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Mine residue & environmental engineering consultants

# CQA Plan

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**Project Number:** 144-023

**Report Number:** 144-023-REP-2023-10-31

**Date:** 2023-10-31

EPOCH

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# List of Abbreviations

| ABBREVIATION | DESCRIPTION |
|---|---|
| HDPE | High Density Polyethylene |
| DD | Detailed Design |
| PSD | Particle Size Distribution |
| MAP | Mean Annual Precipitation |
| MAE | Mean Annual Evaporation |
| MRD | Mine Residue Deposits |
| MPRDA | Minerals and Petroleum Resources Development Act |
| EIA | Environmental Impact Assessment |
| EMPR | Environmental Management Plan Report |
| NWA | National Water Act |
| GN | General Notice |
| MRDF | Mine Residue Disposal Facility |
| NEMA | National Environmental Management Act |
| SANRAL | South African National Roads Agency |
| RFI | Request For Information |
| WUL | Water Use License |
| ARUP | Infrastructure Consultant |
| BFS | Bankable Feasibility Study |
| PSG | Particle Specific Gravity |

# List of Units

| UNIT | DESCRIPTION |
|---|---|
| **Mt** | Million Tonnes |
| **m** | Meter |
| **yrs** | years |
| **Y** | Year |
| **ktpa** | Kilo tonnes per annum |
| **kt** | Kilo tonnes |
| **$m^3$** | Cubic Meters |
| **$t/m^3$** | Tonnes per cubic meter |
| **mm** | millimetres |

# 1. Introduction

This plan addresses the Construction Quality Assurance (CQA) procedures required during the construction of the proposed raising of the Tailings Storage Facilities (TSF) 1 and 2 at Tharisa Minerals Mine (Tharisa).

This CQA Plan establishes procedures to verify that construction is in accordance with the Construction Drawings and Construction Specifications, meets the appropriate regulatory requirements, and develops the necessary documentation for submittal to the regulatory authority.

The objective of this plan is to establish:

- Duties of parties responsible for the CQA program
- Qualification requirements of the CQA Engineer(s)
- Inspection activities
- Sampling procedures
- Document control measures
- Procedures for approving the materials used for construction
- Methods for assuring compliance with design standards and Construction Specifications during construction
- Procedures for resolving issues that may occur concerning the design and construction
- Documentation of construction and testing for submittal to the regulatory authority for their review

The intent of the CQA Plan is to provide independent third-party verification and testing, to demonstrate that the Contractors and Installers have met their obligations in the supply and installation of components and materials according to the Construction Drawings, Construction Specifications, and regulatory requirements.

Quality control is provided by the Manufacturers, Installers, and Contractors and refers only to their actions taken to ensure that materials and workmanship meet the requirements of the Construction Drawings and Construction Specifications.

# 2. Parties involved with construction quality assurance

The following section provides descriptions of the parties referred to in this CQA Plan, including their responsibilities and qualifications. Specific qualified personnel will be chosen once the work has been approved and the schedule is confirmed for the selected CQA project members. (The SANS 10409 standard specification as amended has particular reference).

## 2.1. Owner/Operator

For the purpose of this CQA Plan and the PROJECT Specifications, all references to the "OWNER" shall mean the party identified as such on the title and signatory page of this document and is the license holder.

## 2.2. Project Manager

The Project Manager is the official representative of the OWNER and is responsible for construction activities at the facility, including oversight and construction management. The Project Manager is responsible for coordinating construction and quality assurance activities for the project. The Project Manager shall be responsible for the resolution of all quality assurance issues that arise during construction and must be involved in any decisions that may affect future operations of the impoundments.

For the purpose of this CQA Plan and the Project Specifications, all references to the “PROJECT MANAGER” shall mean the party identified as such on the title and signatory page of this document.

## 2.3. Design Engineer

The Design Engineer, also referred to as the “Designer” or “Engineer,” is the individual or firm responsible for the design and preparation of the Construction Drawings and Construction Specifications. The Designer is responsible for approving all design and Construction Specification changes, modifications, or clarifications encountered during construction.

For the purpose of this CQA Plan and the Project Specifications, all references to the “DESIGN ENGINEER” shall mean the party identified as such on the title and signatory page of this document.

## 2.4. CQA Monitor(s)

The CQA Engineer and CQA Monitor(s) will be responsible for understanding this CQA Plan and shall conduct CQA testing, monitoring, documentation, and reporting as required by this CQA Plan. The CQA Engineer will be the Engineer of Record and will stamp the final construction report. The implementation and reporting of this CQA Plan shall be conducted under the direct supervision of an Engineering Council of South Africa registered professional engineer or technologist in the branch of civil engineering.

Multiple CQA monitors may be contracted for specific expertise required for key construction items, e.g., Raising of the decant tower, waste rock walls and catwalks.

For the purpose of this CQA Plan and the Project Specifications, all references to the “CQA MONITOR” shall mean the party identified as such on the title and signatory page of this document.

## 2.5. Geosynthetics manufacturer(s)

The geosynthetics manufacturer(s), also referred to as the "Manufacturer," is responsible for the production of the geosynthetic components outlined in this plan. The Manufacturer may not be aligned with the Geosynthetics Installer as prescribed in the Competition Act, Act 89 of 1998. Each Manufacturer must pre-qualify that they are able to produce material that meets the requirements of the Project Specifications.

## 2.6. Geosynthetics Installer

The Geosynthetics Installer (Installer), also referred to as the "Geosynthetics Installation Contractor" or the "Installer", is responsible for the proper installation of the geosynthetic components in accordance with the Project Drawings and Project Specifications. The Installer may not be aligned with the Manufacturer as prescribed in the Competition Act, Act 89 of 1998.

### 2.7. Earthworks Contractor

The Earthworks Contractor also referred to as the "CONTRACTOR", is responsible for the completion of the site work as defined by the contract with the OWNER and in accordance with the Project Drawings and Project Specifications including materials provided by the Geosynthetics Manufacturer and work performed by the Geosynthetics Installer, but excluding materials provided by the OWNER.

The Earthworks Contractor will be responsible for retaining a surveyor to set lines and grades required for excavation, construction, and preparation of as-built drawings. Surveying shall be performed under the direction of a registered Surveyor.

### 2.8. Independent CQA Laboratory

The Independent CQA Laboratory (CQA Lab) is the third-party laboratory responsible for performing the quality assurance soils and/or geosynthetics laboratory testing tasks listed in this plan. The CQA Lab is directed by the CQA Monitor and may be part of the CQA Consultant firm or company. The geosynthetics testing laboratory shall be accredited by the Geosynthetics Research Institute Laboratory Accreditation Program (GRI-LAP or similar). The CQA Lab shall not be affiliated with the Earthworks Contractor, Geosynthetics Installer or materials suppliers.

## 3. Meetings

Meetings shall be held at inception and during the construction of the project to enhance coordination among the various parties involved. Meetings will include a pre-construction meeting, progress meetings, and resolution meetings if necessary.

### 3.1. Pre-Construction Meetings

A pre-construction meeting will be held at the site prior to the start of construction. The Project Manager, Design Engineer, CQA Monitor, Installer, contractor, and others designated by the Owner shall attend this meeting. The purpose of this meeting will at a minimum:

- Define lines of communication, responsibility, and authority
- Conduct a site inspection to discuss work areas, work plans, stockpiling, lay-down areas, access roads, haul roads, and related items
- Review the project schedule
- Review the Project Drawings, CQA Plan, and Project Specifications and take cognisance of the conditions in regulatory authorisations and licenses
- Review work area security and safety protocol

This meeting will be documented by the CQA Monitor and copies of the meeting minutes will be distributed to all parties and included in the construction completion report submitted to the authorities.

### 3.2. Progress Meetings

Bi-weekly progress meetings will be held. At a minimum, these meetings will be attended by the CQA Monitor, the Engineer or their designee, the Project Manager, the Installer (if applicable), and the

Contractor. The Project Manager is responsible for organizing and conducting the progress meetings. The purpose of this meeting will be to:

- Review the previous week's accomplishments and activities
- Review upcoming scheduled work and project milestones
- Discuss any delays or potential construction problems
- Review the results and status of CQA field and laboratory testing

This meeting will be documented by the CQA Monitor and the minutes transmitted to all in attendance.

## 3.3. Resolution Meetings

Special meetings will be held, as needed, to discuss and resolve potential problems or deficiencies. At a minimum, these meetings will be attended by the Project Manager, Design Engineer, CQA Monitor, Installer (if applicable) and/or Contractor. The meeting will be documented by the CQA Monitor.

When deficiencies (items that do not meet the project requirements stated in the Project Specifications) are discovered, the CQA Monitor shall immediately determine the nature and extent of the problem and notify the Design Engineer and Contractor and vice versa. If unsatisfactory test results identify a deficiency, additional tests will be performed to define the extent of the deficient material or work area.

The Installer or Contractor shall correct the deficiency to the satisfaction of the Design Engineer and CQA Monitor. If the remediation of the deficiency involves a design revision, the Project Manager shall also be contacted. Design revisions can only be made by the Design Engineer.

The corrected deficiency shall be re-tested and/or approved before any additional related work is performed by the Installer or Contractor. Test results of the remediated work shall also be recorded by the CQA Monitor and included in the final report documentation.

# 4. Earthwork Construction Quality Assurance

Construction of the raised embankments of the Tailings Storage Facilities must be in accordance with the approved Project Drawings and Project Specifications. This CQA Plan establishes the CQA monitoring, and testing program designed to ensure compliance with the Project Drawings and Project Specifications. The earthwork quality assurance testing program consists of testing of soil and rock materials used during the excavation and the construction of the raise of the TSF. Quality assurance testing and observation are required during all construction activities (e.g., Excavations, Engineered fills, drainage materials, geofabrics etc.). A checklist has been provided in Appendix E.

## 4.1. Construction Monitoring and Testing

All components of the construction shall be observed and tested as required by the CQA Monitor to verify that the construction is in accordance with the Project Specifications. The Design Engineer shall review the work performed by the CQA Monitor and identify inadequate construction methodologies or materials which may adversely impact the performance of the TSFs' Raise. Visual observations and verification of the independent survey required for specific layers throughout the construction process shall be made to evaluate whether the materials are placed to the lines and grades as shown on the Project Construction Drawings.

The CQA Monitor and Design Engineer will give the Project Manager sufficient notice of the anticipated completion of the construction components so that related CQA documentation may be reviewed and accepted without delay to the Contractor. Specific CQA observation and/or testing are required for the following:

- Excavations
- Engineered Fill
- Soil protection layer (if applicable)
- Geosynthetics installation (if applicable)

### 4.1.1. Excavations

The CQA Monitor shall observe and document the excavation of trenches and foundations and shall include:

- Monitoring the stripping of vegetated soil, and growth media to be stockpiled, if directed, in the area designated by the Owner.
- Monitoring that appropriate dust control measures are implemented.
- Visually inspecting the excavations for moisture seeps, soft or excessively wet areas, and unstable slopes. Inspections should also confirm the required depth of excavations where unsuitable soils are identified for foundations of embankments (e.g. loose soils, highly permeable soils, etc.), to be confirmed by the Engineer.
- Monitoring base preparation and confirming that the surface of the base is free of vegetation and that the surface is firm and unyielding and in accordance with Project Specifications (e.g. compaction density).
- Approving excavation depths are undertaken according to the design depths and that these depths are approved by the Engineer before backfilling and/or base preparation activities commence.

### 4.1.2. Raising of Embankment walls

The CQA Monitor shall observe and document prior to placement of engineered fill and shall include:

- Monitoring that appropriate dust control measures are implemented.
- Monitoring base preparation and confirming that the surface of the base is free of vegetation and that the surface is firm and unyielding and in accordance with Project Specifications (e.g. geofabric placed, lap length, etc.).
- Verify that changes in gradients on which the geofabric is to be placed are not at sharp angles and are slightly rounded.
- Verify that the base is suitable for supporting the overlying embankment layers, as required by the Project Specifications. Borrow materials for engineered fill will be sourced from the open cast mining operation and/or approved stockpile. CQA observation and/or testing is required during construction to verify that the materials and construction are in accordance with the Project Specifications. The tests to be performed, including testing frequency, are shown in

Table 4-1. The testing frequencies specified in Table 4-1 may be increased when construction conditions warrant additional tests. Additional tests may be recommended by the CQA Monitor and approved by the Design Engineer.

**Table 4-1: Engineered Fill and Backfill Construction Testing**

| Test Designation | Test Method | Frequency |
|---|---|---|
| Compaction Test Pad | Epoch Specification PSB.21.2 | Test pads should be utilized at:<br>• Project initiation<br>• 1 per 1 000 000 $m^3$ placed<br>• Occurrence of material change |
| Survey | Epoch Specification PSB.21.2 | 1 per layer (after compaction) |

The raised embankment should be conducted in accordance with the construction specifications found in Appendix C. The CQA Monitor is to ensure that the raised embankment is constructed out of waste rock material which is to be placed in 200mm thick layers after compaction. The minimum number of passes will be determined on-site, jointly by the Contractor and the Engineer, and will be based on the number of passes required to obtain the required density based on the performance specification undertaken on the waste rock. The CQA Monitor is to ensure that no fine materials (Norite) are used in the construction of the raised embankment. The CQA Monitor must ensure that the correct specifications are adhered to as stated in Appendix C.

### 4.1.3. Geosynthetic installation

Non-woven, needle-punched geofabric to be used as cushion protection to the raising of the embankment on top of the deposited tailings. Both pre-construction and construction testing are required for this material.

Construction observation and monitoring required during the geosynthetic installation include:

- Verification that all pre-construction testing has been performed and that laboratory test results indicate compliance with the Project Specifications. The CQA Monitor shall ensure that the Project Manager and the Contractor receive prompt notification of material conformance.

## 4.2. Surveying

Surveying shall be conducted such that all applicable standards are followed. The Surveyor shall furnish "Record Drawings" (also referred to as "as-built" drawings) for review by the Design Engineer. The CQA Monitor shall also review and approve the drawings prior to the placement of a new system component over the work. Required Record Drawings shall be as specified in the Project Specifications. All surveying shall be performed under the direction of a registered surveyor. All Record Drawings shall be signed and certified by the registered surveyor who directed the CQA survey work. The accuracy of the surveying shall be sufficient to determine if the measurements are within the tolerances specified in the Project Specifications.

# 5. Documentation

An effective Quality Assurance program depends on thorough monitoring and documentation of all construction activities during all phases of construction and as a minimum shall comply with SANS 10409 as amended and the inception meeting. Documentation shall consist of daily record keeping (including minutes of meetings), construction problem resolutions, design and specification changes, photographic records, weekly progress reports, chain of custody forms for test sample tracking, and a certification and summary report. During construction, all documentation shall be kept on-site and will be available for review by the Project Manager, Design Engineer, and CQA Monitor.

## 5.1. Daily Record Keeping

Daily records shall consist of field notes, observation and testing data sheets, a summary of the daily meeting with the Installer and Contractor, and a report of construction problems and resolutions. This information shall be submitted weekly along with a weekly summary to the CQA Monitor. Copies of all CQA documentation shall be maintained at the site and be made available for review by the Project Manager.

## 5.2. Soils Observations and Testing Data Sheets

Soil observation and testing data sheets generally include the following information:

- Date, project name, location, and weather data
- A reduced-scale site plan, or full-scale plots, showing work areas and test locations
- Descriptions of ongoing construction
- Summary of test results and samples taken, with locations and elevations
- Off-site materials received including quarry certificates
- Test equipment calibrations, if necessary
- Signature or initials of the CQA Monitor

## 5.3. Geosynthetic Observations and Testing Forms

If required, geosynthetic observation and testing forms generally include the following information:

- Date, project name, location, and weather data
- Identification of panel or seam number
- Numbering system identifying test or sample number
- Location and identification of repairs and date of repair
- Ensure that the correct overlapping length is carried out as per design specifications
- Location of tests and test results
- Identification of testing technicians and time of tests
- Signature or initials of the CQA Monitor

## 5.4. Construction Problem and Resolution Documentation

Any construction problem which cannot be resolved between the Installer, Contractor, and CQA Monitor may require a special meeting in order to resolve the problem. The problem should be discussed with the Project Manager, and Design Engineer if a design issue is involved. Specific written documentation of that problem should be prepared, if warranted, and will generally include the following information:

- Detailed description of the problem
- Location and cause of the problem
- How and when the situation or deficiency was identified
- How the problem was resolved
- Any measures taken to prevent similar problems in the future
- Signature of the Design Engineer and CQA Monitor

Copies of all Construction Problem and Resolution correspondence will be submitted to the Project Manager.

## 5.5. Photographic Documentation

All phases of construction shall be sufficiently photographed and/or audio-video recorded by the CQA Monitor. Photographs shall be identified by separate photographic logs by location, time, date, and name of the person taking the photograph. A camera which records the time and date shall be used. Representative photographs will be included in the certification report.

## 5.6. Design and Specification Changes

If it is necessary to address Project Drawings and/or Projects Specification changes, modifications, or clarifications during construction, the CQA Monitor or Design Engineer will inform the Project Manager. Project Drawing and Project Specification changes shall only be made with written agreement from the Project Manager and Design Engineer, and approval of the regulatory authorities if required.

## 5.7. Construction Report

At the completion of construction, a construction report shall be prepared and signed by the CQA Monitor and Design Engineer to certify that the work has been performed in compliance with the license conditions, Project Drawings and Project Specifications and will contain the following general information:

- Summary of construction activities
- Observation and test data summary sheets, inclusive of a table reflecting statistical analyses i.e. for each test method on all materials the number of tests; minimum, maximum and mean values; standard deviation; number of non-compliances and rectification shall be included.
- Sampling, testing locations, and test results
- Confirmation of interface shear strength parameters (peak and residual) using the actual geosynthetic materials supplied and installed on-site
- A description of significant construction problems and the resolution of these problems

- Changes to the Project Drawings or Project Specifications and the justification for these changes
- Record drawings
- A certification statement signed and certified by the Design Engineer and CQA Monitor, by whom the CQA activities were supervised and work performed in responsible charge.

The Record Drawings shall be prepared by the Surveyor and shall accurately locate all construction items including the lines, grades, and thickness of all soil components for the barrier system.

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# Appendix A: PARTIES INVOLVED IN THE CQA IMPLEMENTATION

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## Parties involved with construction quality assurance

| Company Name | Representatives Name | Email address | Contact number |
|---|---|---|---|
| Owner/Operator | | | |
| Project Manager | | | |
| Design Engineer | | | |
| CQA Monitor | | | |
| Earthworks Contractor | | | |
| Independent CQA Laboratory | | | |

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# Appendix B: DESIGN PARAMETER

1. Site Conditions
   1.1. Surface Water
   - The nearest watercourse:
     - TSF 1 and TSF 2: 4.5 km northeast of Buffelspoort Dam
   - Shortest distance to the 1:100 year flood line:
     - >1 400 m
   - Regional Rainfall: 668 mm/annum
   - Regional evaporation: 1 811 mm/annum
   - 1:10 000 year 24 hr duration storm event: 244 mm

   1.2. Geotechnical profile
   - Residual soil:
     - Residual gabbro norite Clay "Black turf" – Depth range of 0.2 m to 6.2 m
     - Weathered residual norite Sand and Very Soft Rock – Depth range of 0.7 m to 6.7 m
     - Norite Rock – 0.7 m and beyond
   - Depth to hard rock: 4.5 m below NGL (average). Depth Ranges from (0.7 – 6,2 m) until refusal
   - Foundation rock description: Soft to medium hard rock.
   - Seismicity: 0.13 (g)

   1.3. Topography
   - Embankment downstream side slopes: 1v:3h.
   - Embankment Upstream side slopes: 1v:2h

2. Materials Properties
   2.1. Waste (Platinum Tailings)
   - Waste Type assessment: Type 4 as per NEMWA R635 of 2013
   - Material Strength Properties (density and strength):
     - Tailings: 1.6 $t/m^3$, $\varphi' = 32°$, $c' = 0$kPa
   - Degree of saturation: Varies
   - Permeability:
     - Tailings: $4.8 \times 10^{-7}$ m/s
   - Estimating pollution period (years): 101.6 years

3. System Performance Criteria
   - Predicted mechanism of failure: Overtopping and piping.
     - Overtopping is unlikely due to the relatively small catchment of the TSFs and the designed freeboard. Whilst analysing the 1: 10 000 year storm event it had been noted that there was sufficient freeboard available under the storm event.

- Piping is the least likely considering the distance of the pool to the toe of the TSFs. Possible to occur through waste rock dumps. Geofabric is to be installed during operations to mitigate the risk of piping.

- Minimum factor of safety: ≥ 1,1 for seismic loading and ≥ 1,5 for static loading

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# Appendix C: CONSTRUCTION SPECIFICATIONS

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# Appendix D: LIST OF DESIGN DRAWINGS

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| Drawing No. | Description |
|---|---|
| 144-023-001 | GENERAL ARRANGEMENT |
| 144-023-002 | SETTING OUT DATA |
| 144-023-003 | CROSS SECTIONS – SHEET 1 OF 2 |
| 144-023-004 | CROSS SECTIONS – SHEET 2 OF 2 |
| 144-023-005 | DETAILS |
| 144-023-006 | DECANT TOWER STEEL PIPE DETAILS |
| 144-023-007 | CATWALK DETAILS – SHEET 1 OF 2 |
| 144-023-008 | CATWALK DETAILS – SHEET 2 OF 2 |
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# Appendix E: CQA CHECKLIST

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The following checklist may be revised for specific requirements identified during the detailed design. The checklist covers all the works required but may be trimmed/expanded to cover specific work items.

| Category of Works | Summary Description of the Works | CQA Checklist | Hold Point | Witness Point |
|---|---|---|---|---|
| **Site Clearance** | Clear site of vegetation and trees. | Monitor and document that:<br>• Vegetation is sufficiently cleared and grubbed in areas where earth fills are to be placed. Vegetation removal shall be performed as described in the Specifications and the Drawings. | X | |
| **Earthworks** | Bulk Excavation<br><br>Restricted Excavation | Monitor and document that:<br>• Excavations are done to designed/specified depth<br>• All excavations are done to the required width and/or slope as Technical Specifications/design<br>• All grades, trimming and levels are as per Technical Specifications/design<br>• All excavations are safe for entry/work during and after excavation activity | X | |
| | Excavation of unsuitable material | Monitor and document that:<br>• Excavation exposed underlying competent material or as approved by the Engineer<br>• Unsuitable material is stockpiled as per Engineer's instruction<br>• All excavations are safe for entry/work during and after excavation activity | X | |
| | Borrow Area | Monitor and document that:<br>• Excavation exposed underlying competent material or as approved by the Engineer<br>• Unsuitable material is stockpiled as per Engineer's instruction<br>• All excavations are safe for entry/work during and after excavation activity | X | |
| **Base Preparation** | Base preparation of in-situ material to 300mm depth | Monitor and document that:<br>• Base preparation is done according to Technical Specifications<br>• The compaction requirements are reached as per design Technical Specifications<br>• The entire area is compacted evenly and uniformly<br>• All grades, trimming and levels are maintained/restored after compaction activity | X | |

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|---|---|---|---|---|
| **Construction of Embankments** | Construction of engineered fills/embankments | Monitor and document that:<br>• Base surface is prepped as per construction specifications (Ie. clear of vegetation, geofabric etc)<br>• The fill/embankment is constructed using the correct material as per the Specifications/design<br>• The fill/embankment lifts are done in accordance with Specifications/design<br>• The compaction effort adheres to the performance specification of compaction of the fills/embankments<br>• The levels, grades, slopes and trimming are as per Specifications/design | X | |
| **Penstock Valves** | Construction of Penstock Emergnecy Isolating Valves | Monitor and document that:<br>• The structure is constructed using the correct material as per the Specifications/design<br>• The construction methodology aligns with the Specification/design<br>• The concrete/grout curing periods are adhered to<br>• Survey confirmations of the correct levels are undertaken | X | |
| **Decant Tower** | Construction works required to raise the Decant Tower Discharge Structure | Monitor and document that:<br>• The structure is constructed using the correct material as per the Specifications/design<br>• The construction methodology aligns with the Specification/design<br>• Survey confirmations of the correct levels are undertaken | X | |

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# Appendix F: PERFORMANCE PARAMETERS

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| Area | Parameter | Test Method | Criteria | Tolerance | Frequency |
|---|---|---|---|---|---|
| **Subgrade Physical Properties** | Visual Inspection | Free of vegetation or other perishable material and unsuitable materials | N/A | N/A | N/A |
| | Atterberg Limits | • SANS 3001-GR10:2013 (Atterberg Limits) | PI=11 | > 8 and < 20 | 1x to identify suitable borrow area<br>1x per newly identified layer |
| | Compaction Curve | • ASTM D698 (Standard Proctor) | N/A | N/A | 1x to confirm design parameters<br>1x per newly identified layer |
| | Particle Size Distribution | • SANS 3001-GR1:2013 (Wet Sieve)<br>• SANS 3001-GR3:2012 (Hydrometer) | Max size: <2/3 of layer thickness<br>%Passing 75um: >10% and <30%<br>Grading Modulus: >0.9 | N/A | 1x to confirm design parameters<br>1x per newly identified layer |
| **Subgrade Compaction** | Visual Inspection | Free of vegetation or other perishable material and unsuitable materials | N/A | N/A | Continues Monitoring |
| | Scarification Depth | N/A | 300 mm | No more than 10% shallower | Continues Monitoring |
| | Moisture content | • SANS 3001-NG5:2014 (nuclear moisture gauge) | 1.75% Wet of OMC | +- 0.25%<br>(1.5 to 2% Wet of OMC) | 2x Nuclear tests every 5000 m2 |
| | Compaction Density | • SANS 3001-NG5:2014 (nuclear density gauge)<br>• SANS 3001-GR35:2015 (Sand Replacement) | • 95 % of Maximum Dry Density<br>• Field density to be calibrated to Sand Replacement and proctor for the layer | None < 93% or > 102%<br>Both tests to pass per 200m2 block, else add 2 tests, pass on average if within 2% of 95% | 2x Nuclear tests every 5000 m2<br>1x Sand Replacement every 10000 m2 |
| | Compaction Curve | • ASTM D698 (Standard Proctor) | Proctor for density tests performed from samples sourced from Layer | N/A | Every 20000m2 block tested |
| **Borrow** | Atterberg Limits | • SANS 3001-GR10:2013 (Atterberg Limits) | PI=11 | > 8 and < 20 | 1x to identify suitable borrow area<br>Additional tests every 10 000 $m^3$ |
| | Compaction Curve | • ASTM D698 (Standard Proctor) | N/A | N/A | 1x to identify suitable borrow area |
| | Particle Size Distribution | • SANS 3001-GR1:2013 (Wet Sieve)<br>• SANS 3001-GR3:2012 (Hydrometer) | Max size: <2/3 of layer thickness<br>%Passing 75um: >10% and <30% | | 1x to identify suitable borrow area<br>Additional tests every 10 000 $m^3$ |

| | | | | | |
|---|---|---|---|---|---|
| **Embankment** | Layer thickness | • Survey | 2 m | Max size: <2/3 of layer thickness<br><br>No more than 10% of layer thickness | 1x per compacted layer |
| | Moisture content | N/A | N/A | N/A | N/A |
| | Compaction Density | N/A | N/A | N/A | N/A |
| | Compaction Curve | • PSB.21.2 (Project Construction Specifications) | The required number of passes is set at 80% of the total settlement in eight passes or a maximum of six passes | N/A | Every 1 000 000 $m^3$ placed |

EPOCH

Mine residue & environmental engineering consultants

# **Design** Report

**Prepared for:** Tharisa Minerals (Pty) Ltd.

**Project Number:** 144-023

**Report Number:** 144-023-REP-2023-11-06

**Date:** 2023-11-06

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## List of Abbreviations

| ABBREVIATION | DESCRIPTION |
|---|---|
| ARUP | Infrastructure Consultant |
| BFS | Bankable Feasibility Study |
| DD | Detailed Design |

| ABBREVIATION | DESCRIPTION |
|---|---|
| EIA | Environmental Impact Assessment |
| EMPR | Environmental Management Plan Report |
| FSL | Full Supply Level |
| GN | General Notice |
| HDPE | High Density Polyethylene |
| LoF | Life of Facility |
| LoM | Life of Mine |
| MAE | Mean Annual Evaporation |
| MAP | Mean Annual Precipitation |
| MPRDA | Minerals and Petroleum Resources Development Act |
| MRD | Mine Residue Deposits |
| MRDF | Mine Residue Disposal Facility |
| NEMA | National Environmental Management Act |
| NWA | National Water Act |
| PSD | Particle Size Distribution |
| PSG | Particle Specific Gravity |
| RFI | Request For Information |
| SANRAL | South African National Roads Agency |
| TMM | Tharisa Minerals Mine |
| TSF | Tailings Storage Facility |
| WUL | Water Use License |

# List of Units

| UNIT | DESCRIPTION |
|---|---|
| Mt | Million Tonnes |
| kt | Kilo tonnes |
| ktpa | Kilo tonnes per annum |
| l/s | Liters per second |
| m | Meter |
| m.a.m.s.l. | Meters above mean see level |
| m/d | Meters per day |
| m/s | Meters per second |

| UNIT | DESCRIPTION |
|---|---|
| $m^2$ | Square Meters |
| $m^3$ | Cubic Meters |
| mbgl | Meters below ground level |
| mm | Millimetres |
| $t/m^3$ | Tonnes per cubic meter |
| Y | Year |
| yrs | Years |

# 1 Introduction

Epoch Resources (Pty) Ltd (*Epoch*) was appointed by Tharisa Minerals (Pty) Ltd (*Tharisa*) to undertake a Detailed Design (*DD*) for the raising of three (3) of Tharisa Minerals Mine's existing Tailings Storage Facilities (*TSFs*). The facilities to be raised are TSF 1 Expansion, TSF 2 Phase 1, and TSF 2 Phase 2.

## 1.1 Project Location

The Tharisa Minerals Mine (*TMM*) is located on the south-eastern part of the western limb of the Bushveld Igneous Complex - Rustenburg Layered Suite and is approximately 4.5 km northeast of the Buffelspoort Dam, and approximately 8.5 km south-west of the town of Marikana, in the Northwest Province of South Africa. The location of the mine is depicted in Figure 1-1.

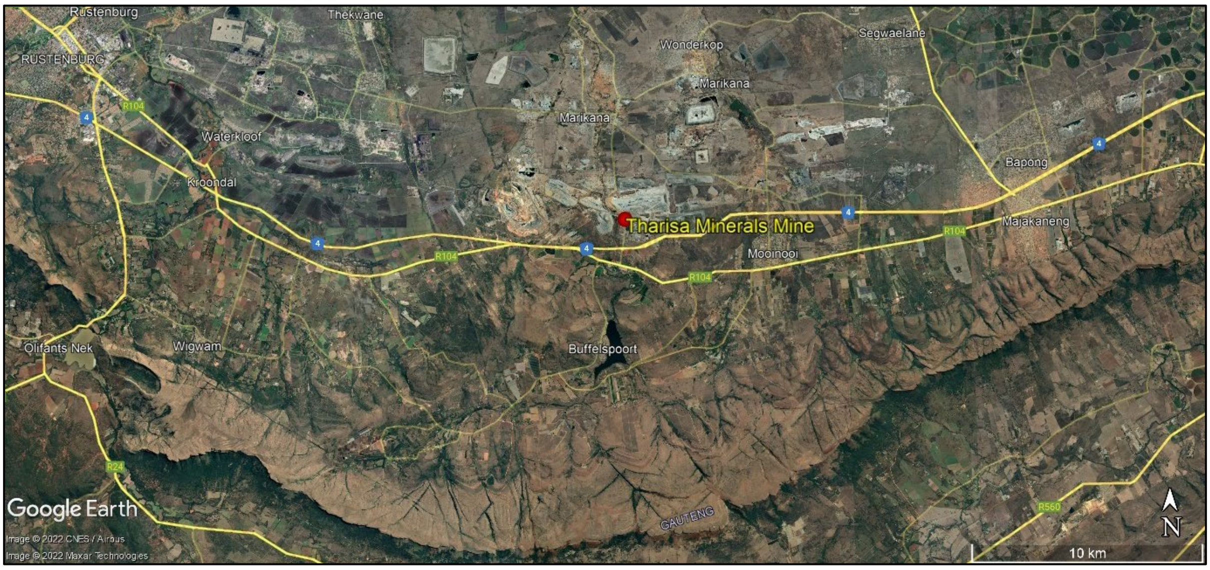



**Figure 1-1: Location of Tharisa Minerals Mine**

## 1.2 Project Background

Tharisa is subdivided into the so-called East and West Mine by the Sterkstroom river that runs from south to north, through the mine property. TSF 1 and 2, along with the majority of the mine's infrastructure, are located in the East Mine, as shown in Figure 1-2.

Tharisa extracts and processes the Middle Group 1 to 4 ores of the Platinum Mineral Group in the Bushveld Igneous Complex. The mine currently operates three processing plants, namely Genesis, Voyager and Vulcan. Genesis and Voyager process 100 kt and 300 kt per month, respectively. The waste product produced by both plants is sent to the Vulcan plant for extraction of additional chrome, after which, the tailings material is hydraulically pumped to the active TSF for storage. TSF 3, a new facility currently awaiting authorization, is earmarked for receiving tailings once TSF 2 Phase 2 has reached its Full Supply Level (FSL). However, the unknown timeline for the water use licence authorisation and the subsequent construction associated with TSF 3, forced TMM to pursue an additional storage solution in lifting the existing TSF 1 Expansion, TSF 2 Phase 1 and TSF 2 Phase 2 facilities.

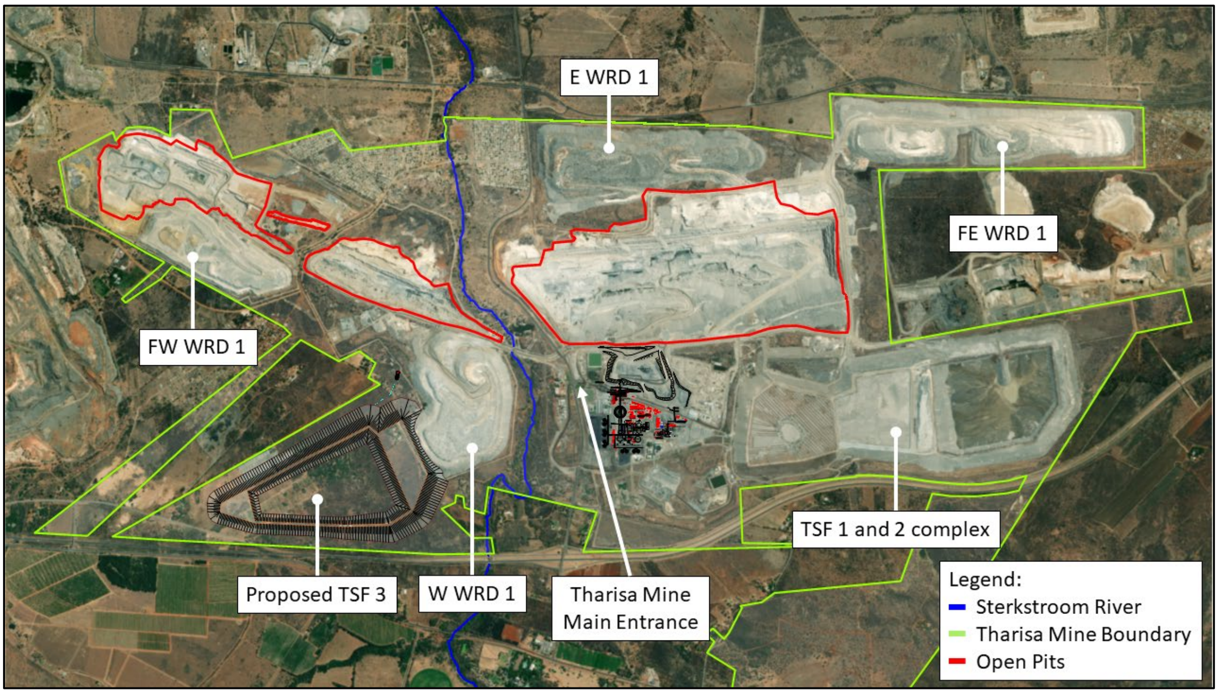



**Figure 1-2: Tharisa Minerals Mine current and planned facilities**

## 1.3 Company Details

Epoch is a consulting engineering firm, operating out of offices in Johannesburg, South Africa, specialising in the design of mining residue storage facilities and mine closure planning and implementation. This report describes the work undertaken to complete the Detailed Design (DD) of the lifting of the existing TSF 1 Expansion, TSF 2 Phase 1, and TSF 2 Phase 2 facilities.

## 1.4 Scope of Work

The scope of work for the lifting of the existing facilities includes the following:

- Collecting and reviewing all information made available and pertinent to the study.
- Detailed design, in compliance with South African Regulations, of the raising of the TSFs comprising of:
  - Seepage and slope stability assessments.
  - Water balance updates.
  - Assessment of the existing decanting infrastructure's bearing and decanting capacities
  - Determination of the Zone of Influence (ZoI)
  - Compilation of a Schedule of Quantities for the construction of the preparatory works.
  - Compilation of construction specifications documents for the TSFs.
  - Basic definition of closure and rehabilitation strategy and management measures.

## 1.5 Battery limits

The battery limits for the project are as follows:

- The perimeter fence line around the TSFs; and

- Downstream of the point where the slurry delivery pipeline intersects the tailings dam embankment and upstream of the suction end of the return water pump located at the respective sumps of each facility.

## 1.6 Clarification

The proposed lifting of the existing facilities allows for the respective TSF footprint areas to remain unchanged. Therefore, the environmental and geotechnical studies undertaken during the detailed design phase for TSF 1 and TSF 2 remain relevant. In light of this, Tharisa will be applying for an amendment to the existing approved Water Use License Application (WULA) for TSF 1 and 2.

This report should be read in conjunction with the original design report for each facility. A summary of the design components of each facility, where relevant, will be provided in this report. However, the focus of this report will be on the additional design elements required and assessments undertaken for the detailed design of the raised facilities.

# 2 Available Information

The following information has been made available to Epoch to undertake the detailed design:

- A 1 m contour interval digital terrain model covering the project area.
- Daily rainfall depth and evaporation records from the Buffelspoort II rainfall station (No. 0511855 A9).
- Waste assessment of the tailings and waste rock completed by SLR (Pty) Ltd.
- Expected and historic tailings production rates.
- Laboratory test results that provide the physical characteristics of a representative Vulcan tailings sample.

## 2.1 Applicable Regulations and Standards

The following regulations have been applied in the design of the TSFs:

- Mineral and Petroleum Resources Development Act (Act 28 of 2002).
- GN 632 - Regulations Regarding the Planning and Management of Residue Stockpiles and
- Residue Deposits from a Prospecting, Mining, Exploration or Production Operation, 24 July 2015 (NEM:WA).
- National Environmental Management: Waste Act 59 of 2008 (NEM:WA).
- National Water Act, 1998 (Act 36 of 1998).
- Mines Health and Safety Act (Act 29 of 1996).
- Minerals Act (Act 50 of 1991).
- National Environmental Management: Waste Act 59 of 2008 (NEM:WA).
- Department of Mineral and Energy (DME) guideline for the compilation of a mandatory code of practice for mine residue (DME 16/3/2/5-A1).
- South African Bureau of Standards (SABS) code of practice for mine residue (SANS 0286:1998).
- Global Industry Standards on Tailings Management (*GSITM*)

### 2.1.1 Waste Classification

The National Environmental Management Waste Act (*NEM:WA*) stipulates threshold values for total concentrate (TCT) and leachable concentration (LCT). TCT refers to the total concentration threshold limit for particular elements or chemical substances in a waste, expressed as mg/kg. LCT means the leachable concentration threshold limit for particular elements and chemical substances in a waste, expressed as mg/l. Both the TCT and LCT elements and chemical substances are prescribed in section 6 of NEM:WA (Act No. 59 of 2008, No. R. 635).

The total and leachable concentrations are determined through geochemical testing by an accredited laboratory and characterised as a Type 0-4 waste. The waste classification dictates the barrier system required to contain the waste body.

### 2.1.2 Target Factors of Safety

The Factor of Safety (*FoS*) against slope or sliding failure is typically defined as the ratio of the total forces resisting destabilisation of the tailings stored within the embankments, to the total destabilising forces. In other words, if the cumulative forces resisting destabilisation exceed the cumulative destabilising forces, the FoS will be greater than 1.0 and therefore deemed safe. On the other hand, a FoS of 1.0 or less, indicates that the destabilising forces exceed the forces resisting destabilisation and, therefore, a situation of incipient failure arises (SANCOLD, 2020).

ICOLD (Bulletin No. 194, 2022) provides target factors of safety for two principal conditions: 1.5 for static conditions and 1.1 for post-liquefaction conditions. ICOLD (Bulletin No. 194, 2022) further goes on to state that these targets are generally considered minimum values unless justification is provided for a lower value. Based on the above discussion, the target factors of safety for TMM were adapted depending on the possible downstream impacts. The target factors of safety in the case where mining operations could be impacted were increased to above the legislated targets of 1.5 and 1.1 for static and pseudo-static conditions, respectively. The target factors of safety assuming static conditions vary between 1.5 and 2.0. Pseudo-static factors of safety vary between 1.1 and 1.5. Section 9.3.3 provides a comprehensive list of the target factors for each scenario assessed.

### 2.1.3 Separation of Clean and Dirty Water

The Water Act stipulates that the contamination of clean water may not occur more than once in 50 years. Deterministically this is equivalent to a 2% probability of annual occurrence and is achieved with the implementation of engineered measures such as a 2 m freeboard between the crest of the facility and the full supply level (*FSL*), storm water diversion channels to prevent contact between the waste rock embankment and the downstream environment, a seepage capturing system and supernatant water decant system.

### 2.1.4 Minimum Freeboard

The Minerals Act and the Water Act respectively state the following on the provision of minimum freeboard:

- A minimum freeboard of 0.5 m with a 1:100-year recurrence interval (1% probability of exceedance), 24-hour duration storm.
- A minimum freeboard of 0.8 m 1:50-year recurrence interval (2% probability of exceedance), 24-hour duration storm.

The SANCOLD guidelines recommend factoring into consideration the following elements affecting available freeboard:

- Wind-generated waves.
- Wind setup.
- Seiches (resonance).
- Flood surges.
- Landslide-induced waves.
- Earthquake-induced waves.

The design uses a storm event with a 2% probability of exceedance (1:50-year) and a duration of 24 hours. A minimum freeboard of 2 m has been applied to the project which exceeds the Water Act requirements and provides additional freeboard to address the SANCOLD guidelines.

## 2.2 Climatic Data

### 2.2.1 Rainfall and Evaporation

Daily rainfall records were made available to Epoch for the TSF water balance from the Buffelspoort II Agricultural Weather Station (No. 0511855 A9, latitude: 25°75', longitude: 27°58') located approximately 2 km west of the project site, and at a similar elevation of 1230 m.a.m.s.l. The rainfall data provides a daily record from 1 January 1938 to 30 June 2021, i.e., for 83.5 years.

Based on the daily rainfall record, the project area receives a recorded Mean Annual Rainfall (*MAR*) depth of 668 mm. The rainfall pattern is seasonal with 80% of rainfall typically occurring in the summer months from October to March. The mean annual evaporation exceeds the average annual rainfall by almost threefold at 1 811 mm per annum. The monthly distribution follows a similar trend to the rainfall with greater evaporation depths occurring in the summer months. The average monthly rainfall and evaporation depths are listed in Table 2-1 and illustrated in Figure 2-1.

**Table 2-1: Rainfall and evaporation depths for the project area**

| Month | Average rainfall (mm) | Cumulative Average Rainfall (mm) | Evaporation (mm) A-Pan | Cumulative Average Evaporation (mm) | Net (Loss/Gain) |
|---|---|---|---|---|---|
| January | 126 | 126 | 195 | 195 | - 69 |
| February | 97 | 223 | 165 | 360 | - 68 |
| March | 85 | 308 | 158 | 518 | - 73 |
| April | 46 | 354 | 125 | 643 | - 79 |
| May | 14 | 368 | 107 | 750 | - 93 |
| June | 8 | 376 | 87 | 837 | - 79 |
| July | 4 | 380 | 97 | 934 | - 93 |
| August | 6 | 386 | 128 | 1062 | - 122 |
| September | 18 | 404 | 168 | 1230 | - 150 |

| Month | Average Rainfall (mm) | Cumulative Average Rainfall (mm) | Evaporation (mm) A-Pan | Cumulative Average Evaporation (mm) | Net (Loss/Gain) |
|---|---|---|---|---|---|
| October | 60 | 464 | 193 | 1423 | - 133 |
| November | 87 | 551 | 189 | 1612 | - 102 |
| December | 117 | 668 | 199 | 1811 | - 82 |
| Total | 668 | 668 | 1811 | 1811 | - 1143 |

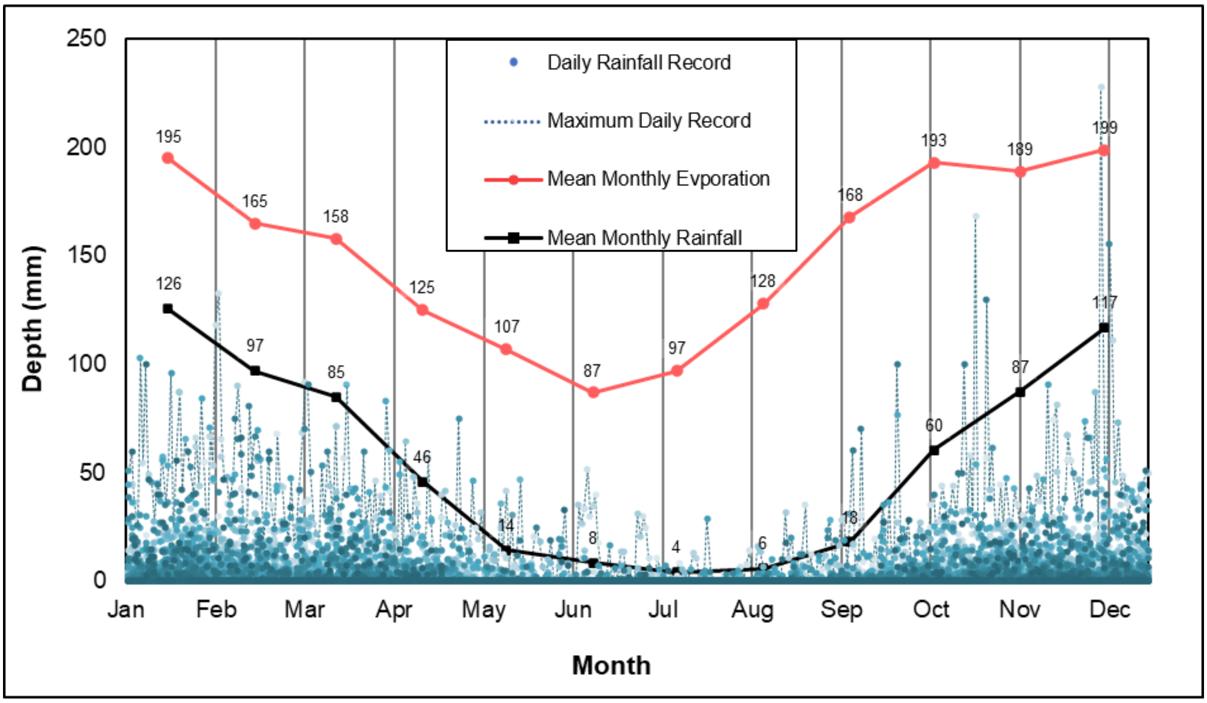



**Figure 2-1: Rainfall and evaporation depths as recorded from the Buffelspoort weather station.**

### 2.2.2 Flood Events

Adamson (1981) estimates the flood depth for recurrence intervals from 2 to 500 years. These flood depths were derived from an empirical relationship, developed from flood depths, based on the daily rainfall and storm event recordings at over 2,400 sites across South Africa and Namibia. Table 2-2 lists the 1-day storm events for Tharisa, based on the empirical relationship. Adamson (1981) states that a 24-hour event is approximated by increasing the equivalent 1-day event by a factor of 1.11.

A distinction is made between the 1-day and 24-hour events. The use of data loggers has allowed rainfall intensity to be captured over short incremental periods (less than a day) which can be grouped chronologically. A sliding 24-hour period is used to determine the true maximum for any 24-hour timestep that will exceed the 1-day rainfall intensity captured at a fixed daily increment.

**Table 2-2: Design flood depths based on Adamson (1981)**

| Duration | Rainfall Depth (mm) for each Recurrence Interval | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 2 Years | 5 Years | 10 Years | 20 Years | 50 Years | 100 Years | 200 Years | 500 Years |
| 1-day | 70 | 87 | 99 | 110 | 126 | 139 | 152 | 170 |
| 24-hour | 78 | 97 | 110 | 122 | 140 | 154 | 167 | 189 |

As per the GISTM, the design of the TSFs should consider storm events with recurrence period that relate to the extreme consequence classification i.e., 1 in 10 000 years or the relevant classification (as assessed), while also indicating what measures can and should be implemented at a later stage to meet the requirements for an extreme consequence classification. The empirical relationship between the precipitation depth and the recurrence intervals was used to determine the flood depth for the 1 in 10 000, 1-day and 24-hour events. The relevant flood depths for the consequence classifications, as set out by the GISTM, are listed in Table 2-3. For the design of the TSFs, a flood depth of 244 mm was considered i.e., the 1 in 10 000 years recurrence period.

**Table 2-3: Storm Design Criteria**

| Consequence Classification | Flood Depth Criteria – Annual Exceedance Probability | | |
|---|---|---|---|
| | Operations and Closure (Active Care) | Design Depth (1-Day) mm | Design Depth (24-hour) mm |
| Low | 1 / 200 | 152 | 167 |
| Significant | 1 / 1 000 | 181 | 199 |
| High | 1 / 2 475 | 197 | 217 |
| Very High | 1 / 5 000 | 210 | 231 |
| Extreme | 1 / 10 000 | 222 | 244 |

## 2.3 Topography

A topographical lidar survey with 1 m contour intervals of the site area was provided to Epoch by Tharisa, with the WGS84 Hartebeesthoek / Lo27 coordinate reference system. A large area of interest, as indicated in Figure 2-2, is covered to provide sufficient data and adequate detail for the design of the facilities.

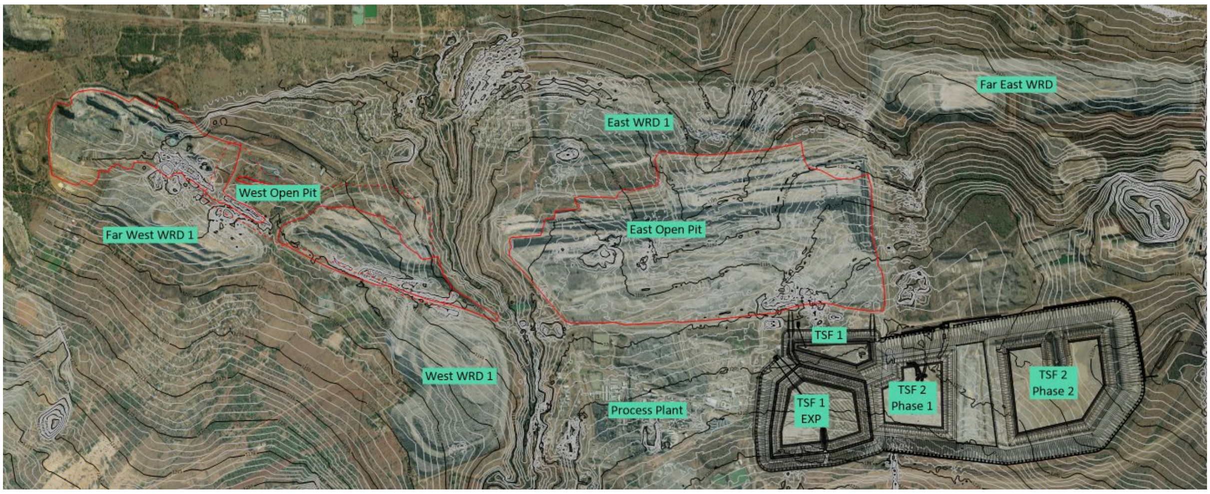



**Figure 2-2: Provided Site Survey**

## 2.4 Site Geology

The Tharisa Minerals Mine is located along the southwestern limb of the mineral-rich Main Zone of the *Bushveld Igneous Complex,* as illustrated in Figure 2-3.

The mine extracts the Middle Group (*MG* and *UG*) Chromitite layers from an open pit with a remaining life expectancy of 15 years. Expectations are for an additional 40 years of underground mining life.

