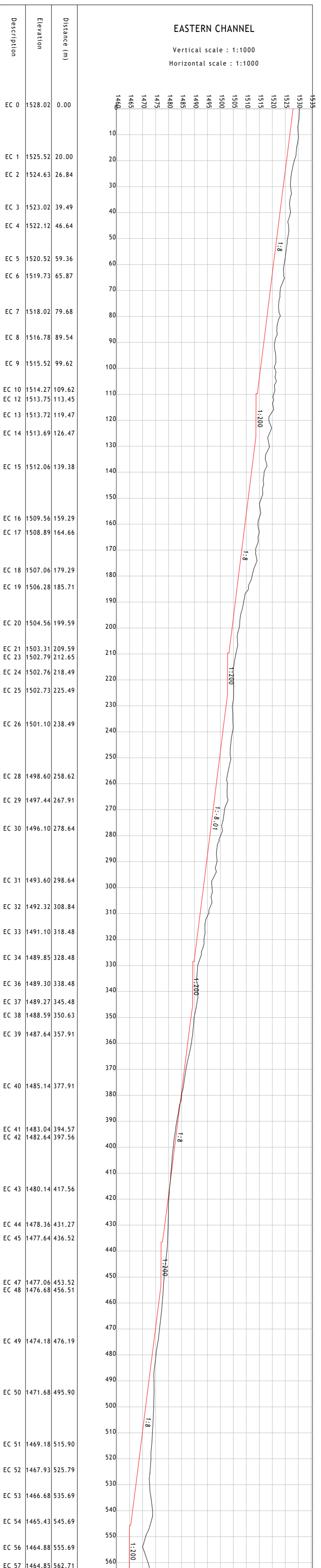
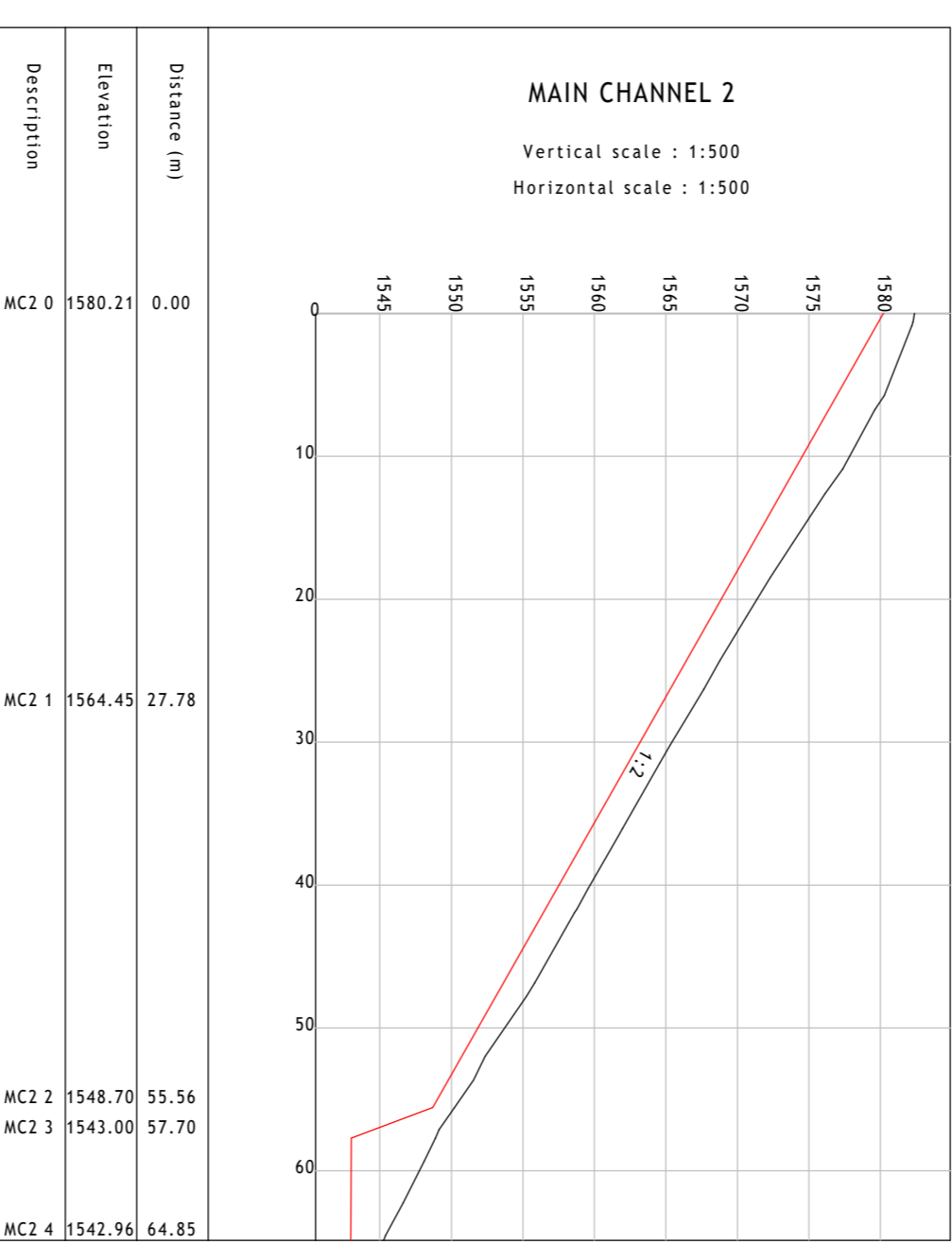
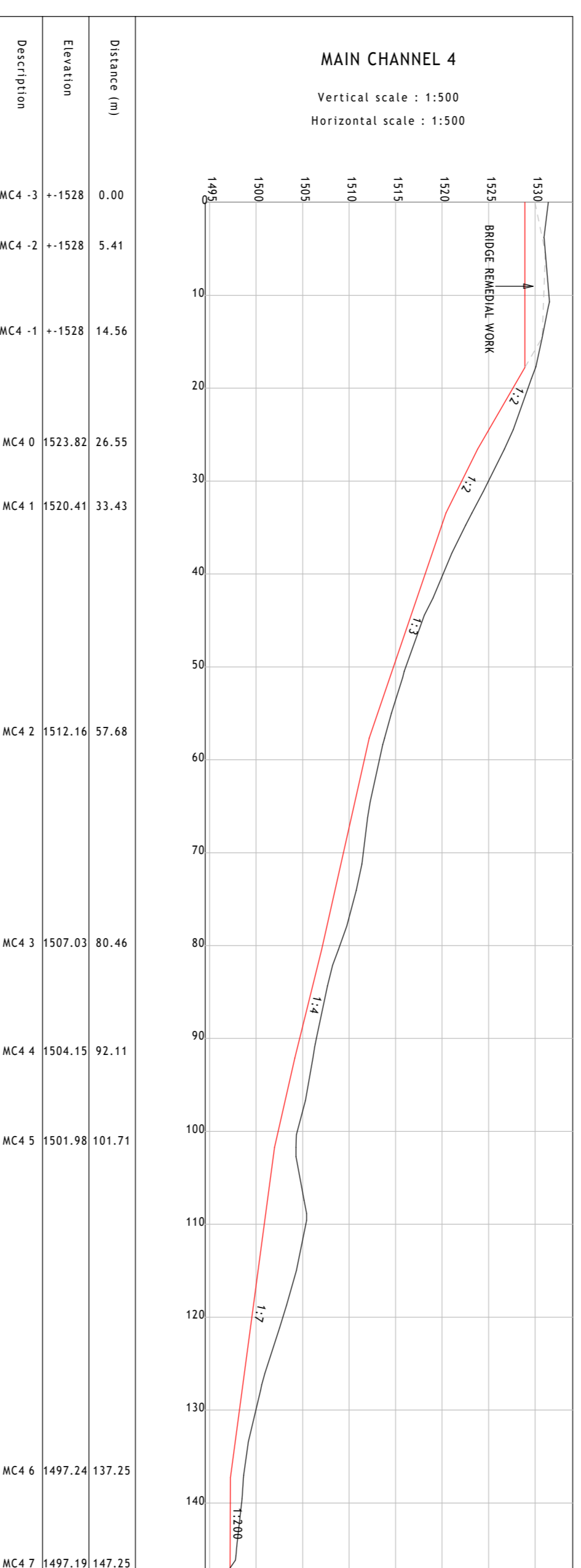
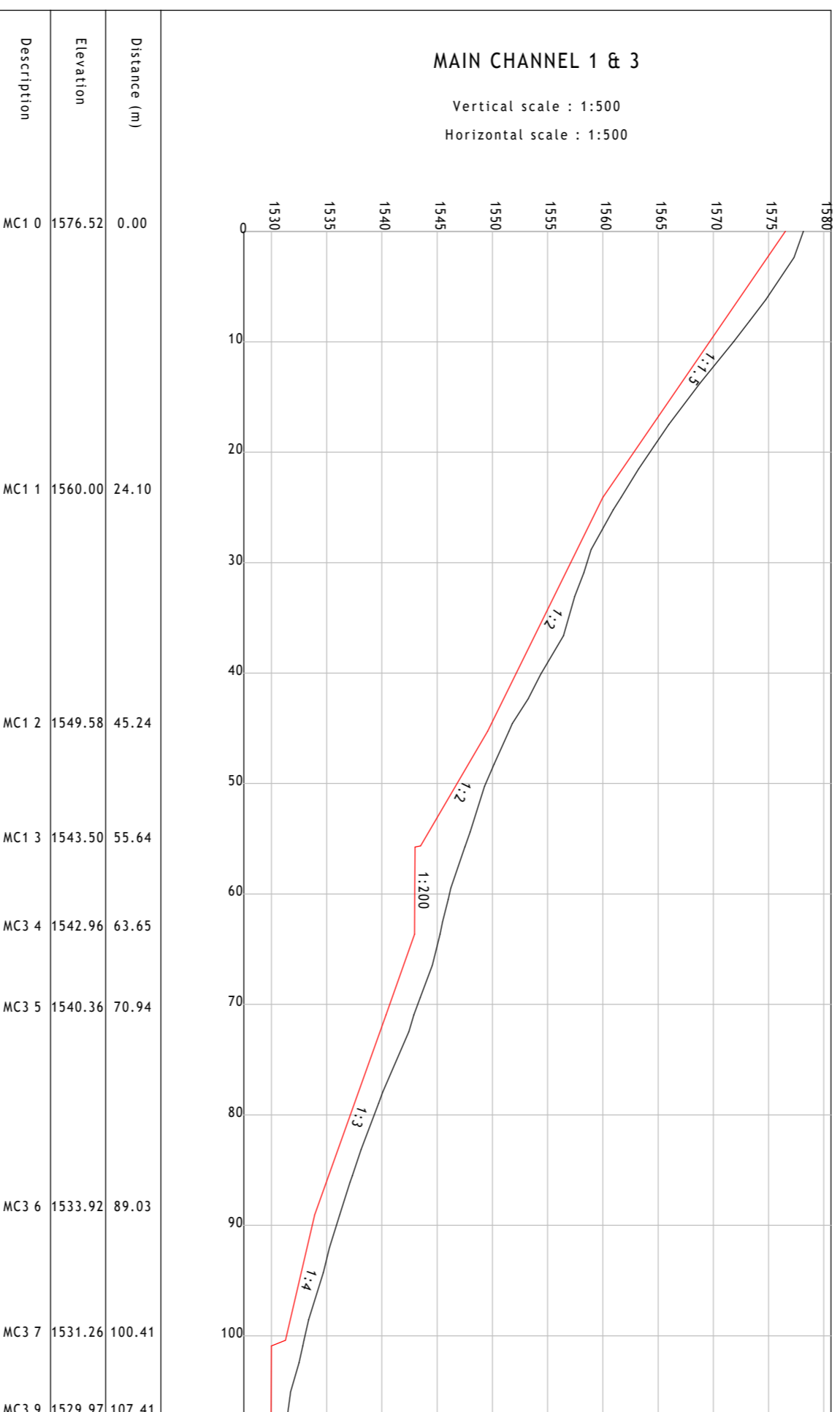
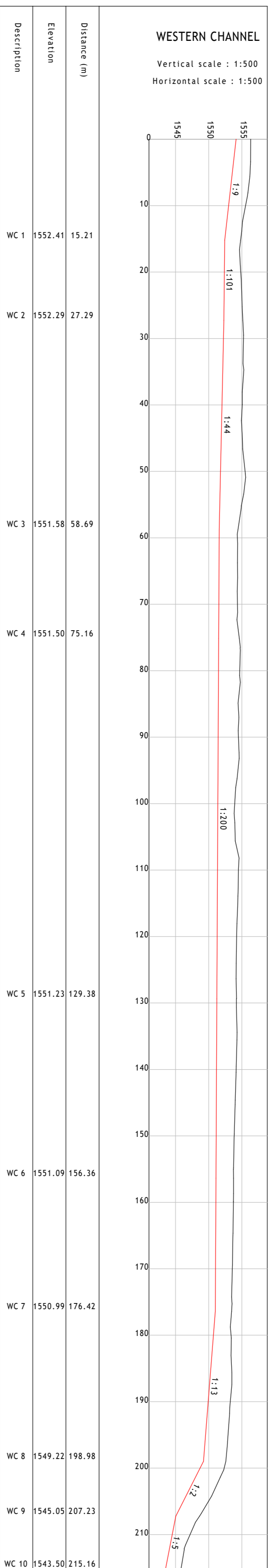
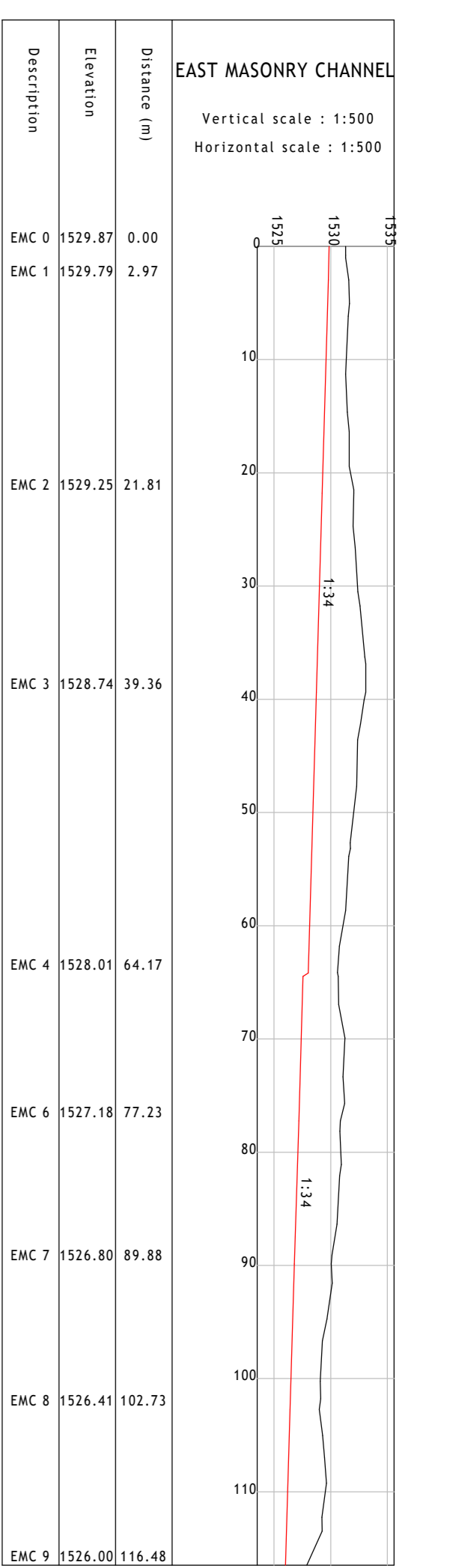