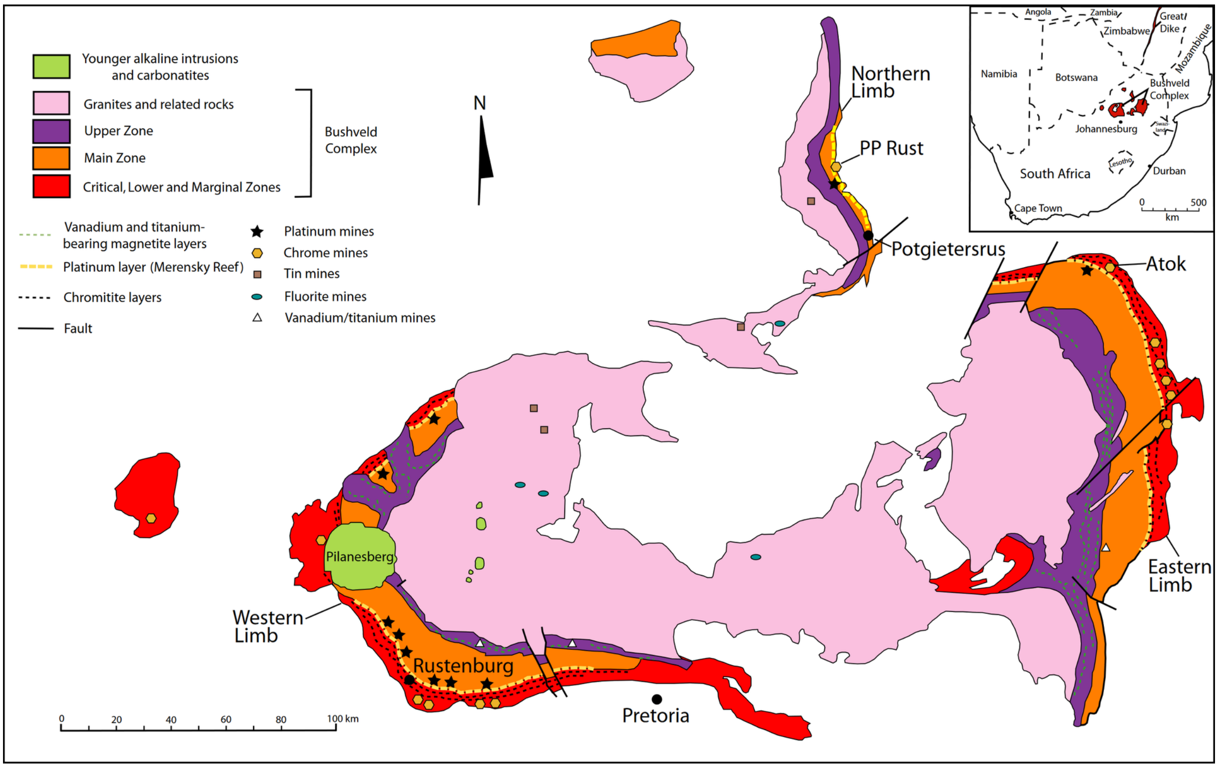



**Figure 2-3: Project location on the geological map of South Africa**

The following lithographic formations underlie the mine according to the geological map of South Africa obtained from the Council for Geoscience (CGS), illustrated in Figure 2-4:

- Kroondal and Kologeng Norite (Rkk) formation to the west comprising of:
- Norite
- Quartz Norite
- Vlakfontein subsuite (Rvl) to the east comprising of:
- Pyroxene
- Harzburgite
- Norite
- Schilpadnest sub-suite (Rsa) to the north, and the location of the mine open pits, comprising of:
- Feldspathic pyroxene
- Leuconorite
- Anorthosite
- Pyroxenite
- Chromite

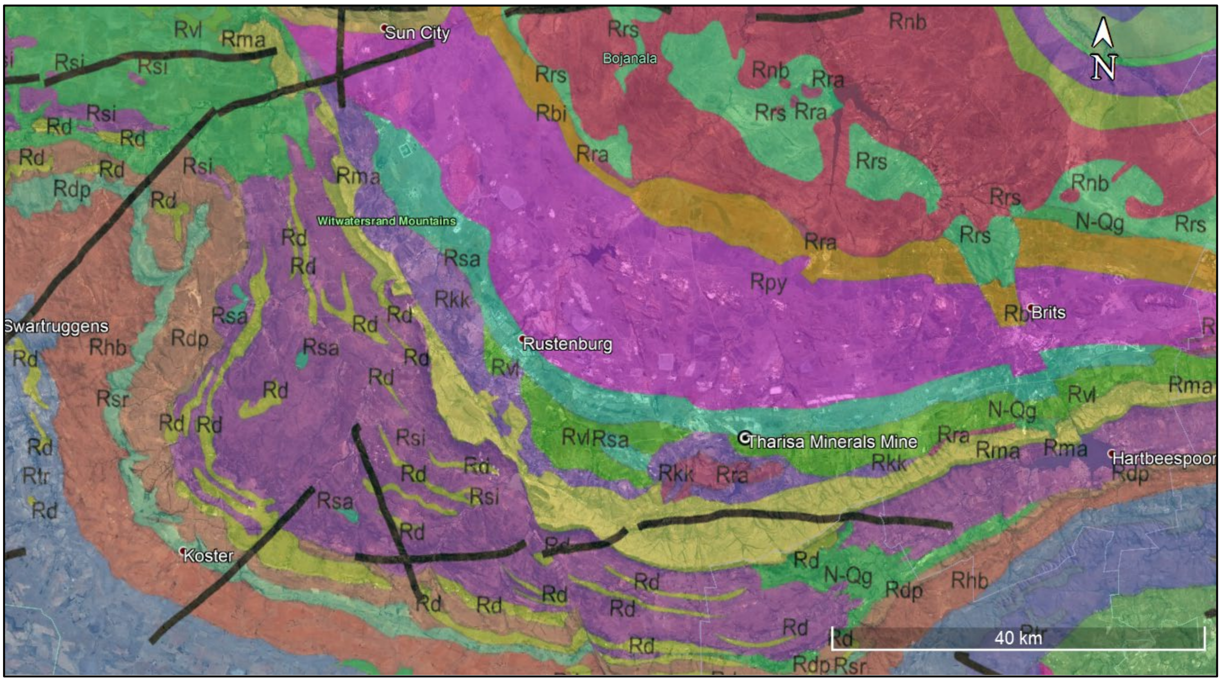



**Figure 2-4: Lithology at the Tharisa Minerals Mine**

## 2.5 Near Surface Geotechnical Investigation

InRoads (Pty) Ltd conducted a near-surface geotechnical investigation of the TSF 1 and 2 site in August 2011 and documented their findings in a report titled: "*Report on a geotechnical investigation for the Tharisa tailings storage facility in Rustenburg*" as contained in Appendix C. Representative samples of the in-situ soil horizons were collected during the site investigation and underwent geotechnical testing to confirm or update observations made during the investigation. Figure 2-5 shows the location of the test pits and surface geology that were used by InRoads to obtain the material properties.

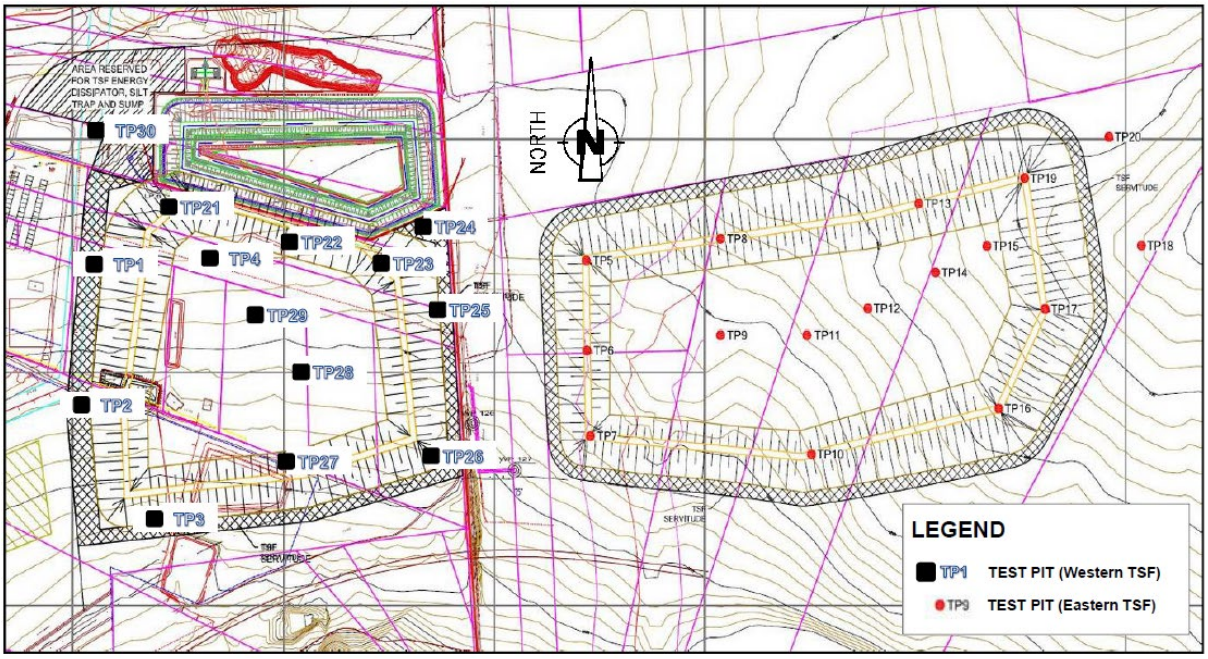



**Figure 2-5: Site plan showing the position of test pits and surface geology**

The subsoils encountered are characterised by dark grey or occasionally dark brown, soft to firm clays commonly referred to as “black turf”. The black turf is underlain by grey and olive predominantly very soft to medium hard rock gabbro norite and occasionally medium dense to dense sand.

The residual clay ‘black turf” ranges from 1.4 m to 3.2 m in depth and 0.7 m to 13 m over the TSF 1 and TSF 2 sites respectively. The black turf was observed to be of very low permeability, typically in the order 1E-9 m/sec and depending on their thickness should contribute significantly to reducing seepage into the underlying sand and rock strata. The underlying rock and sand strata appear to be relatively permeable from the soil profiles, with remoulded sample tests indicating they have a permeability in the range of 3.0E-7 and 2.7E-6 m/sec.

### 2.5.1 Foundation indicators

Foundation indicators categorise the soils in terms of their grain sizes, grain assortment, and their behaviour with changes in water content. The tests conducted to determine the foundation indicators included:

- Particle size distribution (PSD) to determine the fraction of material passing predefined sieve perforation sizes.
- Atterberg Limits define the water content present in a sample to achieve a completely fluid state, known as the Liquid Limit (LL) and the transition point between from semisolid to a plastic consistency, known as the Plastic Limit (PL). The difference between the LL and PL is known as the Plasticity Index (PI) and provides some insight into the behaviour of soil under varying moisture conditions, without completing more complex and definitive testing.
- Classification of the soils based on the PSD results and Atterberg Limits in terms of the United Soil Classification System (USCS).

Foundation Indicators were determined by Civil Engineering Testing laboratories (*Civilab*), a commercial civil engineering testing laboratory in Johannesburg, and are listed in Table 2-4.

**Table 2-4: List of foundation indicator test results**

| Soil Description | Depth (m) | LL | PI | USCS Classification |
|---|---|---|---|---|
| Residual gabbro norite - Sand | 1.2-4.0 | NP | NP | SP-SM, SW |
| Residual gabbro norite - Clay | 1.0 – 4.7 | 60-105 | 32-72 | CH |
| Very soft rock gabbro norite | 4.7 – 5.1 | SP | SP | SW-SM |

LL= Liquid Limit; PI = Plasticity Index; $PI_{ws}$ = Plasticity Index of whole sample; USCS = Unified Soil Classification System

### 2.5.2 Hydraulic and consolidation properties

A flexible wall triaxial cell was used to determine the permeability of both undisturbed and remoulded samples from selected soil horizons. The results of the tests are shown in Table 2-5. The remoulded samples were prepared at sample-specific optimal moisture content to 95% of their Standard Proctor maximum dry density.

Permeability tests were carried out on samples of the residual clay “black turf” and the remoulded residual sand and rock fragments prepared in the triaxial cell, and the results are summarized in Table 2-5. The permeability coefficients for the remoulded sand and rock fragments are in the range 3.0E-7 and 2.7E-6 m/sec, which classify these soils as slightly permeable when remoulded to 95% of their standard proctor density. On the other hand, the “black turf” is regarded as almost impermeable when compacted with a permeability between 4.7E-10 and 1.0E-9 m/sec.

**Table 2-5: List of Hydraulic and consolidation Parameters**

| Soil Description | Moisture Content (%) | Dry Density (kg/m³) | Permeability (m/sec) |
|---|---|---|---|
| Residual gabbro norite - Sand | 14.1 – 16.9 | 1830 - 2209 | 2.7E-6 – 4.5E-6 |
| Residual gabbro norite - Clay | 33.7 – 45.2 | 1121 - 1298 | 1.0E-9 – 9.1E-10 |
| Very soft rock gabbro norite | 10.6 | 1933 | 3.0E-7 |

### 2.5.3 Shear Strength Parameters

Shear strength parameters of undisturbed and remoulded soil samples were determined through triaxial testing at Civilab. Undisturbed samples of the residual clay “black turf”, and remoulded sand and rock fragments samples were subjected to consolidated undrained and drained triaxial tests respectively, and the results are summarized in Table 2-6 below. The residual clay initially tested had in excess of 52 % clay by mass and in terms of effective stresses exhibited cohesion of 20 to 30 kPa with a friction angle of 12 degrees. The remoulded sand and rock fragments exhibit an apparent cohesion of 3 kPa and an angle of friction of between 35 to 43 degrees. Epoch noted that the initial clay shear strength parameters observed were not in line with typical values for this type of material and as a result, the clays were retested. The re-tested results indicated a cohesion of between 3.6 and 6.9 kPa and a friction angle of between 19.9 and 22.5 degrees.

**Table 2-6: Shear strength parameters**

| Soil Description | Dry density (kg/m³) | Moisture Content (%) | Cohesion c' (kPa) | Angle of friction Φ' (degrees) |
|---|---|---|---|---|
| Residual gabbro norite - Sand | 1820 - 1994 | 14.0 – 14.6 | 3 - 22 | 35 - 43 |
| Residual gabbro norite - Clay | 1259 - 1299 | 33.7 – 38.4 | * 4 - 7 | * 20 - 22 |
| Very soft rock gabbro norite | 2051 | 9.5 | 15 | 38 |

* Results received for re-tested samples

# 3 Studies And Investigations in Support of TSF Design

Several studies were conducted in parallel with the scope of work described above in support of the design of the TSF, including:

- Tailings characteristics analysis.
- Site-specific probabilistic seismic hazard assessment (PSHA).
- Sampling and waste classification of tailings to be disposed of at the facilities.
- Groundwater specialist studies and contaminant transportation modelling.
- Cone Penetration Tests with pore water pressure measurement analysis (CPTu).

## 3.1 Tailings and Slurry Properties

A representative tailings sample from the Vulcan plant was collected from a deposition point at TSF 2 Phase 2 to update the tailings material properties. Tailings produced at the Vulcan plant comprise tailings reprocessed directly from the Voyager and Genesis plants. Table 3-1 lists the physical characteristics of the Vulcan tailings sample as determined with laboratory testing, as well as a summary of the tailings production plan and slurry characteristics. The Particle Size Distribution (PSD) of the tailings material is shown in Figure 3-1. A full report detailing the results of the laboratory testing is attached hereto as Appendix A.

**Table 3-1: Properties of the Vulcan tailings and composition of the slurry**

| Descriptor | Value | Unit | Source | Commentary |
|---|---|---|---|---|
| Particle Size Distribution | 68% Passing 75 µm | - | Vietti Slurrytec | - |
| Solids Specific Gravity | 3.41 | - | Specialised Testing Laboratory (STL) | - |
| Liquid Limit | - | | | |
| Plastic Limit | Non-Plastic | | | |
| Plasticity Index | 0 | | | |
| Unified Soil Classification System | SM | - | | |

| Descriptor | Value | Unit | Source | Commentary |
|---|---|---|---|---|
| Final placed Void Ratio | 1.0 | - | Epoch | Assumed |
| Final Placed Dry Density | 1.6 | (t/m$^3$) | | Calculated |
| Slurry Delivery | Hydraulic | - | Tharisa | - |
| Tailings Production (Dry) | 350 000<br>(~11 506.9) | t/month<br>(t/day) | | |
| | 218 750<br>(~7 191.8) | m$^3$/month<br>(m$^3$/day) | | |
| Solids to Water by Mass | 50 | % | | |
| Slurry Water Volume | ~7 191.8 | m$^3$/day | Epoch | Calculated |

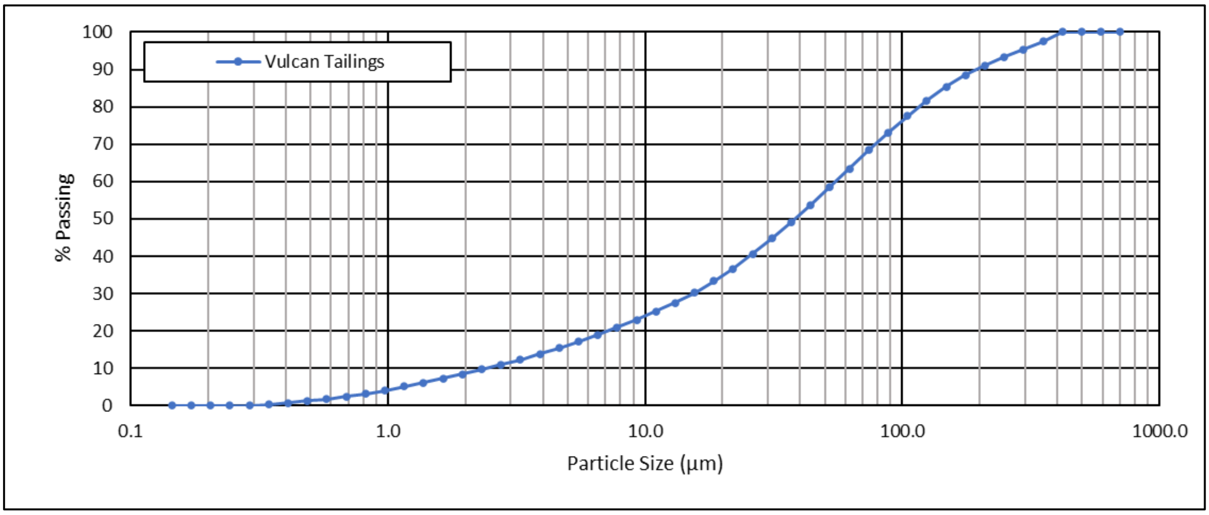



**Figure 3-1: Vulcan tailings particle size distribution (PSD)**

## 3.2 Seismicity

Epoch contracted Natural Hazard Assessment Consultancy CC to undertake the site-specific deterministic and probabilistic seismic hazard assessment for Tharisa. The findings of the study are discussed in section 9.3.2.1 and contained in Appendix B.

## 3.3 Waste Type Classification of Representative Tailings Samples

The Tharisa Minerals tailings stream consists of the discard from the run of mine Chrome and PGM product that has been processed through the Tharisa Process Plant.

In 2022, SLR undertook a study to determine the waste classification of a fresh tailings sample (THTSF-01) obtained from the inlet of the pipe depositing slurry from the Vulcan plant onto the TSF, and a dried sample (THTSF-02) collected from the surface of TMM TSF 2 Phase 2 (currently under operations). Geochemical waste characterisation was also undertaken by Metago (2008) prior to the construction of the existing facilities. Waste is classified according to a hazard classification threshold as prescribed by NEM:WA and based on the:

- Total Concentrate Threshold (TCT) refers to the total existence of a substance present in the residue.
- Leachable Concentration Threshold (LCT) refers to the potential mobilisation of a substance within the residue.

### 3.3.1 Waste assessment (SLR,2022)

The TCT and LCT are determined through geochemical testing by an accredited laboratory and categorised according to the threshold limits. The three TCT and four LCT limit categories (according to NEMWA) are listed in Table 3-2 and Table 3-3 respectively, alongside the results of the waste assessment on the Vulcan tailings as completed by SLR.

**Table 3-2: Total Concentration Threshold Limits and Vulcan tailings results (SLR, 2022)**

| ANALYTES | UNIT | TCT0 | TCT1 | TCT2 | TH-TSF2-01 | TH-TSF2-02 |
|---|---|---|---|---|---|---|
| As, Arsenic | mg/kg | 5,8 | 500 | 2000 | 1,2 | <0,400 |
| B, Boron | mg/kg | 150 | 15000 | 6000 | <10 | <10 |
| Ba, Barium | mg/kg | 62,5 | 6250 | 25000 | 44,4 | 34,5 |
| Cd, Cadmium | mg/kg | 7,5 | 260 | 1040 | <0,400 | <0,400 |
| Co, Cobalt | mg/kg | 50 | 5000 | 20000 | 69,9 | 76,0 |
| CrTotal, Chromium Total | mg/kg | 46000 | 800000 | N/A | 31200,0 | 22000,0 |
| Cu, Copper | mg/kg | 16 | 19500 | 78000 | 10,0 | 18,0 |
| Hg, Mercury | mg/kg | 0,93 | 160 | 640 | <0,400 | <0,400 |
| Mn, Manganese | mg/kg | 1000 | 25000 | 100000 | 809,7 | 1103,0 |
| Mo, Molybdenum | mg/kg | 40 | 1000 | 4000 | <10 | <10 |
| Ni, Nickel | mg/kg | 91 | 10600 | 42400 | 410,0 | 470,4 |
| Pb, Lead | mg/kg | 20 | 1900 | 7600 | 1,4 | 1,0 |
| Sb, Antimony | mg/kg | 10 | 75 | 300 | <0,400 | <0,400 |
| Se, Selenium | mg/kg | 10 | 50 | 200 | <0,400 | <0,400 |
| V, Vanadium | mg/kg | 150 | 2680 | 10720 | 377,1 | 296,3 |
| Zn, Zinc | mg/kg | 240 | 160000 | 640000 | 127,3 | 119,1 |
| Cr(VI), Chromium (VI) | mg/kg | 6,5 | 500 | 2000 | <2 | <2 |
| Total Fluoride [o] | mg/kg | 100 | 10000 | 40000 | 21,6 | <0,5 |
| Total Cyanide as CN [o] | mg/kg | 14 | 10500 | 42000 | <1,55 | <1,55 |

**Table 3-3: Leachate Concentration Threshold Limits and Vulcan tailings results (SLR, 2022)**

| Analytes | Unit | LCT0 | LCT1 | LCT2 | LCT3 | THTSF2-01 | THTSF2-02 |
|---|---|---|---|---|---|---|---|
| As, Arsenic | mg/l | 0,01 | 0,5 | 1 | 4 | <0,001 | <0,001 |
| B, Boron | mg/l | 0,5 | 25 | 50 | 200 | <0,025 | <0,025 |
| Ba, Barium | mg/l | 0,7 | 35 | 70 | 280 | <0,025 | <0,025 |
| Cd, Cadmium | mg/l | 0,003 | 0,15 | 0,3 | 1,2 | <0,001 | <0,001 |
| Co, Cobalt | mg/l | 0,5 | 25 | 50 | 200 | <0,025 | <0,025 |
| CrTotal, Chromium Total | mg/l | 0,1 | 5 | 10 | 40 | <0,025 | <0,025 |
| Cr(VI), Chromium (VI) | mg/l | 0,05 | 2,5 | 5 | 20 | <0,010 | <0,010 |
| Cu, Copper | mg/l | 2 | 100 | 200 | 800 | <0,010 | <0,010 |
| Hg, Mercury | mg/l | 0,006 | 0,3 | 0,6 | 2,4 | 0,003 | <0,001 |
| Mn, Manganese | mg/l | 0,5 | 25 | 50 | 200 | <0,025 | <0,025 |
| Mo, Molybdenum | mg/l | 0,07 | 3,5 | 7 | 28 | <0,025 | <0,025 |
| Ni, Nickel | mg/l | 0,07 | 3,5 | 7 | 28 | <0,025 | <0,025 |
| Pb, Lead | mg/l | 0,01 | 0,5 | 1 | 4 | <0,001 | <0,001 |
| Sb, Antimony | mg/l | 0,02 | 1 | 2 | 8 | <0,001 | <0,001 |
| Se, Selenium | mg/l | 0,01 | 0,5 | 1 | 4 | 0,001 | <0,001 |
| V, Vanadium | mg/l | 0,2 | 10 | 20 | 80 | <0,025 | <0,025 |
| Zn, Zinc | mg/l | 5 | 250 | 500 | 2000 | <0,025 | <0,025 |
| Chloride as Cl | mg/l | 300 | 15000 | 30000 | 120000 | <2 | 4 |
| Sulphate as SO4 | mg/l | 250 | 12500 | 25000 | 100000 | 2 | <2 |
| Nitrate as N | mg/l | 11 | 550 | 1100 | 4400 | 0,2 | <0,1 |
| Fluoride as F | mg/l | 1,5 | 75 | 150 | 600 | 0,2 | 0,2 |
| Total Cyanide as CN [o] | mg/l | 0,07 | 3,5 | 7 | 28 | <0,07 | <0,07 |
| Total Dissolved Solids* | mg/l | 1000 | 12500 | 25000 | 100000 | 412 | 60 |
| pH | mg/l | - | - | - | - | 9,2 | 9,1 |
| Paste pH | mg/l | - | - | - | - | 9,4 | 9,4 |
| Moisture % | mg/l | - | - | - | - | 18,1 | 4,5 |

Based on the waste assessment completed by SLR, the following elements/compounds exceeded the TCT0 limits:

- Cu, Cobalt (TC < TCT1)
- Co, Copper (TC < TCT1)
- Mn, Manganese (TC < TCT1)
- Ni, Nickel (TC < TCT1)
- V, Vanadium (TC < TCT1)

No elements exceed the LCT0 limit.

SLR conducted a Synthetic Precipitation Leaching Procedure (SPLP) test in addition to the total and leachate concentration test. The test is used to determine the mobility/leachability of low volatility organic and inorganic substances and assess the leachability of metals into ground and surface water.

The results of the SPLP test were compared to the following water quality and effluent standards as a preliminary indicator of the potential environmental risk:

- South African National Standards (SANS) 241 Drinking Water (SANS 241:2015).
- Department of Water and Forestry (now Department of Water and Sanitation; DWS) livestock target water quality guidelines (DWAF TWQG).

It should be noted that the comparison with drinking water standards does not indicate that the leachates and drainage from the TSF can be used for drinking water purposes.

The SPLP concentrations for the Tharisa tailings samples returned no “Constituents of Concern” (CoCs) except for a marginal exceedance of Aluminium as per SANS 241: Operational requirements for sample THTSF2-01 (fresh Vulcan tailings).

**Table 3-4: Tharisa Mine composite waste rock and tailings SPLP results (SLR, 2022)**

| Analytes | Unit | 1. DWAF TWQG | 2. IFC: Mining effluent | 3. SANS 241: Operational | 4. SANS 241: Aesthetic | 5. SANS 241: Acute Health | 6. SANS 241: Chronic Health | THTSF2-01 | THTSF2-02 |
|---|---|---|---|---|---|---|---|---|---|
| Silver, Ag | mg/l | | | | | | | <0.010 | <0.010 |
| Aluminium, Al | mg/l | 5 | | 0.3 | | | | 0,508 | 0,169 |
| Arsenic, As | mg/l | 1 | 0.1 | | | | 0.01 | <0.010 | <0.010 |
| Gold, Au | mg/l | | | | | | | <0.010 | <0.010 |
| Boron, B | mg/l | 5 | | | | | 2.4 | <0.010 | <0.010 |
| Barium, Ba | mg/l | | | | | | 0.7 | <0.010 | <0.010 |
| Beryllium, Be | mg/l | | | | | | | <0.010 | <0.010 |
| Bismuth, Bi | mg/l | | | | | | | <0.010 | <0.010 |
| Calcium, Ca* | mg/l | 1000 | | | | | | 7 | 4 |
| Cadmium, Cd | mg/l | 10 | 0.05 | | | | 0.003 | <0.010 | <0.010 |
| Cerium, Ce | mg/l | | | | | | | <0.010 | <0.010 |
| Cobalt, Co | mg/l | 1 | | | | | 0.5 | <0.010 | <0.010 |
| Chromium, Cr (total) | mg/l | | | | | | 0.05 | <0.010 | <0.010 |
| Cesium, Cs | mg/l | | | | | | | <0.010 | <0.010 |
| Copper, Cu | mg/l | 5 | 0.3 | | | | 2.0 | <0.010 | <0.010 |
| Dysprosium, Dy | mg/l | | | | | | | <0.010 | <0.010 |
| Erbium, Er | mg/l | | | | | | | <0.010 | <0.010 |

| Analytes | Unit | 1. DWAF TWQG | 2. IFC: Mining effluent | 3. SANS 241: Operational | 4. SANS 241: Aesthetic | 5. SANS 241: Acute Health | 6. SANS 241: Chronic Health | THTSF2-01 | THTSF2-02 |
|---|---|---|---|---|---|---|---|---|---|
| Europium, Eu | mg/l | | | | | | | <0.010 | <0.010 |
| Iron, Fe* | mg/l | 10 | 2.0 | | 0.3 | | 2.0 | 0,119 | 0,135 |
| Gallium, Ga | mg/l | | | | | | | <0.010 | <0.010 |
| Gadolinium, Gd | mg/l | | | | | | | <0.010 | <0.010 |
| Germanium, Ge | mg/l | | | | | | | <0.010 | <0.010 |
| Hafnium, Hf | mg/l | | | | | | | <0.010 | <0.010 |
| Mercury, Hg | mg/l | 1.0 | 0.002 | | | | 0.006 | <0.010 | <0.010 |
| Holmium, Ho | mg/l | | | | | | | <0.010 | <0.010 |
| Indium, In | mg/l | | | | | | | <0.010 | <0.010 |
| Iridium, Ir | mg/l | | | | | | | <0.010 | <0.010 |
| Potassium, K* | mg/l | | | | | | | 1,305 | 1,282 |
| Lanthanum, La | mg/l | | | | | | | <0.010 | <0.010 |
| Lithium, Li | mg/l | | | | | | | <0.010 | <0.010 |
| Lutetium, Lu | mg/l | | | | | | | <0.010 | <0.010 |
| Magnesium, Mg* | mg/l | 500 | | | | | | 2 | 2 |
| Manganese, Mn* | mg/l | 10 | | | 0.1 | | 0.4 | 0,025 | 0,025 |
| Molybdenum, Mo | mg/l | 0.01 | | | | | | <0.010 | <0.010 |
| Sodium, Na* | mg/l | 2000 | | | 200 | | | 4 | <1 |
| Niobium, Nb | mg/l | | | | | | | <0.010 | <0.010 |
| Neodymium, Nd | mg/l | | | | | | | <0.010 | <0.010 |
| Nickel, Ni | mg/l | 1 | 0.5 | | | | 0.07 | <0.010 | <0.010 |
| Osmium, Os | mg/l | | | | | | | <0.010 | <0.010 |
| Phosphorus, P | mg/l | | | | | | | 0,017 | <0.010 |
| Lead, Pb | mg/l | 0.5 | 0.2 | | | | 0.01 | <0.010 | <0.010 |
| Palladium, Pd | mg/l | | | | | | | <0.010 | <0.010 |
| Praseodymium, Pr | mg/l | | | | | | | <0.010 | <0.010 |
| Platinum, Pt | mg/l | | | | | | | <0.010 | <0.010 |
| Rubidium, Rb | mg/l | | | | | | | <0.010 | <0.010 |
| Rhodium, Rh | mg/l | | | | | | | <0.010 | <0.010 |
| Ruthenium, Ru | mg/l | | | | | | | <0.010 | <0.010 |
| Antimony, Sb | mg/l | | | | | | 0.02 | <0.010 | <0.010 |
| Scandium, Sc | mg/l | | | | | | | <0.010 | <0.010 |
| Selenium, Se | mg/l | 50 | | | | | 0.04 | <0.010 | <0.010 |
| Silicon, Si* | mg/l | | | | | | | 3,172 | 1,561 |
| Samarium, Sm | mg/l | | | | | | | <0.010 | <0.010 |
| Tin, Sn | mg/l | | | | | | | <0.010 | <0.010 |
| Strontium, Sr | mg/l | | | | | | | <0.010 | <0.010 |
| Tantalum, Ta | mg/l | | | | | | | <0.010 | <0.010 |
| Terbium, Tb | mg/l | | | | | | | <0.010 | <0.010 |
| Tellurium, Te | mg/l | | | | | | | <0.010 | <0.010 |
| Thorium, Th | mg/l | | | | | | | <0.010 | <0.010 |
| Titanium, Ti | mg/l | | | | | | | <0.010 | <0.010 |
| Thallium, Tl | mg/l | | | | | | | <0.010 | <0.010 |
| Thulium, Tm | mg/l | | | | | | | <0.010 | <0.010 |
| Uranium, U | mg/l | | | | | | 0.03 | <0.010 | <0.010 |
| Vanadium, V | mg/l | 1 | | | | | 0.2 | <0.010 | <0.010 |
| Tungsten, W | mg/l | | | | | | | <0.010 | <0.010 |
| Yttrium, Y | mg/l | | | | | | | <0.010 | <0.010 |

| Analytes | Unit | 1. DWAF TWQG | 2. IFC: Mining effluent | 3. SANS 241: Operational | 4. SANS 241: Aesthetic | 5. SANS 241: Acute Health | 6. SANS 241: Chronic Health | THTSF2-01 | THTSF2-02 |
|---|---|---|---|---|---|---|---|---|---|
| Ytterbium, Yb | mg/l | | | | | | | <0.010 | <0.010 |
| Zinc, Zn | mg/l | 20 | 0.5 | | 5 | | | <0.010 | <0.010 |
| Zirconium, Zr | mg/l | | | | | | | <0.010 | <0.010 |
| pH | - | | 9 | 5 -9.7 | | | | 8,4 | 7,7 |
| EC | mS/m | | | | 170 | | | 7,8 | 4,5 |
| TDS | mg/l | 3000 | | | 1200 | | | 88 | 52 |
| Tot Alk | mg/l | | | | | | | 24 | 20 |
| Chlorine, Cl | mg/l | 3000 | | | 300 | | | <2 | <2 |
| Sulphate, SO4 | mg/l | 1000 | | | 250 | 500 | | 5 | <2 |
| Nitrate, NO3 | mg/l | 100 | | | | 11 | | 0,3 | <0.1 |
| Nitrogen Dioxide, NO2 | mg/l | 10 | | | | 0.9 | | 0,2 | <0.05 |
| Fluorine, F | mg/l | 6 | | | | | 1.5 | 0,2 | 0,2 |
| Ammonia, Free NH3 | mg/l | | | | 1.5 | | | 0,2 | <0.1 |
| Phosphorus, Ortho-P | mg/l | | | | | | | <0.1 | <0.1 |

### 3.3.2 Waste assessment Comparison

The 2022 SLR investigation compares well with the initial geochemical investigation undertaken by SLR in 2016. Table 3-5 and Table 3-6 indicate the TCT and LCT results, for a sample collected from TSF 1 Phase 1 (OLD TSF 1) and TSF 1 Expansion, respectively. It is evident that the Total Chromium and Fluoride reduced to below their respective TCT0 limits. As with the 2016 investigation, no exceedance of the LCT0 limits was observed in either of the samples tested during the 2022 investigation. Based on the comparison between the LCT and TCT limits, it can be seen that the 2022 study has yielded improved TCT and LCT values, supporting the initial findings.

**Table 3-5: 2016 Total Concentration Threshold Limits for shaking table samples**

| Analyses | Unit | TCT0 | TCT1 | TCT2 | OLD TSF 1 | TSF 1 Exp |
|---|---|---|---|---|---|---|
| As, Arsenic | mg/kg | 5,8 | 500 | 2000 | 0.88 | 0.79 |
| B, Boron | mg/kg | 150 | 15000 | 6000 | 2.68 | 0.98 |
| Ba, Barium | mg/kg | 62,5 | 6250 | 25000 | 40.41 | 54.99 |
| Cd, Cadmium | mg/kg | 7,5 | 260 | 1040 | 0.05 | 0.03 |
| Co, Cobalt | mg/kg | 50 | 5000 | 20000 | 76.91 | 81.17 |
| CrTotal, Chromium Total | mg/kg | 46000 | 800000 | N/A | 113000 | 100400 |
| Cr(VI), Chromium (VI) | mg/kg | 6,5 | 500 | 2000 | 5 | 5 |
| Cu, Copper | mg/kg | 16 | 19500 | 78000 | 39.19 | 43.21 |
| Hg, Mercury | mg/kg | 0,93 | 160 | 640 | 0.04 | 0.04 |
| Mn, Manganese | mg/kg | 1000 | 25000 | 100000 | 1502 | 1564 |
| Mo, Molybdenum | mg/kg | 40 | 1000 | 4000 | 0.3 | 0.3 |
| Ni, Nickel | mg/kg | 91 | 10600 | 42400 | 385 | 390 |
| Pb, Lead | mg/kg | 20 | 1900 | 7600 | 1.27 | 1.18 |
| Sb, Antimony | mg/kg | 10 | 75 | 300 | 0.22 | 0.15 |
| Se, Selenium | mg/kg | 10 | 50 | 200 | 0.65 | 0.67 |

| Analyses | Unit | TCT0 | TCT1 | TCT2 | OLD TSF 1 | TSF 1 Exp |
|---|---|---|---|---|---|---|
| V, Vanadium | mg/kg | 150 | 2680 | 10720 | 343 | 444 |
| Zn, Zinc | mg/kg | 240 | 160000 | 640000 | 113 | 132 |
| Chloride as Cl | mg/kg | - | - | - | - | - |
| Sulphate as SO4 | mg/kg | - | - | - | - | - |
| Nitrate as N | mg/kg | - | - | - | - | - |
| Total Fluoride [o] | mg/kg | 100 | 10000 | 40000 | 451 | 416 |
| Total Cyanide as CN [o] | mg/kg | 14 | 10500 | 42000 | 0.1 | 0.1 |
| Total Dissolved Solids* | mg/kg | - | - | - | - | - |
| pH | mg/kg | - | - | - | - | - |
| Paste pH | mg/kg | - | - | - | - | - |
| Moisture % | mg/kg | - | - | - | - | - |

## Table 3-6: 2016 Total Concentration Threshold Limits for Float samples

| Analyses | Unit | LCT0 | LCT1 | LCT2 | LCT3 | OLD TSF 1 | TSF 1 Exp |
|---|---|---|---|---|---|---|---|
| As, Arsenic | mg/L | 0,01 | 0,5 | 1 | 4 | 0.002 | 0.001 |
| B, Boron | mg/L | 0,5 | 25 | 50 | 200 | 0.03 | 0.031 |
| Ba, Barium | mg/L | 0,7 | 35 | 70 | 280 | 0.12 | 0.177 |
| Cd, Cadmium | mg/L | 0,003 | 0,15 | 0,3 | 1,2 | 0.0002 | 0.0002 |
| Co, Cobalt | mg/L | 0,5 | 25 | 50 | 200 | 0.003 | 0.003 |
| CrTotal, Chromium Total | mg/L | 0,1 | 5 | 10 | 40 | 0.869 | 0.5 |
| Cr(VI), Chromium (VI) | mg/L | 0,05 | 2,5 | 5 | 20 | 0.05 | 0.05 |
| Cu, Copper | mg/L | 2 | 100 | 200 | 800 | 0.013 | 0.04 |
| Hg, Mercury | mg/L | 0,006 | 0,3 | 0,6 | 2,4 | 0.0003 | 0.0002 |
| Mn, Manganese | mg/L | 0,5 | 25 | 50 | 200 | 0.045 | 0.08 |
| Mo, Molybdenum | mg/L | 0,07 | 3,5 | 7 | 28 | 0.002 | 0.001 |
| Ni, Nickel | mg/L | 0,07 | 3,5 | 7 | 28 | 0.019 | 0.019 |
| Pb, Lead | mg/L | 0,01 | 0,5 | 1 | 4 | 0.005 | 0.005 |
| Sb, Antimony | mg/L | 0,02 | 1 | 2 | 8 | 0.002 | 0.002 |
| Se, Selenium | mg/L | 0,01 | 0,5 | 1 | 4 | 0.003 | 0.002 |
| V, Vanadium | mg/L | 0,2 | 10 | 20 | 80 | 0.021 | 0.015 |
| Zn, Zinc | mg/L | 5 | 250 | 500 | 2000 | 0.003 | 0.001 |
| Chloride as Cl | mg/L | 300 | 15000 | 30000 | 120000 | 1.63 | 3.41 |
| Sulphate as SO4 | mg/L | 250 | 12500 | 25000 | 100000 | 11.12 | 11.74 |

| ANALYSES | UNIT | LCT0 | LCT1 | LCT2 | LCT3 | OLD TSF 1 | TSF 1 EXP |
|---|---|---|---|---|---|---|---|
| NITRATE AS N | MG/L | 11 | 550 | 1100 | 4400 | 0.43 | 0.1 |
| FLUORIDE AS F | MG/L | 1,5 | 75 | 150 | 600 | 0.1 | 0.1 |
| TOTAL CYANIDE AS CN [O] | MG/L | 0,07 | 3,5 | 7 | 28 | 0.01 | 0.01 |
| TOTAL DISSOLVED SOLIDS* | MG/L | 1000 | 12500 | 25000 | 100000 | 78 | 88 |
| PH | MG/L | - | - | - | - | - | - |
| PASTE PH | MG/L | - | - | - | - | - | - |
| MOISTURE % | MG/L | - | - | - | - | - | - |

### 3.3.3 Waste Type

NEM:WA categorises waste into four types based on the material's LCT and TCT levels and consequently stipulates a retainment barrier requirement as listed in Table 3-7.

**Table 3-7: Waste type based on TCT and LCT concentration levels (NEM:WA)**

| CONCENTRATION LEVEL | WASTE TYPE | BARRIER REQUIREMENT |
|---|---|---|
| LC > LCT3 OR TC > TCT2 | 0 | Disposal at landfills is not allowed |
| LCT2 < LC ≤ LCT3 OR TCT1 < TC ≤ TCT2 | 1 | Class-A |
| LCT1 < LC ≤ LCT2 AND TC ≤ TCT1 | 2 | Class-B |
| LCT0 < LC ≤ LCT1 AND TC ≤ TCT1 | 3 | Class-C |
| LC ≤ LCT0 AND TC ≤ TCT0 for metal ions and inorganic anions AND all chemical substances are below the total concentration limits provided for organics and pesticides listed | 4 | Class-D |

Based on the above limits, the waste assessment conducted by SLR (2022) for the tailings can be compared to Type 3 waste, based only on some TCT0 limits being slightly exceeded. The 2022 waste classification report by SLR can be found in Appendix D of this report.

No LCT0 limits have been exceeded and Aluminium only marginal exceeded the SANS 241: Operational requirements. The tailings material is classified as inert and non-acid generating. This is in line with the original findings. These findings support the 2012 approval of a Class-D liner system being implemented beneath the TSF which was granted due to the quality of leachate and the presence of thick in-situ, low permeability clays (< $10^{-9}$m/s). A typical Class-D barrier system is illustrated in Figure 3-2.

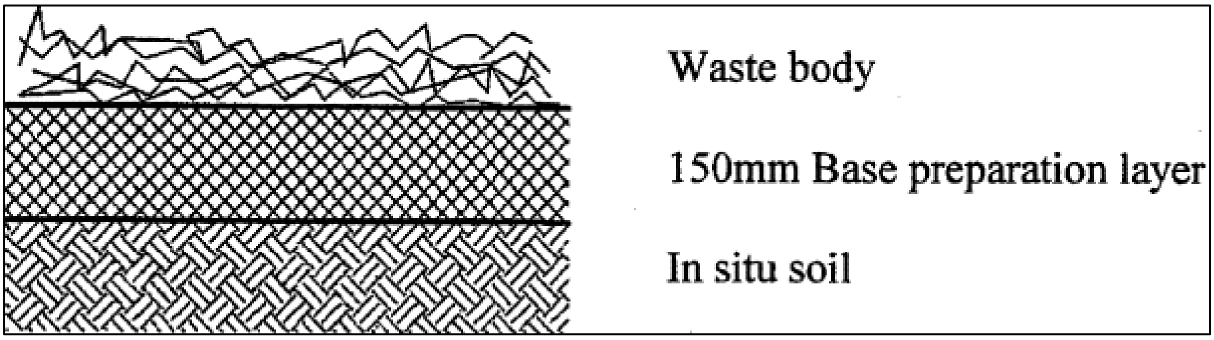



**Figure 3-2: Class-D Seepage containment barrier System as per NEMWA GN. R636**

## 3.4 Design Criteria Summary

The parameters listed in Table 3-8 summarise the design criteria for the TSFs.

**Table 3-8: Design criteria summary for the TSFs water management systems**

| Descriptor | Value | Unit | Source | Commentary |
|---|---|---|---|---|
| Mean Annual Precipitation | 668 | mm | SAWS | - |
| Mean Annual Evaporation | 1 811 | mm | SAWS | - |
| Design Storm Depth (1 day) | 126 | mm | SAWS (Adamson, 1981) | 1: 50-Year Recurrence |
| Design Storm Depth (24-hour) | 140 | mm | | 1: 50-Year Recurrence<br><br>(Factor of 1.11) |
| Design Storm Depth (1 day) | 222 | mm | Epoch | 1: 10 000 Year Recurrence |
| Design Storm Depth (24-hour) | 244 | mm | Epoch | 1: 10 000 Year Recurrence<br><br>(Factor of 1.11) |
| Minimum Freeboard | 2 | m | Tharisa EMP | Water Act requires 0.8 m |
| Seismic Coefficient | 0.131 | g | Natural Hazard Assessment Consultancy | 1: 10 000 Year Recurrence |
| Minimum Static Factor of Safety<br><br>(Downstream Slopes) | 1.5 | - | NEM:WA / SANCOLD | Long Term |
| Minimum Static Factor of Safety<br><br>(Upstream Slopes) | 1.3 | - | Epoch | Short Term |
| Minimum Pseudo-Static Factor of Safety<br><br>(All Slopes) | 1.1 | - | SANCOLD | Long Term |

| Descriptor | Value | Unit | Source | Commentary |
|---|---|---|---|---|
| Particle Size Distribution | 68% Passing 75 µm | - | Vietti Slurrytec | - |
| Solids Specific Gravity | 3.41 | - | Specialised Testing Laboratory (STL) | - |
| Liquid Limit | - | - | | |
| Plastic Limit | Non-Plastic | - | | |
| Plasticity Index | 0 | - | | |
| Unified Soil Classification System | SM | - | | |
| Final Void Ratio | 1.0 | - | Epoch | Assumed |
| Final Dry Density | 1.6 | t/m³ | | Calculated |
| Slurry Delivery | Hydraulic | - | Tharisa | - |
| Tailings Production (Dry) | 350 000<br>(~11 506.9) | t/month<br>(t/day) | | |
| | 218 750<br>(~7 191.8) | m³/month<br>(m³/day) | | |
| Solids to Water by Mass | 50 | % | | |
| Slurry Water Volume | ~7 191.8 | m³/day | Epoch | Calculated |

## 3.5 Hydrogeological investigation

Artesium Consulting Services have been appointed by Epoch and Tharisa to undertake a risk assessment and hydrogeological mass transport model to inform the significance and impact of the lifting of the existing TSF 1 and 2 facilities to receptors through the surface water and groundwater pathways.

### 3.5.1 Hydrogeology

The geological and hydrogeological setting of the site comprises mainly a shallow weathered bedrock aquifer with intergranular porosity and permeability. The site is located in a bore yield class of approximately 0.5 - 2.0 l/s.

Most of the faults strike from NW to SE, with a prominent dyke structure striking W to E. The dyke contacts are inferred to be more permeable and therefore could act as preferential flow zones for potential mass migration towards the East Open Pit. The clayey soil horizons underlying the TSF footprint, which were confirmed by the geotechnical investigation, are of relevance as they could act as a geochemical barrier for mass migration. The geological setting of the site and faults are illustrated in Figure 3-3.

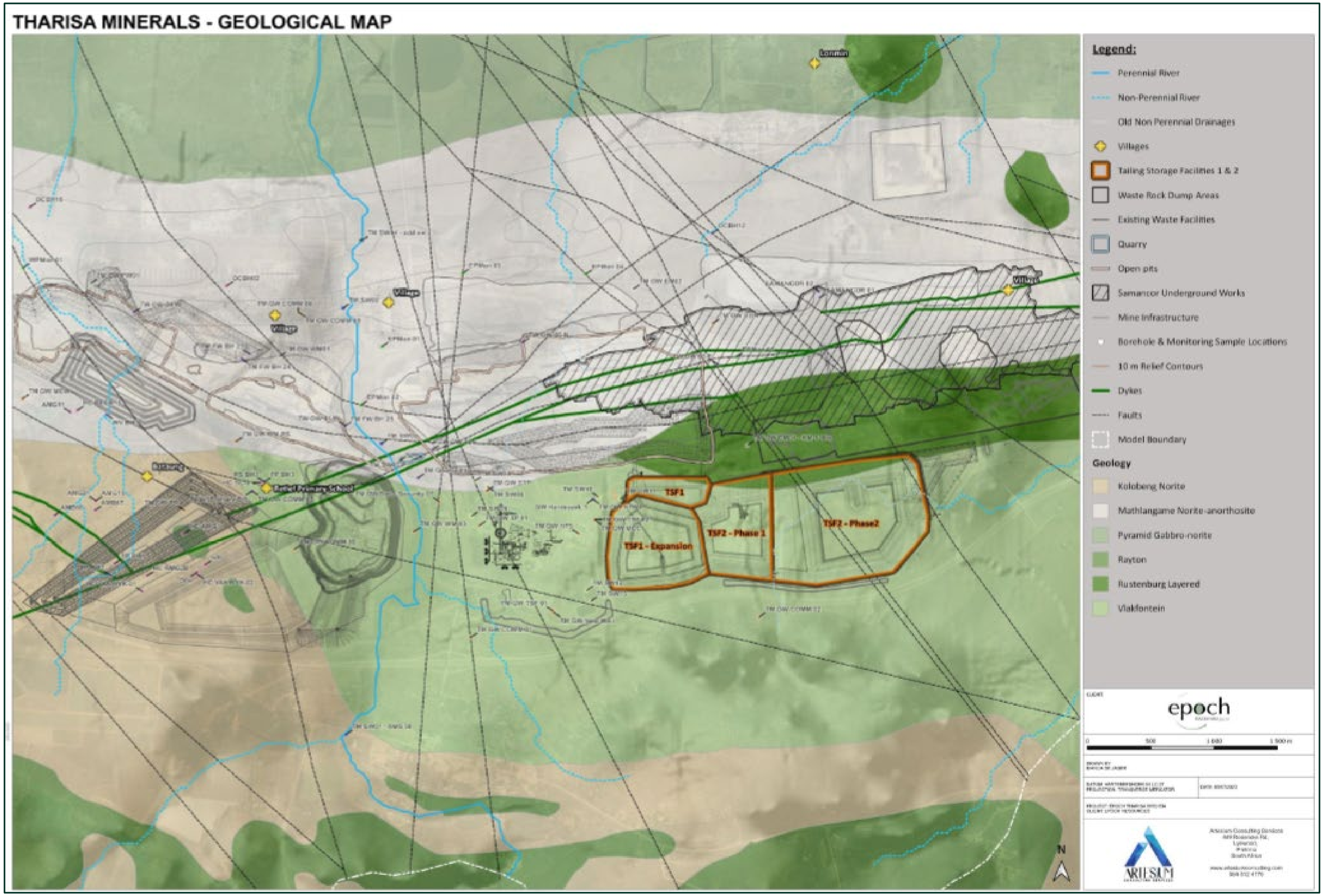



**Figure 3-3: Tharisa Geological setting**

### 3.5.2 Aquifer classification and vulnerability

The aquifer vulnerability is based on the map originally compiled by Reynders and Lynch (1993) which utilizes the DRASTIC method of classification and considers seven factors that affect aquifer characterization:

1. Depth to groundwater
2. Aquifer Recharge
3. Aquifer media
4. Soil media
5. Site Topography
6. Impact on vadose zone and
7. Hydraulic Conductivity

It was inferred by Artesium that the Tharisa Minerals Mine is situated in a special aquifer region, characterized by poor to minor groundwater quality with the main water source in the region being surface water. Based on the Aquifer Vulnerability map of South Africa the aquifer region is rated as least vulnerable. In addition, the localized aquifer at Tharisa Minerals has low susceptibility to mass transport. It was concluded that the aquifer exhibits low permeability values (1 – 1E-03 m/d) and low borehole yields of 0.1 - 1 L/s.

### 3.5.3 POTENTIAL RECEPTORS ANALYSIS

Considering the topographical and groundwater level data reviewed and analysed by Artesium, the potential mass migration plume from the TSF1 & TSF2 raising will move in a northern and north-western direction, towards the East Open Pit and small-scale open pit mining towards the east of the east pit. Given this pathway, there are no affected sensitive receptors (Figure 3-4).

The study concluded:

- There are no significant sensitive receptors immediately downstream from the TSF1 & TSF2. Surface water runoff is contained by existing water management infrastructure.
- Groundwater seepage is effectively captured by the East Open Pit dewatering and small-scale open pit mining towards the east of the east pit.
- A tertiary drainage which is a tributary of the non-perennial Elandsdrift spruit drainage (situated to the east), could receive runoff from the TSF2, eastern portion. This can effectively be mitigated by surface water management (which formed part of the original design of the facilities).


**Figure 3-4: Spatial locations of potential receptors (Artesium, 2023)**

### 3.5.4 GROUNDWATER NUMERICAL MODELLING

The March 2023 extent of the nitrate mass migration, without lifting the facilities, is shown in Figure 3-5. The model was calibrated based on monitoring data provided by TMM. It is observed that no nitrate impact is present further than 500 m from the mining infrastructure, with the majority of the mass being captured by the West and East Pits.

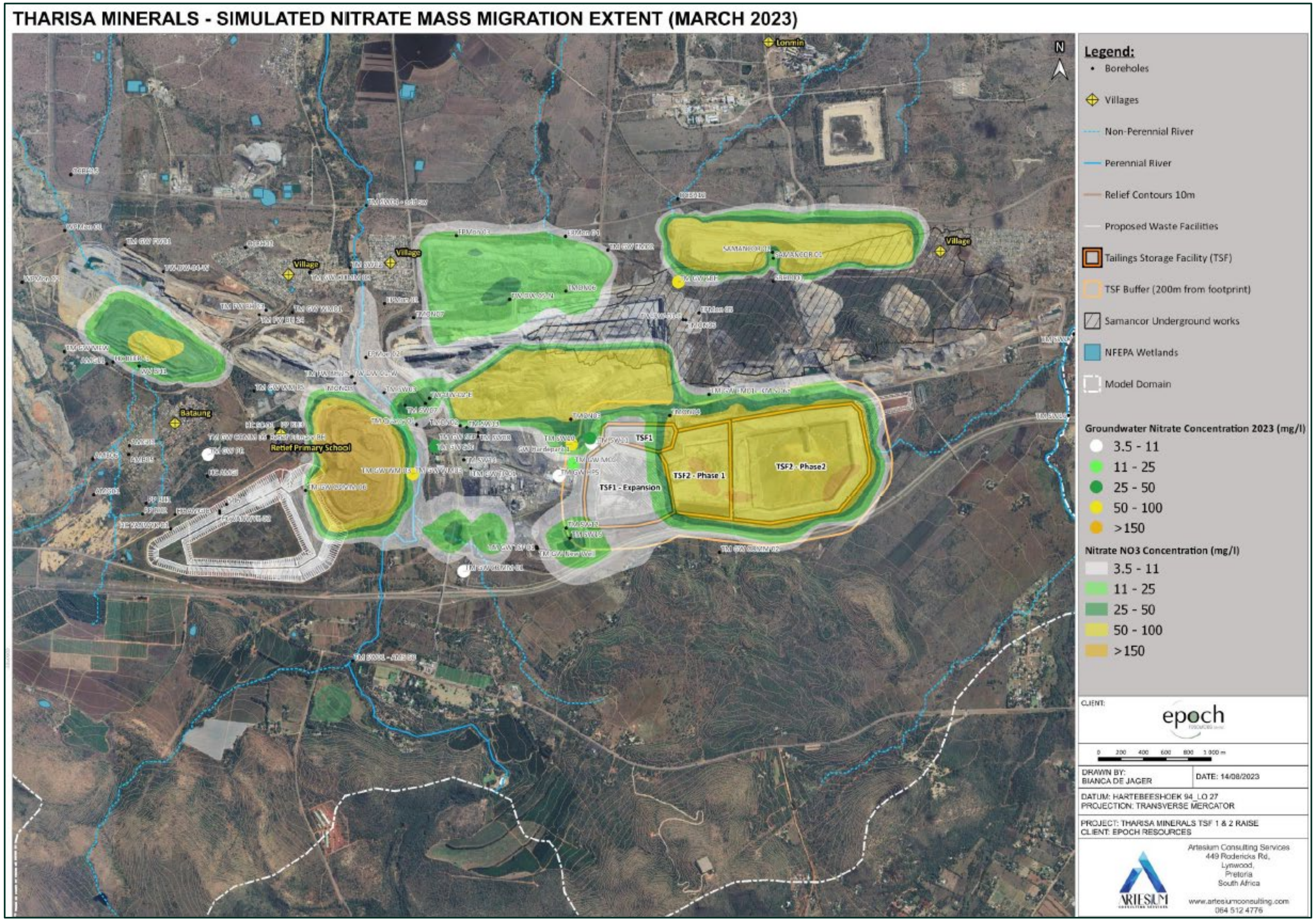



**Figure 3-5: Simulated current (March 2023) nitrate mass migration plume (Artesium, 2023)**

The long-term modelled nitrates mass migration plume with the additional raised facilities is illustrated in Figure 3-6. It shows the TSF 1 and 2 nitrate mass plume only travels ±450 – 500 m to the north of the facilities, as it is primarily drawn towards the East Open Pit and existing smaller pits to the east of the TMM lease area.

Mass migration towards the south is expected to extend less than 200 m, as the nitrates denitrify, limiting the development of the plume from TSF 1 and 2.

Leakage rates, as determined by Artesium (2023), are shown in Table 3-9. During start-up, seepage rates were modelled as approximately 1000 $m^3$/day. As groundwater levels rise due to seepage, a reduction in seepage volumes is observed. Post closure, seepages are negligible due to cladding and revegetation to limit infiltration.

**Table 3-9: TSF leakage volumes through LoF (Artesium, 2023)**

| Date | Leakage rate ($m^3$/day) | | |
|---|---|---|---|
| | TSF 1 Expansion | TSF 2 Phase 1 | TSF 2 Phase 2 |
| Mar-23 | 91 | 249 | 205 |
| Jul-26 | 238 | 205 | 13 |
| Dec-26 | 6 | 198 | 218 |
| Aug-27 | 1 | 159 | 211 |
| 10 years post-closure | 5 | 14 | 14 |

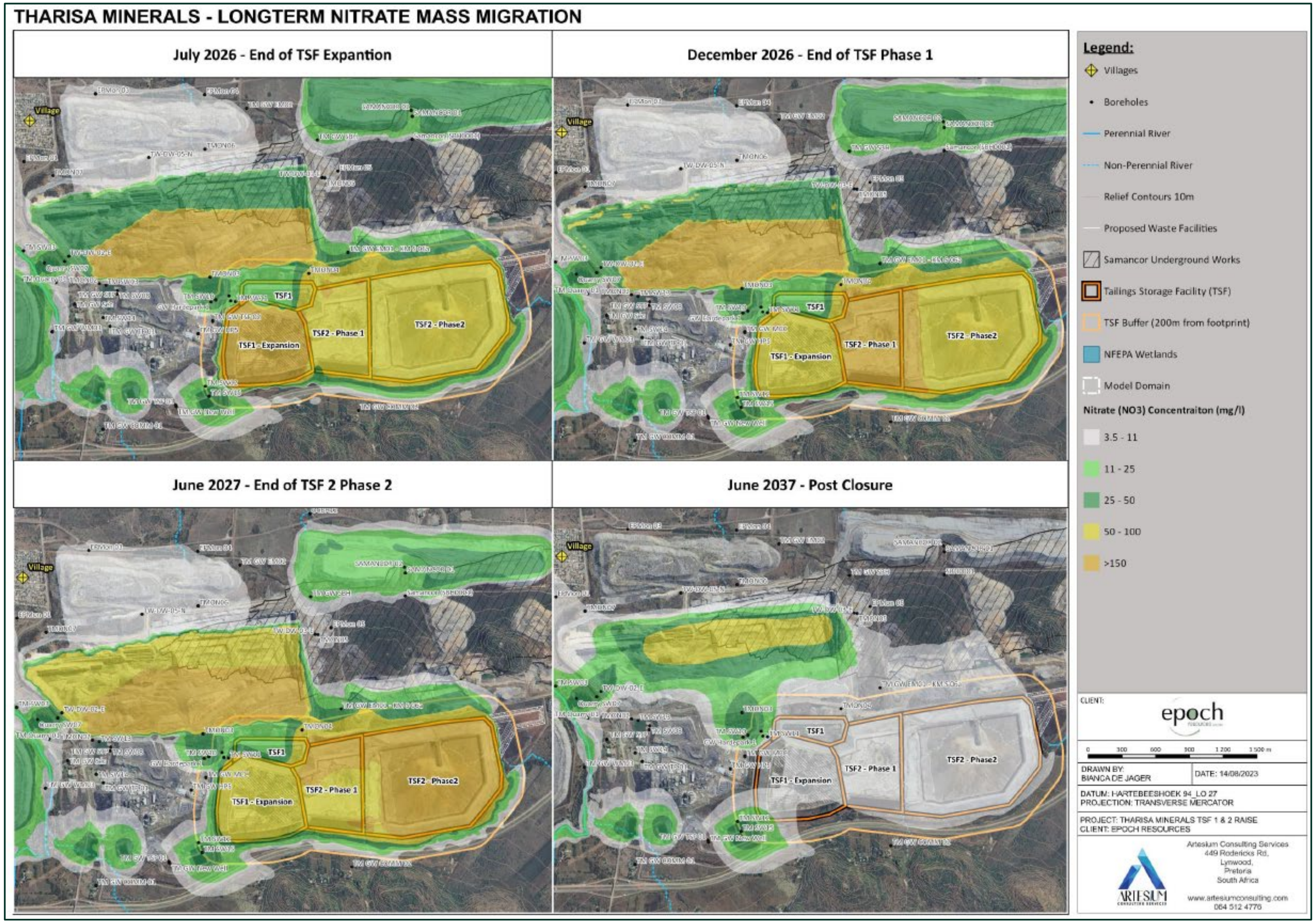



**Figure 3-6: Long-term nitrate mass migration plume (Artesium, 2023)**

### 3.5.5 Conclusion from the Geohydrological Impact Assessment

The following can be concluded from the hydrological impact and risk assessment:

- The site is situated on a minor aquifer region, with a rating of least vulnerability. The aquifer shows moderate to low permeability (1 – 1e-03 m/d) and typical low borehole yields of 0.1 - 1 l/s.
- Nitrate is the main source of mass migration at Tharisa. Nitrate originates from mining explosives and blasting and not from the mine residue storage facilities. Due to the slow migration rates, the water quality impacted due to nitrates is moderate.
- The immediate downstream receptor is the East Open Pit which would capture surface runoff from TSF1 and groundwater seepage from TSF1 & 2. Groundwater seepage is effectively captured by the East Open Pit during the operational and post-operational phases.
- The denitrification of the nitrates limits the plume migration from the TSF 1 & 2 footprint areas.
- The Stekstroom River is not considered a receptor for the operational phase but could potentially become a receptor during the post-operational phase after open pit backfilling (0 – 5 years post-closure)
- The mass migration numerical modelling indicates the nitrate mass migration to not exceed distances of ±500 m from mining sources. The impact assessment indicated that the operational phase is expected to have a moderate impact without mitigation. During the post-operational phase, the nitrate would decay completely within 5 years.
- The pit rewatering and seepage water quality should be useful as a water resource for agricultural and/or domestic supply in the post-closure phase. The TSFs and partially backfilled open pits could be used to store and supply water to increase the water supply yield of the Sterkstroom Catchment. This could leave a long-term future sustainable legacy with specific reference to the management of potential climate change impacts.

Please refer to Appendix E for the full geohydrological impact report by Artesium.

## 3.6 CPTu Assessment

In accordance with the project requirements, Osimo cc was commissioned to conduct Cone Penetration Testing with pore pressure measurements (CPTu) in Phase 1 of Tailings Storage Facility 2 (TSF2) at TMM. The primary objective of this investigation was to assess the consolidation status and determine the presence and depth of a phreatic surface within the Tailings Storage Facilities (TSFs). TSF 2 Phase 1 was selected for this assessment due to the cessation of tailings deposition, with a gap of approximately 2.5 years between the last tailings placement in November 2020 and the CPTu testing in May 2023. The locations where CPTu probing was conducted in TSF 2 Phase 1 are depicted in Figure 3-7. The results of the CPTu investigation can be found in Appendix F of this report.

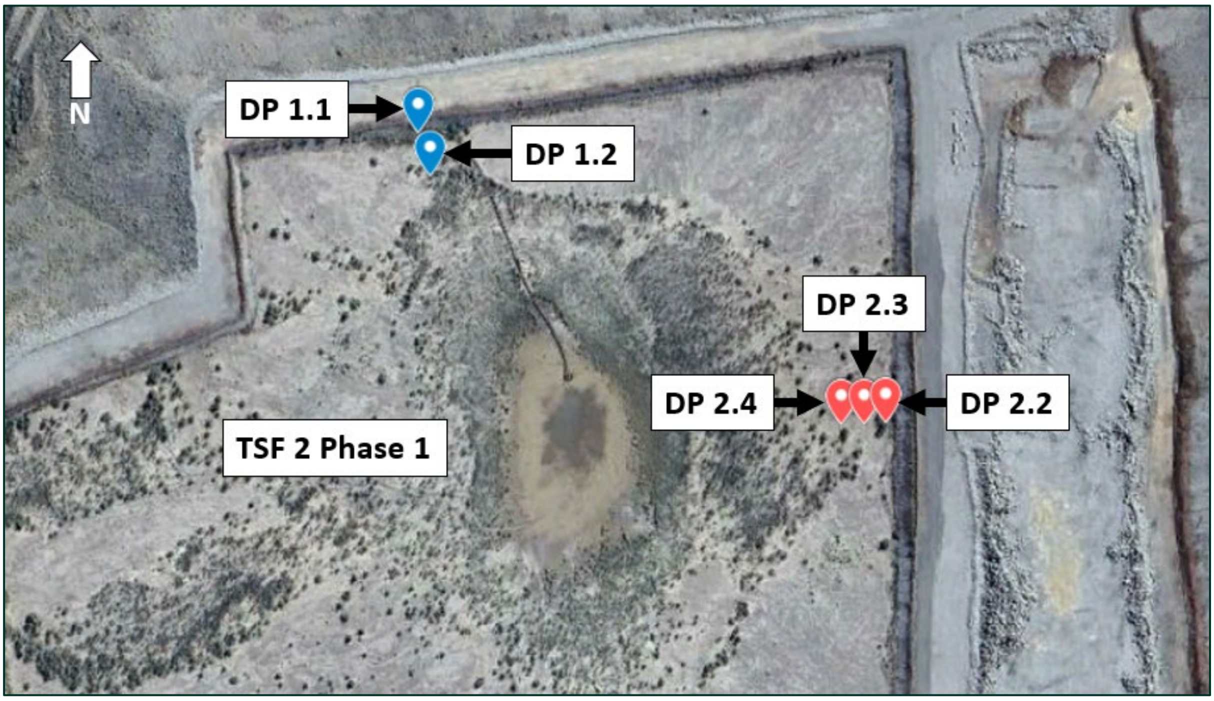



**Figure 3-7: TSF 2 Phase 1 CPTu probing locations**

The results of dissipation tests conducted at various intervals indicate that the consolidation process in TSF 2 Phase 1 is deemed complete. This suggests that the tailings have undergone most of the expected settlement, and no further consolidation is anticipated in this area.

The investigation has revealed that no elevated phreatic surface was identified beneath the area designated for the construction of a raised embankment in TSF 2 Phase 1. This finding implies that the ground in this location is not saturated, rendering it suitable for construction purposes.

In light of the observed consolidation patterns and the cessation of tailings deposition at TSF 1 Expansion since October 2016, it is reasonable to conclude that consolidation at this facility is also complete. Consequently, no phreatic surface is expected beneath the area designated for the construction of a raised embankment.

Subject to pending approval, the project timeline anticipates the commencement and completion of the construction of raised embankments on both TSF 1 Expansion and TSF 2 Phase 1. This will ensure that no deposition occurs on the dormant facilities until the raised embankments are constructed, significantly reducing the risk of a saturated zone developing beneath the construction area.

Regrettably, CPTu probing at TSF 2 Phase 2 was rendered infeasible due to safety concerns arising from ongoing tailings deposition. Nevertheless, it is anticipated that an elevated phreatic surface exists within the tailings at TSF 2 Phase 2. However, considering the insights gained from CPTu results in TSF 2 Phase 1 and the inherent free-draining nature of the waste rock embankment, it is believed that the available time between cessation and resumption of deposition at TSF 2 Phase 2 should allow for partial consolidation and the subsequent construction of a raised embankment.

# 4 TSF Development Methodology

## 4.1 Site Selection

It is expected that the active tailings storage facilities at TMM (TSF 2 Phase 1 and 2) will reach their full supply level by December 2025 based on the current tailings production rate. As previously discussed, due to the uncertainty in the construction and authorisation timelines associated with TSF 3, a decision was made to lift the embankments of TSF 1 Expansion, TSF 2 Phase 1 and TSF 2 Phase 2 through an upstream construction methodology, thus increasing the capacity of the facilities. The raised facilities allow for the TSF footprint areas to remain unchanged with the continued utilization of the existing decanting infrastructure.

## 4.2 Sizing and Layout

The raised TSFs are designed as single paddock, full containment facilities. The existing infrastructure associated with the TSFs comprises the following (Figure 4-1):

- Single, full containment, engineered paddocks, constructed with selected waste rock from the open-pit mining operations.
- 1.5 m high starter embankments along the upstream toe of the existing embankments, constructed from selected in-situ soils in compacted layers.
- Structural key-cuts along the upstream and downstream toe of the TSF embankments, replacing the in-situ soils with engineered rockfill.
- Penstock gravitation water decanting systems for TSF 1 Expansion and TSF 2 Phase 1 and a decant tower for TSF 2 Phase 2.
- The raised facilities will include the addition of:
    - Embankments constructed using selected waste rock from open-pit mining operations, with a height of 5 m for TSF 1 Expansion and TSF 2 Phase 1, and 3 m for TSF 2 Phase 2. The embankments will have a crest width of 15 m with 1V:3H and 1V:2H downstream and upstream slopes, respectively.
    - Geofabric separation layer (750 g/m$^2$) below the raised embankment at the tailings interface.
    - Penstock outfall isolating valves.

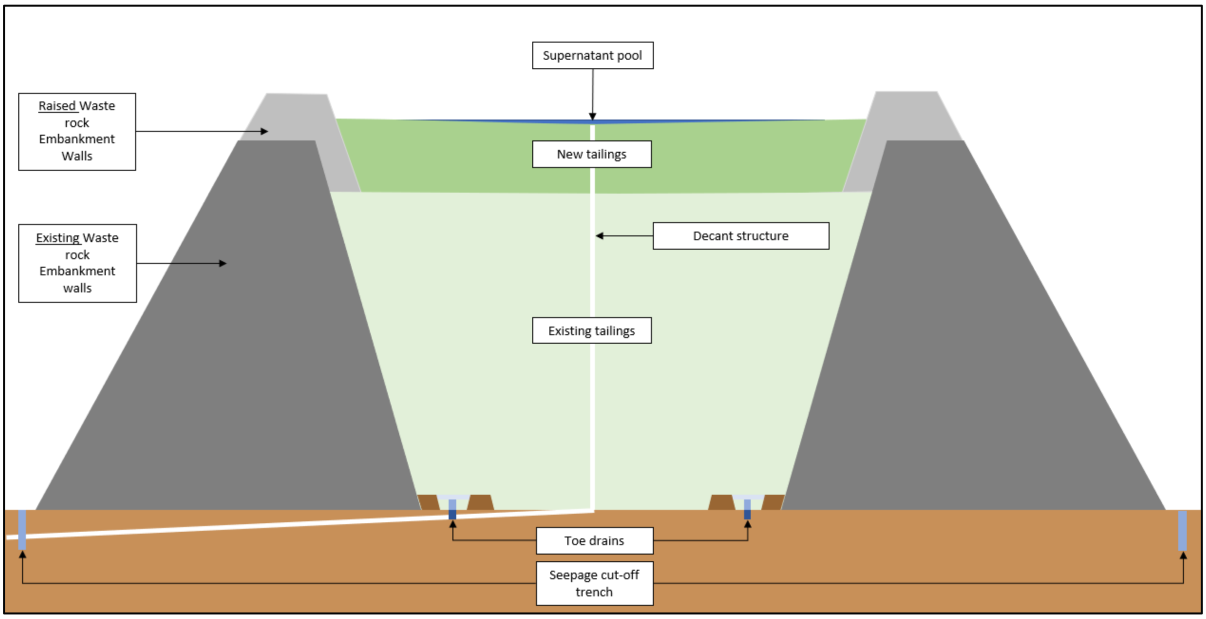



**Figure 4-1: Raised TSF construction methodology**

## 4.3 Stage Capacity Relationship

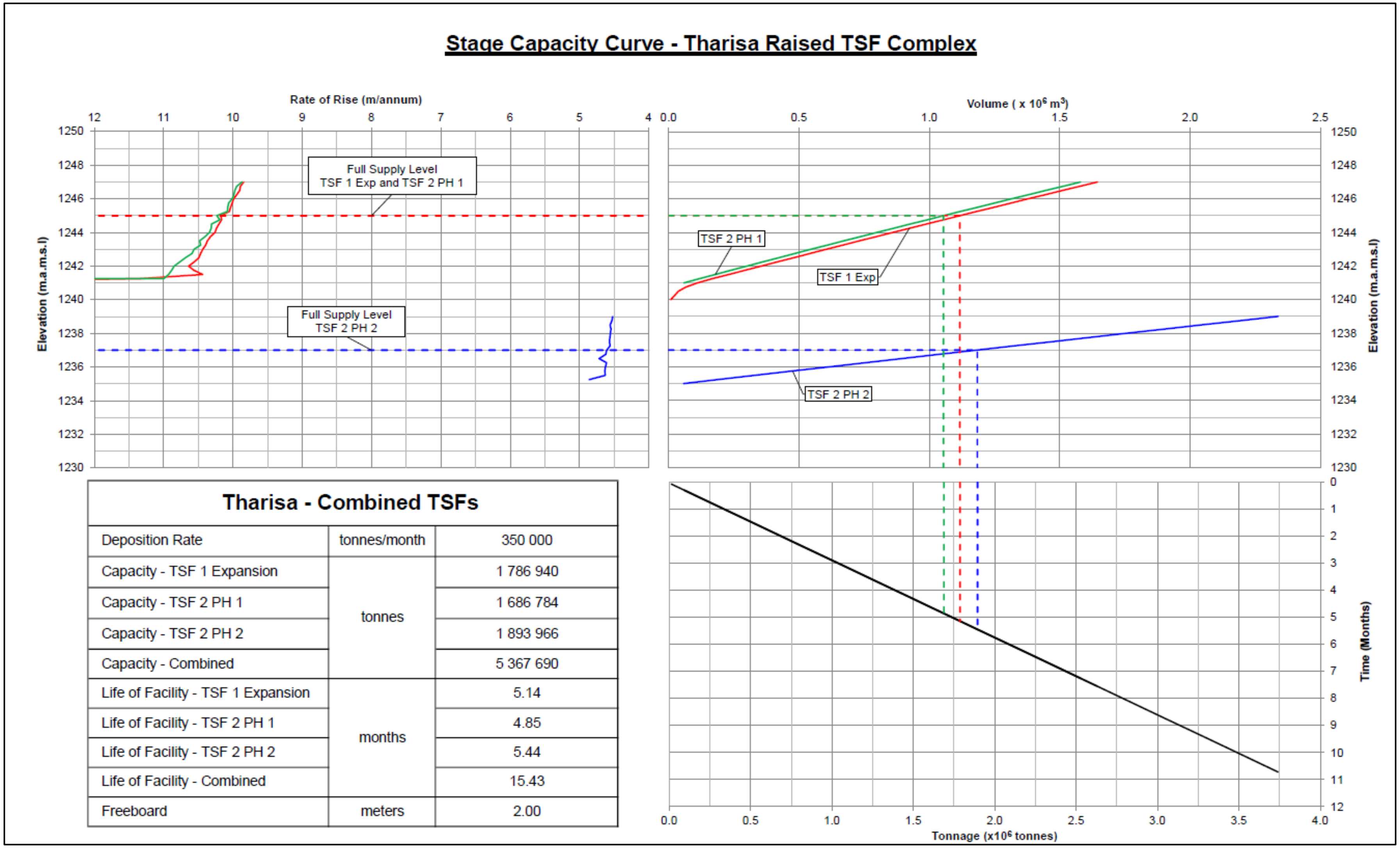
The stage capacity relationship of the raised TSFs was calculated using the detailed survey information supplied by the mine and the process rate of the Vulcan plant.

The stage capacity curve for the raised TSF 1 Expansion, TSF 2 Phase 1, and TSF 2 Phase 2 are illustrated in Figure 4-2 and can be found in Appendix G of this report. The placed dry density for tailings used in the curves is 1.6 t/m$^3$ with a total monthly production rate of 218 750 m$^3$.

In a conventional self-raising tailings dam, the rate of rise of the dam must be at such a rate as to allow for the tailings to drain and consolidate to be able to harvest tailings material to use to raise the “embankment” or outer shell of the facility. As the raised TSFs are full containment facilities, the rate of rise of the tailings does not affect the stability of the dam given that the embankments are constructed to final elevation before deposition is commenced.

The relevant aspects of the raised TSFs’ stage capacity curves are summarised below:

- Maximum tailings height:
  - TSF 1 Expansion = ± 41 m
  - TSF 2 Phase 1 = ± 41 m
  - TSF 2 Phase 2 = ± 45 m
- Additional capacity at maximum height:
  - TSF 1 Expansion = 1 786 940 tonnes (5.14 months)
  - TSF 2 Phase 1 = 1 686 784 tonnes (4.85 months)
  - TSF 2 Phase 2 = 1 893 966 tonnes (5.44 months)




| Tharisa - Combined TSFs | | |
|---|---|---|
| Deposition Rate | tonnes/month | 350 000 |
| Capacity - TSF 1 Expansion | tonnes | 1 786 940 |
| Capacity - TSF 2 PH 1 | | 1 686 784 |
| Capacity - TSF 2 PH 2 | | 1 893 966 |
| Capacity - Combined | | 5 367 690 |
| Life of Facility - TSF 1 Expansion | months | 5.14 |
| Life of Facility - TSF 2 PH 1 | | 4.85 |
| Life of Facility - TSF 2 PH 2 | | 5.44 |
| Life of Facility - Combined | | 15.43 |
| Freeboard | meters | 2.00 |

**Figure 4-2: SCC – Combined TSFs**

# 5 Deposition Methodology

The deposition technique selected for this project will be a full containment, hydraulically deposited, open-ended methodology. The embankment will be constructed using waste rock sourced from the TMM open pits. The tailings will be deposited behind the embankment, into the basin.

Tailings are discharged from the crest of the facility, which creates a *beach slope* and a resulting supernatant pool develops. Where the tailings properties are suitable, natural segregation of coarse and fine particles occurs, such that the coarser particles settle closer to the deposition points, resulting in a decrease in particle size as the tailings migrate towards the supernatant pool.

For the selected deposition methodology, tailings are deposited into the TSF basin via an open-ended pipeline which will be located on the inner crest of the embankment. Offtake pipes placed at standard pipe length intervals will feed the tailings into the basin as illustrated in Figure 5-1.

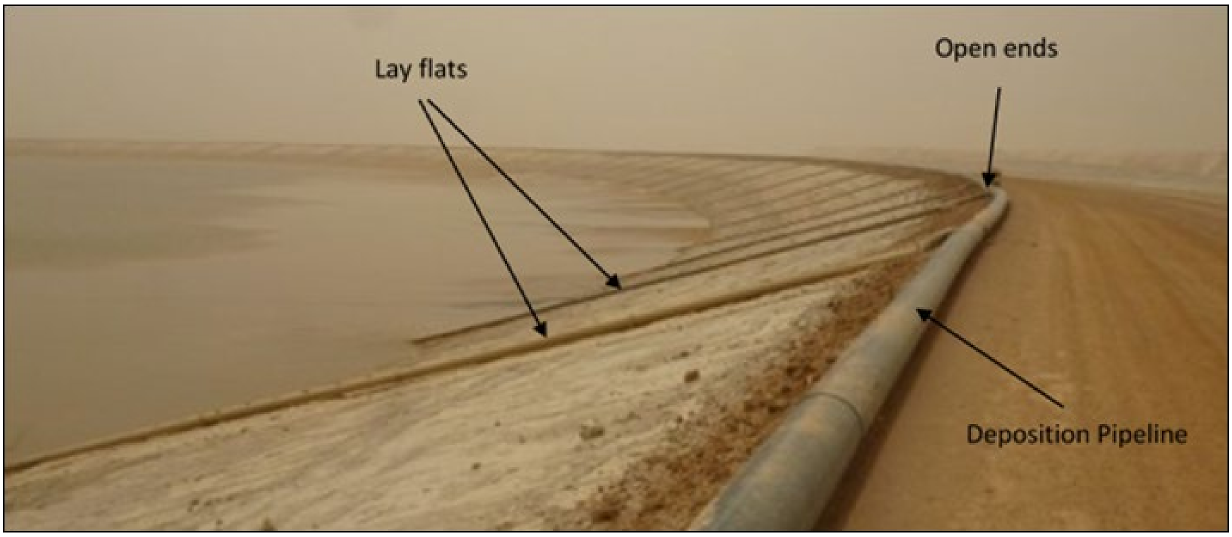



**Figure 5-1: Tailings deposition from multiple open ends**

The deposition must be cycled around the entire perimeter of the crest of the facility to ensure that the supernatant pool remains as far away from the embankments as possible and forms around the decant points. Care must be taken to avoid low spots due to inadequate amounts of tailings placement, as this could lead to the water ponding along the embankment.

The downpipes should be inspected on a daily basis and shortened as required such that the bottom of the downpipe does not become engulfed by tailings. If the open end of the downpipe is covered by tailings the discharged material might be directed towards the embankment and forced into the voids between the waste rock material. The migration of tailings within the embankment could potentially restrict the efficacy of the seepage-capturing conduits such as the internal drains and keys, leading to the uncontrolled discharge of seepage water.

Furthermore, deposition intensity (the rate of flow from a single deposition point) must be monitored and adjusted such that erosion gullies do not form on the tailings beach. Doing so will concentrate the flow of material, reducing the effectiveness of the material in forming a consistent beach slope and reducing the ability of the operator to control the position of the supernatant pool.

An additional measure to prevent tailings from migrating into the embankment is the placement of geofabric material along the upstream face of the embankments, with a panel overlap of 0.5 meters, on an ongoing basis as the tailings level increases.

# 6 Surface Water Management

According to the Water Act, all mining activities must prevent the contamination of clean water sources and all designs must prevent the spillage of dirty water into the environment from occurring more than once every 50 years. Surface water run-off that is affected by the presence of the TSF must thus be diverted around the disturbed footprint to prevent contamination of over land flow by mining activity and infrastructure.

## 6.1 Storm Water Diversion

A cut-to-fill Storm Water Diversion (SWD) was constructed for TSF 1 and 2 to divert clean water run-off from the upstream catchment of the TSF complex, preventing interaction with the TSF footprint, as shown in Figure 6-1. The SWD follows the natural topography and has been designed to accommodate the 1 in 50-year recurrence storm event.

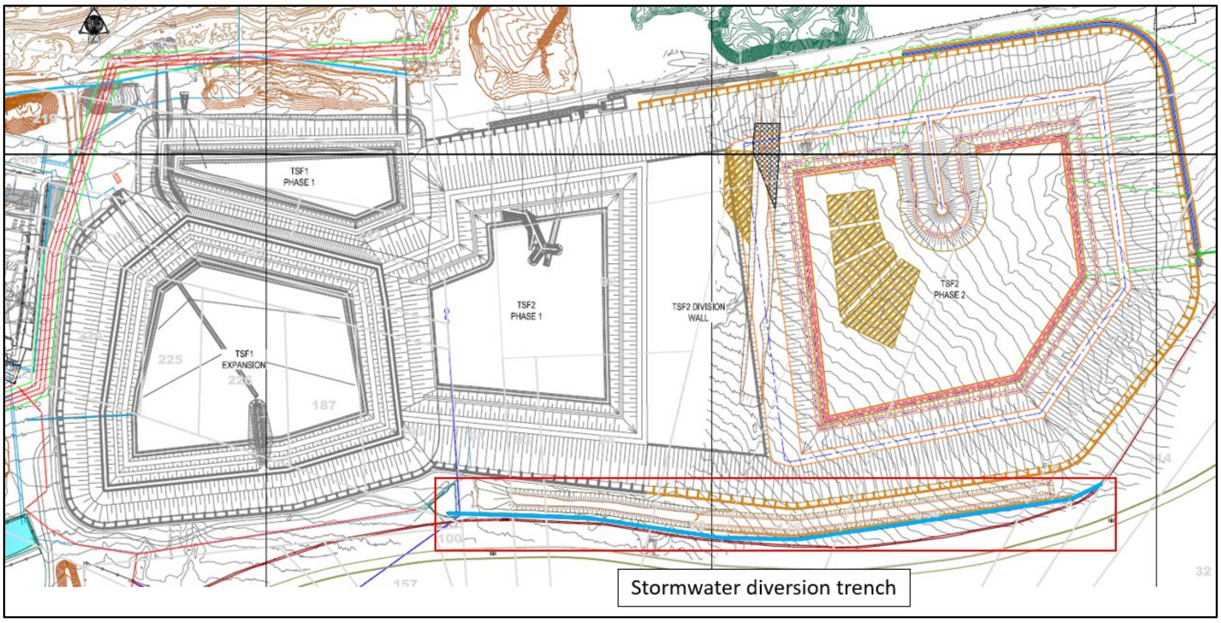



**Figure 6-1: SWD Trench**

The stormwater diversion trench and berm comprise:

- Length: 869 m
- Trench:
    - Side slopes: 1V:1.5H
    - Base width: 200 m
    - Minimum depth: 1 m
- Berm:
    - Side slope: 1V:1.5H
    - Crest wide: 1 m
    - Minimum height: 1.2 m

# 7 WATER MANAGEMENT

## 7.1 Water Balance

A water balance analysis was undertaken by Epoch with the findings documented in this section. The TSF design employs a deterministic water balance model that aims to calculate the relative inflows and outflows of the various sources of water associated with TSFs, as shown in Figure 7-1.

Inflows consist of the following:

- Precipitation run-off originating from the wet and dry beach area as well as the pool area and
- Slurry water originating from the deposition of tailings.

Outflows comprise the following:

- Seepage
- Lock-up
- Evaporation and
- Decant water.

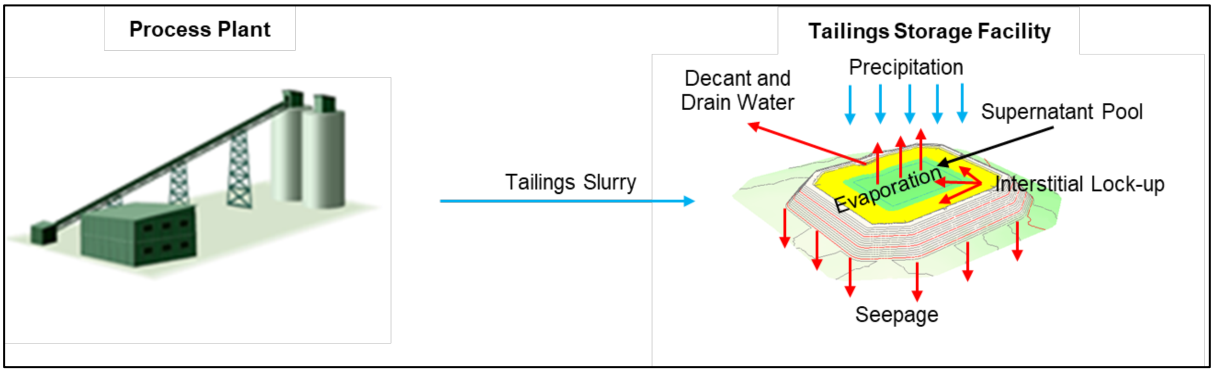



**Figure 7-1: Typical Inflows and Outflows of a TSF**

The analysis is based on daily rainfall records to ascertain the maximum, minimum and average volume of water estimated to be available for return/discharge from the TSF as well as the expected minimum and maximum pool volumes.

Three scenarios were modelled during the analysis namely the driest yearly rainfall, average yearly rainfall, and the wettest year on record. Months with a complete rainfall record nearest to that of the respective month's average rainfall intensity were extracted from the 83 years of daily rainfall records obtained from the Buffelspoort II Agricultural Weather Station (No. 0511855 A9, latitude: 25°75', longitude: 27°58'), to create the average daily rainfall dataset used in the analysis. This dataset was applied to each simulated year of operation of the facility, taking cognisance of the changes to catchment properties as tailings deposition progresses. The minimum, average and maximum returns based on this simulation were extracted for each month and used to create an envelope of expected returns per month over the operational life of the facility. In addition, the 1 in 10 000-year storm event was introduced into the model and the results thereof assessed.

## 7.2 Plant Returns

The original water balance model used for the design of the TSFs was calibrated using the actual recorded date of drain flows and return water volumes from the operations of the TSFs. This calibrated model was used to forecast the expected return water volumes for the raised facilities. Three (3) scenarios were analysed which investigated the effect of varying rainfall intensities based on the driest and wettest years on record as well as the average rainfall year. The result of the analysis is listed in Table 7-1.

**Table 7-1: Available plant returns during normal operating conditions**

| Description | Unit | Scenario | | |
|---|---|---|---|---|
| | | Dry Year | Average Year | Wet Year |
| Total operating days | days | 429 | | |
| Average Return to plant | $m^3$/day | 4524 | 5152 | 5846 |
| | % | 52% | 60% | 68% |
| Max Return to plant | $m^3$/day | 11864 | 11976 | 18181 |
| | % | 100% | 100% | 100% |
| Min Return to plant | $m^3$/day | 47 | 47 | 47 |
| | % | 0% | 0% | 0% |

From Table 7-1 it is evident that variation in rainfall events experienced at the site has a significant impact on the expected returns for the TSF complex. During normal operations, the average daily return volume could be as low as 52% during dry rainfall periods. During high rainfall periods (wet year simulation) the average daily return could increase to 68%.

## 7.3 Storm event

The TSFs have been designed to accommodate the 1 in 10 000-year storm event, as required by the GISTM in addition to the minimum operating pool volume of 20 000 $m^3$. Table 7-2 shows that the TSFs are able to temporarily store the design storm event and maintain the pool a minimum distance of 50 m away from the TSFs' crest, as required by NEM:WA: (Act No. 59 of 2008). The required pool volume resulting in the pool extending to within 50 m of the embankment is also listed in the able.

**Table 7-2: Storm pool scenarios**

| Facility | Maximum temporary storage Pool (NEM:WA) | | | 1 in 10 000 year (GISTM) | | |
|---|---|---|---|---|---|---|
| | Pool volume (m3) | Pool depth (m) | Distance to Crest (m) | Pool volume (m3) | Pool depth (m) | Distance to Crest (m) |
| TSF 1 Expansion | 109 940 | 2.19 | 50 | 82 773 | 1.85 | 72 |
| TSF 2 PH 1 | 101 724 | 2.18 | 50 | 82 862 | 1.90 | 67 |
| TSF 2 PH 2 | 348 868 | 2.67 | 50 | 157 019 | 2.02 | 135 |

## 7.4 Freeboard

The total freeboard of a dam is defined as the vertical distance between the normal Full Supply Level (*FSL*) and the nominal Non-Overspill Crest (*NOC*) of the dam. Freeboard is divided into two components namely the flood surcharge rises above the FSL, the primary component, and a secondary component allowing for wind, wave and surge effects (SANCOLD, 2011). In the case of a TSF, the beach freeboard developed by the deposition of the residue provides additional storage of water within the basin. The different freeboard components are illustrated in Figure 7-2.

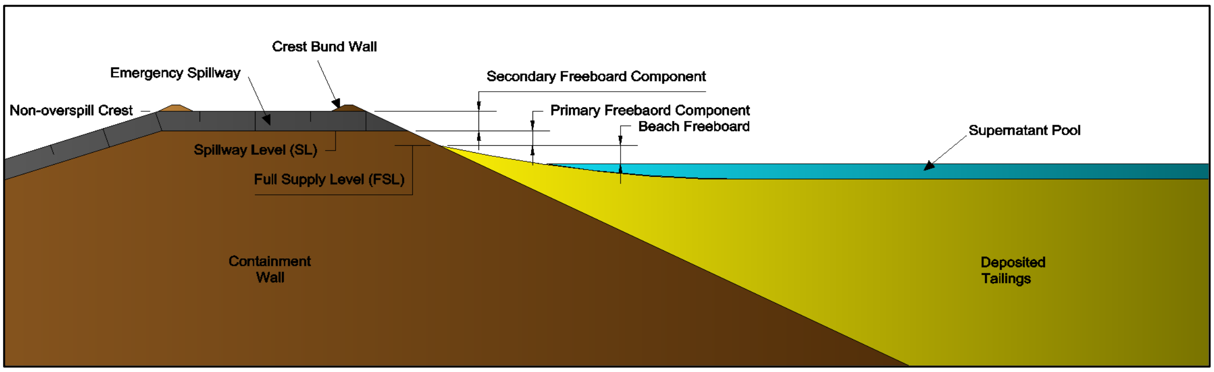



**Figure 7-2: Typical provision of freeboard on a full containment TSF**

Based on South African regulation GN704 of the National Water Act, the minimum freeboard requirement for the TSFs is 0.8 m, over and above the storage of the 1 in 50-year design flood (primary freeboard). Table 7-3 lists the storm pool volumes discussed in section 7.5 and the available freeboard.

**Table 7-3: Freeboard pool volumes**

| Facility | Maximum temporary storage Pool (NEM:WA) | | 1 in 10 000 years (GISTM) | |
|---|---|---|---|---|
| | Primary freeboard (m) | Pool freeboard (m) | Primary freeboard (m) | Pool freeboard (m) |
| TSF 1 Expansion | 2 | 2.31 | 2 | 2.65 |
| TSF 2 PH 1 | 2 | 2.32 | 2 | 2.60 |
| TSF 2 PH 2 | 2 | 2.33 | 2 | 2.98 |

From Table 7-3 it should be noted that adequate freeboard is provided and complies with the limits as set out by NEM:WA.

## 7.5 Supernatant pool

Water contained in the slurry pumped to the TSF, if not lost due to lockup, evaporation and seepage, reports to the supernatant pool, from which water is decanted off the TSF and returned to the plant for reuse.

This pool assists in the settlement of fines suspended in the water. A high fines content in the return water would negatively impact the downstream infrastructure as it increases the wear on pumps and requires that settling facilities be cleaned more frequently. The size of the pool must be optimised to ensure the settlement of a significant amount of fines but also limit evaporation losses and maintain a safe distance from the crest of the facility.

During the operational phases of the facilities, a pool of 20 000 m$^3$ should be maintained. During dry periods, the amount of return water sent to the plant is decreased to prevent the migration of fines into the return water system. During periods of high rainfall, the pool is maintained by returning more water to the plant (if possible). Given that the facility is a full containment facility, it allows for water to be stored on the TSFs during periods of very high to extreme rainfall. During these periods, it is often the case that available return water exceeds the plant's demands, and/or the plant return water dam does not have sufficient capacity to safely store the excess return water. Hence, water is stored on the TSF and gradually bled back to the plant until the stipulated target pool volume is reached.

# 8 TSF Design

The following sections list the different infrastructure components associated with the TSFs and the design thereof along with a description of specific functions and construction details. The raised facilities allow for the majority of the existing infrastructure components to remain in place and function as intended. Refer to Appendix K for detailed construction drawings.

## 8.1 Rockfill embankments

The material used for constructing the waste rock embankment is to be sourced from the TMM open pit mining operations. This material is to be visually assessed to ensure that fine material is placed on the upstream face of the embankment, well-graded material in the centre of the embankment, with the coarse material placed on the downstream face as depicted in Figure 8-1.

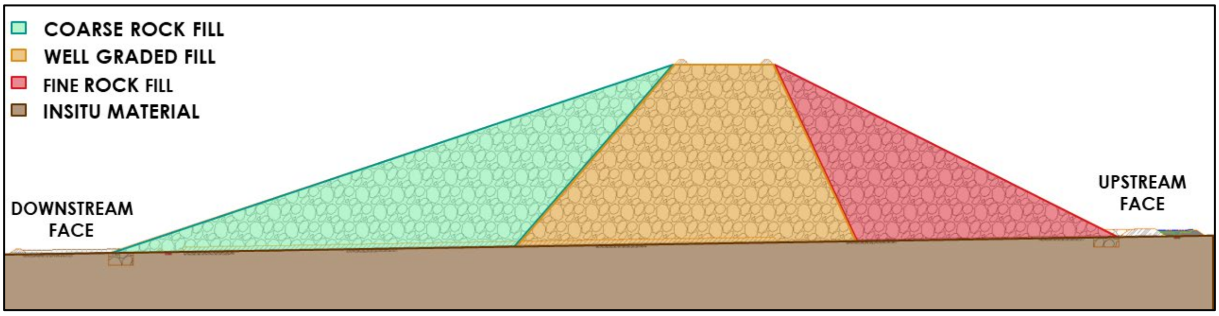



**Figure 8-1: Typical cross-section through the rock fill embankment depicting the placement of different grades of material**

The rock fill is to be constructed in layers not exceeding 2 meters in thickness after compaction. The material is to be dumped on the layer currently under construction, 4 m from the edge and dozed into position to allow for mixing of the material as depicted in Figure 8-2.

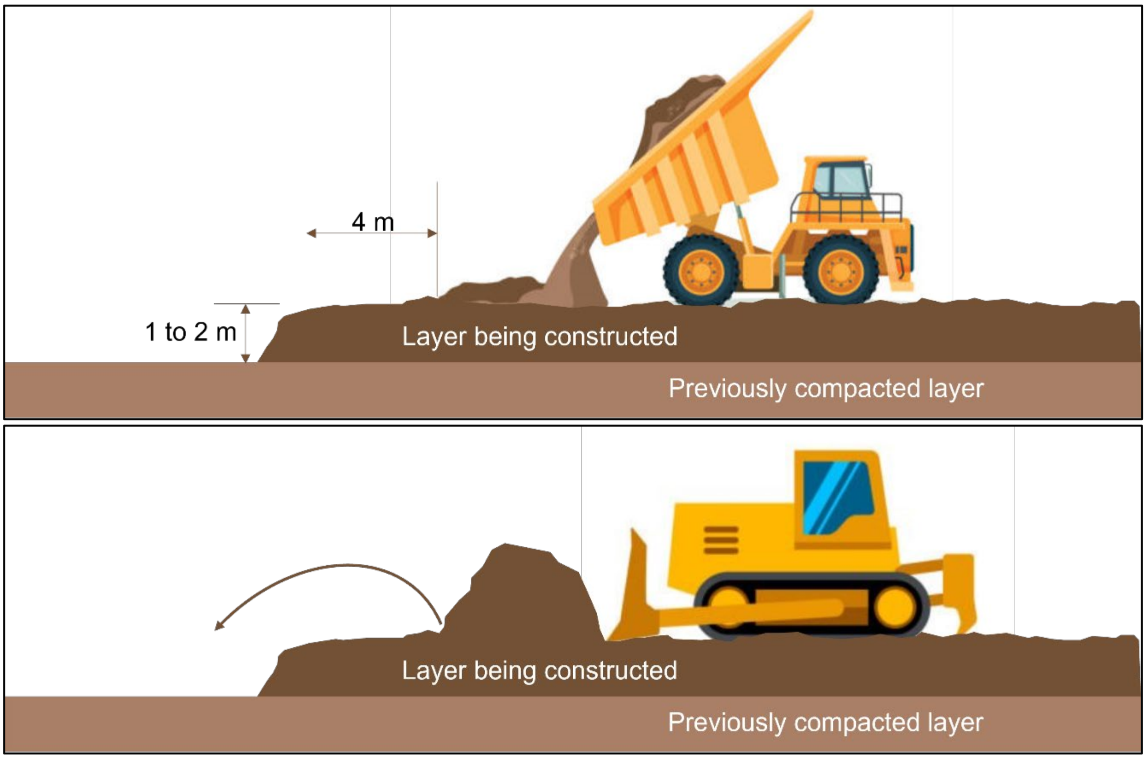



**Figure 8-2: Operating methodology of dumping and dozing of rock fill material**

The rock fill is to be spread so that a uniform layer thickness is obtained. The layer is then given no less than six passes of a twenty-tonne (static weight) vibrating roller, as determined by utilising test pads to measure the change in settlement per roller pass or equivalent specification as described by the Engineer. A roller pass consists of rolling in a longitudinal direction over the whole width of the formation so that each roll laps half the width of the previous roll. The final layer is compacted and graded so as to ensure that the surface is trafficable in both transverse and longitudinal directions.

Even though care will be taken during construction to compact the structure in layers, differential settlement along the final crest will be observed with time which will require reinstatement to design height. Surveys should be undertaken on a yearly basis to ensure that the minimum required freeboard is met at all times.

The downstream and upstream side-slopes of the raised TSFs are 1V:3H and 1V:2H, respectively.

## 8.2 Waste Rock Buttress

As discussed in section 9, the addition of a waste rock buttress along the downstream face of the north embankment of Phase 2 of TSF 2 is required to achieve TMM target factors of safety. It should be noted that the achieved targets of safety, excluding the buttress, meet regulatory requirements. However, TMM requires FoS of 1.3 and 1.75 for undrained and undrained seismic load cases, respectively, should mining activities be present downstream of the respective embankment. The buttress will have a constant height of 15 m with a crest of 25 meters and a downstream slope of 1V:2.5H. Please refer to sections 9.3.3 and 9.7.4 for a comprehensive discussion regarding the target FoSs and mitigation effects of the buttress on the aforementioned downstream stability results.

## 8.3 Toe drains

Resulting seepage from the deposition of tailings material into the basin of the facility is collected primarily through the use of toe drains along the upstream toe of each facility. The toe drains function as a means to reduce the amount of water that could potentially migrate into the embankment of the facility. This could affect the stability of the downstream face or lead to environmental contamination if the water exits the toe of the embankment in an uncontrolled manner.

The toe drains consist of 3 or 4 corrugated HDPE pipes, depending on the facility, with perforated sidewalls surrounded by a 19 mm stone matrix. The 19 mm stone is overlain by a 6 mm stone matrix and a filter sand layer respectively. The sand filter layer prevents the ingress of tailings material into the drainage system, thus decreasing the risk of blinding the drainage system. The toe drains feed into toe drain outlets that discharge the captured seepage water into the solution trench.

The details of the toe drains for each facility are listed in Table 8-1 below.

**Table 8-1: Toe drain description**

| DESCRIPTION | TSF 1 EXPANSION | TSF 2 PHASE 1 | TSF 2 PHASE 2 |
|---|---|---|---|
| **TOE DRAIN** | | | |
| Trench | 1000 – 1250 mm width, 750 mm depth (below ground level to pipe invert) | 1000 – 1250 mm width, 750 mm depth (below ground level to pipe invert) | 1000 – 1250 mm width, 500 mm depth |
| Filter sand layer | 5800 m wide and 250 mm thick | 5800 m wide and 250 mm thick | 6500 m wide and 250 mm thick |
| Stone layer (Fine aggregate) | 1000 – 1250 mm width, 750 mm thick | 1000 – 1250 mm width, 750 mm thick | 1000 – 1250 mm width, 400 mm thick |
| Stone layer (Coarse aggregate) | 1000 – 1250 mm width, 500 mm thick | 1000 – 1250 mm width, 500 mm thick | 1000 – 1250 mm width, 500 mm thick |
| Geofabric | A4 separating soil and filter layers | A4 separating soil and filter layers | A4 separating soil and filter layers |
| Drainage pipes | 2 - 4 corrugated 160 mm HDPE pipes (perforated) | 2 - 4 corrugated 160 mm HDPE pipes (perforated) | 3 - 4 corrugated 160 mm HDPE pipes (perforated) |
| **TOE DRAIN OUTLETS** | | | |
| Trench | 1250 mm width, depth varies | 1250 mm width, depth varies | 1000 – 1750 mm width, depth varies |
| Stone layer (Coarse aggregate) | 1250mm width, 500 mm thick | 1250mm width, 500 mm thick | 1000 – 1750 mm width, 500 mm thick |
| Geofabric | A4 separating soil and filter layers | A4 separating soil and filter layers | A4 separating soil and filter layers |
| Drainage pipes | 3-4 corrugated 160 mm HDPE pipes (non-perforated) | 3-4 corrugated 160 mm HDPE pipes (non-perforated) | 3, 4, and 6 corrugated 160 mm HDPE pipes (non-perforated) |

## 8.4 Seepage cut-off drains

Seepage cut-off drains below the downstream toe of each facility were constructed as a means to capture seepage water migrating through the embankment and potential seepage water not captured by the upstream toe drains. This prevents water from entering the downstream environment and reduces the risk of piping along the downstream embankment slope. The seepage cut-off trenches for TSF 1 Expansion have been excavated to a depth of 3.5 m with the trenches for TSF 2 Phase 1 and Phase 2 excavated to a depth of 3 m. The trenches were backfilled with selected waste rock material. Water captured in these drains report to collection manholes equipped with dewatering pumps.

## 8.5 Decant System

Water from the supernatant pool is decanted from the facility through a gravity fed penstock system for TSF 1 Expansion and TSF 2 Phase 1. TSF 2 Phase 2 makes use of a decant tower consisting of a 2.1m diameter slotted steel pipe surrounded by coarse rockfill selectively sourced from the mine's waste rock material.

The details of the penstock system for TSF 1 Expansion and TSF 2 Phase 1 are as follows:

- TSF 1 Expansion:
    - 600 ND class 150D reinforced concrete spigot and socket outfall pipeline.
    - 510 ID machined fibre-reinforced concrete penstock rings.
    - 2 single intermediary intake structures approximately 2 m below natural ground level and
    - 1 double final intake structure approximately 2 m below natural ground level.
- TSF 2 Phase 1:
    - 600 ND class 150D reinforced concrete spigot and socket outfall pipeline.
    - 510 ID machined fibre-reinforced concrete penstock rings.
    - 1 single intermediary intake structure approximately 0.5 m above natural ground level and
    - 1 double final intake structure approximately 7 m above natural ground level.

## 8.6 Penstock Energy Dissipator

An energy dissipator is located at the outlet of the penstock pipeline for TSF 1 Exp and TSF 2 Phase 1. The dissipator retards the flow velocity discharged at the outlet, preventing the decant water from eroding the solution trench, and assisting in settling out fines decanted from the TSF. The dissipator for TSF 1 Expansion and TSF 2 Phase 1 is lined with 300mm of reinforced concrete, allowing for the removal of settled fines with the use of an excavator. Due to TSF 2 Phase 2 utilizing a decant tower, the water is pumped from the decant tower to a discharge point upstream of the sump for TSF 2 Phase 1, from where it is conveyed to the plants as return water.

## 8.7 Pool wall and Wing Walls

Waste rock walls extend from the northern and southern embankments of TSF1 Expansion and TSF 2 Phase 1, respectively. The walls extend towards the final intake towers, forming a pool wall with diagonally extended wing walls. The pool walls, constructed of the same waste rock as the TSF embankments, allow for access to the decant inlets. The wing walls increase the flow path length of tailings from the discharge point to the decant point, resulting in the formation of a low point around the intake tower. This design aids in maintaining the position of the pool during initial operating conditions i.e. before tailings deposition has broken ground.

A waste rock pool wall constructed along the Northern wall of TSF 2 Phase 2 provides access to the decant tower.

## 8.8 Catwalk

Wooden catwalks were constructed off the edge of the access ramp, extending to the intermediate and final intakes, with a platform around each intake. The catwalk extends up to the final penstock tower and is raised as the level of the tailings increases. No catwalk is used at TSF 2 Phase 2.

## 8.9 Geofabric

In order to reduce the risk of piping through the rockfill embankment, geofabric was placed on the upstream faces of the TSFs, extending from the crest of the starter bund to the crest of the facility. The specific placement location and orientation thereof are:

- TSF 1 Expansion
  - The entire upstream embankment perimeter up to an elevation of 1223 m.a.m.s.l.
- TSF 2 Phase 1
  - Placed along the entire upstream face of the northern embankment.
  - Extended 200m onto the eastern embankment
  - Installed along the entire vertical junction where the north and south embankments intercept the eastern embankment of TSF 1 Expansion
- TSF 2 Phase 2
  - Placed on the upstream face of the facility, extending from the crest of the clay starter wall to the top of the waste rock embankment.

## 8.10 Solution Trench

Water released from the toe drains through the toe drain outlets, along with the discharge from the energy dissipator, is conveyed in the solution trench. The solution trench for each facility is detailed below:

- TSF 1 Expansion:
  - Located along the North-western embankment
  - 1500 mm deep excavation
  - 1000 mm base width
  - 1V:1H trench side slopes
- TSF 2 Phase 1:
  - Located along the Northern embankment
  - 1000 mm base width
  - 1V:1.5H trench side slopes
  - partially lined with 300 mm thick concrete
- TSF 2 Phase 2:

- Originating along the Northern embankment and extending along the Eastern embankment.
- 1000 mm base width
- 1V:1.5H trench side slopes

## 8.11 Collection Sump

Water is discharged from the solution trench into a reinforced 300mm thick dual concrete chamber sump that functions as a silt trap. The chambers are constructed with access ramps allowing access for a front end loader for cleaning purposes. Water overflows from the sump into a wet chamber, equipped with pumps, from where it is directly pumped to the process plant.

## 8.12 Drainage design

Subsoil drains were designed to control the phreatic surface in the tailings and embankment, as well as to aid in the draining of water from the tailings. All facilities comprise a toe drain situated along the upstream toe of the starter bund with a seepage cut-off drain situated below the downstream toe of each facility. A detailed list and discussion on the drain components for each facility is discussed in section 8.3 of this report.

### 8.12.1 Pipe Loading

A finite element model was developed to predict the load that would be exerted by the placed tailings on an HDPE pipe. The rock matrix surrounding the HDPE pipes provides high stiffness that absorbs most of the exerted load and as a result, provides additional support to ensure the integrity of the drainage system will be able to accommodate the exerted load. It was determined that a maximum axial force of 93 kN will be exerted on the pipe with the maximum expected deflection of the pipe void being only 1.3%, as shown in Figure 8-3. The observed maximum axial force and deflection do not exceed the maximum permissible values for a 160 mm HPDE pipe of 5% and 150 kN, respectively. Therefore, the existing drainage design will be sufficient to ensure that the pipes do not crush under loading.

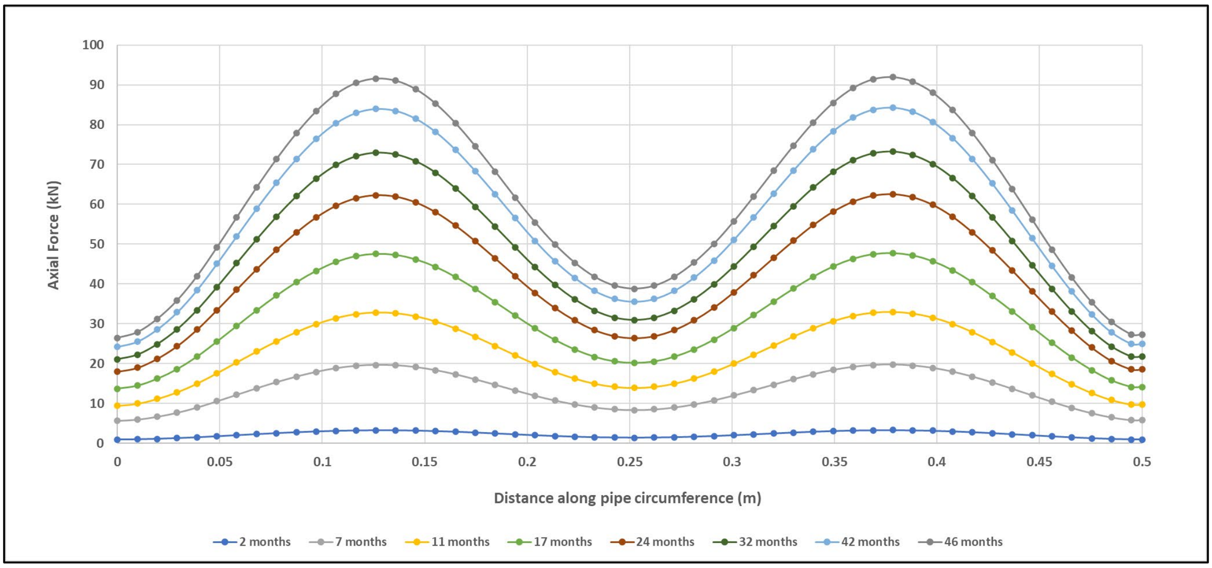



**Figure 8-3: Pipe Loading results**

### 8.12.2 Penstock outfall pipeline bearing capacity

Raising the current facilities to accommodate additional tailings storage, causes an additional surcharge load to be applied to the penstock decant system for TSF 1 Expansion and TSF 2 Phase 1. Bearing capacity calculations were based on the methodology proposed by the South African National Standard (SANS) (SANS 10102-2:2011) for the *"Selection of Pipes for Buried Pipelines"* and verified using the methodology proposed by the British Standard (BS EN) (BS EN 1295-1:1997) for the *"Structural Design of Buried Pipelines under various conditions of loading*". Table 8-2 lists the characteristics of the existing penstock outfall pipelines as well as the input parameters to the calculations.

**Table 8-2: Existing penstock outfall pipeline characteristics**

| PARAMETER | UNITS | TSF 1 EXPANSION | TSF 2 PHASE 1 |
|---|---|---|---|
| Nominal diameter | m | 600 | 600 |
| Inside Diameter | m | 550 | 550 |
| Wall thickness | mm | 75 | 75 |
| Strength Class | - | 150D | 150D |
| Average Slope | m/m | 0.011 | 0.004 |
| Bedding Class | - | A | A |
| Final tailings depth | m | 39.4 | 40.8 |
| Soil Unit Weight | $kN/m^3$ | 22 | 22 |
| Trench Width | m | 1.3 | 1.3 |
| Soil internal friction angle | Degrees | 32 | 32 |

Both pipeline systems were installed so that negative projection conditions exist. For both TSFs, the plane of equal settlement exists above the level of the final tailings and as a result, complete negative projection conditions exist, as shown in Table 8-3.