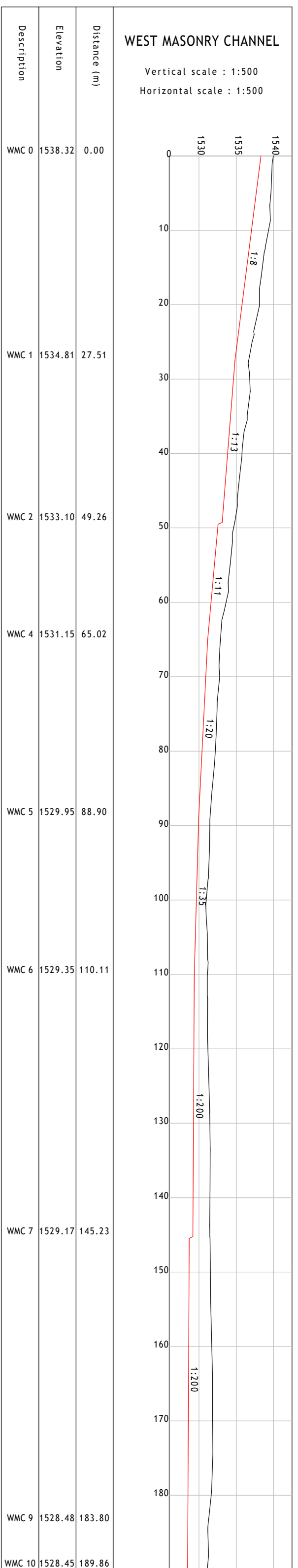
NOTE:
Masonry wall to be constructed using local skills. Masonry channel is similar to the channels used at Nyakabingo Mine next to the roadways.

Koos Davel
813 Richmond St.
Wingate Park, Pretoria.
Tel. 082 067 2347
koos@tailings.solutions

Client:
TRINITY METALS

Title:
NYAMYUMBA MINE
STORMWATER CONTROL
DETAILS

Date: Nov. 2025	Surveyed:
Scale: NTS (A1)	Designed: LS
Reference No.:	Drawn: RAS
Drawing No.: ETS TM NMB SWC DTL 002	



tailings SOLUTIONS

Wingate Park, Pretoria.
Tel. 082 067 2347
koos@tailings.solutions

Koos Davel

TRINITY METALS

NYAM-YUMBA MINE
STORMWATER CONTROL
CHANNEL LONG SECTIONS

Date: Nov. 2025	Surveyed:
Scale: As Shown (A1)	Designed: LS
Reference No.:	Drawn: RAS
Drawing No.: ETS TM NMB SWC CLS 003	

Appendix E: Bill of Quantities (BoQ)