**Table 8-3: Pipeline bearing capacity results**

| PARAMETER | UNITS | TSF 1 EXPANSION | TSF 2 PHASE 1 |
|---|---|---|---|
| Total expected soil load, Wc | kN/m | 96.8 | 96.9 |
| Total expected soil load including surcharge | kN/m | 192.0 | 197.1 |
| Bedding factor | - | 2.6 | 2.6 |
| Required pipe strength | kN/m | 75.4 | 77.3 |
| Allowable pipe crushing strength | kN/m | 90.0 | 90.0 |

| PARAMETER | UNITS | TSF 1 EXPANSION | TSF 2 PHASE 1 |
|---|---|---|---|
| FoS | - | 1.2 | 1.2 |

It was concluded that the applied surcharge loads do not exceed the maximum permissible crushing strength of 90 kN/m for a 150D pipeline.

It is important to note that contingencies will be put in place in the case of a penstock failure. These contingencies include:

- A floating barge system to pump excess water from the TSFs to the return water sump or plant and
- A penstock outfall isolating valve at the outlet of the penstock pipeline to seal the pipeline should a failure occur, to prevent tailings discharged into the environment (discussed in section 8.12.4).

### 8.12.3 Penstock rings

Concrete penstock rings that are not placed with absolutely parallel sides, or placed carelessly, can cause uneven stressing of the concrete. This can cause the rings to crush or spall, resulting in piping and leakage of solids into the penstock shaft, or complete collapse and blocking of the shaft (Blight, 2009)

A method proposed by Blight (2009) to calculate the total downward pressure on the penstock tower, considers the submerged tailings unit weight, the height of the tailings and the shearing resistance angle of the soil. Table 8-4 lists the input parameters and subsequent bearing capacity of the penstock rings.

**Table 8-4: Concrete penstock rings bearing capacity**

| PARAMETER | SYMBOL | UNITS | VALUE |
|---|---|---|---|
| Unit weight of water | $\gamma_w$ | kN/m3 | 9.81 |
| Submerged unit weight of tailings | $\gamma'$ | kN/m3 | 28.6 |
| Angle of shearing resistance | $\varphi'$ | Degrees | 28 |
| Assumed tailings depth above penstock tower | h | m | 20 |
| Penstock ring wall thickness | t | m | 0.1 |
| Total vertical frictional load | V | kN/m | 2627.8 |
| Vertical compressive stress | $\sigma_v$ | MPa | 26.28 |
| Concrete crushing strength | $\sigma_c$ | MPa | 30 |

It was observed that the penstock rings should have sufficient bearing capacity as the crushing strength of the concrete (30 MPa) exceeds the vertical compressive stress exerted by the tailings (26.3 MPa). All penstock intakes at Tharisa have been reinforced through internal sleeving with 30 MPa concrete and a steel lost shutter. This improves the structural integrity of the system as well as reduces the risk of tailings migration through the rings.

### 8.12.4 Penstock outfall valves

Epoch approached Delmon Mining & Civils (Delmon) to undertake the comprehensive design of the penstock isolating valve, mitigating the potential risk of an environmental spill should the structural integrity of the existing penstock be jeopardised.

The outfall pipelines to TSF 1 Expansion and TSF 2 Phase 1 will include a 500 mm diameter gate valve to prohibit the outflow of tailings. The valve will be in an open position during normal operations and closed if an emergency occurs.

The existing outfall pipeline, with an inside diameter (ID) of 585 mm, will be slip-lined with a DN 500 (OD of 508 mm) steel pipe, grouted in position with a non-shrink cementitious grout. The DN500 pipe will be fitted with a corresponding DN500 flange and the DN500 gate valve bolted to the flange. Refer to Figure 8-4 for an isolated view of the above-discussed components. The design report as well as a descriptive drawing is included in Appendix I.

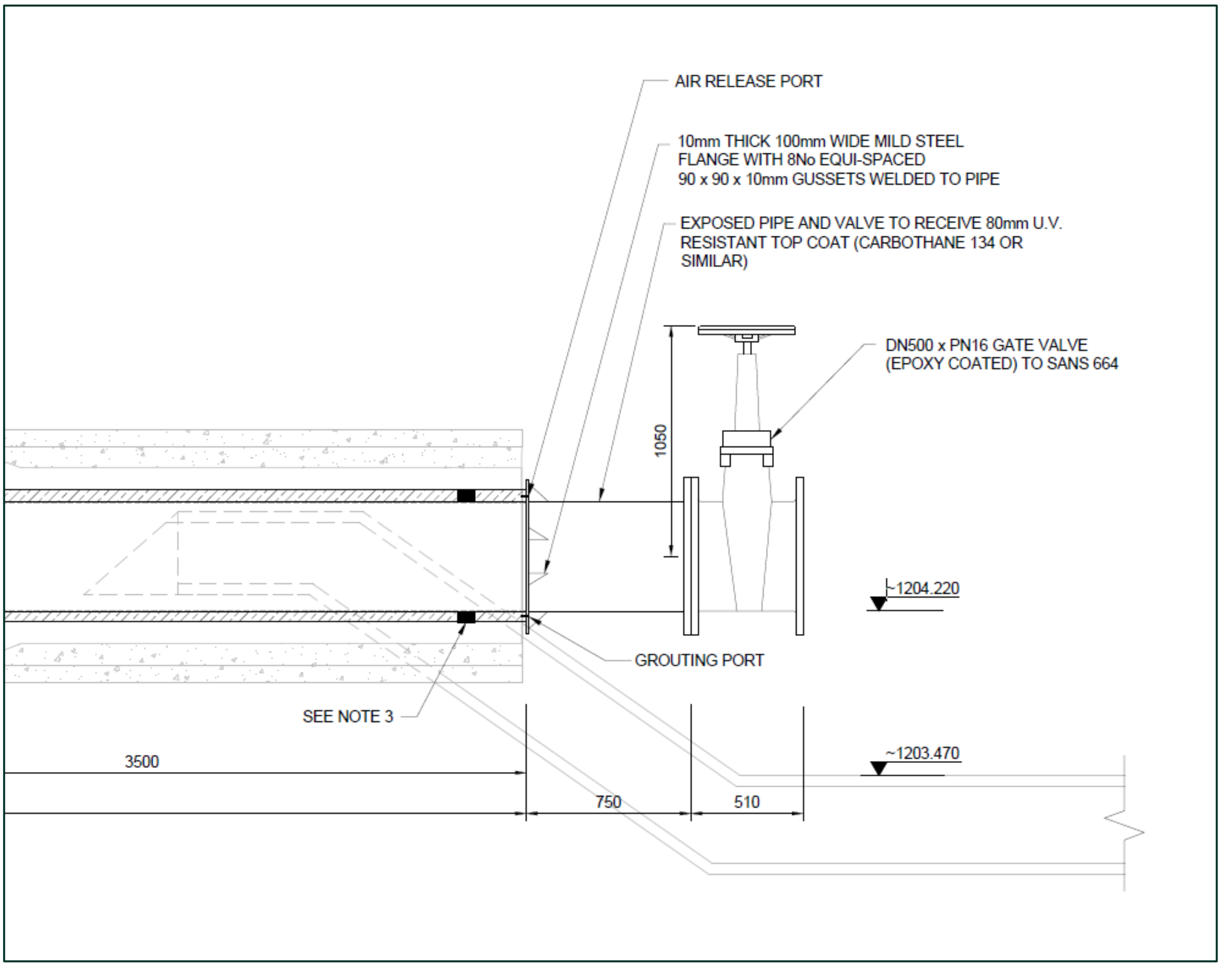



Figure 8-4: Penstock outfall pipeline isolating valve

Furthermore, it needed to be shown that the system would be able to manage the longitudinal force imposed by the constant through flow of return water. From Delmon's report, it was determined that the most critical element would be at the steel grout interface with an allowable shear stress of 0.35 N/mm$^2$. The maximum shear stress exerted on this interface was determined to be 0.0089 N/mm$^2$ which indicates the system would be able to accommodate the forces imposed by the decant water.

### 8.12.5 Drainage Sizing

The drains have been sized to accommodate the potential seepage emanating from the supernatant pool during the design of the existing facilities. The plan area of the drains, together with the permeability of the tailings and hydraulic gradient, dictates the flow rate into the drains.

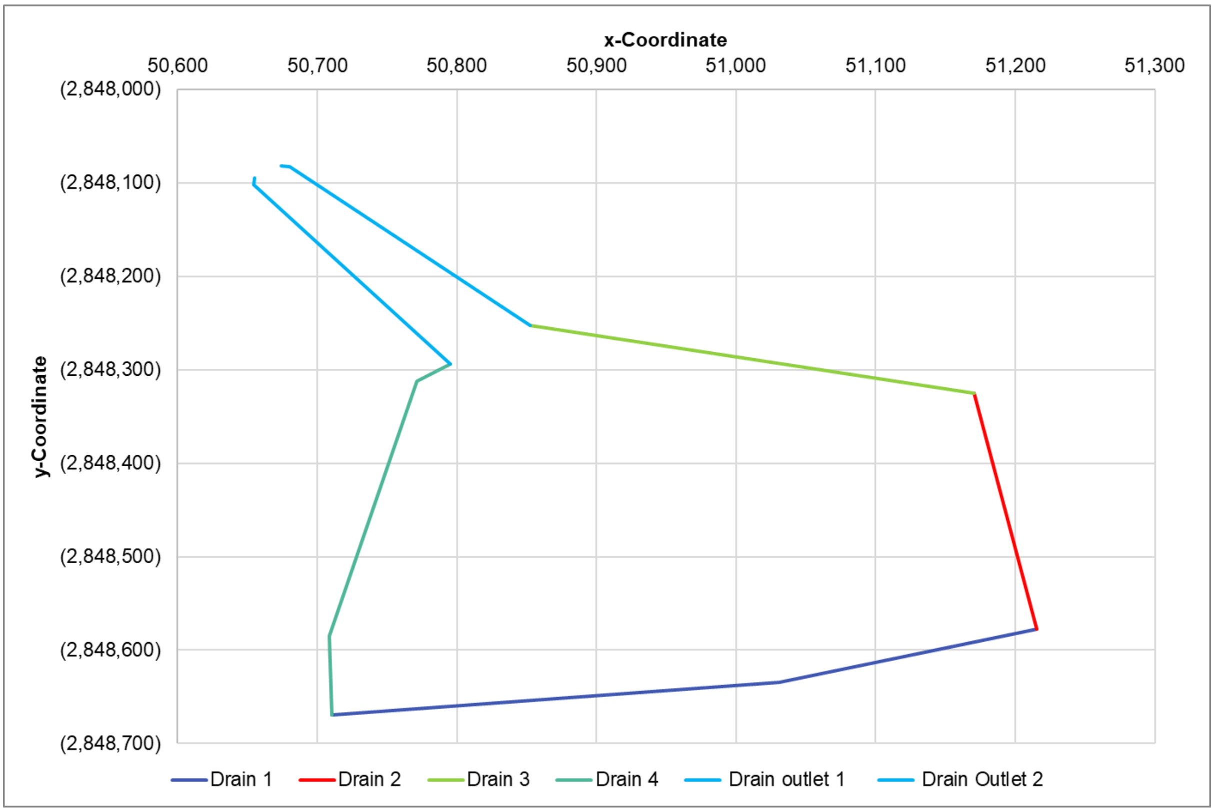



**Figure 8-5: TSF 1 Expansion Drainage layout**

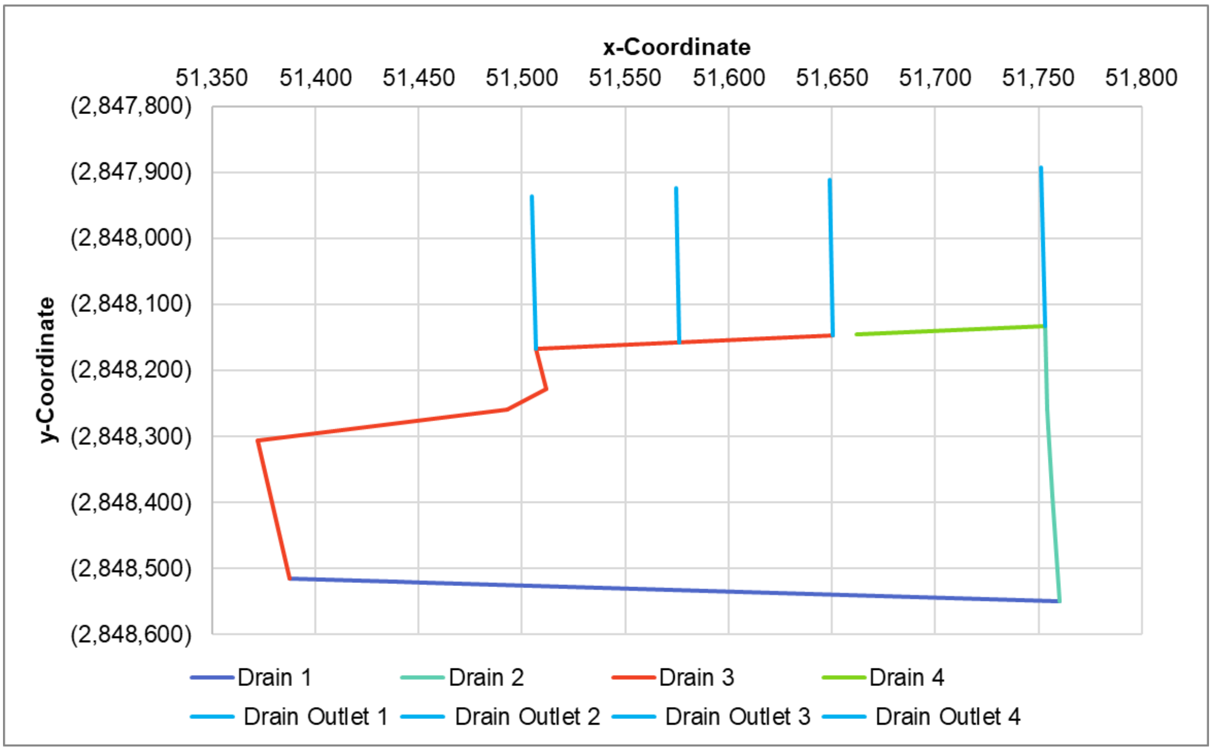



**Figure 8-6: TSF 2 Phase 1 Drainage layout**

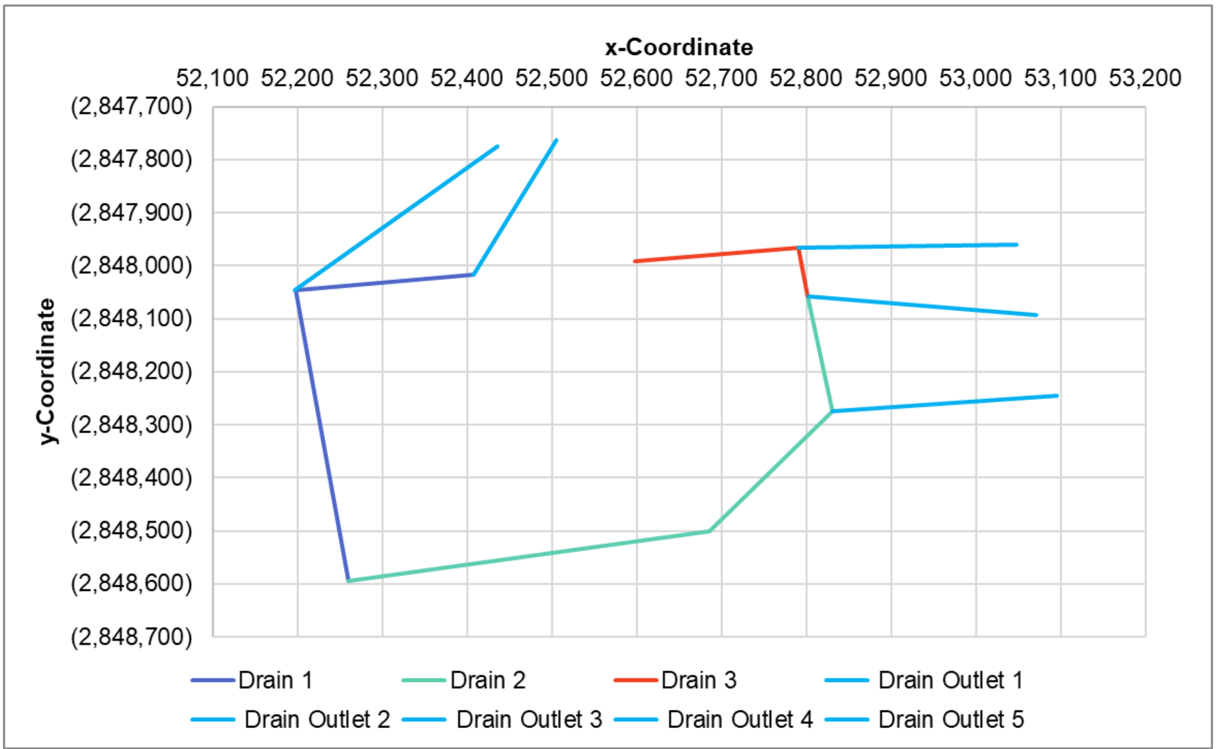



**Figure 8-7: TSF 2 Phase 2 drainage layout**

Table 8-5 shows the available flow rate for each drain segment, as well as the possible flow rate from the supernatant pool for each facility.

**Table 8-5: Drain Capacity**

| Drain | Description | Pool-Generated Flow Rate (m³/day) | Drain Area (m²) | Drain Available Flow Rate (m³/day) | Surplus Available Flow (m³/day) |
|---|---|---|---|---|---|
| **TSF 1 Expansion** | | | | | |
| Drain 1 | South Embankment | 107 | 2 993 | 956 | 849 |
| Drain 2 | East Embankment | 58 | 1 485 | 2 100 | 2 042 |
| Drain 3 | North Embankment | 80 | 1 897 | 1 263 | 1 183 |
| Drain 4 | West Embankment | 89 | 2 291 | 1 654 | 1 565 |
| **TSF 2 Phase 1** | | | | | |
| Drain 1 | South Embankment | 151 | 2 438 | 902 | 751 |
| Drain 2 | East Embankment | 188 | 2 717 | 1 127 | 939 |
| Drain 3 | West and partial North Embankment | 188 | 2 841 | 1 405 | 1 217 |
| Drain 4 | Partial North Embankment | 43 | 605 | 1 402 | 1 359 |
| **TSF 2 Phase 2** | | | | | |
| Drain 1 | West and partial North Embankment | 110 | 4 973 | 1 495 | 1 385 |
| Drain 2 | South and partial East Embankment | 152 | 6 006 | 1 855 | 1 703 |
| Drain 3 | Partial North Embankment | 54 | 1 872 | 1 776 | 1 722 |
| TAILINGS PERMEABILITY (m/s) | | 4.84E-7 | | | |
| SAND PERMEABILITY (m/s) | | 1.00E-5 | | | |

It is shown that the toe drains still have sufficient capacity to cater for the seepage originating from the supernatant pool. It must be noted that the seepage originating from the pool is for normal operating conditions. The seepage rates, as listed in Table 8-5, align well with what is recorded monthly from the existing facilities.

The flow rate that would be expected in each pipe, based on the pool generated seepage, is given in Table 8-6 and illustrates that sufficient flow capacity is provided by the pipes.

**Table 8-6: Drain flows**

| Drain | Description | Pipe Flow Rate (m³/day) | Flow Depth In Pipes (%) |
|---|---|---|---|
| **TSF 1 Expansion** | | | |
| Drain 1 | South Embankment | 53.7 | 26.5 |

| Drain | Description | Pipe Flow Rate ($m^3$/day) | Flow Depth in Pipes (%) |
|---|---|---|---|
| Drain 2 | East Embankment | 19.5 | 16.1 |
| Drain 3 | North Embankment | 20.0 | 16.3 |
| Drain 4 | West Embankment | 44.5 | 24.1 |
| **TSF 2 Phase 1** | | | |
| Drain 1 | South Embankment | 50.2 | 16.5 |
| Drain 2 | East Embankment | 46.9 | 14.4 |
| Drain 3 | West and partial North Embankment | 62.8 | 14.9 |
| Drain 4 | Partial North Embankment | 21.5 | 8.9 |
| **TSF 2 Phase 2** | | | |
| Drain 1 | West and partial North Embankment | 27.6 | 9.7 |
| Drain 2 | South and partial East Embankment | 50.7 | 11.7 |
| Drain 3 | Partial North Embankment | 18.0 | 7.3 |

The following is noted:

- Given the size of the drain's trench, the stone matrix surrounding the pipes will also provide additional drainage capacity over and above the pipe flow volume which has not been accounted for.
- The service life of the drains is expected to be greater than the operational life of the facility. This is ensured by undertaking a comprehensive filter design to prevent the washing-out of filter material from the drains (discussed in section 8.12.7).
- The clogging of drain pipelines is managed with periodic jet rodding.
- Upturns or goosenecks are installed at the drain outlets to prevent oxygen from entering the pipeline, reducing the growth of vegetation within the pipes and discourages animals from nesting in the pipelines.

### 8.12.6 Outlet Piping

Outlet pipes have been located at intervals around the TSFs. The locations of the outlets considered the elevations of the drain and the outlet elevations to ensure there is a minimum slope of 1V:400H.

Each outlet comprises a 160 mm diameter HDPE pipe, with a ring stiffness of 450 kPa. The pipe is surrounded by 19 mm stone and wrapped in a 210 g/$m^2$ nonwoven geofabric. Flow rates were based on the flow through the pipe only, with the potential flow through the stone being ignored.

### 8.12.7 Filter Compatibility

In order to ensure compatibility of the filter sand and tailings, the filter sand and the 6 mm stone, and the 6 mm stone with the 19 mm stone, a filter design was undertaken during the detailed design of the respective facilities. The required grading envelopes of the filter sand, 6 mm stone and 19 mm stone applicable to TSF 1 Expansion, TSF 2 Phase 1, and TSF 2 Phase 2 are shown in Figure 8-8.

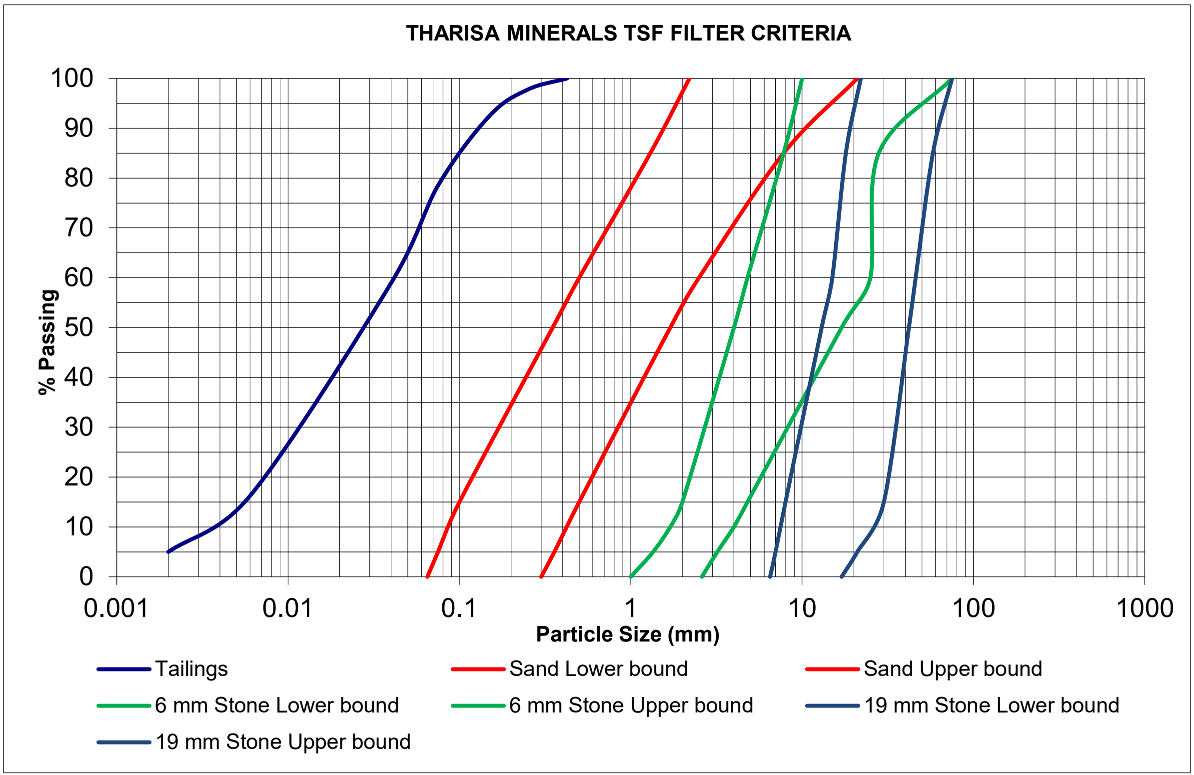



**Figure 8-8: TSF 1 and 2 filter design**

## 8.13 Geofabric Separation Layer

The raising of the TSFs, following the current facilities reaching their respective capacities, will include the placement of a geotextile on the consolidated tailings along the perimeter of the facility prior to the placement of waste rock. This will reduce the risk of tailings ingress and seepage through the rockfill embankment. The geotextile will be anchored on the crest of the existing facility and within the tailings at the downstream toe of the raised embankment. The geotextile will extend approximately 0.5 m from the downstream toe of the raised embankment and will be anchored in a trench of approximately 600 mm deep and 300 mm wide. The geotextile will also be anchored in the same manner within the existing embankment prior to the placement of waste rock. A geotextile with a density of 750 g/m$^2$ was specified.

## 8.14 Barrier system

As previously discussed, the design of the existing facilities was accepted as a class-D liner due to the nature of the tailings material and the presence of a thick layer of “black turf” beneath the footprint of the facilities. The black turf is known for its low permeability, which ranges from 1E-9 m/sec to 4.7E-10 m/sec while maintaining a high plasticity index ranging between 32 and 72.

# 9 Seepage and Slope stability Analyses

Seepage and slope stability analyses for the lifting of the existing TSF 1 Expansion, TSF 2 Phase 1 and Phase 2 facilities were undertaken by Epoch. Figure 9-1 shows the layout of the TMM TSF Complex and the cross-sections used for each facility for the seepage and slope stability analyses.


**Figure 9-1: Layout of the TSF complex with the critical sections used for each respective paddock for all its analyses.**

Steady state seepage and slope stability analyses were carried out using SEEP/W and SLOPE/W, respectively, to assess the likely seepage regimes and instabilities within the facilities. Methodological inputs to the stability analyses were sourced from Hynnes-Griffin & Franklin (1984) with further guidance from ICOLD (Bulletin No. 194, 2022). Analyses were carried out using the current profiles of the TSFs along the critical sections illustrated above at their respective ultimate heights (at full capacity). In addition, simplified deformation analyses, as required from ICOLD (Bulletin No. 194, 2022), were undertaken using the methodology brought forward by Bray & Macedo (2019).

## 9.1 Foundation and structural material parameters

The initial geotechnical assessment of the TSF 1 and 2 facilities was undertaken by Inroads Consulting in 2011 and is documented in their geotechnical investigation report, Inroads (2011). The report documents the average soil profiles and soil strength parameters assessed through laboratory test-work which included compaction, shear strength (shear box tests) and permeability tests.

Additional testing was undertaken on the clays ("Black Turf") underlying the TSF 1 and 2 sites in 2013 as it was observed that the initial tested strength parameters were not replicable of the actual shear strength parameters of the in-situ clays. The results of these tests were also used to determine a preliminary estimate of the undrained shear strength ratio of the clays to be used in the undrained slope stability assessment. Further elaboration on the calculated undrained shear strength ratio can be sourced from section 9.1.1.2.

The design phase material parameters were updated to those presented in Table 9-1.

**Table 9-1: Foundation and structural material parameters**

| TSF | Unit Weight (kN/m3) | Saturated Conductivity (ky) (m/s) | ky/kx | Effective Friction Angle (□') | Effective Cohesion (c') (kPa) |
|---|---|---|---|---|---|
| **Platinum tailings** | | | | | |
| TSF 1 Phase 1 | 22 (±2.0) | 1x10-7 | 1/5 | 32° (±2.5°) | 0 |
| TSF 1 Expansion | 22 (±2.0) | 1x10-7 | 1/5 | 32° (±2.5°) | 0 |
| TSF 2 Phase 1 | 22 (±2.0) | 1x10-7 | 0.6 | 32° (±2.5°) | 0 |
| TSF 2 Phase 2 | 22 (±2.0) | 1x10-7 | 0.6 | 32° (±2.5°) | 0 |
| **Waste rock walls** | | | | | |
| TSF 1 Phase 1 | 22 (±2.0) | 1x10-5 | 1 | 40° (±5.0°) | 0 |
| TSF 1 Expansion | 22 (±2.0) | 1x10-5 | 1 | 40° (±5.0°) | 0 |
| TSF 2 Phase 1 | 22 (±2.0) | 1x10-5 | 1 | 40° (±5.0°) | 0 |
| TSF 2 Phase 2 | 22 (±2.0) | 1x10-5 | 1 | 40° (±5.0°) | 0 |
| **In-situ Black Clay material (see Note 1)** | | | | | |
| TSF 1 Phase 1 | 16 (±2.0) | 7.3 x 10-10 | 1 | 21.2° (±2.0°) | 2.5 (±2.5) |
| TSF 1 Expansion | 16 (±2.0) | 7.3 x 10-10 | 1 | 21.2° (±2.0°) | 2.5 (±2.5) |
| TSF 2 Phase 1 | 16 (±2.0) | 7.3 x 10-10 | 1 | 21.2° (±2.0°) | 2.5 (±2.5) |
| TSF 2 Phase 2 | 16 (±2.0) | 7.3 x 10-10 | 1 | 21.2° (±2.0°) | 2.5 (±2.5) |
| **In-situ Gabbro Norite Material (Silty Sand)** | | | | | |
| TSF 1 Phase 1 | 20 (±2.0) | 1 x 10-8 | 1 | 35° (±5.0°) | 0 |
| TSF 1 Expansion | 20 (±2.0) | 1 x 10-8 | 1 | 35° (±5.0°) | 0 |
| TSF 2 Phase 1 | 20 (±2.0) | 1 x 10-8 | 1 | 35° (±5.0°) | 0 |

| TSF | Unit Weight (kN/m3) | Saturated Conductivity (ky) (m/s) | ky/kx | Effective Friction Angle (□') | Effective Cohesion (c') (kPa) |
|---|---|---|---|---|---|
| TSF 2 Phase 2 | 20 (±2.0) | 1 x 10-8 | 1 | 35° (±5.0°) | 0 |
| **In-situ Norite Material (Weathered Norite Bedrock)** | | | | | |
| TSF 1 Phase 1 | 22 (±2.0) | 8.4 x 10-9 | 1 | 40° | 40 |
| TSF 1 Expansion | 22 (±2.0) | 8.4 x 10-9 | 1 | 40° | 40 |
| TSF 2 Phase 1 | 22 (±2.0) | 8.4 x 10-9 | 1 | 40° | 40 |
| TSF 2 Phase 2 | 22 (±2.0) | 8.4 x 10-9 | 1 | 40° | 40 |

*Note 1 = Drained parameters (see section 9.1.1.2 for undrained parameters)*

The hydraulic and shear strength parameters were updated from the parameters used during the initial design phase. These updates were based on literature. Updates to the clay and tailings material were also made based on additional test work conducted specifically on representative tailings and black turf samples. Recent permeability tests conducted on representative tailings samples obtained from TSF 2 Phase 1 and 2 indicated permeabilities ranging between $2.3x10^{-8}$ and $2.04x10^{-6}$. An average tailings permeability of $1x10^{-7}$ was used as a result.

Jehring (2014) noted that waste rock generally exhibits a friction angle of greater than 40 degrees and saturated hydraulic conductivity in the order of $1x10^{-4}$ m/s. The friction angles were based on consolidated drained and undrained tests with the consolidated drained tests indicating an average friction angle of 41.4 degrees and consolidated undrained tests indicating an average friction angle of 37.0 degrees. This was further supported by Williams et al., (1999) who noted friction angles of between 35.7 and 42.3 degrees. However, it must be noted that these friction angles were based on fresh oxide waste rock with particle sizes of between 1.18 and 9.50 mm which is much less than those of the waste rock sourced from TMM. In support of this, Williams et al., (1999) further noted that an increase in the particle size is generally coupled with a decrease in cohesion and an increase in the friction angle of the material.

Based on the above findings, the friction angle for the rock was conservatively chosen as 40 degrees with a saturated hydraulic conductivity of $1x10^{-5}$ m/s as indicated in Table 9-1.

#### 9.1.1.1 Black Turf

The presence of the black turf clay underlying the TSF footprint areas potentially poses a stability risk to the TSFs, specifically when these clays are considered to behave undrained, resulting in a decrease in shear strength. Due to insufficient information as to the degree of saturation of the clays beneath the embankments, it was conservatively assumed that the clays are fully saturated and modelled as such for the stability analyses. The clay depths vary across the TSF 1 and 2 footprint as listed in Table 9-2.

All clay material beneath TSF 1 Expansion embankments was removed. Clays were only partially removed beneath the TSF 2 Phase 1 and Phase 2 embankments along the upstream and downstream toes as listed in Table 9-2. These voids were then filled with waste rock to increase the stabilities along these sections.

**Table 9-2: TSF 1 and TSF 2 clay removal**

| Facility | Section | Clays beneath embankment | Key width (m) | Clay depth (m) |
|---|---|---|---|---|
| TSF 1 Expansion | North, East, South, West | Removed | N/A | 1.7 - 2.2 m |
| TSF 2 Phase 1 | North | Removed | N/A | 0.98 - 1.5 m |
| | East | Partially removed | Upstream – 20 m<br>Downstream – 30 m | 4.2 – 5.3 m |
| | South | Partially removed | Upstream – 20 m<br>Downstream – 30 m | 6.7 m |
| TSF 2 Phase 2 | North | Partially removed | Upstream – 10 m<br>Downstream – 10 m | 1 - 1.6 m |
| | East | Partially removed | Upstream – 15 m<br>Downstream – 15 m | 1.4 - 3 m |
| | South | Partially removed | Upstream – 20 m<br>Downstream – 25 m | 3.5 - 6 m |

#### 9.1.1.2 Undrained shear strength ratio

The shear strength of saturated contractive materials is often expressed as a ratio between the undrained shear strength ($S_u$) and the initial effective vertical stress ($\sigma'_{v,0}$) within the soil mass, i.e., $S_u/\sigma'_{v,0}$. For clays, this ratio can also be modified to consider stress history, using the SHANSEP approach presented by Ladd & Foott (1974).

The determination of the undrained shear strength ratio of the black turf was based on the triaxial tests conducted on the clay samples in 2013 and is presented in Table 9-3. The final undrained shear strength ratio was determined from the gradient of a linear trendline fitted through the data points.

**Table 9-3: Black turf undrained shear strength ratio determination**

| Sample | Effective consolidation stress, $\sigma'_v$ (kPa) | Peak deviatoric stress, qf (kPa) | Undrained shear strength, Su (kPa) | Su/ $\sigma'_v$ |
|---|---|---|---|---|
| 1782-1 (Test 1) | 49.4 | 37 | 18.5 | 0.37 |
| 1782-1 (Test 2) | 100 | 60.4 | 30.2 | 0.29 |
| 1782-1 (Test 3) | 200 | 108.9 | 54.5 | 0.27 |
| **Final undrained shear strength ratio** | | | | **0.24** |

## 9.2 Seepage analyses methodology

Seepage analyses for the TSFs were carried out assuming steady state conditions, using the finite element program SEEP/W. The operational status of the toe drains and seepage cut-off trenches were varied to determine the possible seepage regimes within each TSF with regard to the level of the phreatic surface. Varying the different configurations influences the degree to which the phreatic surface is drawn down within the facility and can cause possible slope instabilities.

The objective of seepage modelling is to ensure that the phreatic surface is correctly defined before determining the stability of the facility. An increase in pore-water pressure brought on by the onset of seepage can result in the reduction in the stability of an earth structure's slope and have other adverse secondary effects such as:

- Piping (erosive loss of material)
- Loss of effective strength of material
- Increase in the liquefaction potential of a soil
- Increase in the collapse potential of sensitive soils

It is therefore imperative not only for the designer to take cognisance of the above but also for the construction of the facility to comply with the design specifications and for the operator of the TSF to ensure that best operating practices are always adhered to.

Due to the 1 in 10 000 year storm event complying with the required limits governed by DWA (2008), seepage and slope stability analyses during flooded conditions were undertaken based on a pool situated 50 m from the embankment crest as this scenario was deemed to be the worst-case. The effect of the application of the 1 in 10 000-year storm event on the stability of the various embankment sections is not comprehensively discussed in this section; however, the results of the analyses are included in Appendix H.

## 9.3 Slope stability analyses methodology

Slope stability analyses were carried out to assess the stability of the TSFs at final elevation. The results from the seepage analyses, SEEP/W, were integrated with SLOPE/W, which was used to carry out the slope stability analyses.

The slope stability model was defined in terms of the physical configuration of the structure and its foundations as well as the geotechnical properties of the tailings material, and the foundation material.

In 2023, Cone Penetration Tests (CPTu) were performed at TSF 2 Phase 1 to determine the various geotechnical properties of the tailings and underlying foundation material. However, probing did not extend into the black turf underlying the TSF footprint. As a result, stability analyses were undertaken assuming the clay behaves both in a drained manner (drained analyses) and an undrained manner (undrained analyses) to determine the variability in the factors of safety. Sections where clays were removed in their entirety below the embankment such as for TSF 1 Expansion, were only assessed assuming drained behaviour of the clays as the stability is not expected to be influenced. In addition, the CPTu data did not indicate excess pore water pressures in the waste rock (up to depth analysed) resulting in limited to no suctions. It was therefore assumed that the waste rock would not fail in an undrained manner and as a result were modelled using drained parameters. Embankment sections that contain waste rock keys below the upstream and downstream toes, were analysed assuming both the drained and undrained behaviours of the clays.

### 9.3.1 Static analyses

The seepage regimes, determined through SEEP/W, were imported into SLOPE/W in order to analyse the slope stability of the TSFs. The software carries out Monte Carlo based probabilistic slope stability analyses to account for the variability of input parameters, such as material strength, and to statistically quantify the probability of failure. The program permits Monte Carlo based probabilistic analyses where a mean factor of safety is reported as well as the probability that the factor of safety is less than 1, i.e. the probability of failure. The calculation of the mean factor of safety for the most critical slip surface was done through an iterative process and approximately 6000 Monte Carlo trials were carried out to calculate the probability of failure.

The Morgenstern-Price method of calculation produces a factor of safety against slope failure satisfying both moment and force equilibrium and was used to obtain the minimum factor of safety. Analyses were conducted for all the scenarios for which a seepage analysis was undertaken with regard to the operational status of drains.

### 9.3.2 Pseudo-static analyses

#### 9.3.2.1 Seismicity

Pseudo-static analyses in SLOPE/W incorporate a horizontal seismic coefficient to determine the seismic load of possible seismic events on the structures. The horizontal force imposed on the structure when undertaking a pseudo-static analysis is derived from the Peak Ground Acceleration (PGA) parameter. PGA values are based on prior earthquakes and fault studies and are measured as factors of the earth's gravitational acceleration (i.e. 1g is equivalent to 9.81 m.s-2).

Probabilistic Seismic Hazard Assessments make use of Ground Motion Models (GMM) or Ground Motion Prediction Equations (GMPE). These models provide a means of predicting the level of ground shaking and its associated uncertainty at a site based on an earthquake's magnitude, source-to-site distance, local soil conditions and fault mechanisms (reference). The Ground Motion Models that are applicable to the investigated site and surrounding areas are:

- ChY – 2014 (Chiou and Youngs, 2014);
- ASB – 2014 (Akkar et al., 2014); and
- Pez – 2018 (Pezeshk et al., 2018)

The ASB-2014 and Pez-2018 are models based on seismic records recorded at Stable Continental Regions (SCR) with the ChY-2014 model based seismic records recorded for Active Crustal Regions. It was noted by Kjko (2023) that these models best describe the tectonic setting for Southern Africa.

The GMMs are reliant on inputs of shear wave velocities occurring in the upper 30m of a site ($VS_{30}$). Where shear wave velocities in the upper 30m of a site are unknown, such values have been estimated based on the expected soil profiles at the site. Soil profiles observed from test pits can reveal information for several metres of the upper layers of a site's profile. This information along with a known or estimated depth to hard rock or bedrock allows for a more educated estimation of the upper 30m of a site's composition. Estimated shear wave velocities can be derived from soil profiles as shown in Table 9-4.

**Table 9-4: Seismic site characterisation**

| Site Class | Soil Profile Name | Average Properties in Top 30m | | |
|---|---|---|---|---|
| | | Soil Shear Wave Velocity, Vs, (m/s) | Standard Penetration Resistance, N | Soil Undrained Shear Strength, Su, (kPa) |
| A | Hard rock | Vs > 1,500 | N/A | N/A |
| B | Rock | 760 < Vs ≤ 1,500 | N/A | N/A |
| C | Very dense soil and soft rock | 360 < Vs ≤ 760 | N ≥ 50 | Su ≥ 96 |
| D | Stiff soil | 180 < Vs ≤ 360 | 15 ≤ N ≤ 50 | 48 ≤ Su ≤96 |
| E | Soft clay soil | Vs < 180 | N ≤ 15 | Su ≤ 48 |
| | | Any profile with more than 3m of soil with the following characteristics: Plasticity index PI > 20 | | |

| Site Class | Soil Profile Name | Average Properties in Top 30m | | |
|---|---|---|---|---|
| | | Soil Shear Wave Velocity, Vs, (m/s) | Standard Penetration Resistance, N | Soil Undrained Shear Strength, Su, (kPa) |
| | | Moisture content w ≥ 40%; and<br>Undrained shear strength Su < 24 | | |
| F | Soils requiring site response analysis in accordance with Section 21.1 | Any profile containing soils having one or more of the following characteristics:<br>Soils vulnerable to potential failure or collapse under seismic loading, such as liquefiable soils, quick and highly sensitive clays and collapsible, weakly cemented soils<br>Peats and/or highly organic clays (H>3m) of peat and/or highly organic clay (where H = thickness of soil)<br>Very high plasticity clays (H > 7.6m with PI > 75)<br>Very thick soft/medium stiff clays (H > 37m) with Su < 48 | | |

A $VS_{30}$ value of ± 655 m/s was identified for the site resulting in a site class C. The seven PGA earthquake design levels (EDLs), based on the seismic activity observed within a radius of 500 km from the TSF site, are listed in Table 9-5.

**Table 9-5: Earthquake design levels (Kijko, 2023)**

| Earthquake Design Level | Return Period | PGA |
|---|---|---|
| EDL1 | 1 in 145 years | 0.020 ± 0.011 g |
| EDL 2 | 1 in 200 years | 0.023 ± 0.013 g |
| EDL 3 | 1 in 475 years | 0.035 ± 0.033 g |
| EDL 4 | 1 in 1 000 years | 0.050 ± 0.022 g |
| EDL 5 | 1 in 2 475 years | 0.074 ± 0.029 g |
| EDL 6 | 1 in 5 000 years | 0.100 ± 0.035 g |
| EDL 7 | 1 in 10 000 years | 0.131 ± 0.042 g (MCE) |

The GISTM states that TSFs should be designed based on an extreme consequence classification or classification corresponding to the relevant consequence. If the latter is to be used, it should be indicated what measures are to be implemented at a later stage to meet the requirements for an extreme consequence classification.

As either scenario requires the extreme consequence classification to be analysed, it was decided to conduct analyses based on the extreme consequence classification. This requires a seismic coefficient of 0.131 be used in the slope stability analyses. The conventional pseudo-static analyses incorporate a seismic loading, and although not considered best practice as of late, was included as is required by certain regulatory bodies.

Hynes-Griffin & Franklin (1984) stated that a pseudo-static, seismic coefficient analysis can serve as a useful screening procedure to separate dams that are clearly safe against earthquake-induced sliding failure from those that require further analyses. It is further suggested to carry out a conventional pseudo-static stability analysis, using a seismic coefficient equal to one-half the peak acceleration (0.5 x 0.131 = 0.066 g) coupled with an undrained shear strength of 80% of the undrained shear strength.

The black turf material does not exhibit any significant residual undrained shear strengths and as such the peak undrained strengths were used. The conventional pseudo-static methodology incorporated assumed a reduction in the peak undrained shear strength of 20% to account for the dynamic behaviour (cyclic softening) that could occur during a seismic event. This was coupled with half of the 1 in 10 000 year PGA, which was calculated as 0.066 g.

In addition, ICOLD (Bulletin No. 194, 2022) requires slope stability analyses to be undertaken based on the process illustrated in Figure 9-2 and as ICOLD encompasses the GISTM technical requirements, the appropriate analyses to satisfy ICOLD (Bulletin No. 194, 2022), was undertaken.

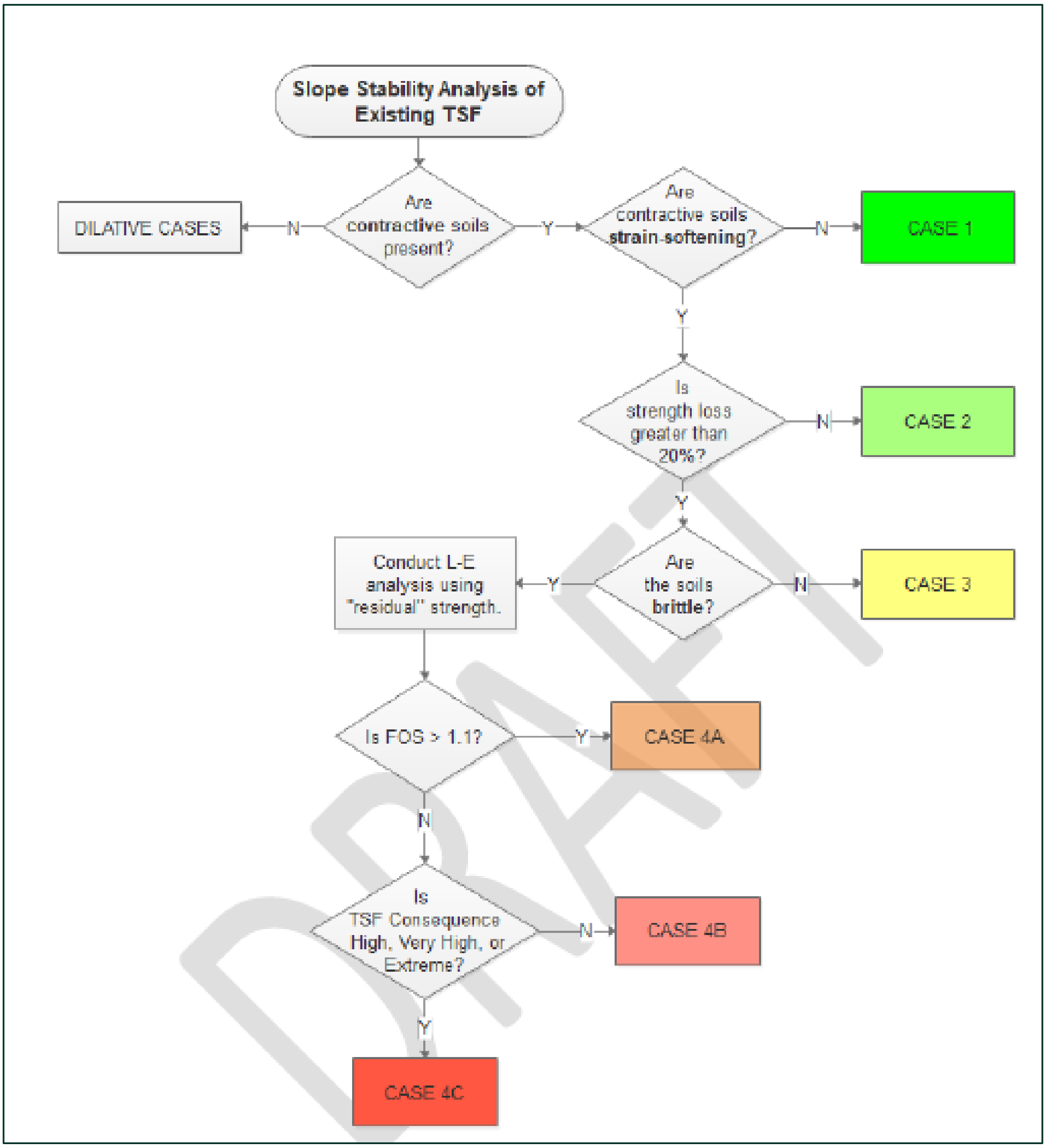



**Figure 9-2: Flowchart for slope stability analyses (ICOLD Bulletin No. 194, 2022)**

Given that the clays do not exhibit significant contractive behaviour and are also not strain-softening, ICOLD only requires the peak undrained strengths to be used and if not prone to liquefaction, only post-seismic simple deformation modelling be applied, as required for a CASE 1 scenario.

### 9.3.3 Target Factors of safety

Table 9-6 lists the allocated target factors of safety for each embankment analysed for slope stability. It should however be noted that the target factors of safety for seismic conditions listed below are for pseudo-static conditions, which are required by certain regulatory bodies, and not factors of safety relating to post-liquefaction which are governed by ICOLD (2022). ICOLD (2022) states that if the foundation material(s) in question are not subjected to liquefaction, deformation modelling is required which is further discussed in section 9.4.

**Table 9-6: Target Factors of Safety**

| Scenario | Analyses | Target FoS | | Embankment |
|---|---|---|---|---|
| Static | Drained | Normal | 1.5 | • TSF 2 Phase 1 (South)<br>• TSF 2 Phase 2 (East)<br>• TSF 2 Phase 2 (South) |
| | | Mining | 2.0 | • TSF 1 Expansion<br>• TSF 2 Phase 1 (North)<br>• TSF 2 Phase 2 (North) |
| | Undrained | Normal | 1.5 | • TSF 2 Phase 1 (South)<br>• TSF 2 Phase 2 (East)<br>• TSF 2 Phase 2 (South) |
| | | Mining | 1.75 | • TSF 2 Phase 2 (North) |
| Seismic | Drained | Normal | 1.1 | • TSF 2 Phase 1 (South)<br>• TSF 2 Phase 2 (East)<br>• TSF 2 Phase 2 (South) |
| | | Mining | 1.5 | • TSF 1 Expansion<br>• TSF 2 Phase 1 (North)<br>• TSF 2 Phase 2 (North) |
| | Undrained | Normal | 1.1 | • TSF 2 Phase 1 (South)<br>• TSF 2 Phase 2 (East)<br>• TSF 2 Phase 2 (South) |
| | | Mining | 1.3 | • TSF 2 Phase 2 (North) |

## 9.4 Post-seismic deformation

As alluded to in section 9.3.3, if the foundation materials are not subjected to liquefaction, post-seismic deformation modelling is required. Various papers have been published, most notably by Jonathan D. Bray, detailing a simple approach to estimating slope displacement post seismic events. These methods estimate the displacement of an embankment's crest and the extent of settlement that may occur. The method used to determine the above parameters was based on Bray & Macedo (2019) and Bray & Macedo (2021). Inputs required for the above methods were sourced from Kijko (2023). Kijko (2023) undertook a deterministic and probabilistic seismic hazard analysis for the TMM's TSFs as discussed in section 9.3.2.1.

Equation 1 below pertains to the determination of the probability of non-zero displacement and subsequently determines the estimated displacement:

$$Ln(D) = a_1 - 2.491\,\mathrm{Ln}(k_y) - 0.245\left(\mathrm{Ln}(k_y)\right)^2 + 0.344Ln(k_y)Ln(S_a(1.3T_s)) + 2.703Ln(S_a(1.3T_s)) - 0.089\left(Ln(S_a(1.3T_s))\right)^2 + a2T_s + a3(T_s)^2 + 0.607M_w + a4Ln(PGV) + a5$$

Equation (1)

Where:

| | | |
|---|---|---|
| D | = | Seismic slope displacement |
| a1 | = | -5.894 (Site specific empirical parameter) |
| a2 | = | 3.152 (Site specific empirical parameter) |
| a3 | = | -0.910 (Site specific empirical parameter) |
| a4 | = | 0 (Site specific empirical parameter) |
| a5 | = | 0 (Site specific empirical parameter) |
| $k_y$ | = | Yield coefficient |
| $T_s$ | = | Initial fundamental period |
| $S_a$ (1.3$T_s$) | = | Spectral acceleration |
| Mw | = | Earthquake moment magnitude |

The input parameters to Equation 1 for each facility are listed in Table 9-7.

**Table 9-7: Deformation modelling input parameters**

| Parameter | Facility | | |
|---|---|---|---|
| | TSF 1 Expansion | TSF 2 Phase 1 | TSF 2 Phase 2 |
| $k_y$ | 0.34 | 0.16 | 0.08 |
| $T_s$ | 1.00 | 0.81 | 1.07 |
| $S_a$ | 0.295 | 0.35 | 0.25 |
| Mw | 7.63 | 7.63 | 7.63 |

## 9.5 TSF 1 Expansion

### 9.5.1 Model set-up

The material model indicating the foundation and structural materials are illustrated in Figure 9-3. It is also shown that all clays beneath the embankment were removed.

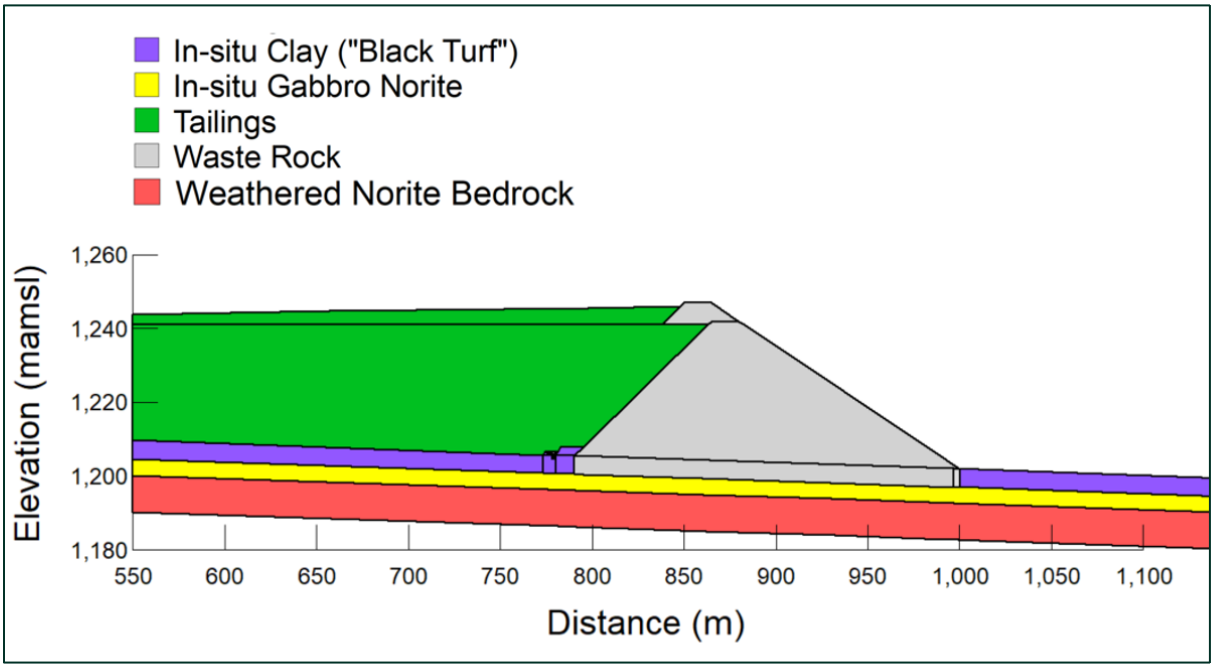



**Figure 9-3: TSF 1 Expansion Western Embankment (section B-B)**

The model geometry parameters used in the seepage and slope stability analyses are listed in Table 9-8.

**Table 9-8: TSF 1 Expansion model geometry**

| Wall section | Wall elevation (mamsl) | Maximum wall height (m) | Crest width (m) | Upstream slope | Downstream slope |
|---|---|---|---|---|---|
| West | 1242 | 40 | 15 | 1V:12H | 1V:3H |

### 9.5.2 Seepage analyses results

The behaviour of the phreatic surface with a variation in pool conditions and drain functionality for the Western embankment are illustrated in Figure 9-4, Figure 9-5, and Figure 9-6 below and listed in Table 9-9 for ease of reference.

**Table 9-9: TSF 1 Expansion seepage analyses results**

| Wall section | Reference | Pool condition | | Drains functionality | | Basin seepage (m3/s/m) |
|---|---|---|---|---|---|---|
| | | Normal operating | DWA | Active | Inactive | |
| West | Figure 9-4 | X | | X | | 9.3x10-9 |
| | Figure 9-5 | | X | X | | 9.8x10-9 |
| | Figure 9-6 | | X | | X | 1.12x10-8 |

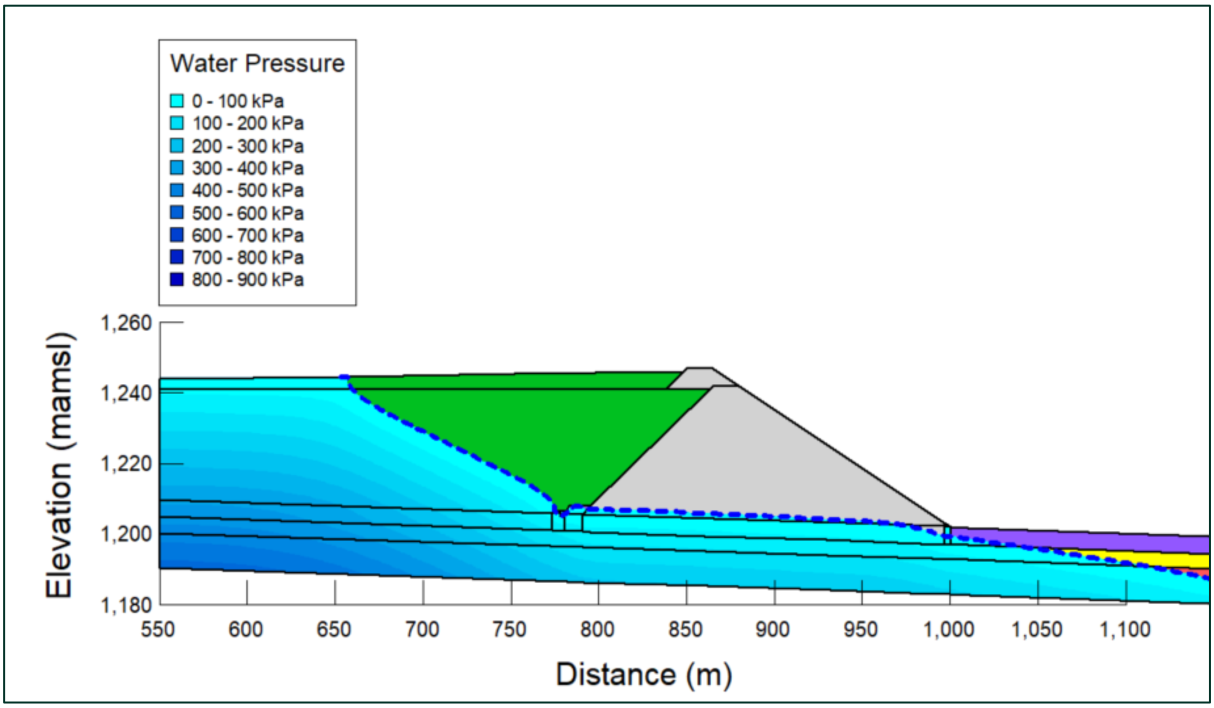



**Figure 9-4: TSF 1 Expansion phreatic surface behaviour during normal operating conditions**

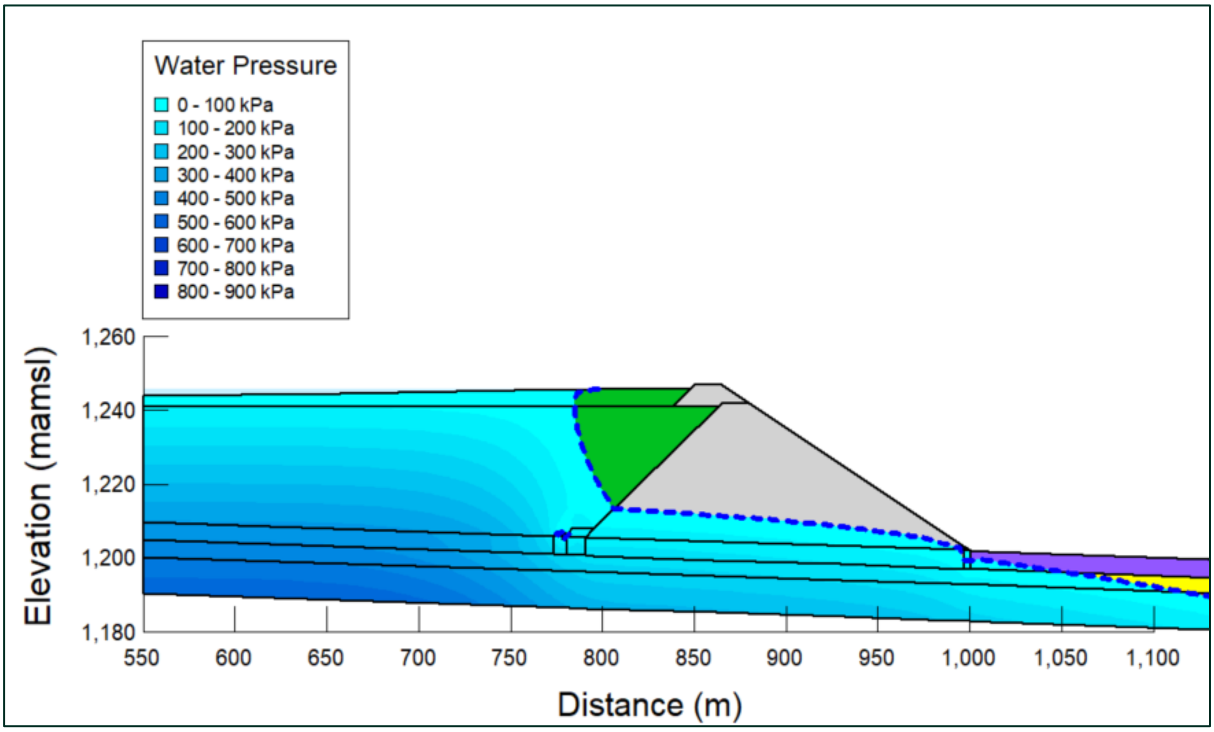



**Figure 9-5: TSF 1 Expansion phreatic surface behaviour with a pool situated 50 m from the crest and active drains**

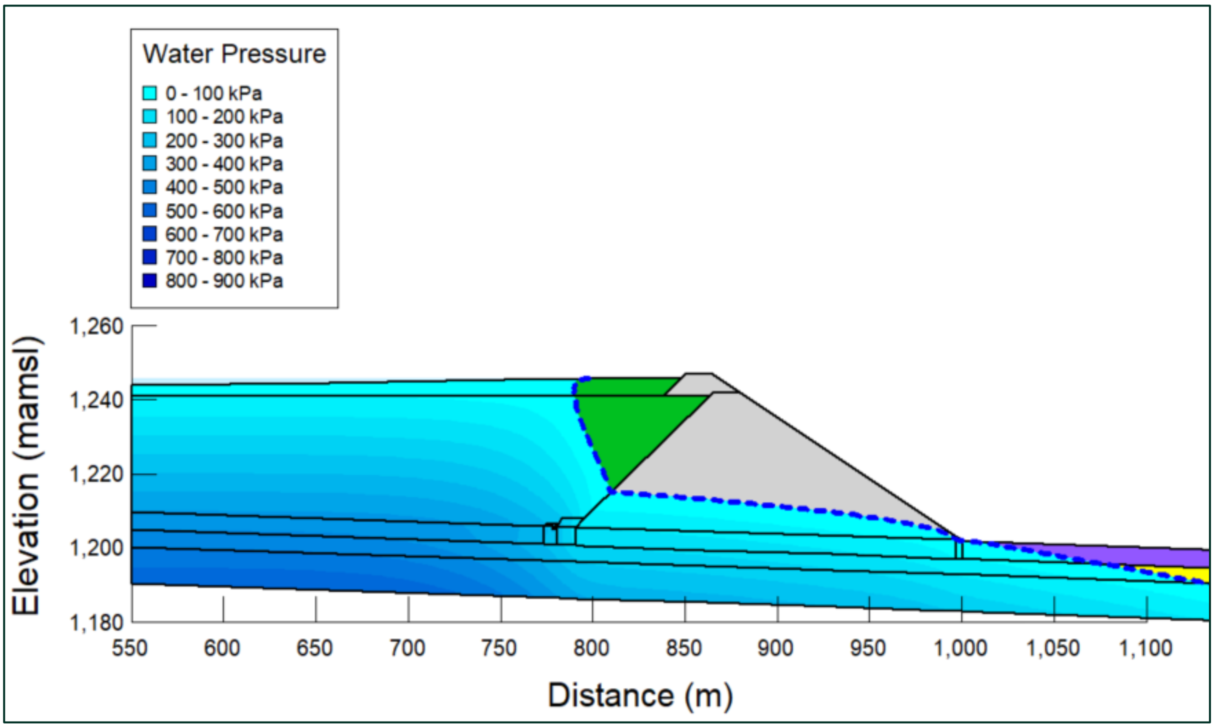



**Figure 9-6: TSF 1 Expansion phreatic surface behaviour with a pool situated 50 m from the crest and inactive drains**

From the above figures, an elevated phreatic surface is observed with an increase in pool extent and inactive drains resulting in an increase in seepage entering the basin and escaping the TSF footprint as depicted in Table 9-9.

### 9.5.3 Slope stability analyses results assuming drained clay parameters

Slope stability analyses for TSF 1 Expansion embankments assumed the drained parameters of the clay as all clays were removed from beneath the embankment. The slip surfaces that would result in a breach of tailings during static and pseudo-static conditions for flooded conditions are illustrated in Figure 9-7 and Figure 9-8, respectively.

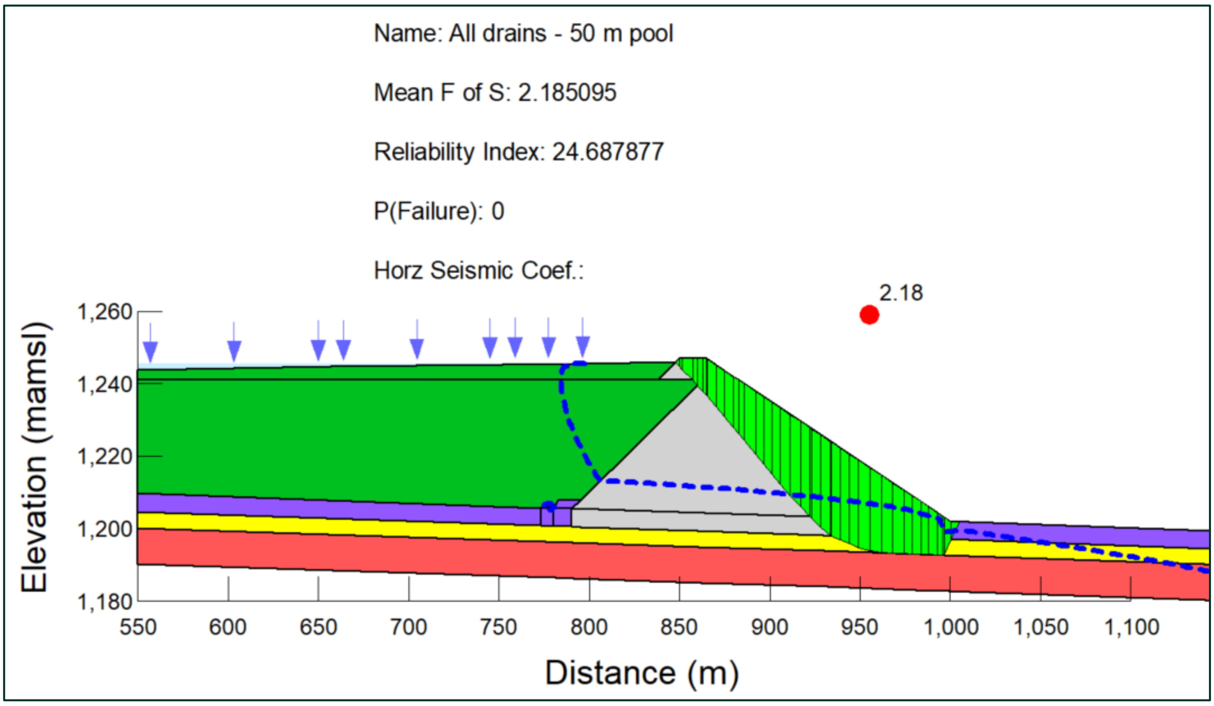



**Figure 9-7: TSF 1 Expansion breached slip surface during flooded conditions assuming static conditions – active drains (FoS = 2.18)**

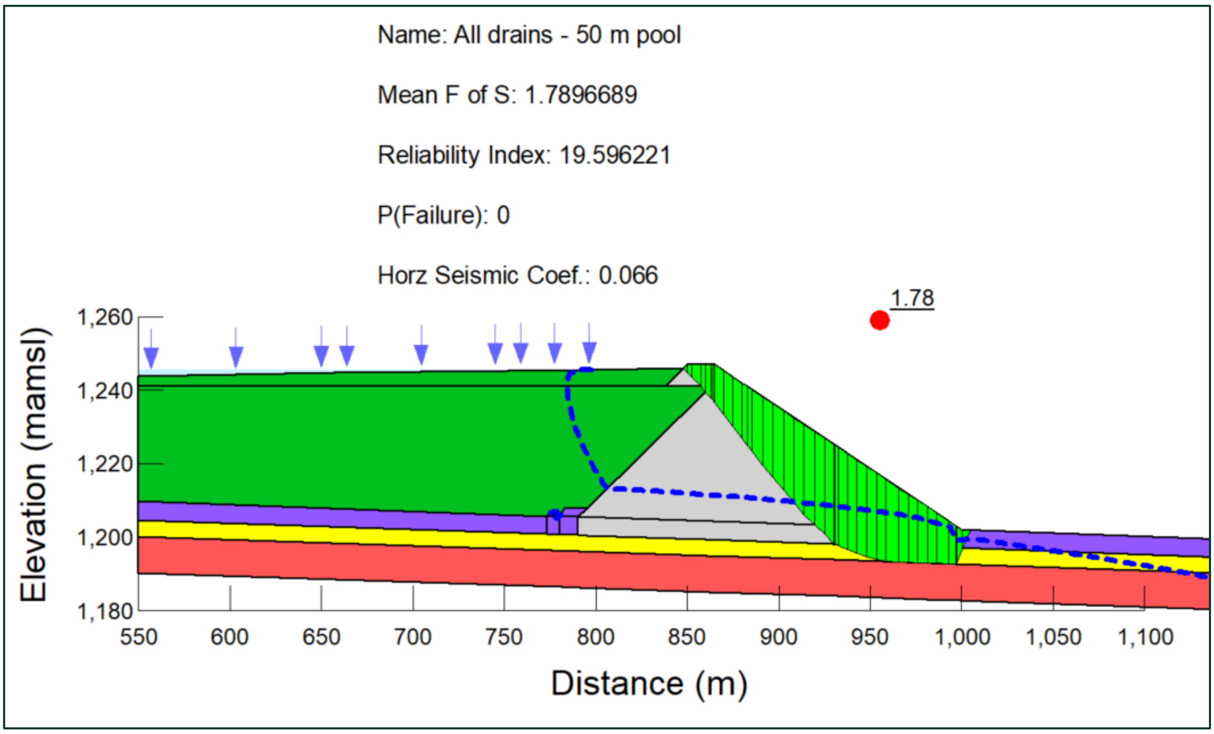



**Figure 9-8: TSF 1 Expansion breached slip surface during flooded conditions assuming pseudo-static conditions – active drains (FoS = 1.78)**

Table 9-10 lists the factors of safety relating to the breached slip surfaces for the various pool and drain conditions analysed.

**Table 9-10: TSF 1 Expansion drained slope stability results**

| Reference in Appendix | Condition | | Pool | | Drains | | FoS | RI | PoF |
|---|---|---|---|---|---|---|---|---|---|
| | Static | Pseudo-static | Normal Operating | DWA | Active | Inactive | | | |
| Required FoS (static conditions) = 2 (Mining) - OK<br>Required FoS (pseudo-static conditions) = 1.5 (Mining) - OK | | | | | | | | | |
| Analyses: 2 | X | | X | | X | | 2.32* | 25.50 | 0 |
| Analyses: 4 | | X | X | | X | | 1.89* | 21.34 | 0 |
| Analyses: 6 | X | | | X | X | | 2.18* | 24.69 | 0 |
| Analyses: 8 | | X | | X | X | | 1.78* | 19.59 | 0 |
| Analyses: 10 | X | | | X | | X | 2.10* | 23.84 | 0 |
| Analyses: 12 | | X | | X | | X | 1.71* | 18.67 | 0 |
| Analyses: 14 | X | | | X | X | | 2.26* | 25.16 | 0 |
| Analyses: 16 | | X | | X | X | | 1.84* | 20.56 | 0 |

** = Factor of safety relating to a slip surface leading to a breach in tailings*

It is shown in Table 9-10 that all analyses yielded results that satisfy the target factors of safety. It should be noted that the factors of safety listed in Table 9-10 relate to slip surfaces that would result in a breach of tailings. Refer to Appendix H for all analysis results.

### 9.5.4 Deformation analyses

The post-seismic deformation analyses yielded results that indicated an estimated crest settlement of 1.495 cm.

## 9.6 TSF 2 Phase 1

### 9.6.1 Model set-up

The material model indicating the foundation and structural materials are illustrated in Figure 9-9 and Figure 9-10 for the Northern and Southern embankment of TSF 2 Phase 1, respectively. All the clays beneath the Northern embankment were removed up to norite with clays only removed beneath the Southern embankment's upstream and downstream toe.

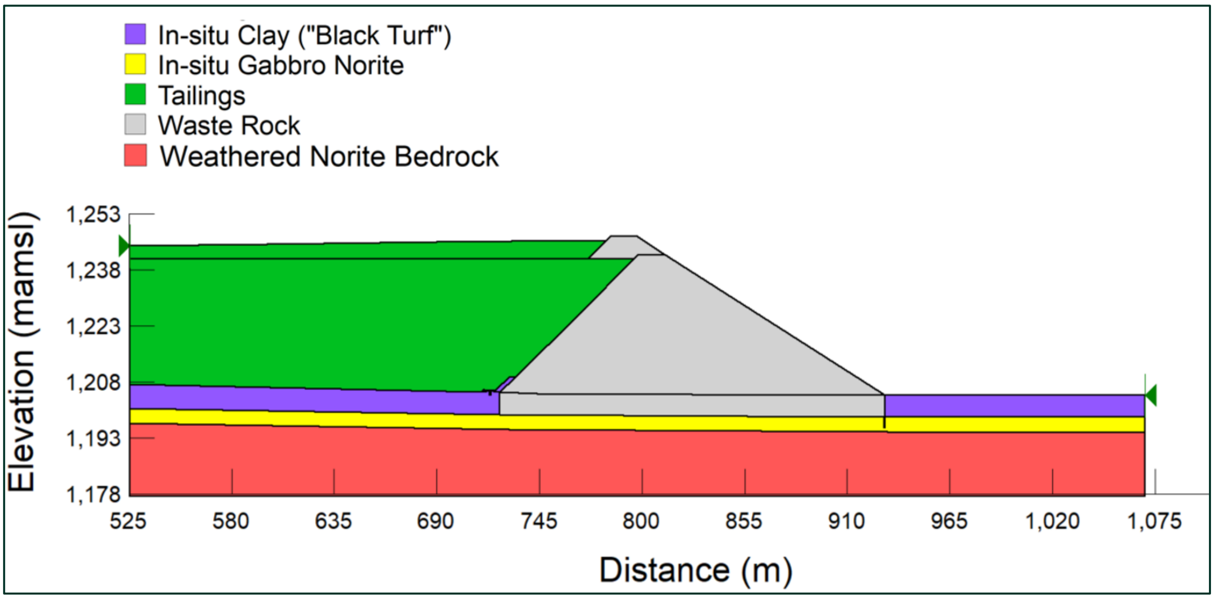



**Figure 9-9: TSF 2 Phase 1 North Embankment (section C-C)**

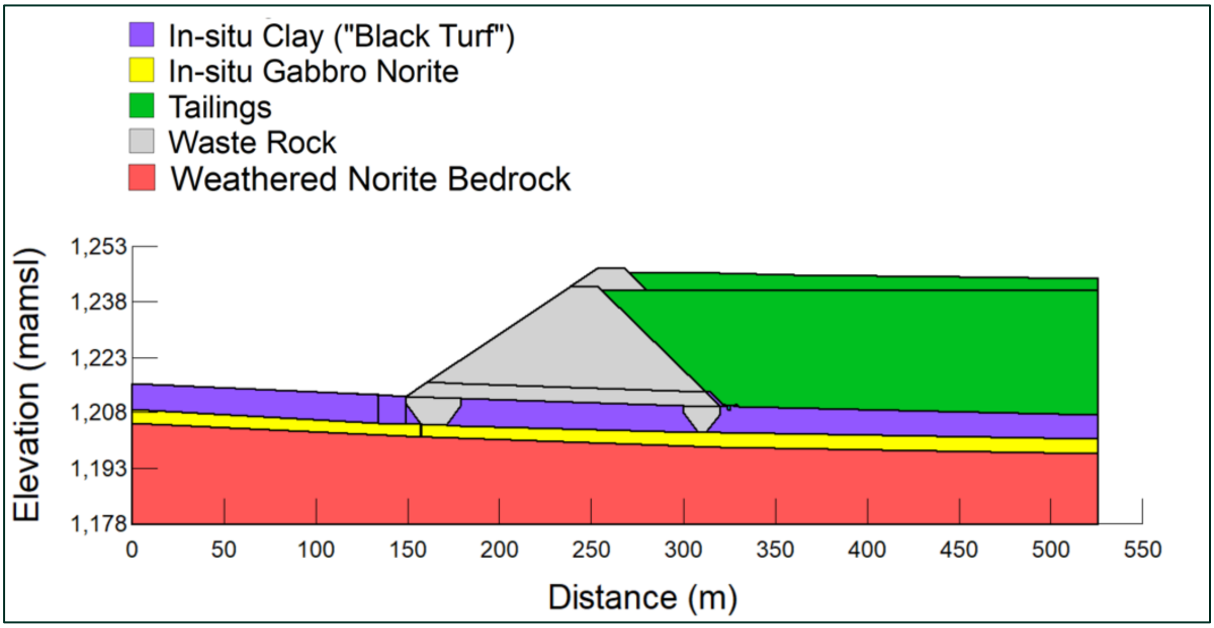



**Figure 9-10: TSF 2 Phase 1 South Embankment (section C-C)**

The model geometry for TSF 2 Phase 1 is listed in Table 9-11

**Table 9-11: TSF 2 Phase 1 model geometry**

| Wall section | Wall elevation (mamsl) | Maximum wall height (m) | Crest width (m) | Key width (m) | Upstream slope | Downstream slope |
|---|---|---|---|---|---|---|
| North | 1242 | 37.5 | 15 | None | 1V:12H | 1V:3H |
| South | 1242 | 31.5 | 15 | Upstream – 20 m<br>Downstream – 30 m | 1V:12H | 1V:3H |

### 9.6.2 Seepage analyses results

The behaviour of the phreatic surface with the variation in pool extents and drain functionality for the Northern and Southern embankments is illustrated in the figures below and listed in Table 9-12 for ease of reference.

**Table 9-12: TSF 2 Phase 1 seepage analyses results**

| Wall section | Reference | Pool condition | | Drains functionality | | Basin seepage (m3/s/m) |
|---|---|---|---|---|---|---|
| | | Normal operating | DWA | Active | Inactive | |
| North | Figure 9-11 | X | | X | | 1.3x10-8 |
| | Figure 9-12 | | X | X | | 1.5x10-8 |
| | Figure 9-13 | | X | | X | 2.4x10-8 |
| South | Figure 9-14 | X | | X | | 1.3x10-8 |
| | Figure 9-15 | | X | X | | 1.5x10-8 |
| | Figure 9-16 | | X | | X | 2.4x10-8 |

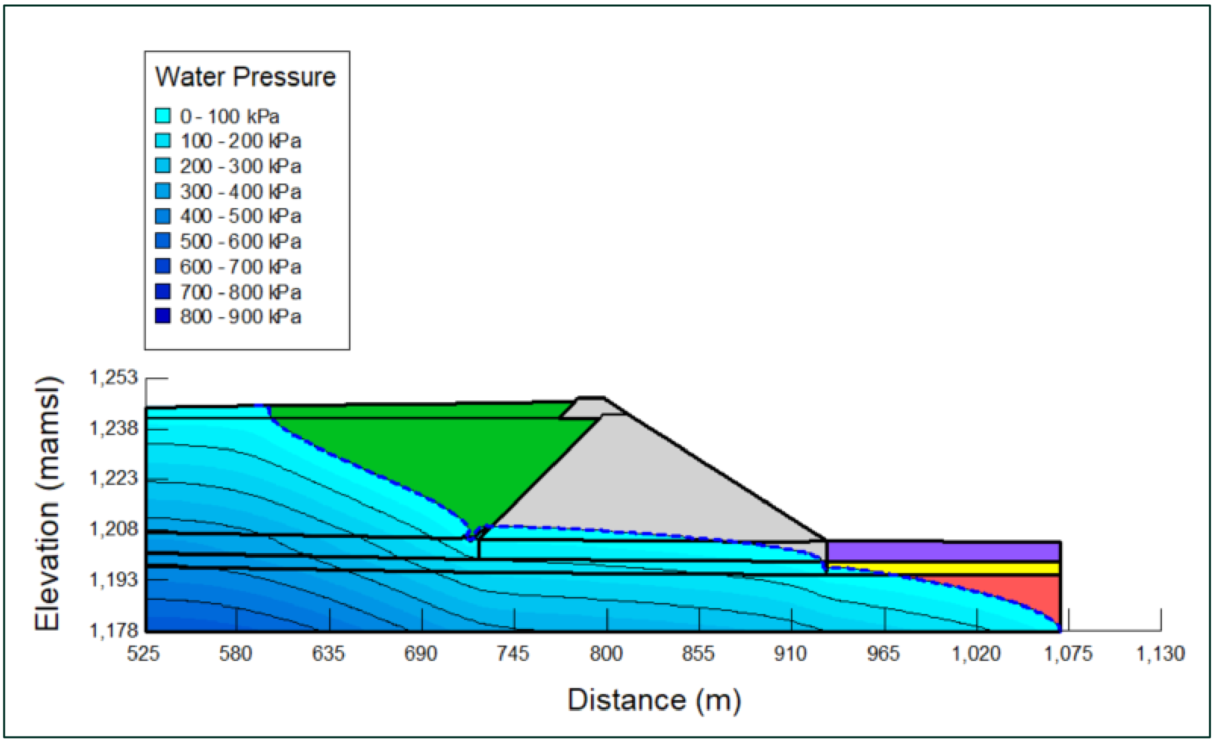



**Figure 9-11: TSF 2 Phase 1 North embankment phreatic surface behaviour during normal operating conditions**

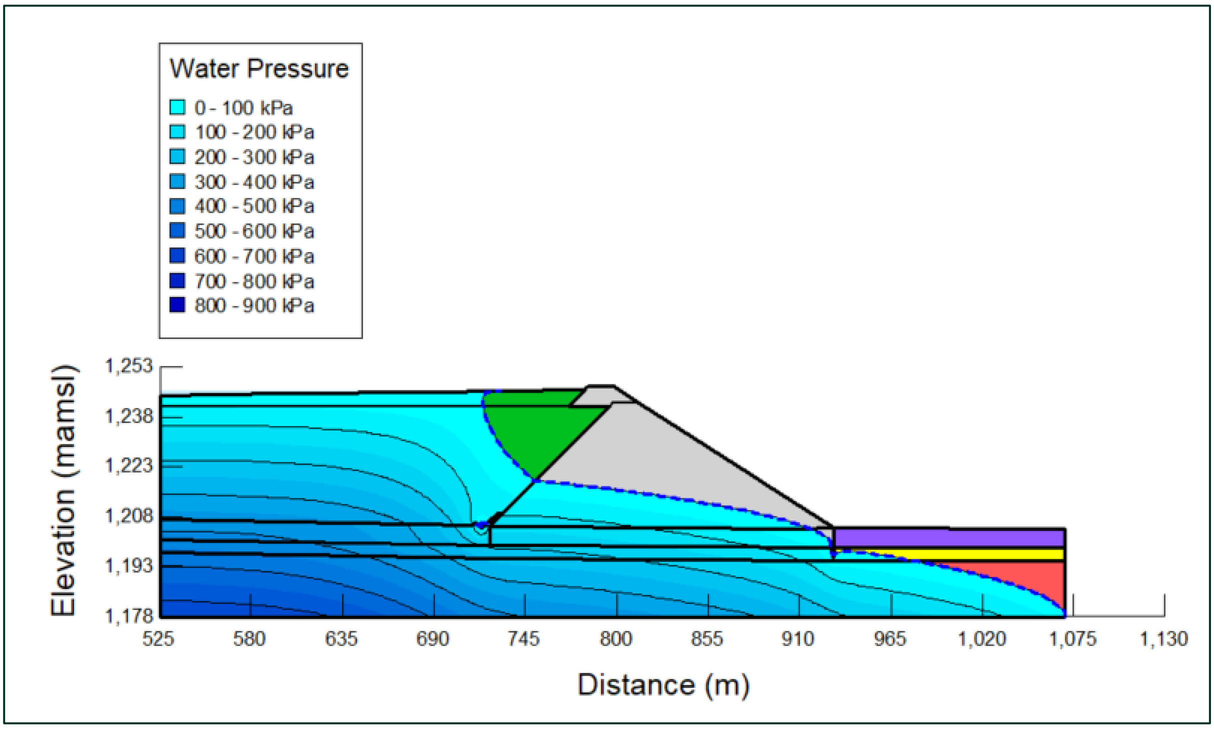



**Figure 9-12: TSF 2 Phase 1 North embankment phreatic surface behaviour with a pool situated 50 m from the crest and active drains**

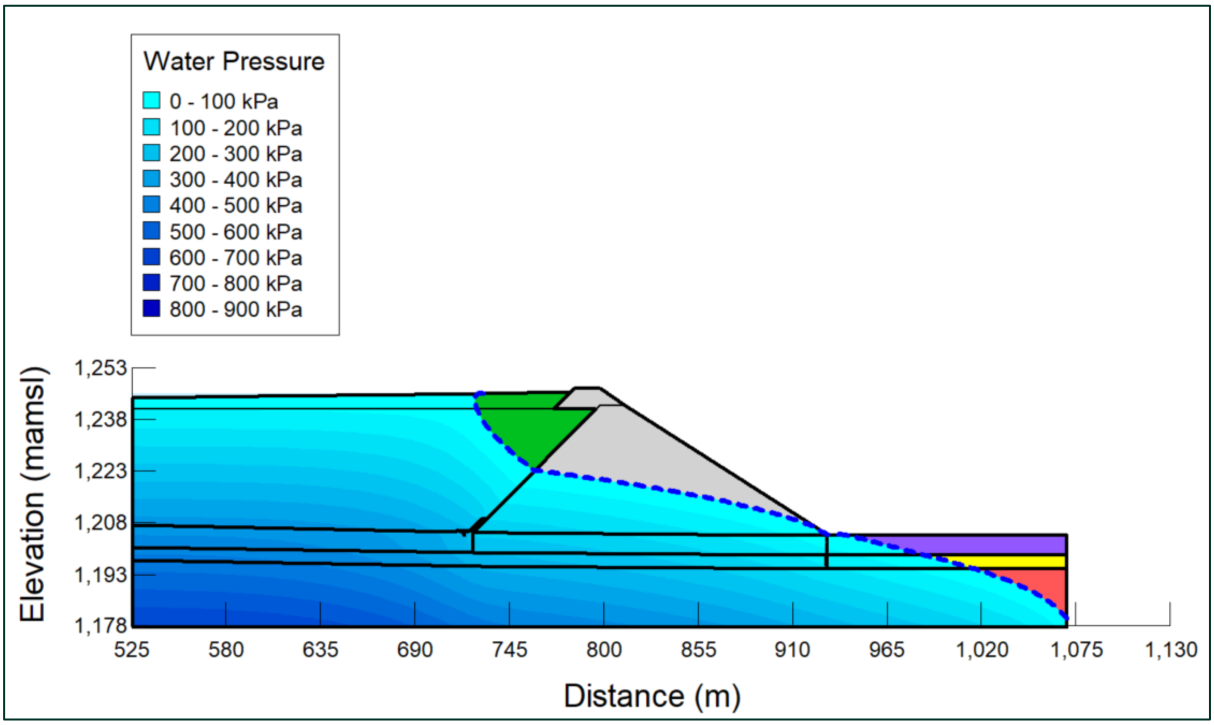



**Figure 9-13: TSF 2 Phase 1 North embankment phreatic surface behaviour with a pool situated 50 m from the crest and inactive drains**

Varying the pool extent and drain functionality yielded phreatic surfaces as illustrated in Figure 9-14, Figure 9-15, and Figure 9-16.

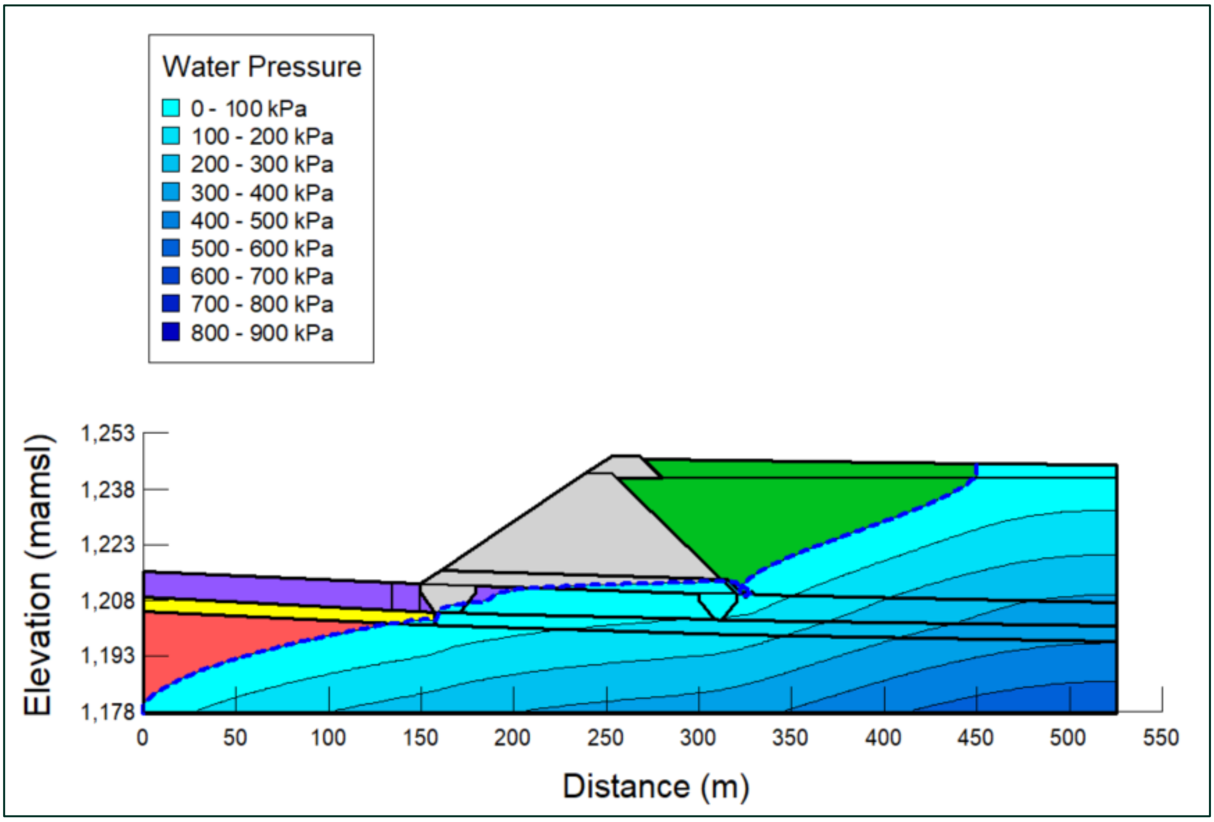



**Figure 9-14: TSF 2 Phase 1 South embankment phreatic surface behaviour during normal operating conditions**

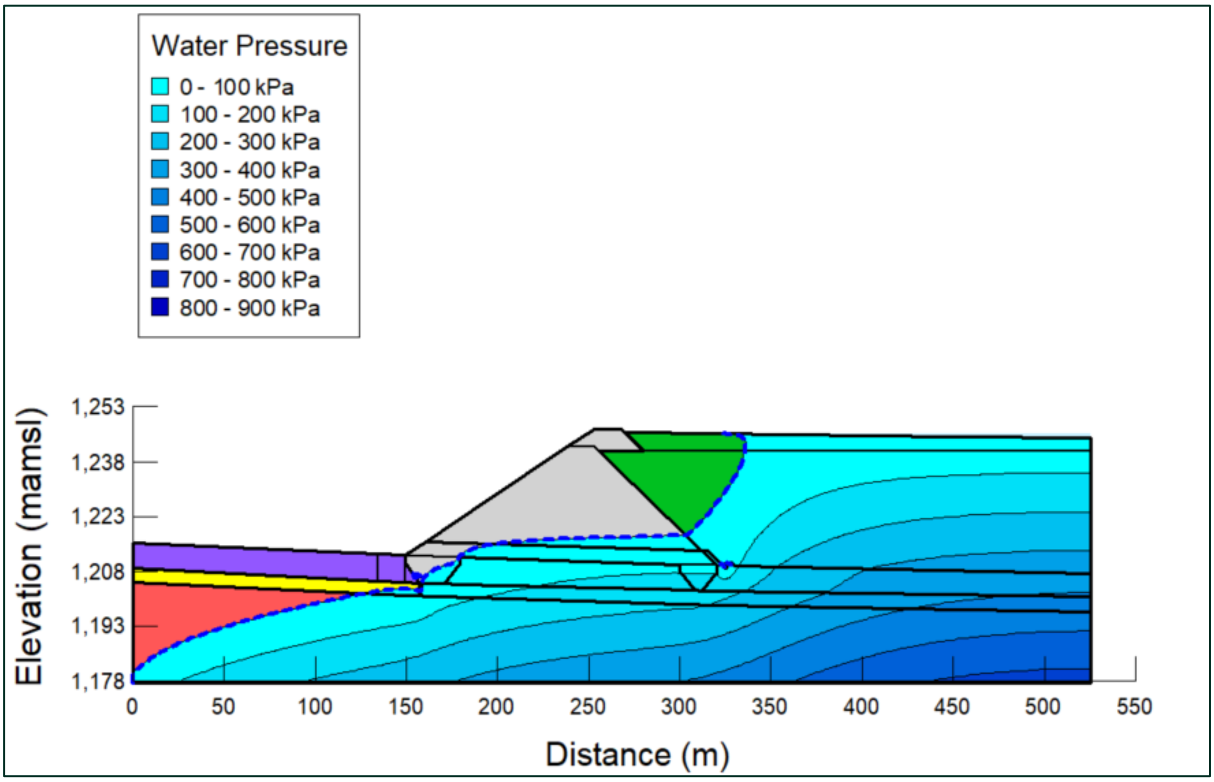



**Figure 9-15: TSF 2 Phase 1 South embankment phreatic surface behaviour with a pool situated 50 m from the crest and active drains**

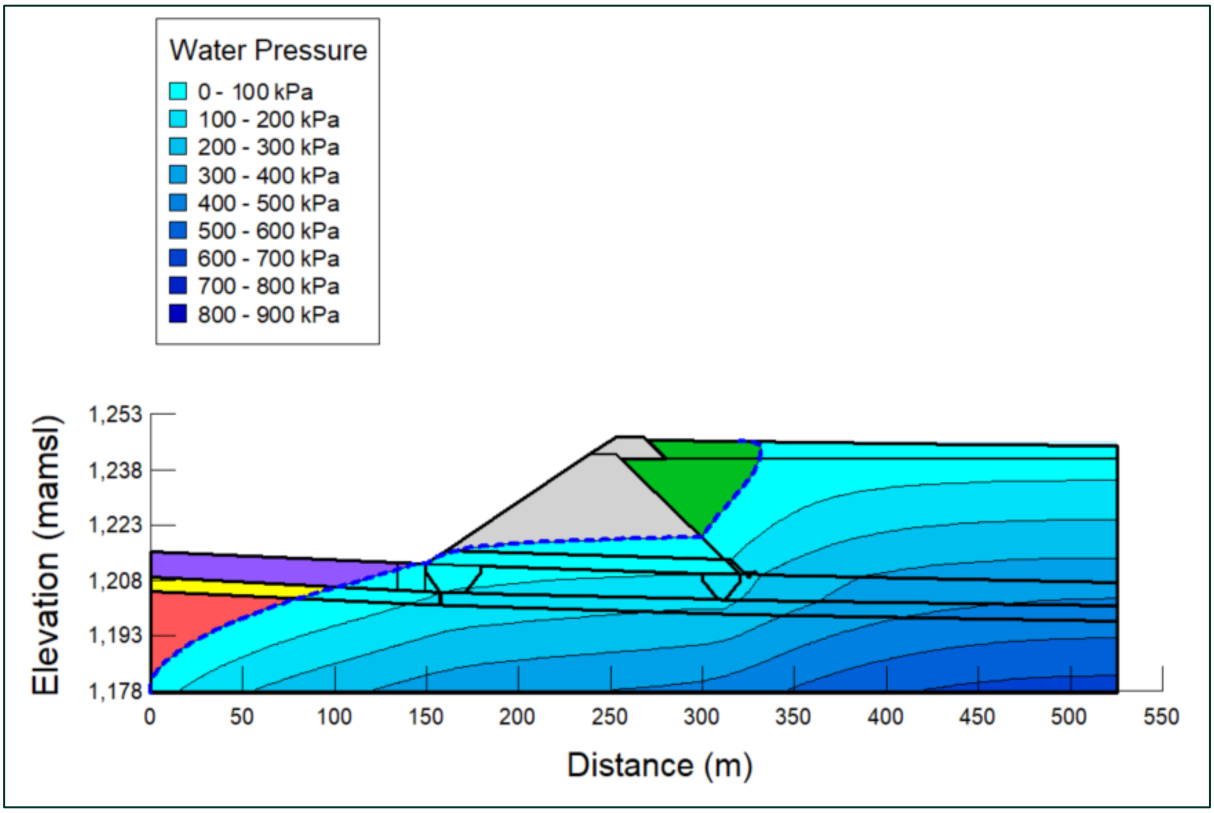



**Figure 9-16: TSF 2 Phase 1 South embankment phreatic surface behaviour with a pool situated 50 m from the crest and inactive drains**

From the above figures, an elevated phreatic surface is observed with an increase in pool extent and inactive drains resulting in an increase in seepage entering the basin and escaping the TSF footprint as depicted in Table 9-12.

### 9.6.3 Slope stability analyses results assuming drained clay parameters

The slope stability results for TSF 2 Phase 1 for each embankment section analysis are listed in Table 9-13 below. As previously indicated, due to all the clays being removed below the Northern embankment, the drained parameters of the clay were used. Slope stability analyses for the Southern embankment were undertaken using both the drained and undrained parameters of the clay. The slip surfaces that would result in a breach of tailings for flooded conditions during static and pseudo-static conditions for the Northern embankment are illustrated Figure 9-17 and Figure 9-18, respectively.

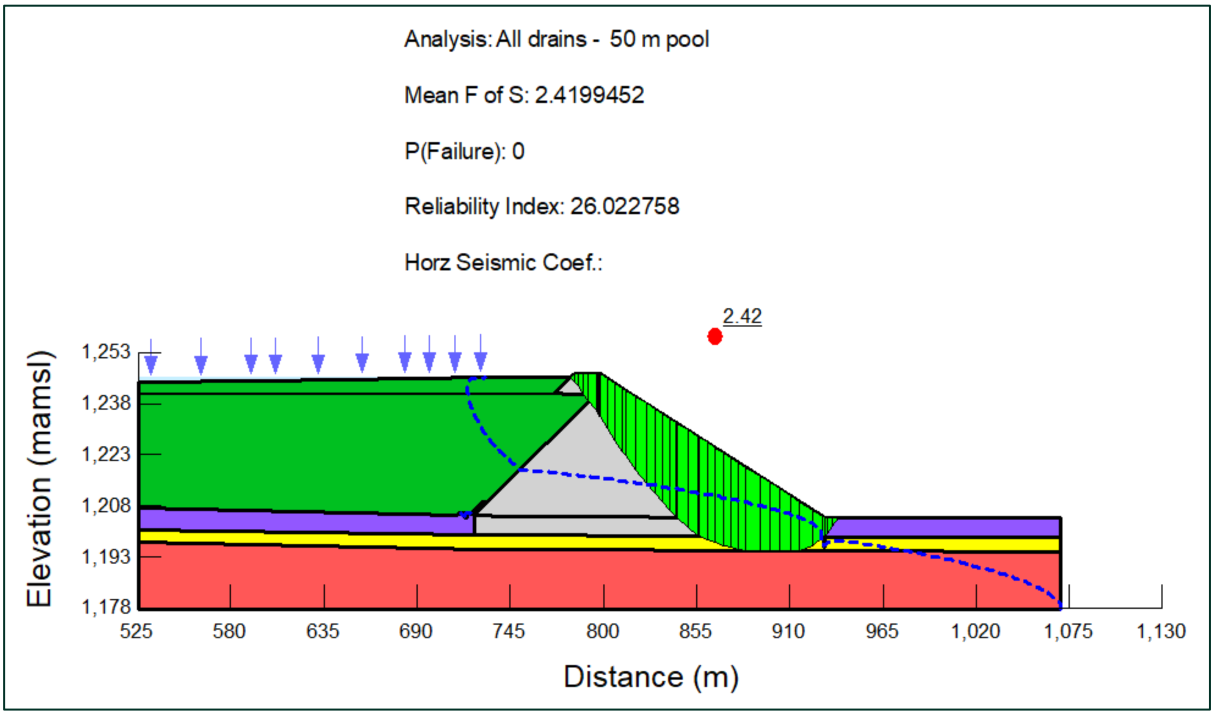



**Figure 9-17: TSF 2 Phase 1 Northern breached slip surface during flooded conditions assuming static conditions – active drains (FoS = 2.18)**

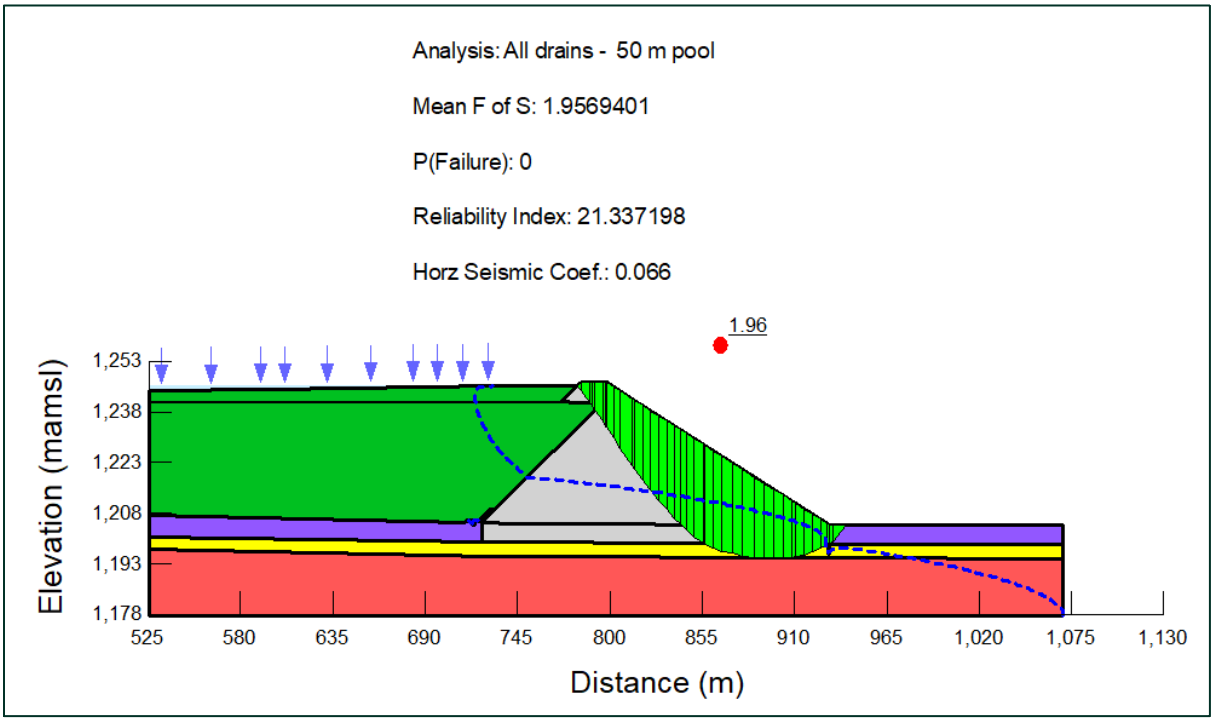



**Figure 9-18: TSF 2 Phase 1 Northern breached slip surface during flooded conditions assuming pseudo-static conditions – active drains (FoS = 1.96)**

The slip surfaces assuming flooded conditions for the Southern Embankment during static and pseudo-static conditions are illustrated in Figure 9-21 and Figure 9-22, respectively.

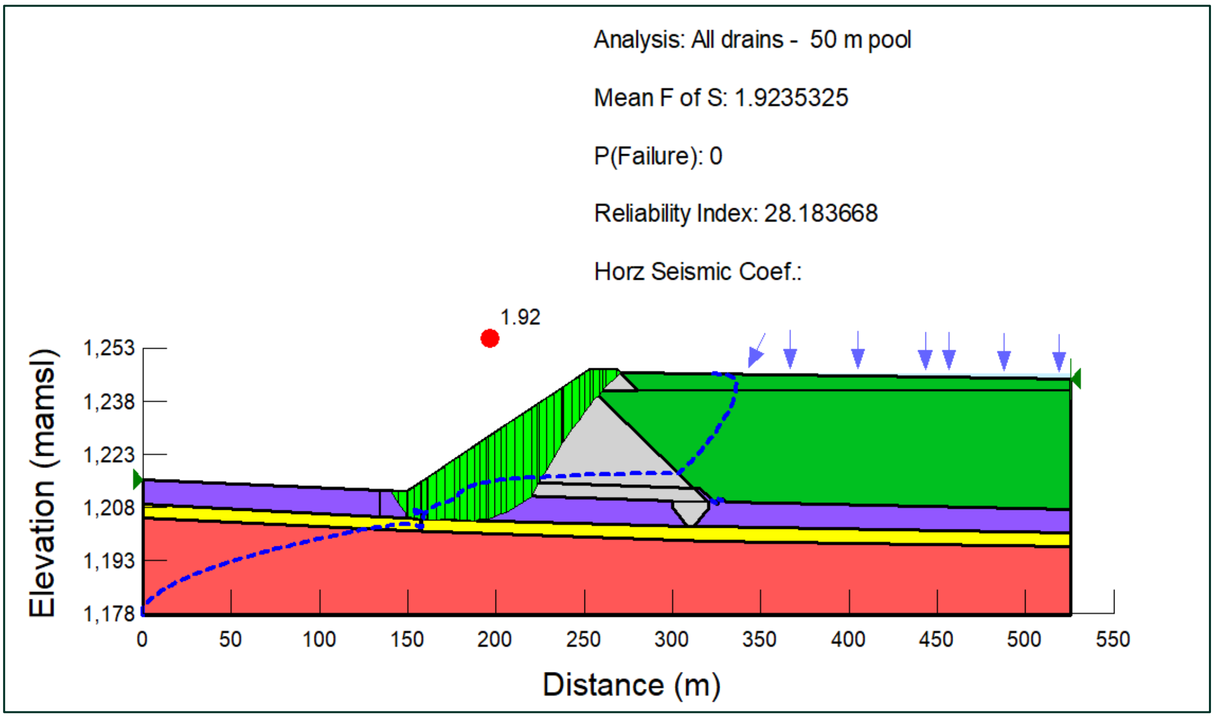



**Figure 9-19: TSF 2 Phase 1 Southern embankment breached slip surface during flooded conditions assuming static conditions – active drains (FoS = 1.92)**

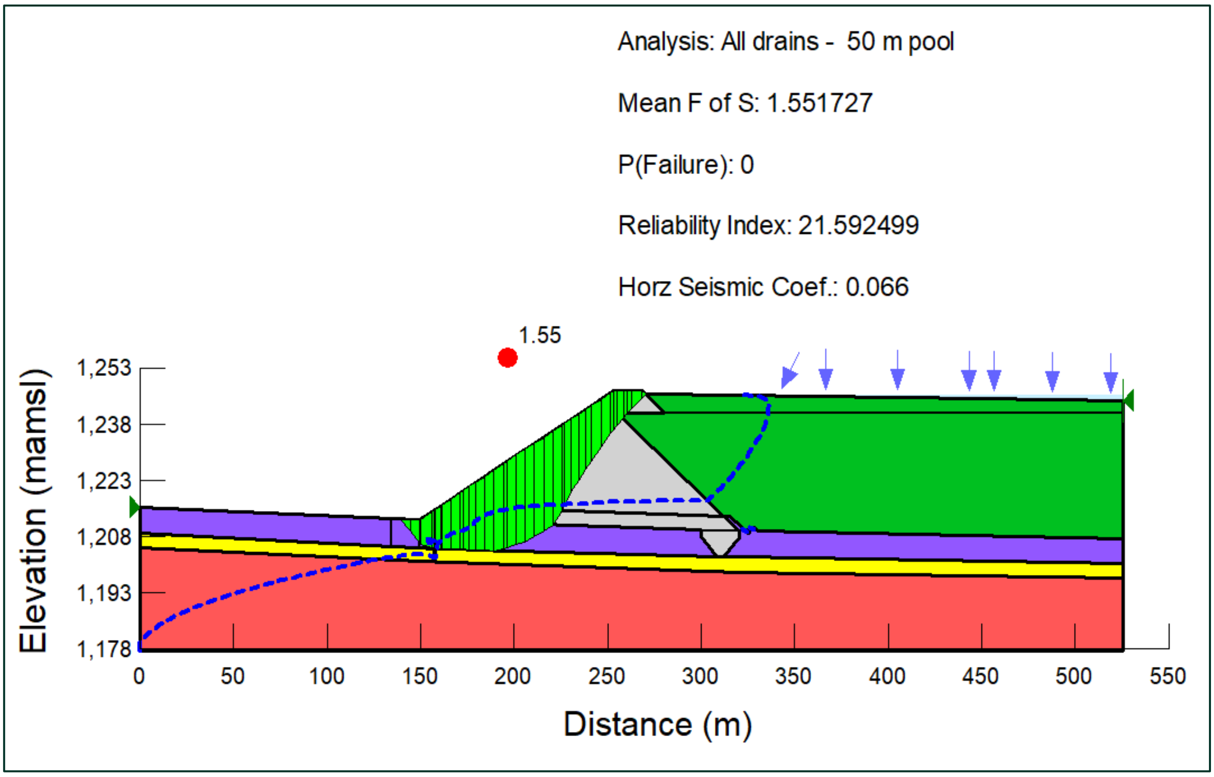



**Figure 9-20: TSF 2 Phase 1 Southern embankment breached slip surface during flooded conditions assuming static conditions – active drains (FoS = 1.55)**

Table 9-13 lists the factors of safety relating to the breached slip surfaces for the various scenarios analysed including the normal operating conditions.

**Table 9-13: TSF 2 Phase 1 drained Slope Stability Results**

| Reference in Appendix | Condition | | Pool | | Drains | | FoS | RI | PoF |
|---|---|---|---|---|---|---|---|---|---|
| | Static | Pseudo-static | Normal Operating | DWA | Active | Inactive | | | |
| North Embankment<br>Required FoS (static conditions) = 2 (Mining) - OK<br>Required FoS (pseudo-static conditions) = 1.5 (Mining) - OK | | | | | | | | | |
| Analyses: 18 | X | | X | | X | | 2.60* | 27.15 | 0 |
| Analyses: 20 | | X | X | | X | | 2.11* | 23.54 | 0 |
| Analyses: 22 | X | | | X | X | | 2.42* | 26.02 | 0 |
| Analyses: 24 | | X | | X | X | | 1.96* | 21.34 | 0 |
| Analyses: 26 | X | | | X | | X | 2.15* | 23.64 | 0 |
| Analyses: 28 | | X | | X | | X | 1.76* | 19.35 | 0 |
| South Embankment<br>Required FoS (static conditions) = 1.5 (Normal) - OK<br>Required FoS (pseudo-static conditions) = 1.1 (Normal) – OK | | | | | | | | | |
| Analyses: 34 | X | | X | | X | | 2.02* | 29.53 | 0 |
| Analyses: 36 | | X | X | | X | | 1.63* | 23.50 | 0 |
| Analyses: 38 | X | | | X | X | | 1.92* | 28.18 | 0 |
| Analyses: 40 | | X | | X | X | | 1.55* | 21.60 | 0 |
| Analyses: 42 | X | | | X | | X | 1.71* | 23.47 | 0 |
| Analyses: 44 | | X | | X | | X | 1.36* | 15.66 | 0 |

** = Factor of safety relating to a slip surface leading to a breach in tailings*

It is shown in Table 9-13 that the target factors of safety for each embankment section were achieved. Refer to Appendix H for all drained slope stability analysis results, critical and breached slip surfaces, for TSF 2 Phase 1.

### 9.6.4 Slope stability analyses results assuming undrained clay parameters

The undrained stability analyses for the Southern embankment were undertaken for an undrained shear strength ratio of 0.24 for static conditions and 0.19 for pseudo-static conditions (80% of the undrained shear strength ratio) which yielded factors of safety as listed in Table 9-14. Figure 9-21 and Figure 9-22 illustrate the breached slip surfaces assuming undrained clay parameters for the Southern embankment during static and pseudo-static conditions, respectively.

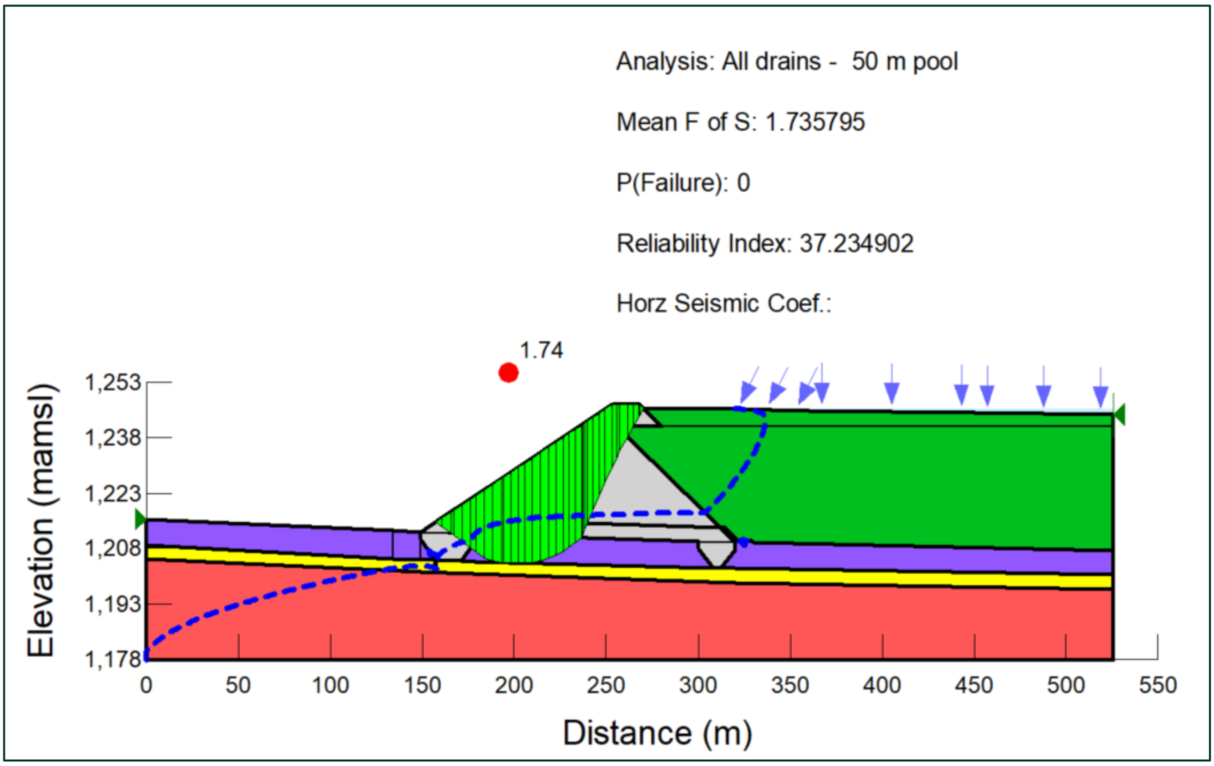



**Figure 9-21: TSF 2 Phase 1 Southern embankment breached slip surface during flooded conditions assuming static conditions – active drains and undrained clay parameters (FoS = 1.74)**

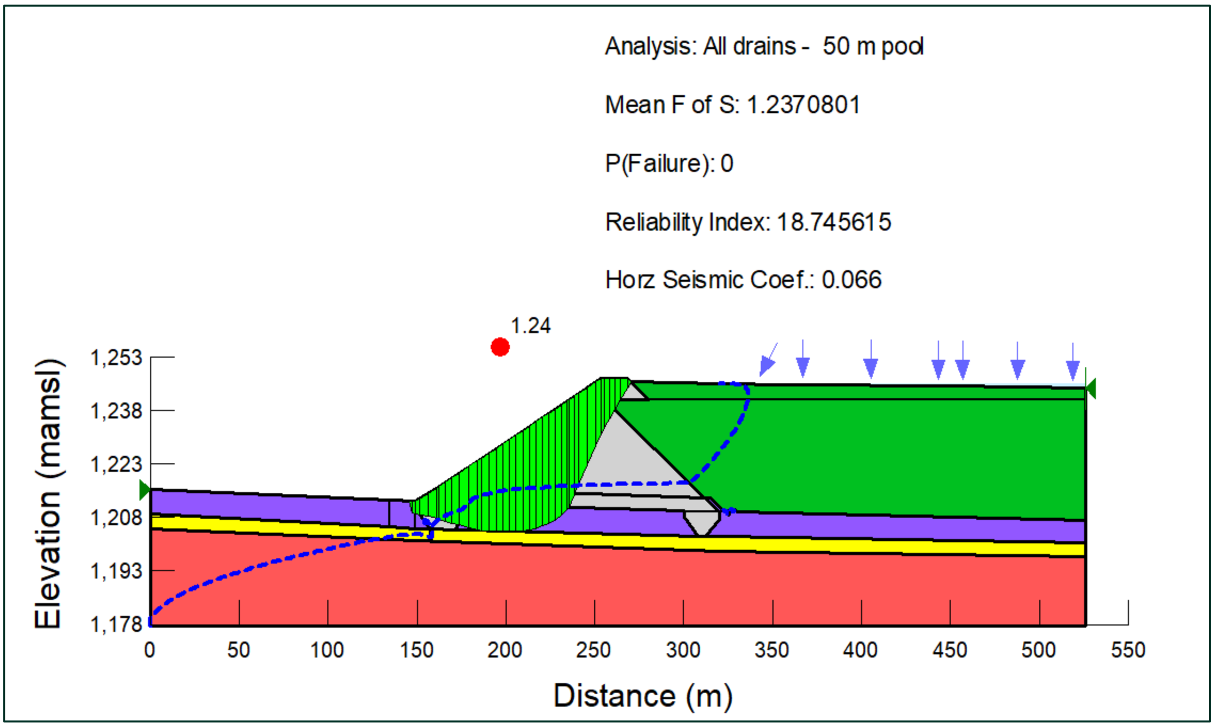



**Figure 9-22: TSF 2 Phase 1 Southern embankment breached slip surface during flooded conditions assuming pseudo-static conditions – active drains and undrained clay parameters (FoS = 1.24)**

Table 9-14 lists the undrained slope stability results assuming undrained clay parameters for the various scenarios analysed.

**Table 9-14: TSF 2 Phase 1 undrained Slope Stability Results**

| Reference in Appendix | Condition | | Pool | | Drains | | FoS | RI | PoF |
|---|---|---|---|---|---|---|---|---|---|
| | Static | Pseudo-static | Normal Operating | DWA | Active | Inactive | | | |
| South Embankment<br>USR = 0.24 (0.19 for pseudo-static conditions)<br>Required undrained FoS (static conditions) = 1.5 (Normal) - OK<br>Required undrained FoS (pseudo-static conditions) = 1.1 (Normal) - OK | | | | | | | | | |
| Analyses: 50 | X | | X | | X | | 1.78* | 37.53 | 0 |
| Analyses: 52 | | X | X | | X | | 1.29* | 25.17 | 0 |
| Analyses: 54 | X | | | X | X | | 1.74* | 37.23 | 0 |
| Analyses: 56 | | X | | X | X | | 1.24* | 18.75 | 0 |
| Analyses: 58 | X | | | X | | X | 1.34* | 17.34 | 0 |
| Analyses: 60 | | X | | X | | X | 1.16* | 13.25 | 0 |

** = Factor of safety relating to a slip surface leading to a breach in tailings*

The results listed in Table 9-14 indicate that the target factors of safety for the Southern embankment are achieved. Refer to Appendix H for all undrained slope stability analyses results for TSF 2 Phase 1 along the Southern embankment section.

### 9.6.5 Deformation analyses

The post-seismic deformation analyses yielded results that indicated an estimated crest settlement of 8.702 cm.

## 9.7 TSF 2 Phase 2

### 9.7.1 Model set-up

The material model indicating the foundation and structural materials are illustrated in Figure 9-23, Figure 9-24, and Figure 9-25 for the Northern, Eastern and Southern embankments, respectively. Clays were only partially removed beneath each embankment with waste rock keys constructed below the upstream and downstream toe.

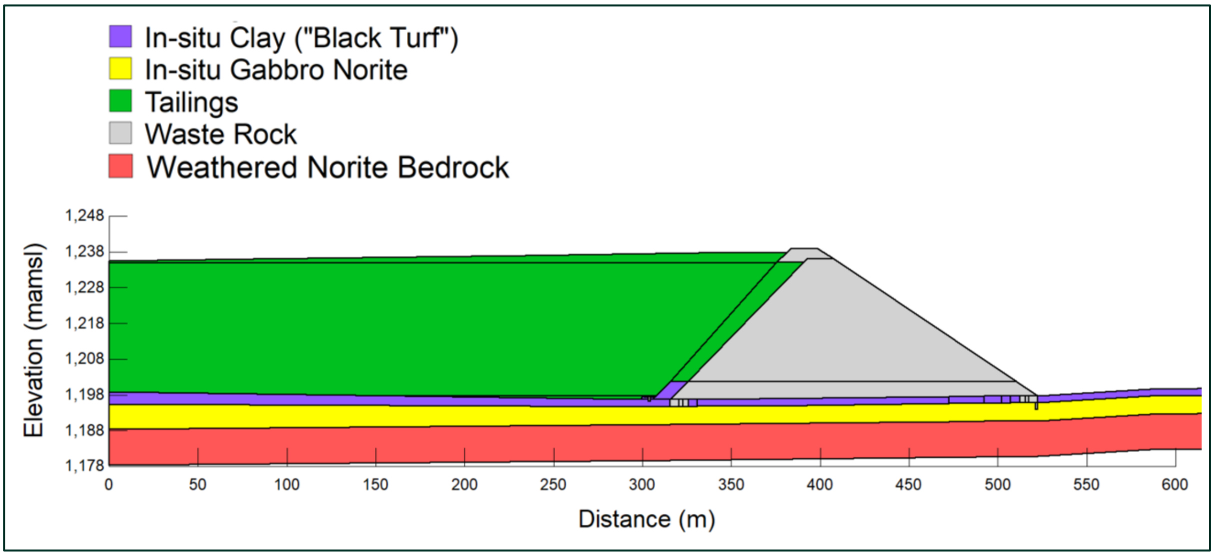



**Figure 9-23: TSF 2 Phase 2 North Embankment (section D-D)**

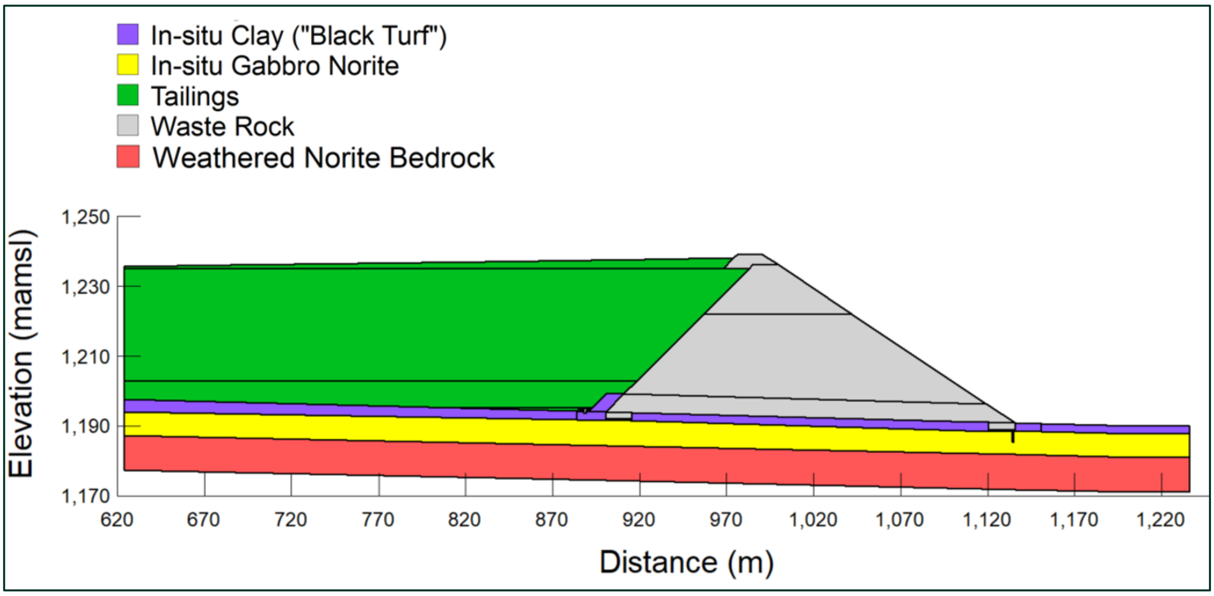



**Figure 9-24: TSF 2 Phase 2 East Embankment (section E-E)**

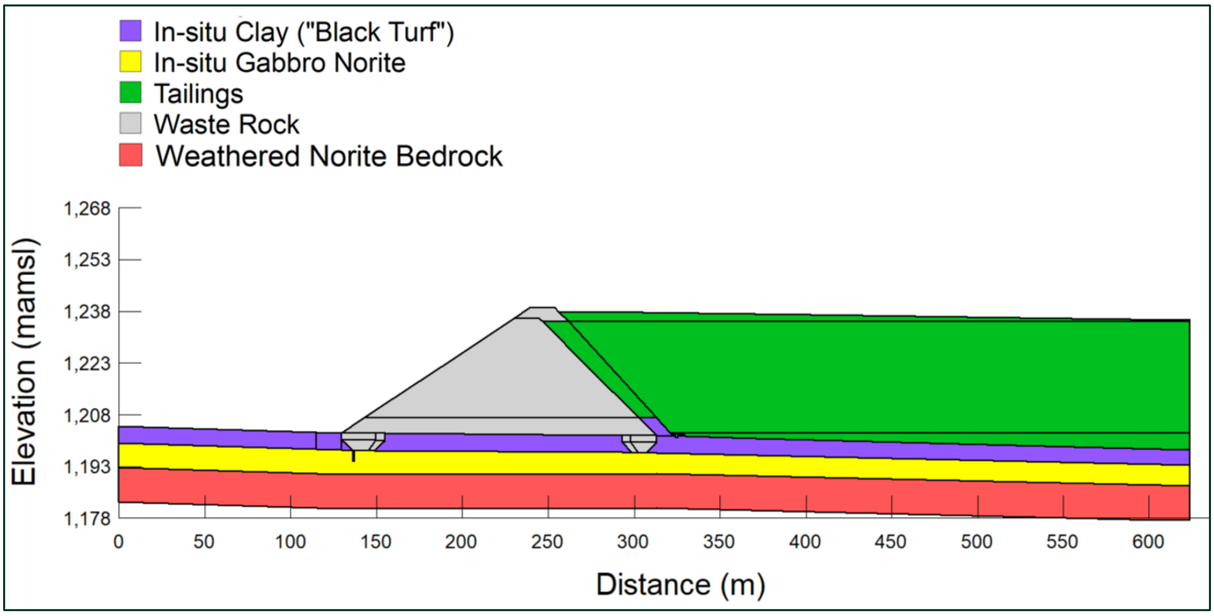



**Figure 9-25: TSF 2 Phase 2 South Embankment (section E-E)**

The TSF model geometry parameters for each wall section are listed in Table 9-15.

**Table 9-15: TSF 2 Phase 2 model geometry**

| Wall section | Wall elevation (mamsl) | Maximum wall height (m) | Crest width (m) | Key width (m) | Upstream slope | Downstream slope |
|---|---|---|---|---|---|---|
| North | 1236 | 38 | 15 | Upstream – 10 m Downstream – 10 m | 1V:2H | 1V:3H |
| East | 1236 | 45 | 15 | Upstream – 15 m Downstream – 15 m | 1V:2H | 1V:3H |
| South | 1236 | 33 | 15 | Upstream – 20 m | 1V:2H | 1V:3H |

| Wall section | Wall elevation (mamsl) | Maximum wall height (m) | Crest width (m) | Key width (m) | Upstream slope | Downstream slope |
|---|---|---|---|---|---|---|
| | | | | Downstream – 25 m | | |

### 9.7.2 Seepage analyses results

The behaviour of the phreatic surface with a variation in pool conditions and drain functionality for the Northern, Eastern, and Southern embankments are illustrated in the figures below and listed in Table 9-16 for ease of reference.

**Table 9-16: TSF 2 Phase 2 seepage analyses results**

| Wall section | Reference | Pool condition | | Drains functionality | | Basin seepage (m3/s/m) |
|---|---|---|---|---|---|---|
| | | Normal operating | DWA | Active | Inactive | |
| North | Figure 9-26 | X | | X | | 5.1x10-9 |
| | Figure 9-27 | | X | X | | 6.0x10-9 |
| | Figure 9-28 | | X | | X | 8.5x10-9 |
| East | Figure 9-29 | X | | X | | 5.1x10-9 |
| | Figure 9-30 | | X | X | | 6.0x10-9 |
| | Figure 9-31 | | X | | X | 8.5x10-9 |
| South | Figure 9-32 | X | | X | | 5.1x10-9 |
| | Figure 9-33 | | X | X | | 6.0x10-9 |
| | Figure 9-34 | | X | | X | 8.5x10-9 |

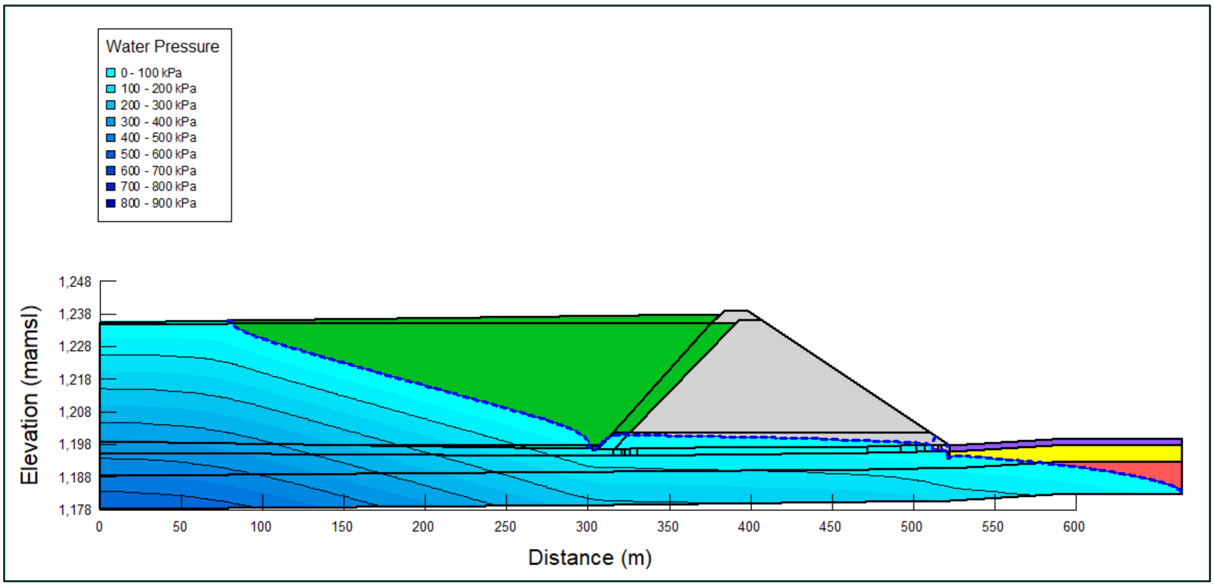



**Figure 9-26: TSF 2 Phase 2 North embankment phreatic surface behaviour during normal operating conditions**

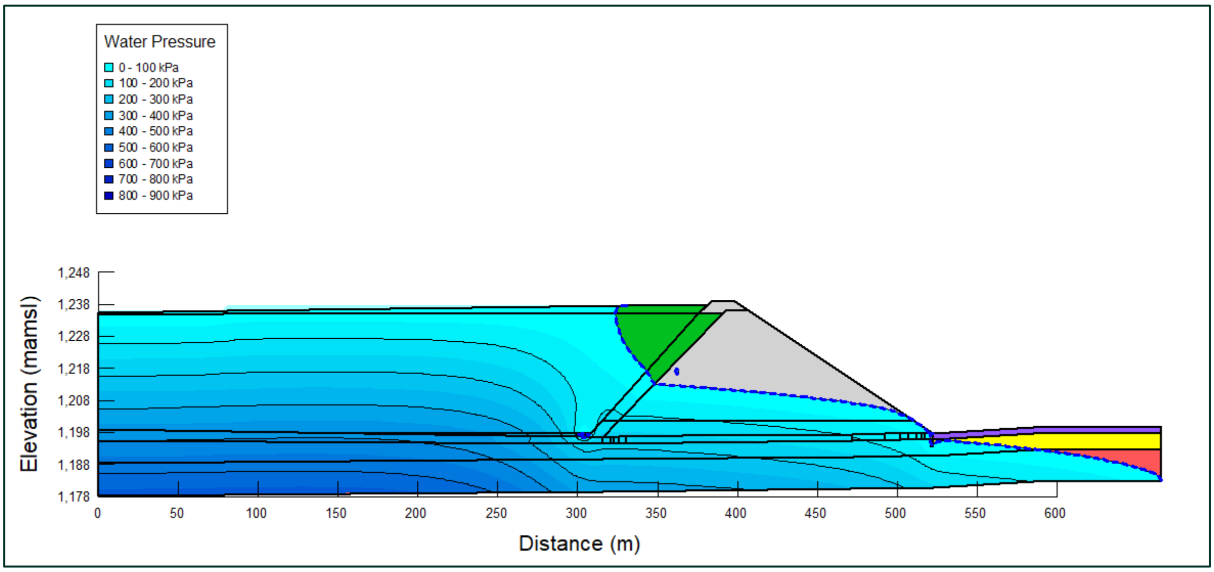



**Figure 9-27: TSF 2 Phase 2 North embankment phreatic surface behaviour with a pool situated 50 m from the crest and active drains**

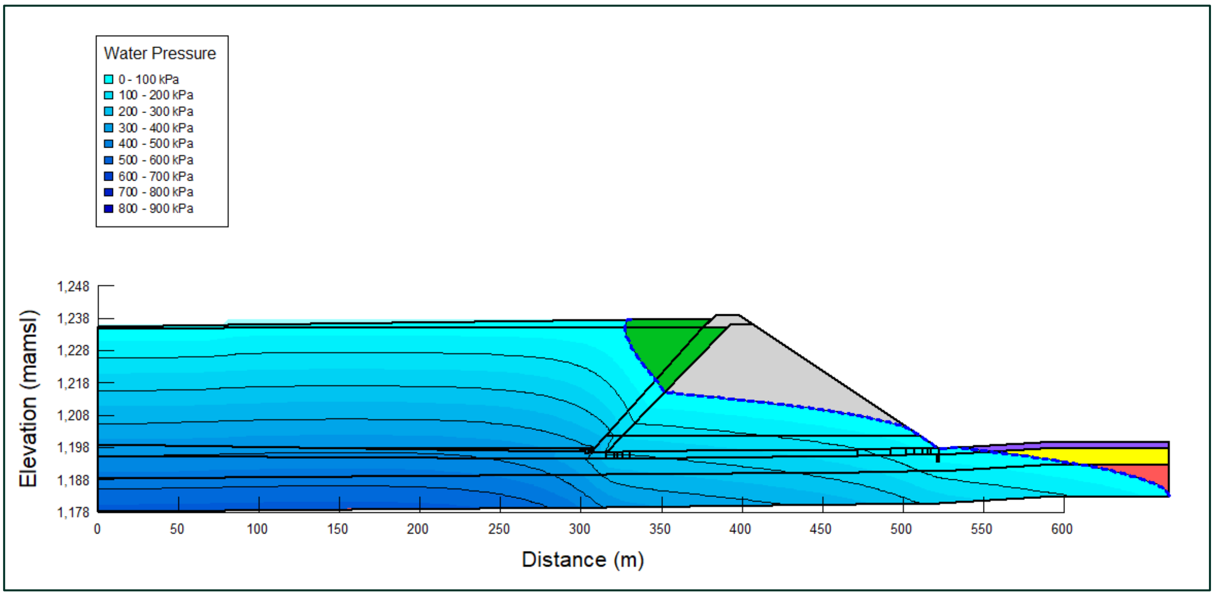



**Figure 9-28: TSF 2 Phase 2 North embankment phreatic surface behaviour with a pool situated 50 m from the crest and inactive drains**

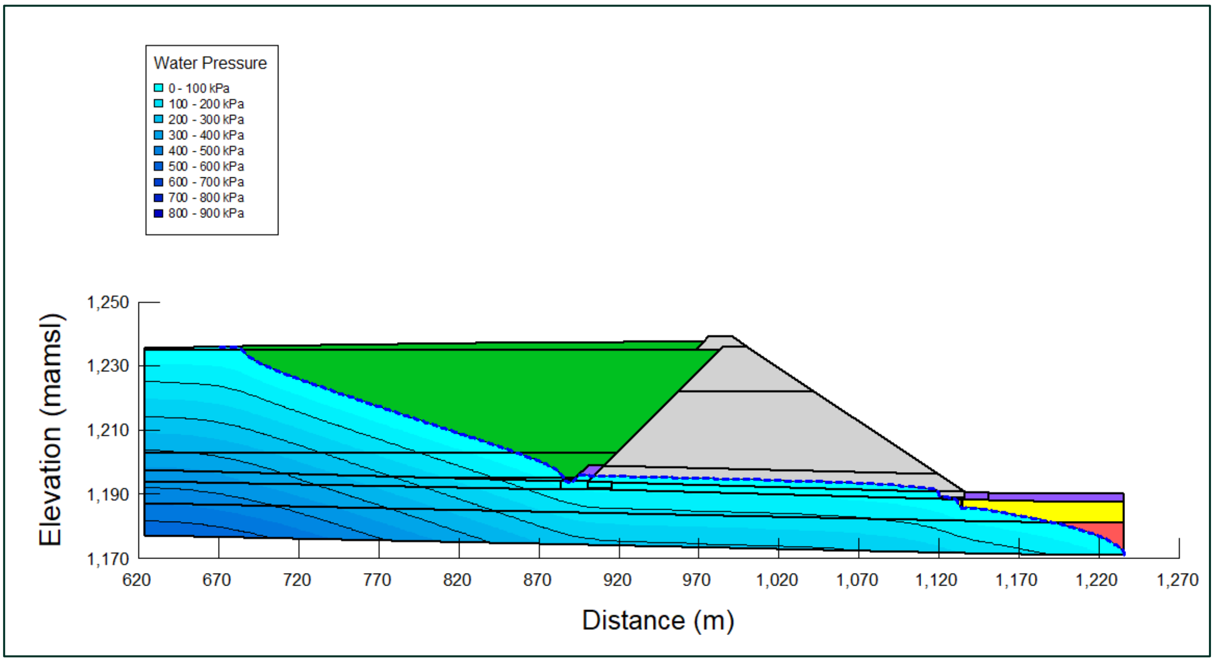



**Figure 9-29: TSF 2 Phase 2 East embankment phreatic surface behaviour during normal operating conditions**

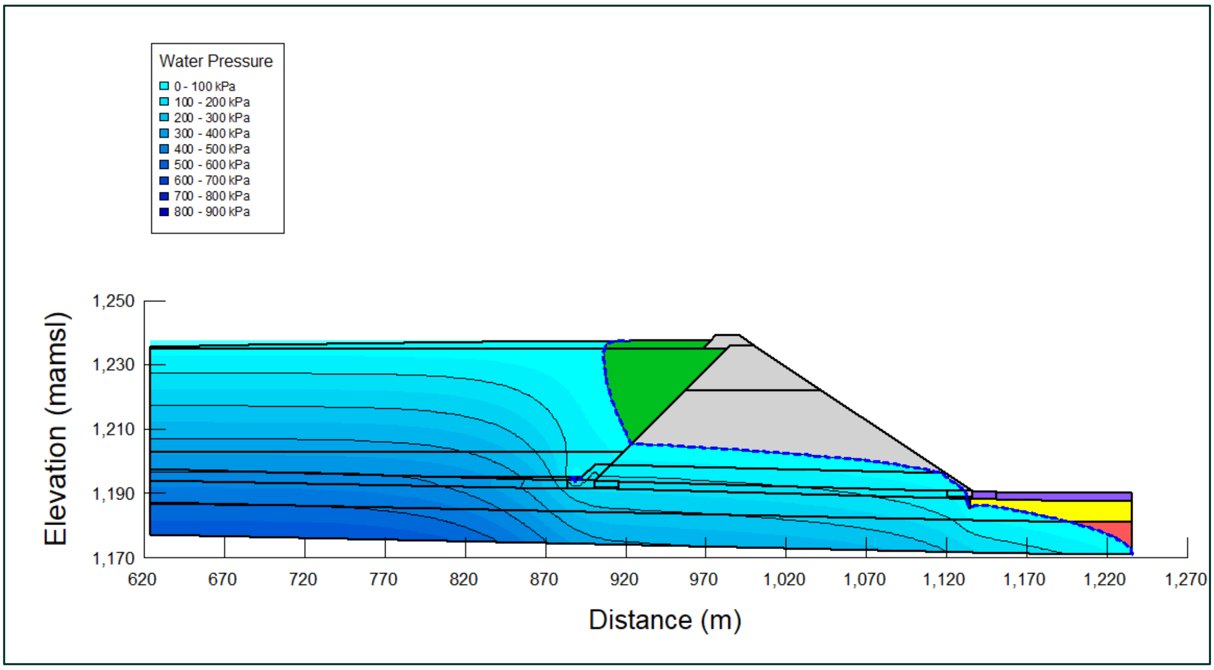



**Figure 9-30: TSF 2 Phase 2 East embankment phreatic surface behaviour with a pool situated 50 m from the crest and active drains**

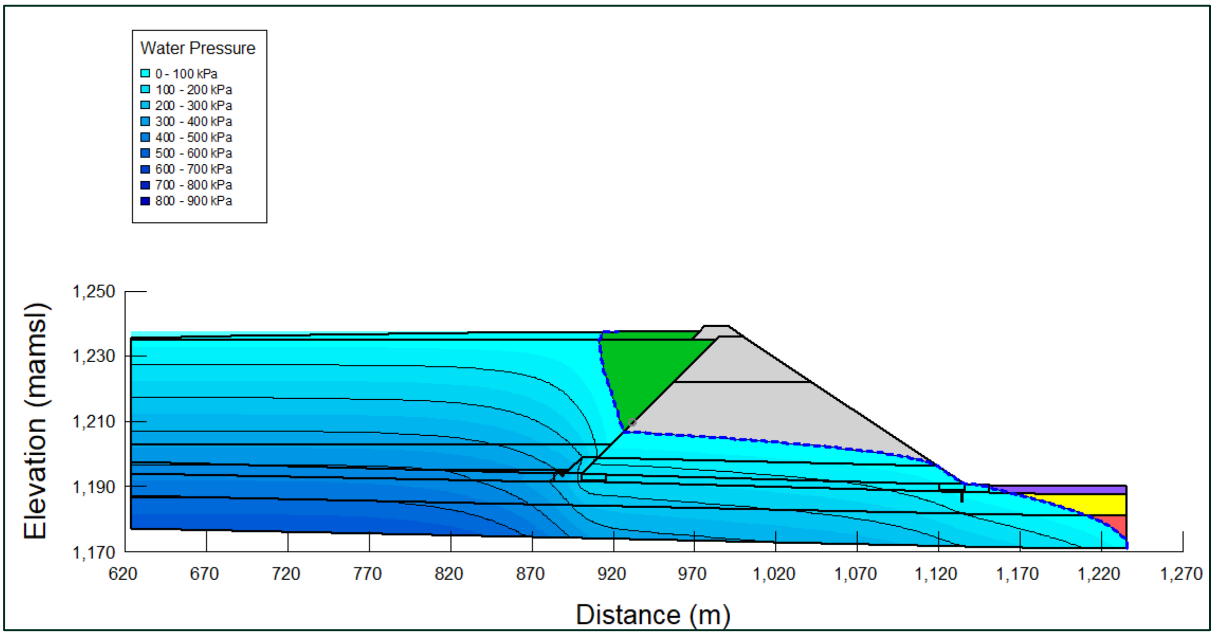



**Figure 9-31: TSF 2 Phase 2 East embankment phreatic surface behaviour with a pool situated 50 m from the crest and inactive drains**

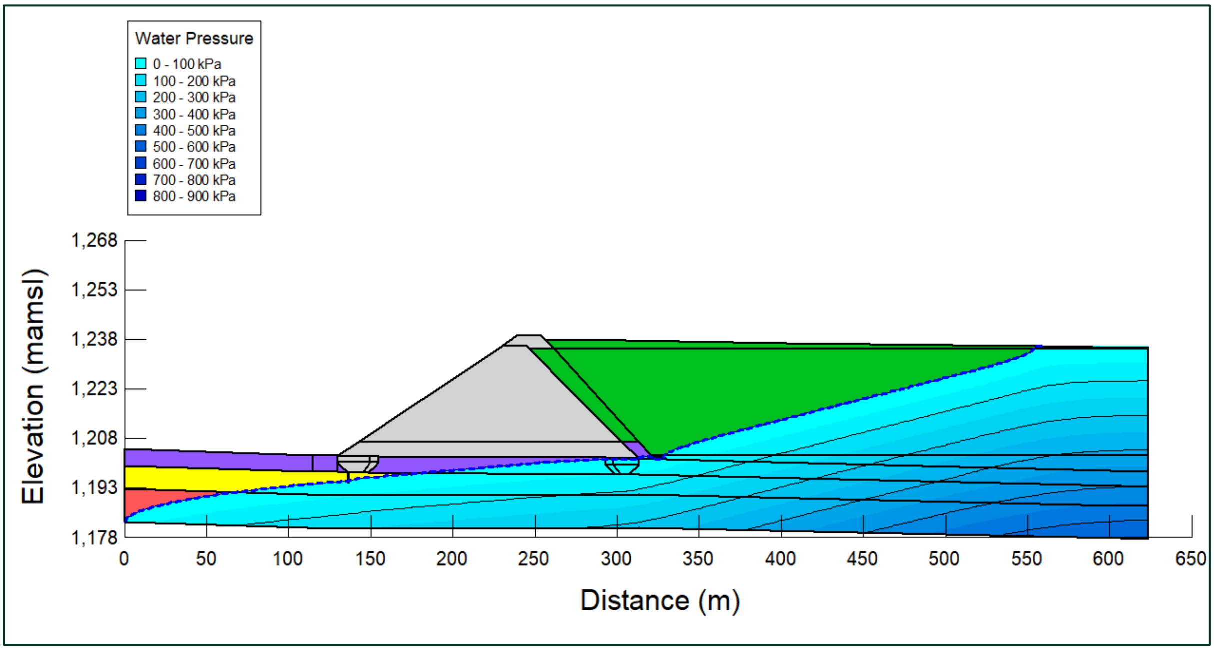



**Figure 9-32: TSF 2 Phase 2 South embankment phreatic surface behaviour during normal operating conditions**

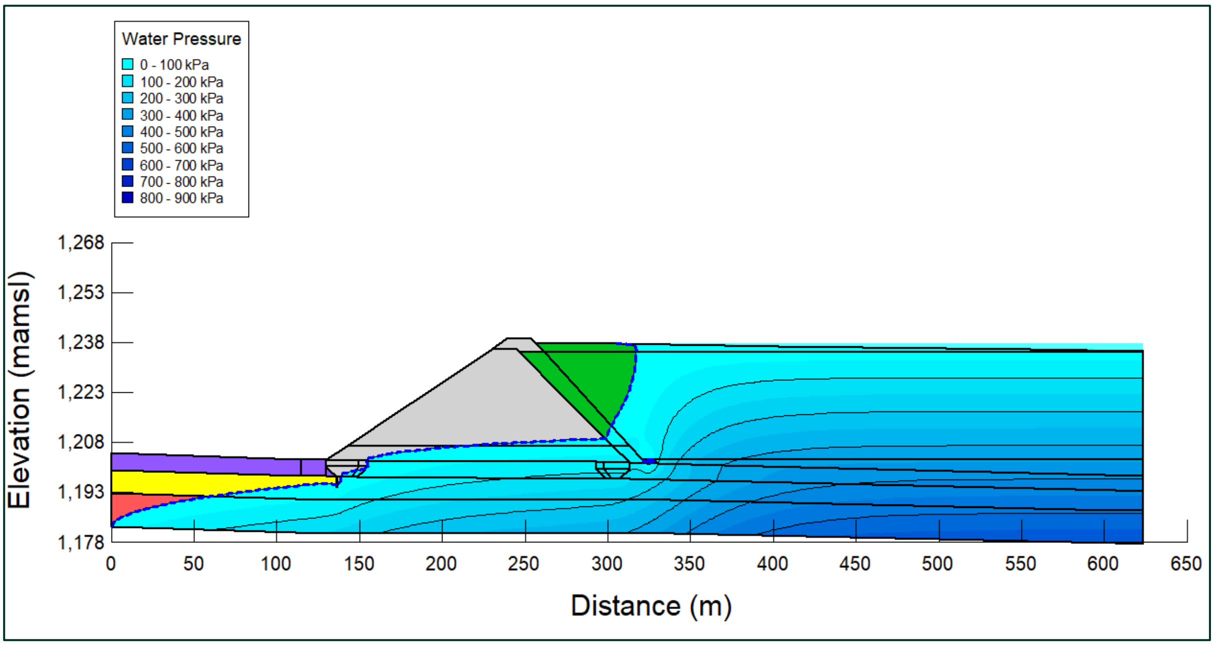



**Figure 9-33: TSF 2 Phase 2 South embankment phreatic surface behaviour with a pool situated 50 m from the crest and active drains**

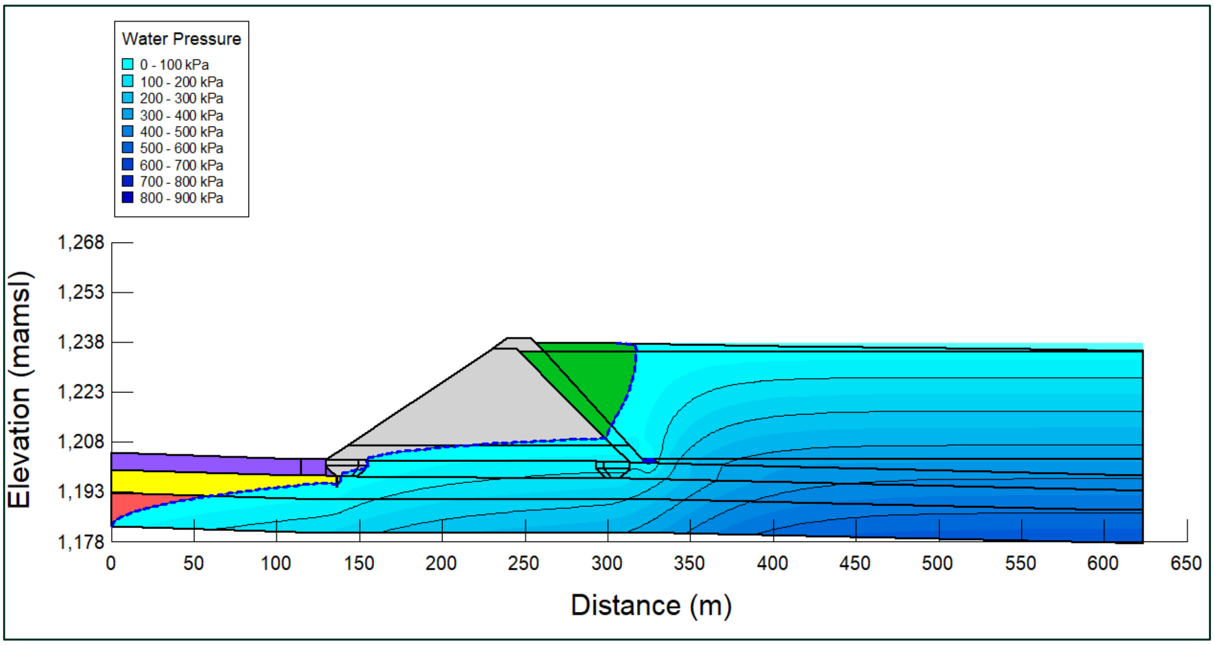



**Figure 9-34: TSF 2 Phase 2 South embankment phreatic surface behaviour with a pool situated 50 m from the crest and inactive drains**

From the above figures, an elevated phreatic surface is observed with an increase in pool extent and inactive drains resulting in an increase in seepage entering the basin and escaping the TSF footprint as depicted in Table 9-16.

### 9.7.3 Slope stability analyses results assuming drained clay parameters

The slope stability results for TSF 2 Phase 2 for each embankment section analysed are listed in Table 9-17 below. The slope stability analyses were conducted assuming drained clay behaviour for sections where clay was only partially removed below the embankments as is the case for the Northern, Eastern, and Southern embankments. The figures below illustrate the breached slip surfaces for the Northern, Southern, and Eastern embankments during static and pseudo-static conditions and assuming drained clay parameters.

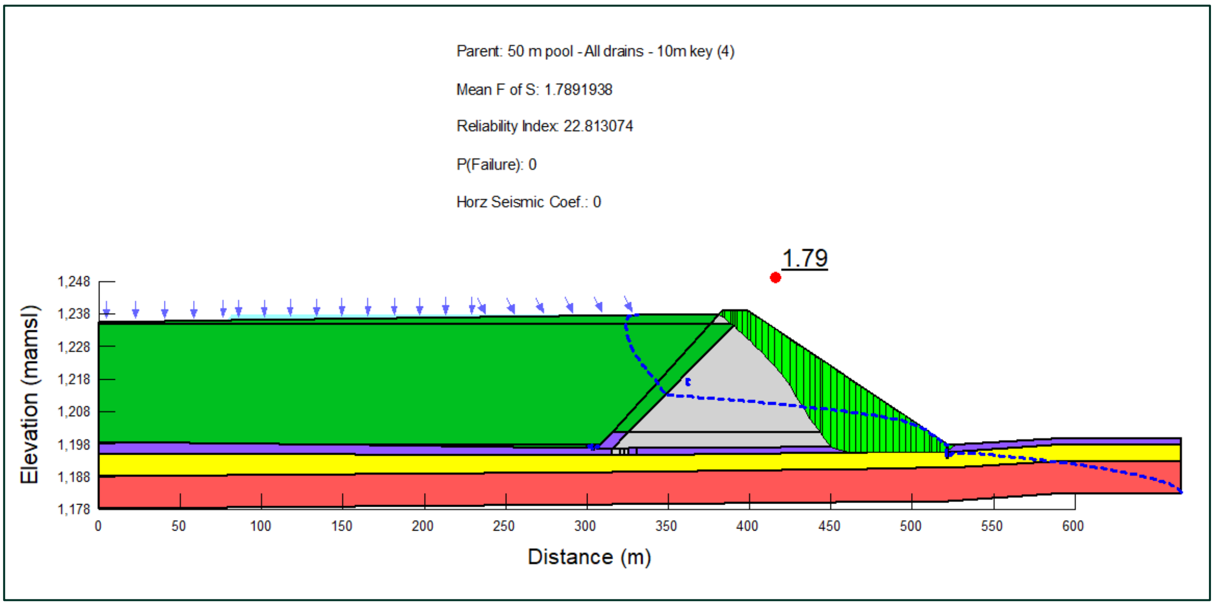



**Figure 9-35: TSF 2 Phase 2 Northern embankment breached slip surface during flooded conditions assuming static conditions – active drains (FoS = 1.79)**

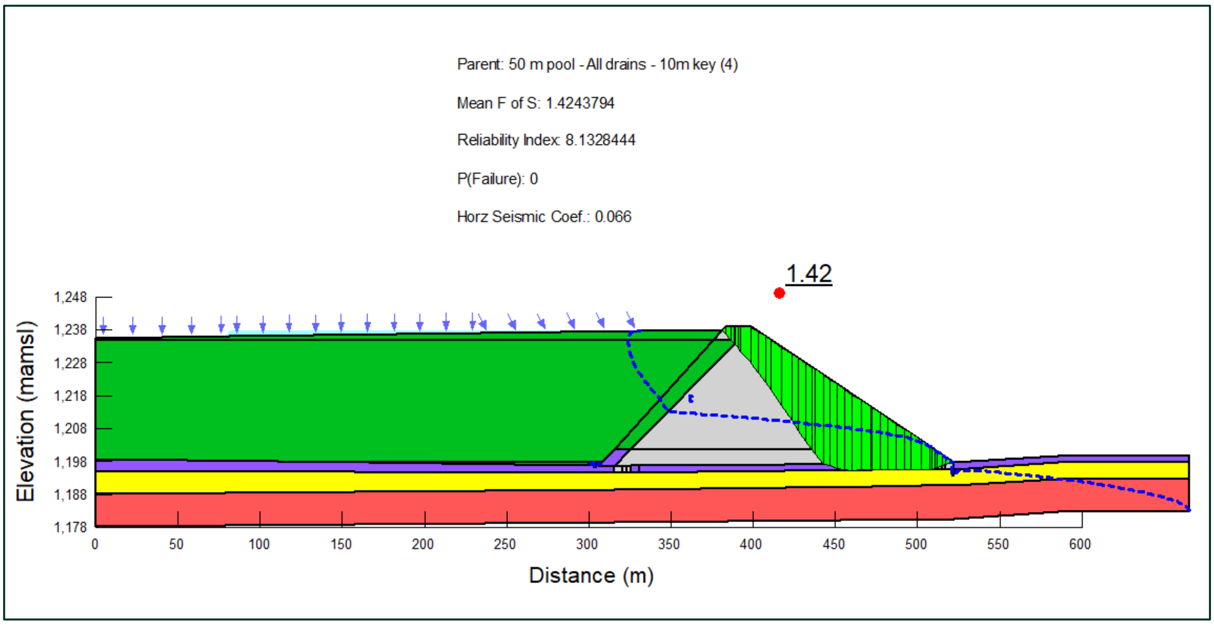



**Figure 9-36: TSF 2 Phase 2 Northern embankment breached slip surface during flooded conditions assuming pseudo-static conditions – active drains (FoS = 1.42)**

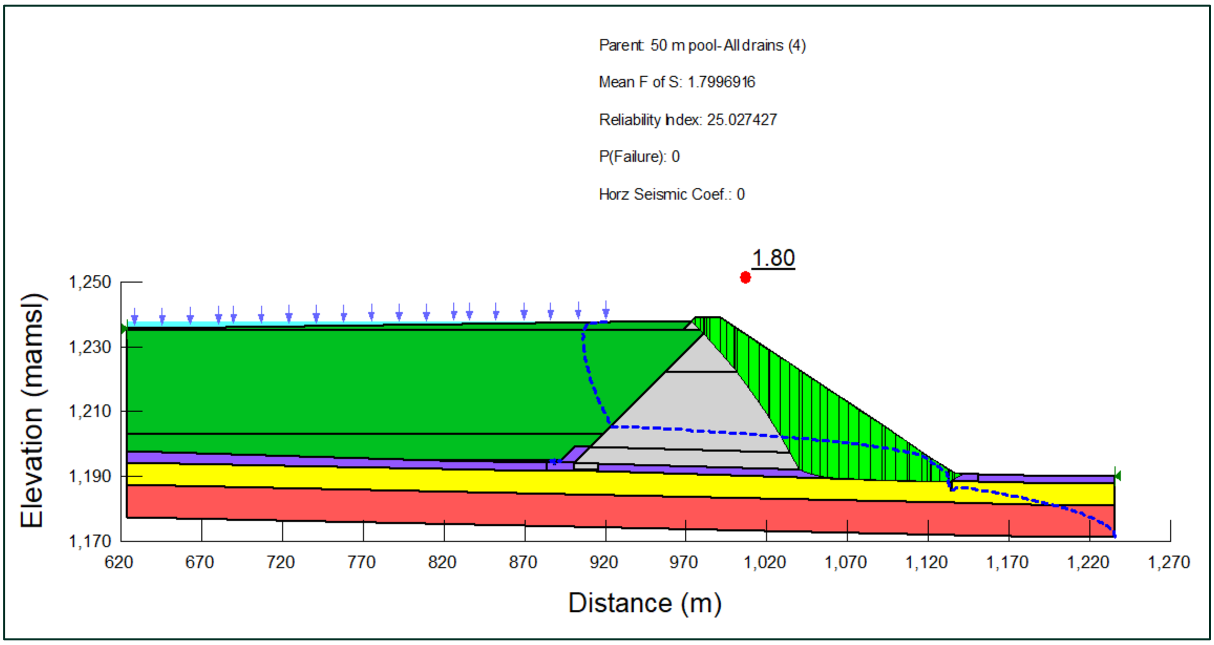



**Figure 9-37: TSF 2 Phase 2 Eastern embankment breached slip surface during flooded conditions assuming static conditions – active drains (FoS = 1.80)**

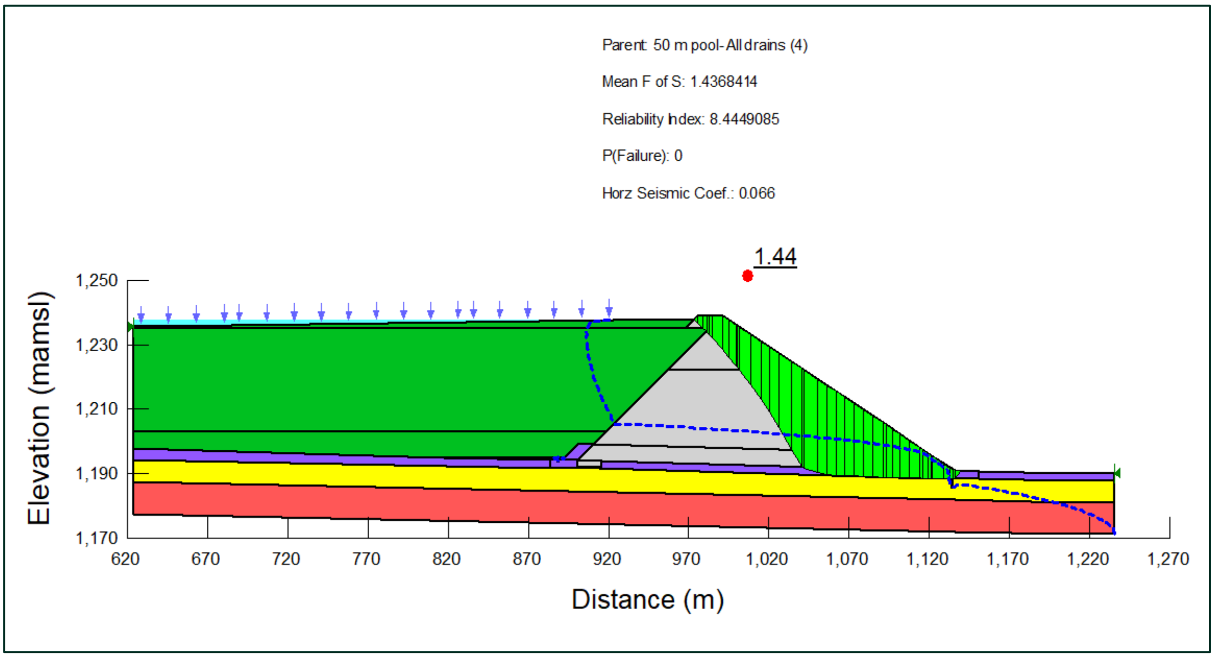



**Figure 9-38: TSF 2 Phase 2 Eastern embankment breached slip surface during flooded conditions assuming pseudo-static conditions – active drains (FoS = 2.18)**

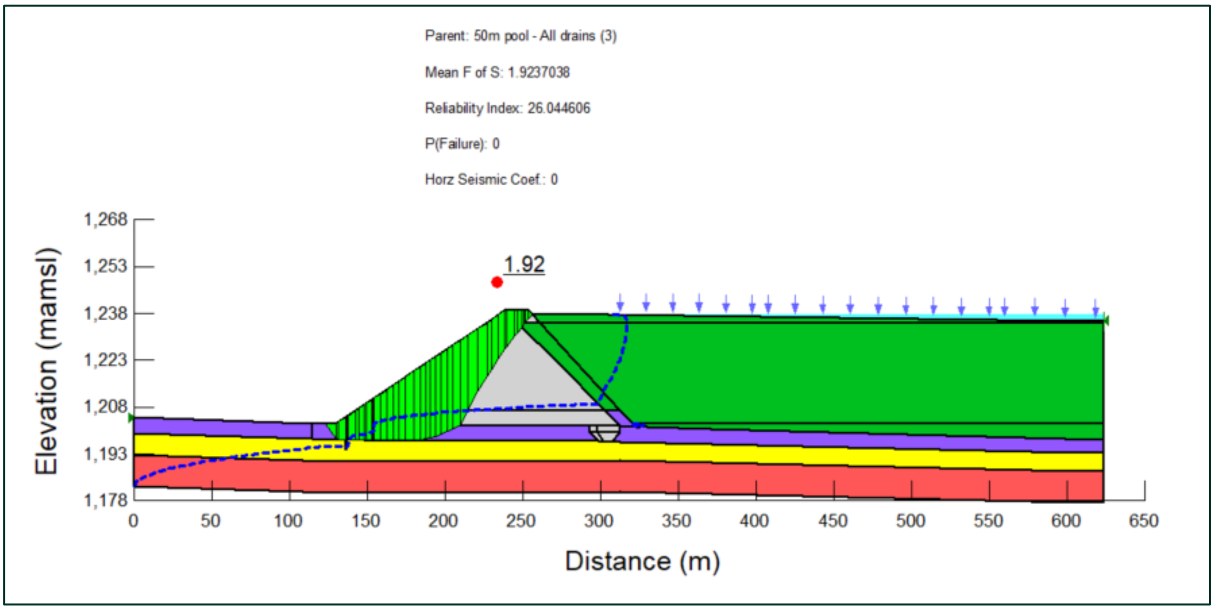



**Figure 9-39: TSF 2 Phase 2 Southern embankment breached slip surface during flooded conditions assuming static conditions – active drains (FoS = 1.92)**

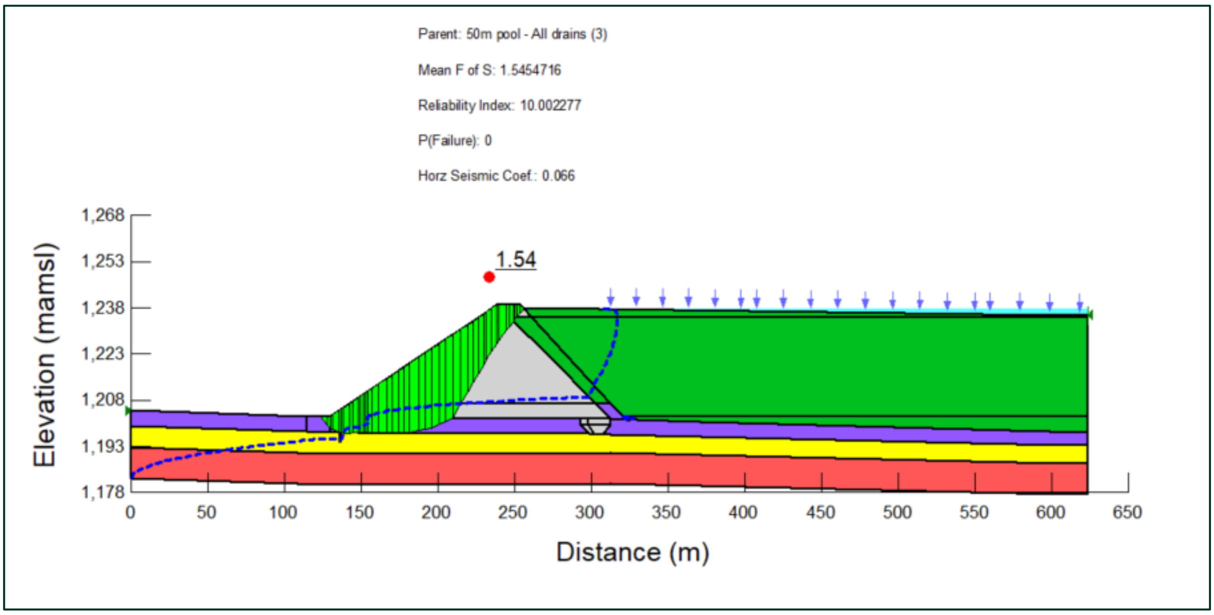



**Figure 9-40: TSF 2 Phase 2 Southern embankment breached slip surface during flooded conditions assuming pseudo-static conditions – active drains (FoS = 1.54)**

Table 9-17 lists the drained slope stability analyses results for TSF 2 Phase 2 for the various scenarios analysed.

**Table 9-17: TSF 2 Phase 2 drained Slope Stability Results**

| Reference in Appendix | Condition | | Pool | | Drains | | FoS | RI | PoF |
|---|---|---|---|---|---|---|---|---|---|
| | Static | Pseudo-static | Normal Operating | DWA | Active | Inactive | | | |
| North Embankment<br>Required FoS (static conditions) = 2.0 (Mining) - OK<br>Required FoS (pseudo-static conditions) = 1.5 (Mining) - OK | | | | | | | | | |
| Analyses: 66 | X | | X | | X | | 2.07* | 26.12 | 0 |
| Analyses: 68 | | X | X | | X | | 1.70* | 11.30 | 0 |
| Analyses: 70 | X | | | X | X | | 1.79* | 22.81 | 0 |
| Analyses: 72 | | X | | X | X | | 1.42* | 8.13 | 0 |
| Analyses: 74 | X | | | X | | X | 1.74* | 22.17 | 0 |
| Analyses: 76 | | X | | X | | X | 1.39* | 7.70 | 0 |
| East Embankment<br>Required FoS (static conditions) = 1.5 (Normal) - OK<br>Required FoS (pseudo-static conditions) = 1.1 (Normal) - OK | | | | | | | | | |
| Analyses: 104 | X | | X | | X | | 2.02* | 27.62 | 0 |
| Analyses: 106 | | X | X | | X | | 1.60* | 10.73 | 0 |
| Analyses: 108 | X | | | X | X | | 1.80* | 25.03 | 0 |
| Analyses: 110 | | X | | X | X | | 1.44* | 8.44 | 0 |
| Analyses: 112 | X | | | X | | X | 1.75* | 23.68 | 0 |
| Analyses: 114 | | X | | X | | X | 1.39* | 7.83 | 0 |
| South Embankment<br>Required FoS (static conditions) = 1.5 (Normal) - OK<br>Required FoS (pseudo-static conditions) = 1.1 (Normal) - OK | | | | | | | | | |
| Analyses: 136 | X | | X | | X | | 2.05* | 27.44 | 0 |
| Analyses: 138 | | X | X | | X | | 1.65* | 11.17 | 0 |
| Analyses: 140 | X | | | X | X | | 1.92* | 26.04 | 0 |
| Analyses: 142 | | X | | X | X | | 1.54* | 10.00 | 0 |
| Analyses: 144 | X | | | X | | X | 1.83* | 21.80 | 0 |
| Analyses:146 | | X | | X | | X | 1.46* | 8.82 | 0 |

** = Factor of safety relating to a slip surface leading to a breach in tailings*

It is shown in Table 9-17 that the target factors of safety for each embankment section were achieved. Only the factors of safety that would result in a breach of tailing are listed above. Refer to Appendix H for all drained slope stability analyses results for TSF 2 Phase 2.

### 9.7.4 Slope stability analyses results assuming undrained clay parameters

The undrained stability analyses were undertaken for an undrained shear strength ratio of 0.24 for static conditions and 0.19 for pseudo-static conditions which yielded factors of safety as listed in Table 9-18. It must be noted that the factors of safety listed below relate to slip surfaces that would result in a breach of tailings. The figures below illustrate the breached slip surfaces for the Northern, Southern, and Eastern embankments during static and pseudo-static conditions and assuming undrained clay parameters.

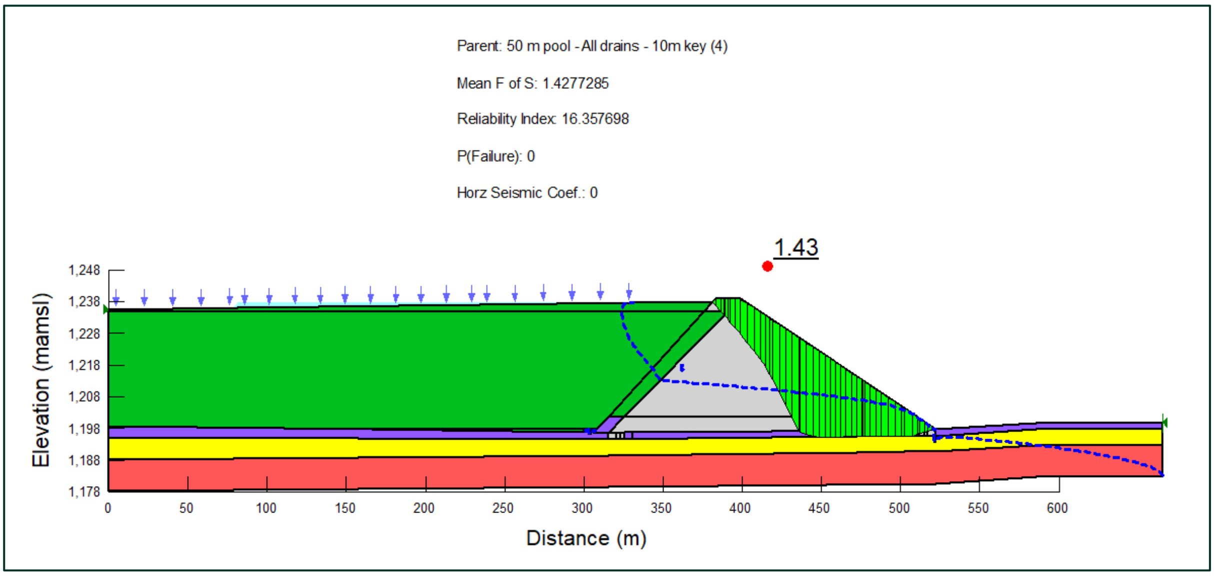



**Figure 9-41: TSF 2 Phase 2 Northern embankment breached slip surface during flooded conditions assuming static conditions – active drains and undrained clay parameters (FoS = 1.43)**

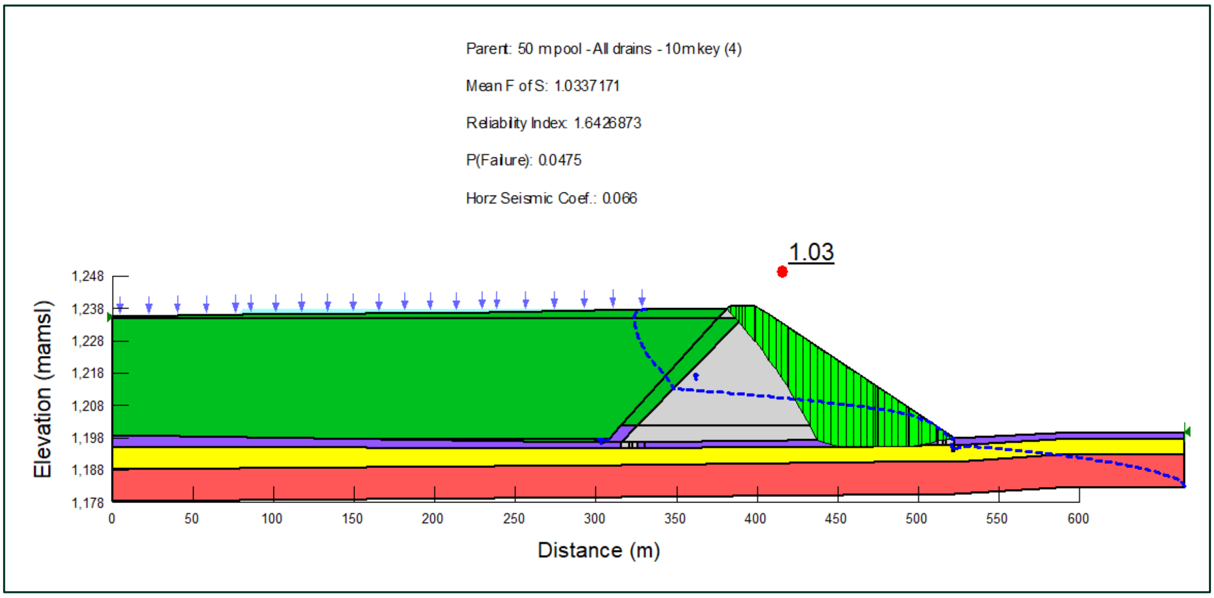



**Figure 9-42: TSF 2 Phase 2 Northern embankment breached slip surface during flooded conditions assuming pseudo-static conditions – active drains and undrained clay parameters (FoS = 1.03)**

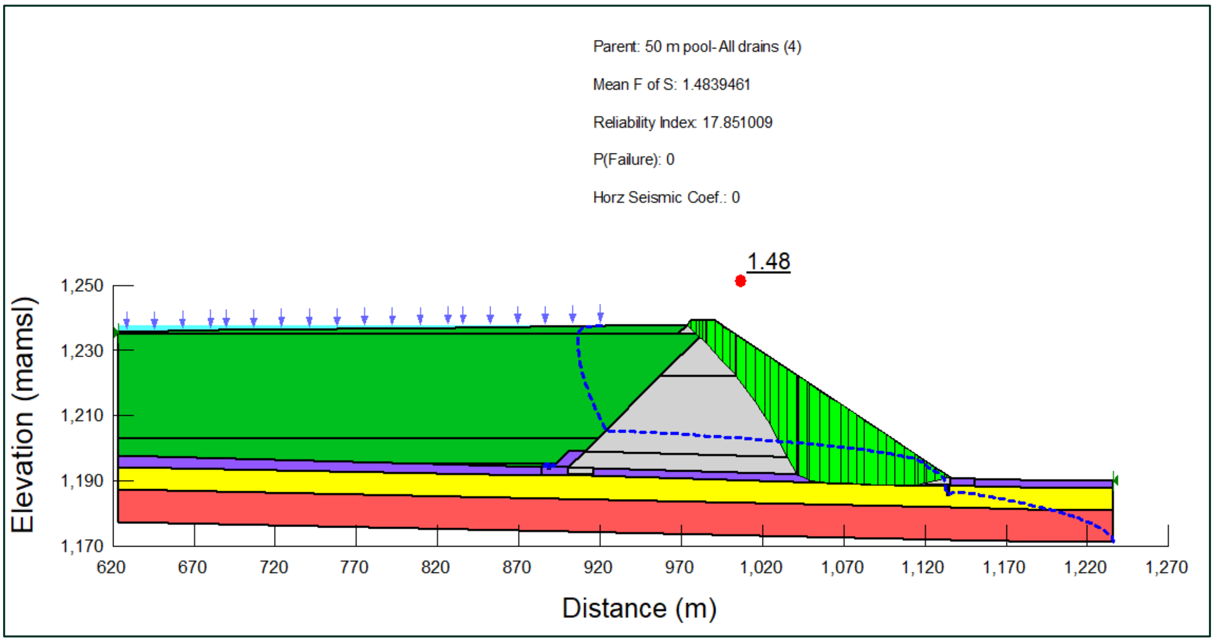



**Figure 9-43: TSF 2 Phase 2 Eastern embankment breached slip surface during flooded conditions assuming static conditions – active drains and undrained clay parameters (FoS = 1.46)**

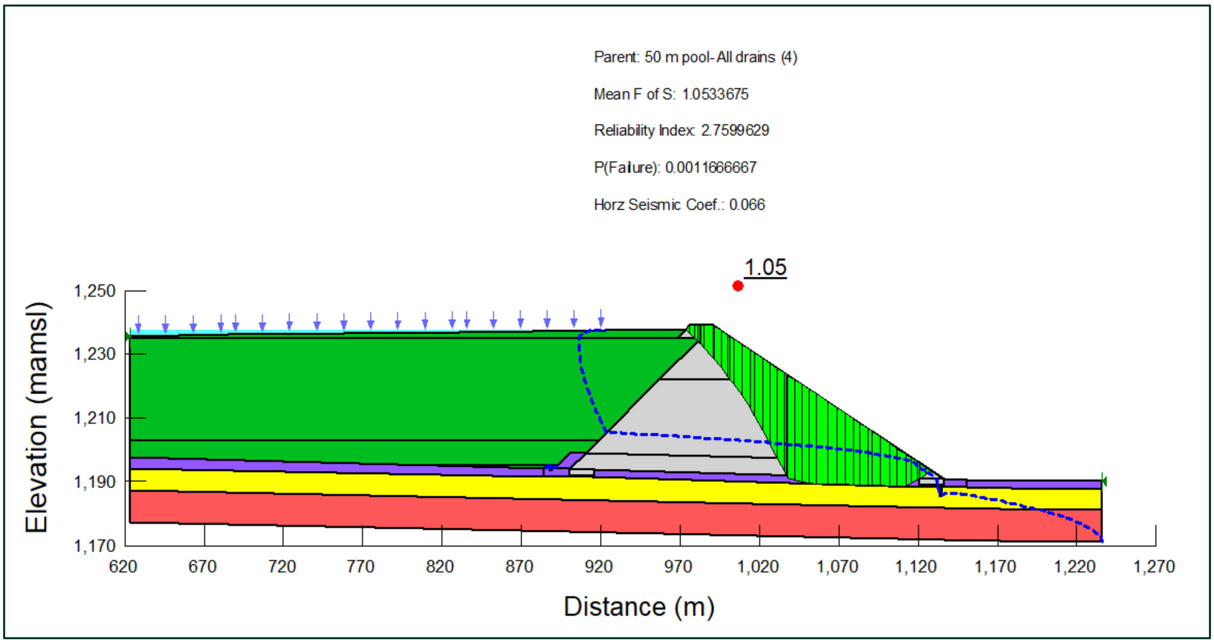



**Figure 9-44: TSF 2 Phase 2 Eastern embankment breached slip surface during flooded conditions assuming pseudo-static conditions – active drains and undrained clay parameters (FoS = 1.05)**

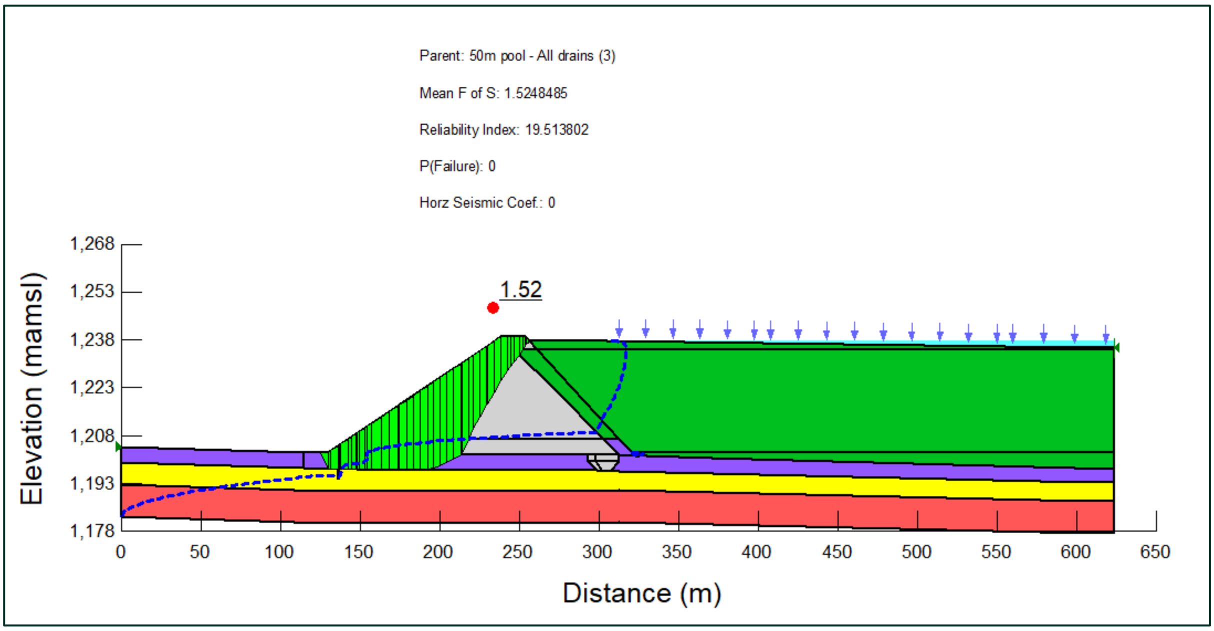



**Figure 9-45: TSF 2 Phase 2 Southern embankment breached slip surface during flooded conditions assuming static conditions – active drains and undrained clay parameters (FoS = 1.52)**

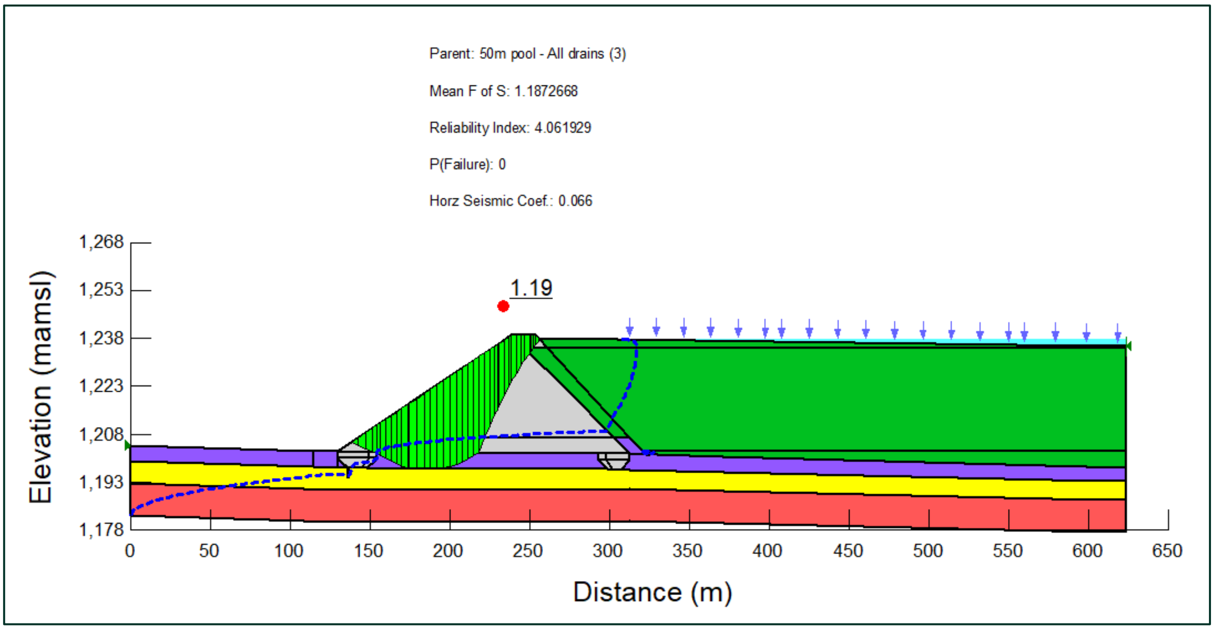



**Figure 9-46: TSF 2 Phase 2 Southern embankment breached slip surface during flooded conditions assuming pseudo-static conditions – active drains and undrained clay parameters (FoS = 1.05)**

Table 9-18 lists the undrained slope stability analyses results for TSF 2 Phase 2 for the various scenarios analysed.

### Table 9-18: TSF 2 Phase 2 undrained Slope Stability Results

| Reference in Appendix | Condition | | Pool | | Drains | | FoS | RI | PoF |
|---|---|---|---|---|---|---|---|---|---|
| | Static | Pseudo-static | Normal Operating | DWA | Active | Inactive | | | |
| North Embankment<br>Required undrained FoS (static conditions) = 1.75 (Mining) – Mitigation required<br>Required undrained FoS (pseudo-static conditions) = 1.3 (Mining) – Mitigation required | | | | | | | | | |
| Analyses: 82 | X | | X | | X | | 1.67* | 20.86 | 0 |
| Analyses: 84 | | X | X | | X | | 1.21* | 8.59 | 0 |
| Analyses: 86 | X | | | X | X | | 1.43* | 16.36 | 0 |
| Analyses: 88 | | X | | X | X | | 1.03* | 1.64 | |
| Analyses: 90 | X | | | X | | X | 1.42* | 14.96 | 0 |
| Analyses: 92 | | X | | X | | X | 1.00* | 0.04 | 0.5 |
| East Embankment<br>Required FoS (static conditions) = 1.5 (Normal) - OK<br>Required FoS (pseudo-static conditions) = 1.1 (Normal) - OK | | | | | | | | | |
| | X | | X | | X | | 1.62* | 21.11 | 0 |
| Analyses: 120 | | X | X | | X | | 1.20* | 8.70 | |
| Analyses: 122 | X | | | X | X | | 1.48* | 17.85 | 0 |
| Analyses: 124 | | X | | X | X | | 1.05* | 2.76 | 0 |
| Analyses: 126 | X | | | X | | X | 1.43* | 16.51 | 0 |
| Analyses: 128 | | X | | X | | X | 1.05* | 2.32 | 0 |
| South Embankment<br>Required FoS (static conditions) = 1.5 (Normal) - OK<br>Required FoS (pseudo-static conditions) = 1.1 (Normal) - OK | | | | | | | | | |
| Analyses: 152 | X | | X | | X | | 1.71* | 20.49 | 0 |
| Analyses: 154 | | X | X | | X | | 1.26* | 5.40 | 0 |
| Analyses: 156 | X | | | X | X | | 1.52* | 19.52 | 0 |
| Analyses 158 | | X | | X | X | | 1.19* | 4.06 | 0 |
| Analyses: 160 | X | | | X | | X | 1.41* | 17.05 | 0 |
| Analyses: 162 | | X | | X | | X | 1.11* | 2.60 | 0 |

** = Factor of safety relating to a slip surface leading to a breach in tailings*

The results listed in Table 9-18 indicate that the target factors of safety for the Eastern and Southern embankment section were achieved whereas for the Northern section, factors of safety below the target values were observed for both static and pseudo-static conditions indicating mitigation measures required. The factors of safety with the introduction of mitigation in the form of a buttress are listed in Table 9-19. The buttress introduced includes a crest width of 25 m with a downstream slope of 1V:2.5H. The modelled buttress has a height of 15 m.

**Table 9-19: TSF 2 Phase 2 North Embankment Undrained Slope Stability Results – Mitigation measures**

| Reference in Appendix | Condition | | Pool | | Drains | | FoS | FoS - Mitigation |
|---|---|---|---|---|---|---|---|---|
| | Static | Pseudo-static | Normal Operating | DWA | Active | Inactive | | |
| USR = 0.24 (0.19 for pseudo-static conditions)<br>Required undrained FoS (static conditions) = 1.75 (Mining) – OK<br>Required undrained FoS (pseudo-static conditions) = 1.3 (Mining) – OK | | | | | | | | |
| Analyses: 97 | X | | X | | X | | 1.67* | 2.07* |
| Analyses: 98 | | X | X | | X | | 1.21* | 1.55* |
| Analyses: 99 | X | | | X | X | | 1.43* | 1.80* |
| Analyses: 100 | | X | | X | X | | 1.03* | 1.36* |

** = Factor of safety relating to a slip surface leading to a breach in tailings*

It is shown in Table 9-19 that with the inclusion of a buttress, the target factors of safety are achieved. Refer to Appendix H for all undrained slope stability analyses results for TSF 2 Phase 2 which includes the mitigation measures and associated factors of safety.

### 9.7.5 Deformation analyses

The post-seismic deformation analyses yielded results that indicated an estimated crest settlement of 21.739 cm

## 9.8 Conclusions from the seepage and slope stability analysis

A summary of the slope stability analyses results for each TSF is listed in Table 9-20 below.

**Table 9-20: Summary of the Slope Stability analyses results for all 3 TSFs**

| Static | Pseudo-static | Operating condition | FoS | | Post seismic crest settlement (cm) | Target FoS achieved? | Mitigation required? |
|---|---|---|---|---|---|---|---|
| | | | Drained | Undrained | | | |
| TSF 1 Expansion | | | | | | | |
| X | | Normal | 2.32 | N/A | N/A | √ | X |
| | X | | 1.89 | | 1.495 | √ | X |
| X | | Flooded | 2.18 | | N/A | √ | X |
| | X | | 1.78 | | 1.495 | √ | X |
| TSF 2 Phase 1 – Northern embankment | | | | | | | |
| X | | Normal | 2.60 | N/A | N/A | √ | X |
| | X | | 2.11 | | 8.70 | √ | X |
| X | | Flooded | 2.42 | | N/A | √ | X |

| Static | Pseudo-static | Operating condition | FoS | | Post seismic crest settlement (cm) | Target FoS achieved? | Mitigation required? |
|---|---|---|---|---|---|---|---|
| | | | Drained | Undrained | | | |
| | X | | 1.96 | | 8.70 | √ | X |
| TSF 2 Phase 1 – Southern embankment | | | | | | | |
| X | | Normal | 2.02 | 1.78 | N/A | √ | X |
| | X | | 1.63 | 1.29 | 8.70 | √ | X |
| X | | Flooded | 1.92 | 1.74 | N/A | √ | X |
| | X | | 1.55 | 1.24 | 8.70 | √ | X |
| TSF 2 Phase 2 – Northern embankment | | | | | | | |
| X | | Normal | 2.07 | 1.67 | N/A | √ (Drained conditions)<br>X (Undrained conditions) | √ |
| | X | | 1.70 | 1.21 | 21.74 | | √ |
| X | | Flooded | 1.79 | 1.43 | N/A | | √ |
| | X | | 1.42 | 1.03 | 21.74 | | √ |
| TSF 2 Phase 2 – Eastern embankment | | | | | | | |
| X | | Normal | 2.02 | 1.62 | N/A | √ | X |
| | X | | 1.60 | 1.20 | 21.74 | √ | X |
| X | | Flooded | 1.80 | 1.48 | N/A | √ | X |
| | X | | 1.44 | 1.05 | 21.74 | √ | X |
| TSF 2 Phase 2 – Southern embankment | | | | | | | |
| X | | Normal | 2.05 | 1.71 | N/A | √ | X |
| | X | | 1.65 | 1.26 | 21.74 | √ | X |
| X | | Flooded | 1.92 | 1.52 | N/A | √ | X |
| | X | | 1.54 | 1.19 | 21.74 | √ | X |

*Note 1: The listed factors of safety relate to a slip surface leading to a breach in tailings*

The following can be concluded from the seepage and slope stability analyses:

- The undrained behaviour of the clays was analysed and introduced in the slope stability analyses for which an undrained shear strength ratio of 0.24 was calculated.
- Seepage analyses indicated elevated phreatic surfaces for flooded conditions and increased basin seepage rates.
- Target factors of safety were selected with guidance from ICOLD (Bulletin No. 194, 2022). Embankment sections where a probable breach in tailings could influence mining operations were increased.
- All facilities adhere to the target factors of safety assuming drained clay parameters for static and pseudo-static conditions, respectively.

- All facilities adhere to the target factors of safety assuming undrained clay parameters for static and pseudo-static conditions, respectively except for the Northern embankment of TSF 2 Phase 2 requiring mitigation measures to be implemented in the form of a buttress along the downstream toe of the embankment.
- Implementing mitigation measures for the Northern embankment of TSF 2 Phase 2 allows for the target factors of safety to be met.

# 10 Deformation analyses during construction

## 10.1 Methodology

The deformation analyses were based on a deformation assessment using the SIGMA/W software package. The analyses incorporated conservative material behavioural parameters and assessed the deformation expected at the interface of waste rock and tailings during the construction of the embankment.

## 10.2 Deformation analyses from SIGMA/W

Figure 10-1 illustrates the model setup with the relevant material input parameters listed in Table 10-1. The model incorporated the incremental loading of waste rock in layers, as would be the case during construction, to determine the deformation behaviour at the respective locations.

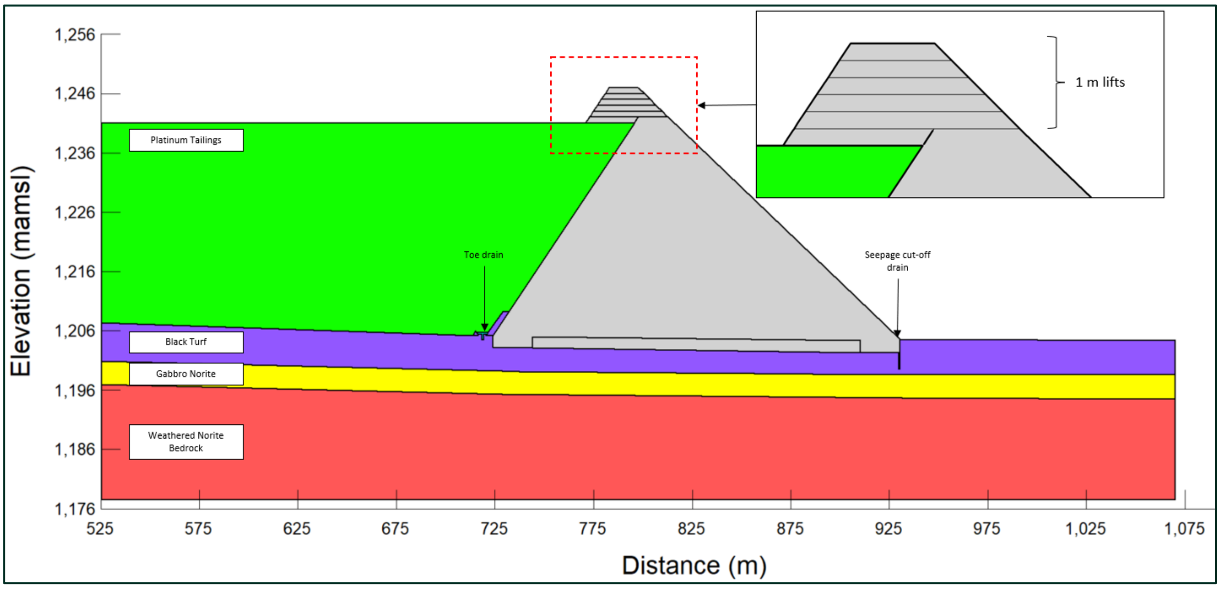



**Figure 10-1: Methodology**

The material input parameters were based on conservative estimates with deformation or settlement measurements taken along the crest and waste rock and tailings interface. It was assumed that the material models behave according to the mohar-coulomb failure criterium. The stiffness of the tailings was varied to assess the deformation behaviour for the different scenarios. All material parameters used in the model are shown in Table 10-1.

**Table 10-1: Deformation material input parameters**

| Material | Material model | Initial void ratio | Unit weight | Effective elastic modulus | Drained/Undrained behaviour | Effective Poisson's ratio |
|---|---|---|---|---|---|---|
| Tailings (scenario 1) | Mohr-coulomb | 1 | 22 | 2 000 | Undrained | 0.334 |
| Tailings (scenario 2) | Mohr-coulomb | 1 | 22 | 10 000 | Undrained | 0.334 |
| Waste rock | Mohr-coulomb | 1 | 22 | 50 000 | Drained | 0.334 |
| Clay ("Black Turf") | Mohr-coulomb | 1 | 16 | 20 000 | Drained | 0.334 |
| Gabbro Norite | Mohr-coulomb | 1 | 20 | 30 000 | Drained | 0.334 |
| Weathered Norite Bedrock | Mohr-coulomb | 1 | 22 | 50 000 | Drained | 0.334 |

## 10.2.1 SIGMA/W Deformation results

The vertical deformation below the raised embankment using SIGMA/W was analysed to be in the region of 220 mm as illustrated in Figure 10-2. It is observed that some vertical settlement is expected at the intersection of the raised and existing embankment with the maximum settlement expected at approximately 12 m from the outside toe of the raised embankment.

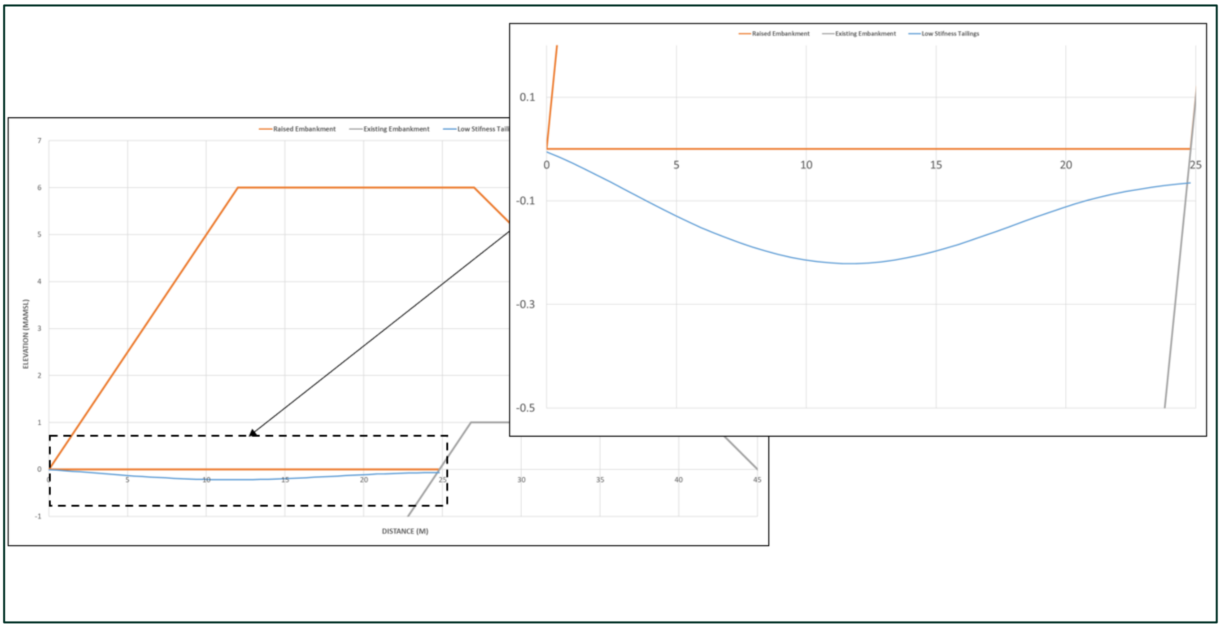



**Figure 10-2: Vertical deformation using SIGMA/W**

## 10.3 Interpretation of the deformation analysis

Based on the conceptual modelling using SIGMA/W, some vertical deformation along the tailings-waste rock interface is expected. However, any vertical settlement observed during the construction of each lift of the raised embankment will be rectified through the additional placement of waste rock over the settled portion to form a continuous and uniform layer. This methodology will be followed until no significant vertical settlement is observed. Some advantage is also provided in this methodology as the base of the raised embankment will be strengthened by the continuous placement of waste rock. In addition, a geotextile separation layer will be provided at the tailings-waste rock interface which will allow a constant flow through of water whilst retaining tailings particles.

# 11 TSF Hazard classification

TSFs pose a significant hazard to people and property around them as well as significant costs to the client.

The size and degree of the potential hazard depend on the location and size of the TSF, site-specific characteristics, method of construction, residue material characteristics, construction materials, method of TSF development, operational control, closure planning and monitoring, and overall management.

## 11.1 Safety Classification

The SANS 10286:1998: (Code of Practice for Mine Residue) safety classification provides a consistent means of classifying *low, medium*, and *high* hazard facilities based on their potential to cause harm to human life, property, and the environment. The classification system furthermore provides a basis for the implementation of safety management practices for specified stages of the life cycle of the TSFs. The code of practice recommends the minimum requirements applying to the respective hazard classification, including:

- Investigation
- Design
- Construction
- Operation
- Decommissioning

A so-called Zone of Influence for a facility corresponds to the area considered most likely to be affected by a flow slide emanating from the facility. The TSFs embankments comprise a compacted rockfill embankment that is unlikely to liquefy should a seismic event take place.

The tailings had not undergone a liquefaction assessment, and it is assumed the saturated tailings shall liquefy following an earthquake.

It is assumed that, if a structural failure were to occur, it is probable that the failure would result in a breach of the embankment and that the saturated, liquefied tailings would be released and cause a flow slide affecting the areas downstream of the facility and would be further conveyed by existing water courses.

Based on the nature of the materials to be deposited in the TSFs and the assessment criteria specified by SANS 10286:1998 (Table 11-1), the TSFs are considered to be a High Hazard Facility. The number of residents downstream of the TSFs is unknown, however, satellite imagery shows that the informal settlement of Elansdrift, Mooinooi Bakamoso and a few small holdings are located in the Zones of Influence along with third party mining activities immediately downstream of the TSF 2 Phase 2. Therefore, it is assumed that the number of residents in the zone of influence will exceed 10.

The minimum requirements associated with the design, operation, management and closure of High Hazard Facilities are summarised in Table 11-2. The downstream catchment that may be potentially affected in the event of a spill or catastrophic event from the TSF is illustrated in Figure 11-1.

**Table 11-1: Safety classification (Source: SANS 10286:1998, Table 2 – Safety Classification Criteria)**

| No. of Residents in Zone of Influence | No. of Workers in Zone of Influence | Value of 3rd Party Property in Zone of Influence | Depth to Underground Mine Workings | Classification |
|---|---|---|---|---|
| 0 | < 10 | 0 – ZAR 2 m | > 200 m | Low Hazard |
| 1 – 10 | 11 – 100 | ZAR2 m – ZAR 20 m | 50 m – 200 m | Medium Hazard |
| > 10 | > 100 | > ZAR20 m | < 50 m | High Hazard |

Note:
(1) Not including workers employed solely for the purpose of operating the deposit.
(2) The value of third party property should be in the replacement value in 1996 terms.
(3) The potential for collapse of the residue deposit into the underground workings effectively extends the zone of influence to below ground.

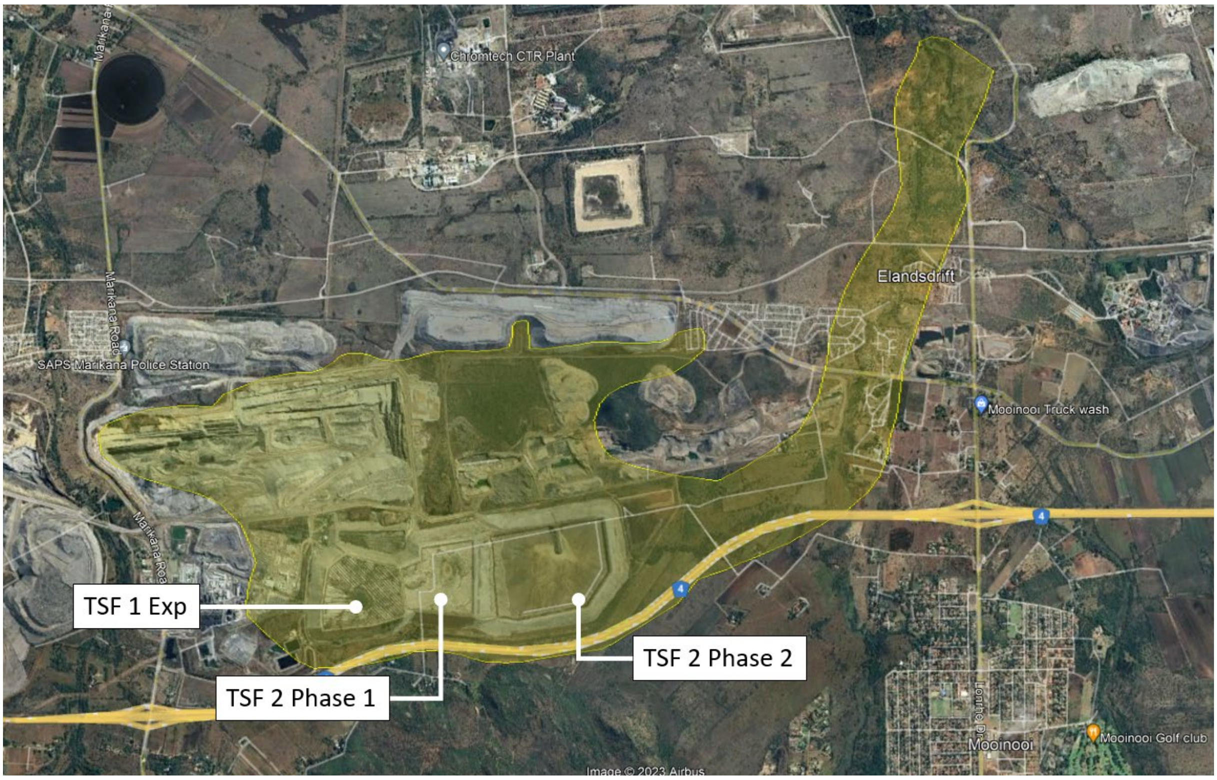



**Figure 11-1: TSF 1 and 2 Zones of Influence**

**Table 11-2: Summary of minimum requirements associated with high hazard safety Classification**

| Requirement | Planning Stage | Design Stage | Operation / Commissioning Stage | Decommissioning Stage |
|---|---|---|---|---|
| 1 | Conceptualisation by owner – Professional Engineer to assist | Geotechnical report mandatory | Risk Analysis by suitably qualified person | Professional Engineer appointed to monitor |
| 2 | Preliminary site selection by appropriate specialist | Residue characterisation verified by laboratory analysis | Suitably qualified person responsible for operation | Professional Engineer to audit annually |
| 3 | Geotechnical investigation by suitably qualified person (assisted by specialist if necessary) | Design by Professional Engineer | Professional Engineer appointed to monitor | - |
| 4 | - | Risk Analysis by suitably qualified person | Professional Engineer to audit annually | - |
| 5 | - | Construction supervision by suitable Professional Engineer | - | - |

## 11.2 Risks Associated with the TSF during Construction

The risk issues associated with construction are summarised as follows:

- Large earthmoving vehicles will be on site during construction and staff must be made aware of the dangers involved with working near these large machines. Health and Safety procedures must be adhered to.
- The construction of the decanting systems on TSF 2 Phase 2 will be undertaken by third party contractors while the mine will complete the construction of the embankments. It is expected these activities will be undertaken concurrently. A thorough traffic management plan should be developed to coordinate the interactions of construction vehicles and personnel from various construction teams.
- The dust generated by the works is to be monitored and if required dust suppression measures must be implemented.

## 11.3 Risks Associated with the TSF During Operations

The risks associated with the operation facility and the associated mitigation measures incorporated into the design are summarised as follows:

- The uncontrolled release of seepage from the TSFs is a key risk. This must be managed through an intense QA / QC system, construction management/supervision during the construction of the facilities and competent operational management so as to reduce the risk of an uncontrolled release. More specific issues and mitigation measures are identified including:

  - The placement of a geotextile along the upstream face of the facilities. It is expected that the geofabric will blind over time, reducing the rate of seepage from the facility. The geotextile will also prevent tailings from migrating through the embankment from where it could emerge on the downstream face, resulting in an environmental spill.
  - Monitoring deposition to ensure no low spots form along the embankment. Low spots allow water to pool on the upstream face of the embankment, promoting migration of water into the embankment which increases the risk of piping and internal erosion of fine material and seepage along the downstream toe.
  - Tailings discharge pipes are to be raised frequently to ensure that they always remain above the tailings beach elevation. Submerged outlets can increase the likelihood of tailings migrating into the embankment, leading to the formation of preferential flow paths within the embankment and an increased risk of piping and release of tailings.
  - The entire perimeter of the TDs must be inspected on a daily basis to ensure any defects are noted as early as possible. Such as sloughing, slips, ratholing, seepage, etc.
  - The failure of the downstream slope is not a major concern due to the high friction angle of the waste rock, as demonstrated by the slope stability analysis. However, it is advised that standpipes be installed along the embankment to monitor the level of the phreatic surface and assess the functionality of the drainage system.
- The Supernatant water originating from the hydraulic deposition process will form a pool around the decant points. As part of the decant process, penstock rings have to be placed on and removed from the inlets (where applicable) as the level of the pool fluctuates. The following are concerns related to operating the decant system:
  - During rainfall periods the planks of the catwalks used to access the tower could become slick, increasing the risk that operators could slip and fall into the pond. Emergency measures (e.g. life preservers, ropes, etc.) should be available to allow team members to aid those who have fallen off the catwalk. It is suggested that sufficient signage, warning people of the dangers, be provided.
  - The planks of the catwalks will decay over time. These planks should be maintained to prevent any injuries due to a lack of firm footing and to maintain access to the decant towers at all times.
  - It is plausible that the flow of water entering the decant system can be such that extracting individuals who have fallen into the decant system will either be extremely difficult or impossible, leading to the possible loss of life from drowning. A cage or grid should be placed over the penstock rings after the necessary number of rings have been added or removed to prevent individuals from slipping and falling into the inlet.

## 11.4 Risks Associated with the TSF During and After Closure

The risks associated with the TSFs during closure and post-closure are not as extreme as those during construction and operation. However, for closure, some design work is required to accommodate the stormwater management system and to mitigate against soil erosion, as this can result in extensive damage downstream, if not controlled.

Key risks to closure are:

- The time taken to clad the top surface area is dependent on the rate of consolidation of the residue. This may result in a lengthy closure period.
- It will be difficult to predict the long-term effectiveness of the re-vegetation of side slopes and crest or the TSFs.

# 12 CLOSURE, REHABILITATION AND AFTERCARE REQUIREMENTS

The rehabilitation, closure and aftercare plan are based on the assumption that the objective of the process is to rehabilitate, as far as possible, the area disturbed during the establishment and operation phases of the project.

## 12.1 Closure Activities Before and During Operations

Because of the visibility of the TSFs from the N4 highway to the south and south-east of the site, the rehabilitation of the southern and eastern raised embankments of the TSFs is to be undertaken as soon as the construction of the respective section of the embankment is complete.

The rehabilitation involves the placement of a 500 mm soil layer over the downstream face of the waste rock embankment. The soil is sourced from stockpiles created during the removal of material beneath the footprint of the facility during construction. This material contains plant seeds that will germinate and vegetate the side slopes. The rehabilitation of the remainder of the side slopes should be undertaken as soon as possible during the construction and early operational phase. The advantages of rehabilitating the embankments during operation are:

- The cost incurred is absorbed as operating costs.
- Reduced environmental impact due to the separation of rainfall run-off from mine waste.
- Assist in dust suppression.
- Improve the overall visual impact of the TSF.

## 12.2 Closure Activities at Cessation of Operations

At the cessation of operation of the TSFs, the focus will be to cover and vegetate the top surface of the facility, the decommissioning facilities associated with the TSF and the construction of stormwater control measures if required, such as an overflow spillway. Specific activities that will be carried out will include:

- The dismantling and removal of pumps, piping and valves associated with the deposition of tailings material and the decanting of supernatant water.
- Rehabilitation of any remaining unrehabilitated downstream slopes.
- Sealing/closing off the Penstock tower intakes.
- The Environmental Management Plan (EMP) of 2019 stipulates that the top surface of the facility should be shaped such that a low area will be created in the centre of the facility. The area will function as a collection point for rainfall and be developed into a wetland. This approach will be substituted with the creation of compartments along the entire beach profile. The compartment will offer localised storage, preventing the formation of a large waterbody on the surface of the facility after closure. The increased surface area of the accumulated water will increase the rate of evaporation as opposed to that of a single runoff collection point and will function as an effective means of removing water from the facility as the annual evaporation exceeds that of the annual rainfall depths. The compartments will be constructed using tailings material from the beach area with adequate storage to contain the 1 in 10 000 year 24-hour storm event.
- The final cover to the top surface of the TSFs will be constructed by importing topsoil from the topsoil stockpiles and covering the top surfaces with a minimum depth of topsoil of 0.3m.
- Minor earthworks.

## 12.3 Aftercare and Maintenance Requirements

Upon completion of the closure and rehabilitation measures, an aftercare programme is to be implemented to ensure that the closure measures are performed adequately and that no further closure liabilities arise. The aftercare period is normally not less than 5 years, however, may extend into decades depending on the physical and chemical characteristics of the mine residue material and TSF design. In the case of a platinum residue, a minimum period of 5 years of aftercare has been proposed. The typical aftercare activities for the TSF include the following:

- Monitoring of the closure measures to ascertain whether they are performing adequately, failing which some remediation work would be required e.g. successful establishment of top surface vegetation, erosion control etc.
- Monitoring the drop in the phreatic surface within each paddock and the quality and quantity of seepage water exiting from the toe drains.
- Surface and groundwater quality will be monitored regularly for a period to be agreed upon with the relevant authorities.
- Remediation of the seepage water collected in the sump, if required.
- Repairing areas that have degraded since closure.

# 13 Life of mine cost estimate

An estimate of the Life of Mine (LoM) costs associated with the construction, operation, rehabilitation and closure of the raising of the TSFs was compiled.

Capital and sustaining capital costs associated with the TSFs have been determined to an accuracy of -20% to +10% while the quantities for the various activities of the preliminary works for the TSF have been determined based on an accuracy of ±5%. The construction cost of the project has been separated into two groups i.e. external activities that will be undertaken by contractors and internal activities that will be undertaken by Tharisa Minerals. The costs associated with external contractors are based on construction rates received from Frazer Alexander. Cost estimates for the internal construction activities are based on rates provided by Tharisa Minerals for the spread and compaction of embankment fill material.

Operational costs were determined based on similar projects in South Africa to an accuracy of ±25%. Closure costs are indicative and to an accuracy of ±50%.

## 13.1 Capital Cost

The estimated capital costs associated with the construction of the preparatory works (as described above) have been compiled based on a schedule of quantities describing the works and prices in Appendix J. Similar projects in South Africa were used where rates were not available in the initial tender documentation. The estimated capital cost associated with the construction of the facility is ZAR 23.4 million, as summarised in Table 13-1.

**Table 13-1: Summary of capital costs**

| PHASE | CAPITAL COST | |
|---|---|---|
| SCHEDULE A: PRELIMINARY & GENERAL (@ 25%) | R | 4 675 692.17 |
| SCHEDULE B: SITE CLEARANCE | R | 2 178 262.15 |
| SCHEDULE C: EARTHWORKS | R | 6 792 275.93 |

| PHASE | CAPITAL COST | |
|---|---|---|
| SCHEDULE D: DRAINAGE | R | 7 398 792.60 |
| SCHEDULE E: MISCELLANEOUS | R | 2 333 438.00 |
| **Total** | **R** | **23 378 460.85** |

The above capital cost estimate excludes the following:

- The slurry delivery, ring-main and downpipe(s) from the process plant to the TSF.
- All electrical, mechanical and instrumentation/equipment.

Tharisa Minerals will undertake the task of transporting, placing and compacting the embankment fill material. The cost associated with the load and haul of the waste rock from the open pit mining operation has been excluded from this estimate as it is already included in the waste management budget for Tharisa Minerals. The cost related to spreading and compacting the material amounts to ZAR 3.6 million over a period of 1-2 years.

## 13.2 Operating Cost

The operating costs comprise the management of tailings deposition, as well as general maintenance of the TD and return water system. Epoch has compiled an estimate of the cost to manage the deposition of the tailings as well as general maintenance, to an accuracy of ±25%. Operating costs for the TSF are expected to be in the range of R3.00/dry tonne of tailings which amounts to ZAR 25.20 million for the project duration. The operating entity is expected to employ sufficient personnel and acquire the necessary equipment to undertake the following routine operations:

- Maintaining the functionality of the infrastructure.
- Supplying and installing penstock rings.
- Sleeving of the vertical penstock intakes.
- Routine lifting of the spigot pipeline along the pool wall.
- Routine lifting of the catwalk and intake platforms.
- Routine maintenance and upkeep of the TSF e.g. cleaning of solution trenches, etc.
- Effective Management of the Tailings Storage Facility
- Logging data such as deposition quantities, slurry properties, return water volumes, etc.
- Cyclic deposition to maintain a centralised pool.
- Daily inspections of the penstock, catwalk, drains, etc.
- Technical Inspections
- Monthly inspections and reports.
- Quarterly inspections.
- Drain flow readings.
- Monitoring of available deposition capacity.

## 13.3 Rehabilitation, Closure and Aftercare Cost

Closure, rehabilitation and aftercare costs (accuracy of ±50 %) have been estimated at ZAR 1.49 million with ZAR 0.63 million of this cost being incurred over a period of approximately 5 years following mine closure. These costs are indicative and have been based on closure cost estimates undertaken, for similar operations, by Epoch.

## 13.4 Annualised Cash Flow

The cost estimates of the TSFs, as discussed, are presented in Figure 13-1, which shows the annualised cash flow of the facility over the duration of the project. The total LoM cost associated with the raising of the TSFs over the duration of the project life (Detailed Design to Closure) is estimated at ZAR 50.57 million.

The components of the operational cost outlined in section 13.2 include the cost associated with managing the facilities. The operational cost associated with the facility amounts to ZAR 25.2 million. All monitoring activities are intended to continue for a period of 5 years past the end of the operational life of the facility, which amounts to ZAR 0.63 million of the total operating cost.

| Item | Description | Total | Construction Phase | | Operational Phase | | Closure Phase | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2031 | 2032 |
| **1** | **TSF Capital Cost (Contractor)** | | | | | | | | | | |
| 1.1 | A: P & G's (25% of total works) | R 4 675 692.17 | R 2 242 634.52 | R 2 433 057.65 | R - | R - | R - | R - | R - | R - | R - |
| 1.2 | B: Site Clearance | R 2 178 262.15 | R 2 178 262.15 | R - | R - | R - | R - | R - | R - | R - | R - |
| 1.3 | C: Earthworks | R 6 792 275.93 | R 6 792 275.93 | R - | R - | R - | R - | R - | R - | R - | R - |
| 1.4 | D: Drainage | R 7 398 792.60 | R - | R 7 398 792.60 | R - | R - | R - | R - | R - | R - | R - |
| 1.5 | E: Miscellaneous | R 2 333 438.00 | R - | R 2 333 438.00 | R - | R - | R - | R - | R - | R - | R - |
| | **Sub-Total** | **R 23 378 460.85** | **R 11 213 172.60** | **R 12 165 288.25** | **R -** | **R -** | **R -** | **R -** | **R -** | **R -** | **R -** |
| 3 | **TSF Consulting/Design Costs** | | | | | | | | | | |
| 3.1 | Engineering Detail Design | R 500 000.00 | R 500 000.00 | R - | R - | R - | R - | R - | R - | R - | R - |
| 3.2 | *Engineering Construction Supervision | R - | R - | R - | R - | R - | R - | R - | R - | R - | R - |
| | **Sub-Total** | **R 500 000.00** | **R 500 000.00** | **R -** | **R -** | **R -** | **R -** | **R -** | **R -** | **R -** | **R -** |
| 4 | **TSF Operating Costs** | | | | | | | | | | |
| 4.1 | TSF Operational Costs (i.e. pipeline and valve replacement costs, maintenance, etc.) | R 25 200 000.00 | R - | R - | R 12 600 000.00 | R 12 600 000.00 | R - | R - | R - | R - | R - |
| 4.2 | *Consulting Services (i.e. quarterly inspections, annual reports, etc.) | R - | R - | R - | R - | R - | R - | R - | R - | R - | R - |
| | **Sub-Total** | **R 25 200 000.00** | **R -** | **R -** | **R 12 600 000.00** | **R 12 600 000.00** | **R -** | **R -** | **R -** | **R -** | **R -** |
| 5 | **TSF Closure, Rehabilitation and Aftercare Costs** | | | | | | | | | | |
| 5.1 | * Engineering Costs (i.e. design and supervision of closure and rehabilitation measures) | R - | R - | R - | R - | R - | R - | R - | R - | R - | R - |
| 5.2 | Rehabilitation of side slopes | R 863 355.32 | R - | R - | R 431 677.66 | R 431 677.66 | R - | R - | R - | R - | R - |
| 5.3 | Miscellaneous Works (i.e. post closure remedial measures, etc.) | R 500 000.00 | R - | R - | R - | R - | R 100 000.00 | R 100 000.00 | R 100 000.00 | R 100 000.00 | R 100 000.00 |
| 5.4 | P & G's (25% of total works) | R 125 000.00 | R - | R - | R - | R - | R 25 000.00 | R 25 000.00 | R 25 000.00 | R 25 000.00 | R 25 000.00 |
| 5.5 | *Monitoring of Closure Activities | R - | R - | R - | R - | R - | R - | R - | R - | R - | R - |
| | **Sub-Total** | **R 1 488 355.32** | **R -** | **R -** | **R 431 677.66** | **R 431 677.66** | **R 125 000.00** | **R 125 000.00** | **R 125 000.00** | **R 125 000.00** | **R 125 000.00** |
| | **TOTAL (ZAR)** | **R 50 566 816.17** | **R 11 713 172.60** | **R 12 165 288.25** | **R 13 031 677.66** | **R 13 031 677.66** | **R 125 000.00** | **R 125 000.00** | **R 125 000.00** | **R 125 000.00** | **R 125 000.00** |

* Included in the Tharisa existing budget for the TSFs

**Figure 13-1: TSF 1 and 2 Annualised Cash Flow**

# 14 Conclusions

The following can be concluded from the detailed design of the lifting of TSF 1 Expansion, TSF 2 Phase 1 and Phase 2:

- Based on the expected tailings production rates of 350 kt/m, TSF 1 Expansion will reach its maximum capacity of tailings deposition in 5.11 months, TSF 2 Phase 1 in 4.85 months and TSF 2 Phase 2 in 5.44 months.
- The 2022 classification of the Vulcan tailings, conducted by SLR, reveals no significant deviations from the 2016 classification. This reaffirms that the barrier requirements of the facilities conform to the approved design standards.
- Artesium concluded that the extent of the nitrate plume migration varies between 200 and 500 m, depending on the direction of the seepage.
- The undrained behaviour of the clays was analysed and introduced in the slope stability analyses for which an undrained shear strength ratio of 0.24 was calculated.
- All facilities adhere to the target factors of safety assuming drained clay parameters for static and pseudo-static conditions, respectively.
- All facilities adhere to the target factors of safety assuming undrained clay parameters for static and pseudo-static conditions, respectively except for the Northern embankment of TSF 2 Phase 2 requiring mitigation measures to be implemented in the form of a buttress along the downstream toe of the embankment. Implementing mitigation measures for the Northern embankment of TSF 2 Phase 2 allows for the target factors of safety to be met.
- The water balance analysis indicates that the average yearly expected return is equal to 61 % of the slurry water requirements. During the wet season, an estimated daily average of 69% can be returned whereas, during the dry season, the average daily return could equal 54 % of the slurry water requirements.
- Capital costs associated with the TSF are estimated at ZAR 23.4 million (+10%, -20% accuracy). This has been determined based on construction rates acquired in 2022. It is advised that rates be confirmed through a tender process before the project is commenced.
- Operating costs associated with the TSF were estimated at ZAR 25.2 million per year (±25% accuracy).
- Rehabilitation, Closure and Aftercare costs are estimated at ZAR 1.49 million (50% accuracy).

# 15 Recommendations

The following recommendations are made:

- Rehabilitation of the downstream side slopes of the TSF should take place during the operational phase of the facility where possible.
- Monitoring, quarterly and annual inspections are recommended to ensure the operation and construction of the facilities are managed correctly. All data collected should be summarised by the custodian of all of the information related to the TSF, i.e. the Engineer of Record.
- Capital costs for the project are to be confirmed through a thorough tender process to confirm the predicted rates provided in this report.

# 16 References

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# Appendix A: LABORATORY TEST RESULTS (STL & VIETTI SLURRYTEC)

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# Appendix B: SEISMIC REPORT (NATURAL HAZARD ASSESSMENT CONSULTANCY)

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# Appendix C: GEOTECHNICAL INVESTIGATION (INROADS)

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# Appendix D: WASTE CLASSIFICATION REPORTS

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# Appendix E: HYDROGEOLOGICAL INVESTIGATION (ARTESIUM)

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# Appendix F: CPTu INVESTIGATION (OSIMO)

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# Appendix G: STAGE CAPACITY CURVE (EPOCH)

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# Appendix H: SLOPE STABILITY ANALYSIS RESULTS (EPOCH)

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# Appendix I: PENSTOCK ISOLATING VALVE (DELOM)

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# Appendix J: BOQ (EPOCH)

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# Appendix K: CONSTRUCTION DRAWINGS (EPOCH)

# THARISA MINERALS (PTY) LTD

tharisa

# CONSTRUCTION SPECIFICATIONS FOR:

# CONSTRUCTION OF THE RAISED TAILINGS STORAGE FACILITY COMPLEX AND ASSOCIATED INFRASTRUCTURE

# CONTRACT ORDER NO.

______________________________

# 1 PROJECT SPECIFICATIONS

## PS 1. GENERAL DESCRIPTION

The contract comprises the construction of the raised Tailings Storage Facility (TSF) complex (i.e., TSF 1 Expansion, TSF 2 Phase 1 and TSF 2 Phase 2) and associated infrastructure.

## PS 2. DESCRIPTION OF SITE AND ACCESS

The site of the Works is located in the Northwest Province, 7km south-west of the town of Marikana and 28km south-east of Rustenburg.

## PS 3. NATURE OF GROUND AND SUBSOIL CONDITIONS

The construction site is situated on an existing Tailings Storage Facility (TSF) and north of the N4 highway. The existing facilities consist of an engineering embamkment constructed with waste rock sources from the Tharisa Minerals open pit mining operation forming a ring dyke impoundment. The embankment. Platinum/chrome tailings, produced by the Tharisa process plant, are contained within the impoundment. The in-situ soil layers consist of black turf of variable thickness (0.7 to 6.2 m), of which significant portions have been removed beneath the ebmankments. The black turf is underlain by weatherd gabbro norite consisting of sand to very soft rock of variable thichness which transitions to residual gabbro norite.

## PS 4. DETAILS OF CONTRACT

The contract scope of work is covered in Section 2.

## PS 5. PROGRAMME OF CONSTRUCTION

The successful and URGENT completion of this contract is of paramount importance.

The following pertinent dates are applicable:

- Construction Start Date:
  - TBD
- Construction Ending Date:
  - TBD

Tenderers are to note that should the contract period extend into the rainy season adequate protection of the works will be required.

# PS 6. SITE FACILITIES AVAILABLE

## PS 6.1. WATER

It is the Employer's intention to provide supplies of potable water free of charge at a convenient location. The water supply point will be indicated at the site inspection meeting. It will be incumbent on the successful Tenderer to make his own arrangements for collection and transportation from the source of water supply to the place of work.

## PS 6.2. POWER

The Contractor must make his own arrangements regarding this facility unless otherwise indicated during the during the site inspection meeting.

## PS 6.3. SITE ESTABLISHMENT

The position of the Contractor's camp will be indicated at the site inspection meeting.

# PS 7. SITE FACILITIES REQUIRED

## PS 7.1. CONTRACTOR'S OFFICES

The Contractor shall provide, erect, on or about the site of the works, move and re-erect as necessary, maintain and remove at completion, ample temporary office/s for the use of his site agent and staff.

## PS 7.2. TEMPORARY SHEDS/FENCING

The Contractor shall provide, erect, move and re-erect as necessary, on or about the site of the works, maintain and remove at completion, ample temporary sheds/fencing for the proper storage of materials and tools and for the use of the workmen and watchmen, including special weatherproof sheds for the storage of cement.

## PS 7.3. ENGINEER'S SITE OFFICES

The Contractor shall provide, maintain and remove on completion of works, an office for a Resident Engineer who would be The Engineer's representative on site. The offices must be well insulated, air-conditioned and of the semi-permanent type, with dimensions of not less than 4 m x 4 m. The furnishings shall include a desk, a drawing table, a lockable filing cabinet, a plan cabinet or hanging rack, six stackable chairs, a fridge, a white drawing board, a boardroom table, washing facilities and external covered parking for two vehicles.

## PS 7.4. SITE LABORATORY

The Contractor shall provide an adequate site laboratory, equipment, facilities and personnel for carrying out the required quality control tests on the construction materials.

Should the Engineer at any time consider any of the facilities above to be inadequate, he shall instruct the Contractor to cease further work until such time as the Contractor has remedied the deficiency.

## PS 7.5. SANITARY ACCOMMODATION

The Contractor shall supply suitable and adequate sanitary accommodation for the use of his staff and workmen. Such accommodation shall be to the satisfaction of the Employer and the Engineer and shall conform to Local Authority requirements and the Minerals Act. The Contractor shall during tendering acquaint himself fully with these requirements.

The Contractor shall maintain in a thoroughly clean and orderly condition, move as required and finally remove from site all such sanitary accommodation and make good to the approval of the Engineer and Tharisa Minerals Mine.

The siting of the sanitary accommodation must be excluded from public view and their use will be strictly enforced.

## PS 7.6. TELEPHONES

The Contractor must make his own arrangements for communication links.

## PS 7.7. ACCOMMODATION FOR EMPLOYEES

No accommodation for employees is available on site and the Contractor shall make his own arrangements for housing employees.

It is deemed that the Contractor has made full provision for any such accommodation in his tender.

## PS 7.8. LIGHTNING SHELTERS

The Contractor shall provide shelter for workers in the event of the occurrence of a thunderstorm and shall furthermore ensure that all work on the facility and its surrounds ceases for the duration of such an event.

## PS 7.9. TEMPORARY LATRINES

The Contractor shall provide temporary latrines for use by his employees.

## PS 7.10. CHANGE HOUSE FACILITIES

The Contractor shall provide change house facilities for his workmen.

### PS 7.11. GAS BOTTLES

Gas bottles shall be clearly marked as to their contents and their ownership.

Any person removing gas bottles from the Site or using bottles belonging to others within the Site without permission will be evicted from the Site.

### PS 7.12. EXISTING BOREHOLES

The Contractor will be held liable for damages caused by the Contractor's equipment, blasting and activities to boreholes in the vicinity of the facility and any borehole found on Tharisa Mine Property. Damaged boreholes will be reinstated at the Contractors cost.

## PS 8. SPECIAL FEATURES REQUIRING ATTENTION

### PS 8.1. PROTECTION OF EXISTING SERVICES

General

The Contractor shall, during the execution of the Contract, take care that existing services, e.g. cables, pipelines, sewers, etc., are not damaged or interfered with. Any damages caused by the Contractor shall be for his account.

When any such service is encountered and is likely to impede the progress of the Contract, the Engineer shall arrange as far as possible for the re-location of the service.

The Contractor shall have no claim in regard to delays occasioned by alterations to any such services other than a claim for extension of the completion date of the Contract Works.

### PS 8.2. SETTING OUT

The Contractor shall be wholly responsible for the setting out of the various Works in accordance with the drawings supplied. Although the Engineer may require such setting out and levels to be checked from time to time, such checking will not relieve the Contractor of full responsibility for the accuracy of such setting out and levels.

The cost of all survey including setting out shall be deemed to be included in the scheduled rates or specifically allowed for in the Preliminary and General costs.

## PS 9. SITE ESTABLISHMENT

Tenderers should note that the term "Site Establishment" covers all items involved in the establishment by a Contractor of his construction camps for carrying out the works, their maintenance and their removal at the end of the Contract, and includes all accommodation and facilities he considers necessary for his personnel, plant, stores, etc. It also includes all movement of personnel and plant to the site preparatory to starting work and from site after completing work and leaving sites clean and tidy and free of any obstructions.

It shall also be deemed to include site sanitary arrangements, all insurances as called for in various sections of this document, all site and head office supervision and travelling expenses thereby entailed.

## PS 10. SUPERVISION AND ENGINEER'S INSTRUCTIONS

During the execution of the Contract Works on the site and until completion thereof, the Contractor shall keep on the site one competent head representative (approved of in writing by the Engineer, which approval may be withdrawn at any time), who shall superintend the work, receive on behalf of the Contractor instructions from the Employer and/or Engineer and be responsible for the behaviour of the Contractor's employees. The Contractor shall be required to sign a Responsible Person's form.

The Contractor shall have on site, as necessary, competent agents and foremen in charge of the work in progress. The Engineer will require details of the experience of agents and senior foremen to be submitted to him for approval before they take up position on the site.

The Contractor shall carry out and maintain the Contract Works in strict accordance with the Contract to the satisfaction of the Engineer and shall comply with and adhere strictly to the Engineer's instructions on any matter within the scope of the Contract, (whether mentioned in the Contract or not), who may, in his absolute discretion, and from time to time, issue further drawings, details and/or written instructions and/or directions and/or written explanations.

## PS 11. COMMUNICATIONS AND RECORD KEEPING

The contractor shall adhere to the following:

### PS 11.1. COMMUNICATION

a) Language: All correspondence, manuals, drawings, specifications etc. relating to the Contract shall be in the English language.

b) E-Mails: The Site Agent is to have daily access to an e-mail account to which the Engineer may e-mail communication.

### PS 11.2. SITE INSTRUCTION BOOKS

The Contractor shall always supply and have available at the Site, an approved triplicate carbon book with detachable sheets for receiving and recording instructions issued by the Engineer.

### PS 11.3. DAY BOOK

The Contract Price allows for the Contractor to maintain a suitable “Day Book” in his Site office in which daily progress as well as all circumstances that may affect the progress of the Contract to be recorded, e.g. weather conditions, labour difficulties, non-receipt of materials, etc. This book shall be available for daily scrutiny by the Engineer.

### PS 11.4. RECORDS

The Contractor shall maintain written records providing details of:

1. Date and quantity of materials delivered.
2. Date upon which each portion of the Contract Works was constructed, fabricated or erected as the case may be.
3. Daily weather conditions including rainfall measurements and maximum and minimum temperatures.
4. Nature of samples taken and tests made together with relevant dates and the portion of the Contract Works represented by such sample or test.
5. Those sections of the Contract Works which are not measurable for the Contract.
6. Daily resources allocated against work undertaken by the Contractor on a Daywork basis.
7. Record of actual man-hours expended.
8. Labour return.

Records prepared under items 1, 4, and 8 shall be presented to the ENGINEER on a weekly basis while items 5 and 7 shall be presented daily.

## PS 12. SITE MEETINGS

The Engineer will hold regular bi-weekly site meetings, keep and circulate minutes. The Contractor shall attend all scheduled meetings and shall ensure that all subcontractors are represented.

## PS 13. WATCHING AND LIGHTING

The Contractor must programme his work in such a way that the area is secure at all times. The Employer reserves the right to suspend work if, in his opinion, this requirement is not being complied with and, further, to make secure the area and recover any costs involved in labour and materials from monies due to the Contractor.

The Contractor shall make provision in the nature of temporary works as may be required for the purpose of ensuring the safety of adjoining works and property and for the protection of all persons or animals. He shall be responsible for all damage, injuries and accidents that may occur through his omission of any necessary provision in this respect.

The Contractor shall make full provision for all watching and lighting necessary for the protection of all persons, animals, vehicles, etc., from injury by reason of the Works. He shall provide ample warning signs, guard rails, etc. around open trenches, stacks of material, excavated materials, debris or the like, and shall provide walkways over trenches wherever required for the convenience of the public.

The Contractor shall provide and maintain all necessary temporary protection of finished and/or existing work liable to be damaged during the progress of the works by properly covering up, isolating, etc., as required. The Contractor shall be responsible for any damage which may occur and shall make good the same at his own expense.

Fires will only be allowed in such places as are approved by the Engineer. Any workmen lighting fires in an unauthorised place shall immediately be removed permanently from site.

## PS 14. CLAIMS FOR INJURY OR DAMAGE

The Contractor shall notify the Engineer immediately of the receipt by him of any claim for compensation in respect of any damage arising out of his execution of the Contract and if, at the expiry of ninety (90) days from the date of receipt of such claim the Contractor cannot satisfy the Engineer that the matter has been settled, the Employer reserves the right to have the claim investigated and adjudicated by the Engineer and to settle the claim where considered necessary, any costs incurred by the Employer thereby to be recovered from the Contractor by deduction from any monies due to the Contractor.

## PS 15. SAMPLES OF MATERIAL

Samples of materials to be used upon the Works shall, when required be submitted at the Contractor's expense to the Engineer together with test results as necessary for approval before use. Any material brought on to the Works which, in the opinion of the Engineer, does not meet the standard of the sample so submitted or is considered by him in any way unsuitable for its designed purpose, shall be removed immediately instructions to that effect have been given.

## PS 16. MEASUREMENT AND PAYMENT

Measurement of completed work will be made monthly in accordance with the General Conditions of Contract.

## PS 17. ADVANCE PAYMENTS ON MATERIALS

Materials on site are not paid for prior to installation.

Tharisa Minerals reserves the right to pay for principal or major materials supplied and delivered to site but not installed. Any payments of this nature must be completely secured by means of a legally accepted Waiver of Lien.

This payment will only be considered if there is a substantial discount or alternatively beneficial advantages to the Employer.

Should Tharisa Minerals consider paying for Principal Materials on Site then the Contractor/ Supplier has the opportunity to price any items in the Bill of Quantities to show the discount the Contractor will pass, alternatively, the benefit such payment has towards the Employer.

## PS 18. CONTRACTOR'S PLANT AND TOOLS AND SCHEDULES FOR MANPOWER AND PLANT

The Contractor's plant and tools shall be of modern design and construction, suitable for the duties required of them. They shall be in sound working condition and shall be sufficiently ample in capacity or number to enable the work to be carried out efficiently and expeditiously. Should the Engineer be of the opinion that the plant used by the Contractor is insufficient or in any way unsuitable for carrying out the Works in a manner or at a rate commensurate with his requirements, he shall have the right to call upon the Contractor to provide such additional or approved plant and tools as may, in his opinion, be necessary to attain these requirements.

## PS 19. MINES AND WORKS REGULATIONS AND OCCUPATIONAL DISEASES IN MINES ACT

The Contractor shall conform with the requirements of the Occupational Health and Safety Act, Act No. 85 of 1993 as amended, Minerals Act, Act No. 50 of 1991 read together with the Regulations of the Mines and Works Act (Act No. 27) of 1956, as amended, and with the Occupational Diseases in Mines Act, Act No. 78 of 1973 as amended from time to time and the Mine Health and Safety Act (Act 29 0f 1996 as amended) and whilst carrying out this Contract accept full responsibility and liability for the observance of the requirements of these Acts and shall pay all costs involved in the compliance therewith including arranging wherever applicable for the certification and examination of all employees.

In addition, the Contractor shall ensure that all his employees have been tested and certified clear of Tuberculosis.

## PS 20. LOCAL AUTHORITY, PROVINCIAL OR GOVERNMENT ADMINISTRATION, ETC.

The Contractor shall acquaint himself with all and any standards and requirements laid down by a Local Authority, Provincial or Government Administration, etc., for the work about to be executed, and shall abide by such standards and requirements throughout the duration of the Contract.

## PS 21. MAINTENANCE PERIOD

On completion of the Works, the Contractor shall notify the Employer. The Employer's representative shall issue to the Contractor a Notice of Completion on which he shall indicate any items requiring rectification.

The maintenance period shall be twelve (12) months, commencing from the date of issue of the Notice of Completion, except for those items indicated thereon, for which the maintenance period will commence on the date of rectification.

Should the contract be based on a fees retention basis, 50% of the retention money will be released on completion of the works after issue of the Notice of Completion and the remaining 50% will be released at the end of the maintenance period.

## PS 22. CLEANING OF SITE ON COMPLETION

On completion of each section of the Works, or if directed by the Engineer on Completion of any portion of the works, the Contractor shall remove surplus materials, construction plant and equipment, not to be used at or near the same location during later stages of the work.

In the event of the Contractor's failure to comply with the above the same may be accomplished by the owner at the Contractor's expense.

## PS 23. INCLEMENT WEATHER CONDITIONS

An extension of contract completion time for delays due to inclement weather will only be considered when it can be proved that weather conditions were adversely abnormal for the time of year during which site construction works took place.

When considering the claim, the Engineer shall give due consideration to the circumstances pertaining such as amount and intensity of rainfall, when compared to those circumstances statistically anticipated to pertain during the contract period.

Programme completion times should make allowance for those conditions likely to pertain from the date of commencement of contract works, which date must be stated by the Engineer prior to the date of Tender.

Delays will **not include consequential delays** but only take into account those periods of actual interruption due to the primary cause of the delay.

## PS 24. OTHER CONTRACTORS ON SITE

The Contractor is to take cognisance of the fact that other Contractors may be working in the area at the same time as construction of the works is taking place. No claims for delays due to other Contractors operations will be considered.

## PS 25. LIST OF DRAWINGS

The list of drawings accompanying this document is shown in Table 1:

**Table A 1-1: List of Drawings**

| DRAWING NUMBER | DRAWING TITLE |
|---|---|
| 144-023-001 | THARISA MINERALS RAISING OF TSFs GENERAL ARRANGEMENT |
| 144-023-002 | THARISA MINERALS RAISING OF TSFs SETTING OUT DATA |

| DRAWING NUMBER | DRAWING TITLE |
|---|---|
| 144-023-003 | THARISA MINERALS RAISING OF TSFs CROSS SECTIONS SHEET 1 OF 2 |
| 144-023-004 | THARISA MINERALS RAISING OF TSFs CROSS SECTIONS SHEET 2 OF 2 |
| 144-023-005 | THARISA MINERALS RAISING OF TSFs CREST DETAILS |
| 144-023-006 | THARISA MINERALS RAISING OF TSFs DECANT TOWER STEEL PIPE DETAILS |
| 144-023-007 | THARISA MINERALS RAISING OF TSFs CATWALK DETAILS - SHEET 1 OF 2 |
| 144-023-008 | THARISA MINERALS RAISING OF TSFs CATWALK DETAILS - SHEET 2 OF 2 |
| | |
| | |

# 2 SCOPE OF WORK

The site is situated at Tharisa Minerals Mine. Tharisa Minerals Mine is located on the farm Kafferskraal 342JQ, some 7km south west of the town of Marikana in the North West Province.

The scope of work will include the following:

**TAILINGS DAM**

- Construction of the raised embankments of the existing PGM tailings. Approved construction materials to be obtained from suitable sources and borrow pits.
- Construction of decant tower lift for TSF 2 Phase 2.
- Construction of emergency ilsolation valves at the penstock outfall pipe discharge point for TSF 1 Expansion and TSF 2 Phase 1.
- Raising the catwalk on TSF 1 Expansion and TSF 2 Phase 1.

**EXCLUSIONS**

The following items are not included or covered in this contract:

- All electrical installations;
- Pumps;
- Transformers;
- Return water pipelines

# 3 CONSTRUCTION SPECIFICATIONS

Standards and Particular Specifications

The South African Bureau of Standards Standardised Specifications for Civil Engineering Construction (not included in this document), Project Specifications and Particular Specifications that are applicable to this contract is shown in Table 2. The Contractor shall ensure that they are in possession of the specification as listed in Table 2.

**Table 2: LIST OF SANS AND PARTICULAR SPECIFICATION APPLICABLE TO THIS CONTRACT**

| SANS Number / Specification Number | Document Title |
|---|---|
| SANS 1921 | Construction and Management Requirements for Works Contracts |
| SANS 1200 A | General |
| SANS 1200 AA | General (Small Works) |
| SANS 1200 AB | Engineer's Offices |
| SANS 1200 AD | General (Small Dams) |
| SANS 1200 AH | General (Structural) |
| SANS 1200 C | Site Clearance |
| SANS 1200 D | Earthworks |
| SANS 1200 DA | Earthworks (Small Works) |
| SANS 1200 DB | Earthworks (Pipe Trenches) |
| SANS 1200 DE | Small Earth Dams |
| SANS 1200 DK | Gabions and Pitching |
| SANS 1200 DM | Earthworks (Roads, subgrade) |
| SANS 1200 DN | Earthworks (Railway sidings) |
| SANS 1200 F | Piling |
| SANS 1200 G | Concrete (Structural) |
| SANS 1200 GE | Precast Concrete (Structural) |
| SANS 1200 GF | Prestressed Concrete |
| SANS 1200 H | Structural Steelwork |
| SANS 1200 HA | Structural Steelwork (sundry items) |
| SANS 1200 HB | Cladding and Sheeting |
| SANS 1200 HC | Corrosion Protection of Structural Steelwork |
| SANS 1200 HE | Structural Aluminum Work |
| SANS 1200 L | Medium Pressure Pipelines |
| SANS 1200 LB | Bedding (Pipes) |
| SANS 1200 LC | Cable Ducts |
| SANS 1200 LD | Sewers |
| SANS 1200 LE | Storm water Drainage |

| SANS NUMBER / SPECIFICATION NUMBER | DOCUMENT TITLE |
|---|---|
| SANS 1200 LF | Erf Connections (Water) |
| SANS 1200 LG | Pipe Jacking |
| SANS 1200 M | Roads (General) |
| SANS 1200 ME | Subbase |
| SANS 1200 MF | Base |
| SANS 1200 MG | Bituminous Surface Treatment |
| SANS 1200 MH | Asphalt Base and Surfacing |
| SANS 1200 MJ | Segmented Paving |
| SANS 1200 MK | Kerbing and Channelling |
| SANS 1200 MM | Ancillary Roadworks |
| SANS 1200 NB | Railway Sidings |
| PSA - PSF | PROJECT SPECIFICATIONS FOR EXCAVATIONS, EARTHWORKS AND UNDERDRAINAGE |
| PA | PARTICULAR SPECIFICATIONS FOR VEGETATION ESTABLISHMENT |
| PB | PARTICULAR SPECIFICATIONS FOR FENCING |
| PC | PARTICULAR SPECIFICATIONS FOR SMOOTH LINING GEOMEMBRANE |
| PD | SPECIFICATIONS FOR GEOTEXTILES |
| PE | PARTICULAR SPECIFICATIONS FOR PENSTOCK PIPELINE |

**NOTE:** Where there is conflict between SANS 1200 and the Particular Specifications for Excavation, Earthworks and Under-drainage, the Particular Specifications for Excavation, Earthworks and Under-drainage shall rule.

In the event of an ambiguity or conflict between specifications the following order of precedence will apply to the above Specifications:

1. Construction Drawings
2. Construction Specifications
3. Project Specifications
4. SANS Specifications

# VARIATIONS TO REQUIREMENTS OF SANS 1200 SPECIFICATIONS LISTED IN TABLE 2

## PS SPECIFICATIONS FOR EXCAVATIONS, EARTHWORKS AND UNDERDRAINAGE

## PSA GENERAL (SANS 1200A)

## PSA.1 DEFFINITIONS (CLAUSE 2.3)

The SANS 1200 Standard Specifications and the amendments refer to the "Engineer". Where these specifications are used the "Engineer" is deemed to be the officially appointed representative of the Client. The SANS 1200 Standard Specifications and the amendments refer to either the "Client" or "Owner". Where these specifications are used the "Client" or "Owner" is deemed to be Tharisa Minerals.

## PSA.2 MATERIALS (CLAUSE 3)

All the Contractor's suppliers are to be approved by the Engineer prior to the award of the contract.

### PSA.2.1 QUALITY (SUB CLAUSE 3.1)

The following shall be an addition to Sub Clause 3.1:

No used or recycled material may be used in the Works unless authorized by the Engineer.

Where applicable all material supplied, shall bear the official standardization mark. The Engineer's approval is based on tests conducted by the Contractor as required by the contract.

All materials proposed by the Contractor for use in the Works shall where required, be tested in accordance with the Specifications. All test results shall be submitted to the Engineer for approval prior to such materials being built into the Works. All cost involved in this testing shall be deemed to be included in the rates tendered.

### PSA.2.2 DELAY DUE TO SUPPLY OF MATERIALS (CLAUSE 3)

The following new Sub Clause 3.3 shall be added:

The Contractor shall ensure that the Works is not delayed, due to lack of materials on site, by placing orders with suppliers for materials required in a timeously manner.

The Contractor shall, by furnishing copies of written orders or written enquiries for supplies, prove to the satisfaction of the Engineer that any delay caused by non-availability of materials has been caused by the inability of suppliers to supply materials and not by his own lack of timely ordering or lack of exhaustive inquiry for supplies, before any extensions of contract time will be allowed due to lack of such delays.

The decision of the Engineer to either allow or deny such extension of contract time shall be final.

### PSA.2.3 ORDERING OF MATERIALS (CLAUSE 3)

The following new Sub Clause 3.4 shall be added:

The quantities set out in the Bill of Quantities have been carefully determined from calculations based on the available information at the time of its completion but are to be considered as approximate quantities only. Before ordering of materials of any kind the Contractor shall be responsible for determining, from the issued Construction drawings, the actual quantities of materials required for the execution of the Works.

No liability or responsibility whatsoever shall be attached to the Client or the Engineer in respect of materials ordered by the Contractor except when ordered in accordance with the issued Construction Drawings.

## PSA.3 PLANT (CLAUSE 4)

The following shall be an addition to Clause 4:

All the Contractor's plant and vehicles to be used on site will be subject to, and comply with the Client's requirements.

### PSA.3.1 SILENCING OF PLANT (SUB CLAUSE 4.1)

The following shall be an amendment to Sub Clause 4.1:

In line 2 change "Machinery and Occupational Safety Act, 1983 (Act No. 6 of 1983)" to "Occupational Health and Safety Act, 1993".

### PSA.3.2 GENERAL (CLAUSE 4)

The following new Sub Clause 4.3 shall be added:

All plant provided by the Contractor for the execution and maintenance of the Works shall be of a character comparable with the scope of works.

The Contractor shall provide and maintain sufficient plant to meet all requirements of this Contract and shall not remove any of his plant from the site without written approval of the Engineer. The Contractor shall, however, remove unsuitable, obsolete or worn out plant from the site when so instructed by the Engineer and replace these with plant approved by the Engineer.

The approval of any plant on the site by the Engineer shall in no way relieve the Contractor of any of his obligations under the Contract.

# PSA.4 CONSTRUCTION (CLAUSE 5)

## PSA.4.1 SETTING OUT (SUB CLAUSE 5.1)

The following shall be an amendment to Sub Clause 5.1:

All surveying operations shall be completed using GPS surveying equipment. Calibration certificates of all surveying equipment are to be provided to the Engineer.

The Contractor shall be responsible for maintaining accurately ascertained Site datum levels at his own expense. The Contractor shall further ensure that all level control and setting out of the Works is executed in accordance with the survey data given on the construction drawings.

Immediately following the issue of the order to commence, the Contractor shall, at his own expense, carry out and record a check level grid of the Site of Works, in order to confirm the contour levels shown on the construction drawings. Any discrepancies causing non-acceptance by the Contractor of the levels shown on the construction drawings are to be pointed out to the Engineer within two weeks of the above order being given, and the alterations checked and agreed with the Engineer. Failing this, the original levels as shown on the construction drawings will be deemed correct and acceptable. In addition to the above, the following survey tasks shall be undertaken by the Contractor for agreement with the Engineer.

- Original ground levels shall be recorded at 10 m intervals on the centre line and upstream and downstream toe positions of all embankments and fills after Site clearance and again after removal of unsuitable material. In the case of large embankments or fills the Engineer may specify that the spacing of recorded levels be increased to that of a 5 m grid.
- Original ground levels shall be recorded at 2.5 m and 5 m intervals on the entire line left and right bank positions of all trenches, canals and drains prior to excavation and again on completion of the excavation to the required depths and grades.
- Original ground levels shall be recorded at 10 m intervals over material borrow areas. After removal of unsuitable material and/or topsoil and/or fill material as required, the Contractor shall re-survey the ground and record levels as described above. The grids and lines before and after soil removal shall be coincident in plan.
- Final survey of all as-built levels shall be provided for the purpose of verification and final payment purposes.
- All survey info as described above shall be supplied to the Engineer in AutoCad drawing format as well as points in an excel spreadsheet as soon as the surveys have been completed and the information compiled.

The Contractor shall allow for the above survey operations in the Preliminary and General section of the Bill of Quantities. No separate payment will be made for these surveying operations. The agreed survey data shall be the basis of all earthworks measurement.

Any survey submitted by the Contractor is to be approved in writing by the Engineer before being considered valid as a basis of measurement.

The Contractor is to inform the Engineer in writing upon the completion of impoundment walls and trenches to design elevations and cross-sections. Thereafter, a verification survey may be carried out by the Engineer's appointed surveyor to verify these elevations and cross-sections.

The cost of this verification survey will be paid for by the Employer only if the results of the survey show that the design levels and cross-sections have been achieved. The Contractor shall pay for the costs of the verification survey where the results show that the design levels and cross-sections have not been achieved.

Any further costs involved to verify that the required design levels and cross-sections have been obtained after the corrective measures have been applied shall be borne by the Contractor.

## PSA.4.2 PROTECTION OF OVERHEAD AND UNDERGROUND SERVICES (SUB CLAUSE 5.4

The following shall replace Sub Clause 5.4 in its entirety:

### PSA.4.2.1 EXISTING WORKS AND SERVICES

The Contract may include certain work involving the moving and reinstating of existing services that are affected by the construction of the Works.

The Construction drawings will include information regarding the location of known existing services. Although the Construction drawings may indicate the approximate positions of existing works and services, neither the Client nor the Engineer accepts any responsibility for the accuracy thereof nor for the omission for the Construction drawings of possible further existing works and services.

It shall be the responsibility of the Contractor to search and make himself acquainted with the actual location and ownership of existing works and services before any construction work commences.

Where the position of a service cannot be accurately determined by visual inspection, the Contractor shall open up and make further investigations before construction commences, so that the position of such services can be accurately determined to avoid damage during construction. Wherever possible the Contractor shall ascertain the exact position and type of service from the Client.

In addition, where so instructed by the Engineer, the Contractor shall also open up and search for any services not shown on the Construction drawings but which he or the Engineer may believe to exist. The Contractor shall complete such investigations well in advance of the commencement of Construction work in the said area and shall submit a report in good time to enable the Engineer to make whatever arrangements are necessary for the protection, removal or diversion of the services before commencement of Construction in said area.

Before any excavation is carried out within 10 m of the approximate position of an existing service the Contractor shall notify the Engineer and the Client of the service and that the excavation is to be made and shall ascertain and comply with any conditions that are imposed by Excavation Permits.

As soon as any underground service not shown on the Construction drawings is discovered, it shall be deemed to be a known service.

### PSA.4.3 PROTECTION OF EXISTING WORKS AND SERVICES

The following new Sub Clause 5.9 shall be added:

Where during the Contract, services have been located and exposed, they shall be securely shored, and the Contractor shall take adequate measures to prevent damage occurring to them.

The Contractor shall take special care when excavating trenches, when trenches are open, or when carrying out any work under the Contract, not to damage any existing water mains, sewers, cables or other underground services or to disturb the stability of any poles or towers supporting overhead powerlines, telegraphs and telephone wires, etc. the Contractor shall solely be responsible for the protection of all such services and for any claims for damages arising there from.

All work or protective measures shall be subject to the approval of the Engineer.

### PSA.4.4 DAMAGE TO EXISTING WORKS AND SERVICES

The following new Sub Clause 5.10 shall be added:

The Contractor shall take all reasonable precautions to protect existing services during construction and during the relocation of such services. Any damage done to existing works and services shall be reported immediately to the Engineer and the Client in writing. Any known service of any nature whatsoever that has been damaged as a result of the Contractor's operations shall be repaired and reinstated immediately by the Contractor if so directed by the Engineer. The settlement of all claims arising from damage to existing property, works and services shall be solely the responsibility of the Contractor.

In addition, the Contractor will be liable to prosecution for any wilful and/or negligent damage to services in terms of Section 88 and 111 of the Local Government Ordinance and Section 51 of the Electricity Act No. 40 of 1958. It is stressed that damage of this nature is a criminal offence.

### PSA.4.5 ACCESS TO SERVICES

The following new Sub Clause 5.11 shall be added:

Where the Client elects to carry out on its own accord any alterations or protective measures, the Contractor shall co-operate with and allow reasonable access and sufficient space and time to carry out the required work.

### PSA.4.6 ALTERATIONS AND REPAIRS TO EXISTING SERVICES

The following new Sub Clause 5.12 shall be added:

Unless the contrary is clearly specified in the Contract or directed by the Engineer, the Contractor shall not carry out alterations of any nature to existing services. When any such alterations become necessary, the Contractor shall promptly notify the Engineer, who will either make arrangements for such work to be executed by the owner of the service, or instruct the Contractor to make such arrangements.

Should damage occur to any existing services, the Contractor shall immediately inform the Engineer, or when this is not possible, the relevant authority, and obtain instructions as to who should carry out repairs. In urgent cases the Contractor shall take appropriate action to minimize damage to and interruption of the service. No repairs of telecommunication cables, power lines and electrical cables shall be attempted by the Contractor.

The Client and Engineer shall accept no liability for damages due to delay in having alterations or repairs affected by respective service owners. The Contractor shall provide all reasonable opportunity and assistance to persons carrying out alterations or repairs of existing services.

## PSA.4.7 PAYMENT FOR EXPOSING SERVICES

The following new Sub Clause 5.13 shall be added:

The cost associated with opening and searching for existing services shall be paid for as and when it is required. It shall be priced as a rate only for the meter length of trench to accurately determine the position of the existing services.

Permanent alterations to or permanent relocation of services necessitated by the execution of the Works and authorized by the Client will be paid for in terms of the conditions of contract. No such work will be paid for if it has not been previously inspected and if proper written instructions have not been given.

Any work required to be undertaken by the Contractor for protection or moving and relocating services and for which no provision is made in the Contract Documentation, or for which no applicable tender rate exist, shall be classed and paid for as “extra work” as prescribed in the General Conditions of Contract.

## PSA.4.8 POLLUTION (SUB CLAUSE 5.6)

The following new Sub Clause 5.6.1 shall be added:

### PSA.4.8.1 TRANSPORTATION OF MATERIALS (SUB CLAUSE 5.6.1)

Where transportation of materials outside of the site occurs is such that it has the potential to generate a nuisance, the material shall be covered during transportation.

Precautions shall be taken during the transportation of muddy and other materials to prevent the materials falling on finished construction works and roads.

Any rock or debris falling from transportation vehicles shall be removed immediately. Any and all damage occurring from rock or debris material falling from transportation vehicles shall be noted and repaired immediately. The Engineer shall be notified of any such damage immediately after it has occurred.

The cost associated with the repair of such damage shall be for the Contractor’s account.

**PSA.4.9 SAFETY (SUB CLAUSE 5.7)**

The following shall be an amendment to Sub Clause 5.7:

"Pursuant to the provisions of the Conditions of Contract, and without in any way limiting the Contractor's obligations there under, the Contractor shall at his own expense (expect only where specific provision (if any) is made in the Contract for the reimbursement to the Contractor of particular items), provide the following:

- Provide to his Employees on the site of Works, all safety materials, clothing and equipment necessary (Personal Protective Equipment) to ensure full compliance with the provisions of Mine Health and Safety Act (Act No. 29 of 1996), the Occupational Health and Safety Act (Act No. 85 of 1993) and Construction Regulations 2014, as amended at all times, and shall institute appropriate and effective measures to ensure the proper usage of such safety materials, clothing and equipment at all times.
- Provide, install and maintain all barricades, safety signage and other measures to ensure the safety of workman and all persons in, on and around the site, as well as the general public.
- Implement on site, such procedures and systems and keep all records as may be required to ensure compliance with the requirements of the Acts at all times.
- Implement all necessary measures so as to ensure compliance with the Acts by all Sub Contractors engaged by the Contractor and their employees engaged on the Works.
- Full compliance with all other requirements pertaining to safety as may be specified in the Contract.
- Comply with the Client's Standard Practice Instruction.
- Comply with the Client's Code of Practise: Mandatory Code of Practice for Trackless Mobile Machinery (DME 16/3/2/2-A2).
- Comply with the Client's requirements: SHE Management Specification for Contractors.
- Comply with the Construction Regulations, 2014 as promulgated in Government Gazette No. 25207 and Regulation Gazette No. 7721 of 18 July 2003. The proposed type of works, materials to be used and the potential hazards likely to be encountered on this contract are detailed in the Project Specifications, Bill of Quantities and Construction Drawings, as well as in the Client's health and safety requirements. The Contractor shall in terms of Regulation 5(1) provide a comprehensive health and safety plan detailing is proposed compliance with the regulations, for approval by the Client.

The Client and the Engineer shall be entitled, although not obligated, to make such inspections on the site as they shall deem appropriate, for the purpose of verifying the Contractor's compliance with the requirements of the Acts. For this purpose the Contractor shall provide full access to all parts of the site and shall co-operate fully in such inspections and shall make available for inspection all such documents and records as the Client and/or the Engineer may reasonably require.

Should any such investigation reveal or should it come to the Engineers attention that the Contractor is in any way in breach of the requirements of the Acts and requirements and/or failing to comply to the provisions of this Clause, the Engineer shall be entitled to suspend the Works or any part thereof until such time as the Contractor has demonstrated to the satisfaction of the Engineer, that such breach has been rectified.

The Contractor shall have no grounds for a claim against the Client for extension of time and/or additional cost if the progress on the Works or any part thereof is suspended by the Engineer in terms of this Clause. The Contractor shall remain fully liable in respect of the payment of penalties for late completion, should the Contractor fail to complete the Works on or before the specified date of completion in consequences of the suspension.

Persistent and repeated breach by the Contractor of the requirements of the Acts and requirements and/or failing to comply with the provisions of this Clause shall constitute grounds for the Engineer to act in terms of the Contract of the Conditions of Contract and for the Client to cancel the Contract in accordance with the further provisions of said Contract.

## PSA.4.10 GROUNDS AND ACCESS TO WORKS (SUB CLAUSE 5.8)

The following shall be an addition to Sub Clause 5.8:

Once site establishment has been completed, the Contractor shall be responsible for maintaining the site in a neat, clean and orderly condition.

The Contractor shall be responsible for the preservation of the ecology of the area and no tress, bushes or other forms of vegetation shall be interfered with, apart from those specifically involved in the execution of the works.

Upon completion of the Contract, or when ordered in writing by the Engineer, the Contractor shall remove from the site all plant, equipment, temporary housing, offices, sheds, ablution facilities, waste material and other debris. The Contractor shall reinstate all disturbed surfaces of roads, access areas, excavations and borrow pits and shall restore the site to a neat and orderly condition. The contractor shall reinstate all fences to the satisfaction of the Engineer.

### PSA.4.10.1 ACCESS ROADS ON SITE

The following new Sub Clause 5.8.1 shall be added:

The Contractor shall grade or construct and keep in good and constant repair all construction roads, temporary access roads to and on the site, storm water drainage systems and culverts. The Contractor is to repair, at his own cost, any damage caused to existing roads and road edges on site.

Any route the Contractor wishes to use to obtain access to the site or to any other route used by the Contractor shall be subject to the approval of the Client.

Any temporary diversions and construction roads shall be kept watered and damp or sprayed with a chemical dust suppressant, during all sealing operations and all dust shall be removed from surfaces before any binder, aggregate or slurry is applied.

Payment for dust suppression on the temporary diversions, haul and construction roads shall be deemed to be included in the tendered rates.

## PSA.5 TOLERANCES (CLAUSE 6)

The following new Sub Clause 6.4 shall be added:

### PSA.5.1 USE OF TOLERANCES (SUB CLAUSE 6.4)

No guarantee is given that the full specified tolerances will be available independently of each other, and the Contractor is cautioned that the liberal or full use of any one or more tolerances may deprive him of the full or any use of tolerances relating to other aspects of the Works.

Except where the contrary is specified, or when clearly not applicable, all quantities for measurement and payment shall be determined from the 'authorized' dimensions. These are specified dimensions or those shown on the Construction drawings or, if changed, as the final dimensions prescribed by the Engineer, without any allowance for the specified tolerances. Except where otherwise specified, all measurements for determining quantities for payment shall be based on the 'authorized' dimensions.

If the work is constructed in accordance with the 'authorized' dimensions plus or minus the tolerances allowed, the calculation of quantities will be based on the 'authorized' dimensions, regardless of the actual dimensions to which the work has been constructed.

When the work is not constructed in accordance with the 'authorized' dimensions plus or minus the tolerances allowed. The Engineer may nevertheless, at his sole discretion, accept work for payment. In such cases no payment shall be made for quantities of work or materials in excess of those calculated for the 'authorized' dimensions, and where the actual dimensions are less than the 'authorized' dimensions minus the tolerances allowed, quantities for payment shall be calculated based on actual dimensions as constructed.

## PSA.6 TESTING (CLAUSE 7)

### PSA.6.1 APPROVED LABORATORIES (SUB CLAUSE 7.2)

The following shall be an amendment to Sub Clause 7.2:

Unless otherwise specified in the relevant specification or elsewhere in the Specifications, the following shall be deemed to be approved laboratories in which testing in terms of a specification for the purpose of acceptance by the Engineer of the quality of materials used and/or workmanship achieved may be carried out:

Any testing laboratory certified by the South African National Accreditation System (SANAS) in respect of the nature and type of testing to be undertaken for the purpose of the Contract.

Any testing laboratory established and operated on site by or on behalf of the Client or the Engineer.

All laboratories to be used for testing for the purpose of acceptance by the Engineer of the quality of materials used and/or workmanship achieved shall be approved by the Engineer. The Contractor shall ensure to supply the Engineer with all relevant documentation required to confirm the proposed laboratory SANAS accreditation prior to any materials sent for testing and/or onsite testing required for acceptance of workmanship achieved.

## PSA.7 CLEAR SITE (SANS 1200C)

## PSA.8 SCOPE (CLAUSE 1)

The following shall be an addition to Clause 1:

No site clearance will take place without the written approval of the Engineer. The Engineer reserves the right to determine which areas will be cleared and payment for site clearance will only be for the areas specified by the Engineer in writing.

## PSA.9 DISPOSAL OF MATERIALS (SUB-CLAUSE 3.1)

The following shall be an addition to Sub Clause 3.1:

Material from clear and grub activities is to be placed in a neat stockpile(s) or disposed of as directed by the Engineer.

This is to be within the free haul distance of 2 km.

# PSB EARTHWORKS (SANS 1200D)

## PSB.1 CLASSES OF EXCAVATION (SUB CLAUSE 3.1.2)

The following shall replace Sub-Clause 3.1.2:

All excavation quantities throughout in all classes of material will be measured **NETT**. Excavations shall be measured per cubic metre and divided into the following classes: (Note: Excavations shall only be paid in one of the classes of material, i.e. no extra over).

### PSB.1.1 MATERIAL CLASS "A"

This classification shall include all kinds of ground encountered except those defined in Class "B" hereinafter and shall include made-up ground, paving, rubbish, gravel, sand, silt, calcareous material, clay, soft rock, ground interspersed with small boulders of rock not exceeding 0.5 $m^3$ (one half of a cubic metre), dumped waste rock material in compacted embankments and **all other materials which can, in the opinion of the Engineer, be excavated by hand or by machine without drilling and blasting.**

### PSB.1.2 MATERIAL CLASS "B"

In the case of channel, trench and small excavation, this classification shall mean granite, quartz, dolomite or rock of similar hardness which in the opinion of the Engineer or his representative, can only be removed by drilling or blasting. Solid boulders in excess of 0.5 $m^3$ (one half of a cubic meter) will be classified in this category. This classification shall apply whether or not blasting is authorised.

In the case of bulk excavation, this classification shall include granite, quartz, dolomite or rock of similar hardness found in its original position which cannot be loosened by a bulldozer having a minimum fly wheel power of 130 kW and an operating weight of 23 000 kg (e.g. a Caterpillar D7, Komatsu D85 or equivalent in good condition, fitted with an approved single tine ripper and driven by a competent operator). This classification shall apply whether or not blasting is authorised.

One rate has been allowed in the Bill of Quantities for Class "B" material to cover all types and depths of excavation work. Spoiling of Class "B" material shall be the same as for Class "A" material. The excavation rate for Class "B" material shall, therefore, include any extra required for spoiling the rock.

**Note:** If the Contractor considers that any material to be excavated is classified as Class "B" above, he shall submit a written request to the Engineer or his representative for his ruling. Failing such a request, the excavations shall be deemed to be in Class "A". The decision of the Engineer as to the classification of the material shall be final and binding.

## PSB.2 MATERIALS SUITABLE FOR EMBANKMENTS AND TERRACES (SUB CLAUSE 3.2.1)

The following shall be an addition to Sub Clause 3.2.1:

Fill material for all embankments and roads shall be free of all organic matter and shall be approved by the Engineer. This material will generally be obtained from the following sources:

- Basin excavations.
- Borrow pits.
- Stockpile areas.

Should these restrictions not be adhered to, the Contractor shall, at his own expense, restore the original ground level in the areas where the material has been sourced by compacting selected material to the specification of the Engineer.

## PSB.3 MATERIALS SUITABLE FOR REPLACING OVERBREAK IN EXCAVATIONS FOR FOUNDATIONS (SUB CLAUSE 3.2.2)

The following shall be an addition to Sub Clause 3.2.2:

Backfilling to over-excavation outside the levels and geometry specified in the drawings necessary to obtain the specified design levels and geometry is to be carried out to the instructions and satisfaction of the Engineer and entirely at the Contractor's expense as follows:

- Where the material excavated is not required for structural support, the over-excavation will be filled with selected material approved by the Engineer in 200 mm layers and compacted to a density not less than that of the surrounding undisturbed material. Test work required to determine suitable material.
- Where the material excavated is required for structural support, the over-excavation shall be backfilled with 20 Megapascal concrete, (or concrete of other strength to be specified by the Engineer) including all necessary work to prevent its inclusion with the structural concrete.

## PSB.4 SAFEGUARDING EXCAVATIONS (SUB CLAUSE 5.1.1.2)

The following shall be an addition to Sub Clause 5.1.1.2:

The Contractor shall assume full responsibility for the safety of all excavations, and shall at his own expense adopt all measures necessary to secure this end, either by planking and strutting or by side sloping of the ground provided that, the Engineer may instruct the Contractor to plank and strut banks and sides of excavations, and/or side slope such banks and sides of excavations without cost to the Employer over any surface where he may consider the excavations dangerous, and/or to conform with any safety precaution in terms of the relevant regulations.

Such instructions shall be considered final and binding.

All planking and strutting must be of sufficient strength to ensure the safety of all persons in the excavations and must be suitably arranged to permit the construction of whatever is necessary, and the Engineer's decision as to this shall be binding upon the Contractor, who shall immediately proceed to rectify any planking and strutting that is deemed by the Engineer to be unsafe or of such a character as will impede or impair the placing of concrete or the construction of the Works. The Contractor shall be held fully responsible. No under-cutting of excavations will be allowed.

No additional payment will be made for side sloping and timbering and shoring work, and these shall be deemed to be included in the rates for excavation.

The Contractor shall be responsible for making good, or having made good, at his own expense any slips, falls, caving-in of ground, damage to walls, structures or Works cause by reason of his acts or Works, or by causes within his control and shall indemnify the Engineer against any claims made in respect of loss of life, or injury or damage to persons, animals or things, caused by reasons of his Works or through causes in his control. The Contractor's rates will be held to cover all such liabilities and the Engineer shall have the right, if the Client/Engineer shall have suffered loss by reason of the above, to deduct the value of such loss from any monies due or that may become due to the Contractor.

## PSB.5 EXISTING SERVICES (SUB CLAUSE 5.1.2.1)

The following shall be an addition to Sub Clause 5.1.2.1:

The Contractor shall be responsible for any necessary diversions of existing services and drains, such will be paid for as extra work and paid for at scheduled rates.

Where existing services are crossed, care shall be taken to avoid damage to them. The position of existing services shown on the drawings is approximate and the Contractor must ascertain the true position and depth thereof. The Contractor will be responsible for any damage to existing services and shall, at his own expense, take measures to support and protect these services while exposed in excavations and trenches. Any damage to existing services during the contract shall be made good by the Contractor at his own expense.

## PSB.6 STORMWATER AND GROUNDWATER (SUB CLAUSE 5.1.3)

The following shall be an addition to Sub Clause 5.1.3:

The Contractor shall provide, operate and maintain pumps, pumping equipment, well points and all other water devices necessary to properly de-water and maintain free from water all excavations and all natural ground water until completion of the works, at his own expense. No work shall be excavated in water without the written permission of the Engineer.

The Contractor shall be entirely responsible for keeping the whole of the works thoroughly drained and clear of water if may be required, and if considered necessary by the Engineer, continuously day and night.

The Contractor is responsible, at no extras cost over and above the rates for excavation in the priced Schedule of Rates for preventing the ingress of water or storm flow into the excavations and for the construction of proper drainage channels, sumps, supply and running of pumps and everything necessary for the exclusion of water from excavations, whether such water arises through storm flow, ground water, springs or seepage, and is likewise to be responsible for the protection and de-watering of all excavations until all construction and refilling are completed to the satisfaction of the Engineer. Rates for excavation are to include for such de-watering.

Channels or sumps excavated outside the works for de-watering purposes must be refilled and made good to a standard equivalent to original conditions, and directed by the Engineer, when they are no longer required.

The rates in the priced Bill of Quantities will be held to cover the cost of any rectification of work, whether specified under this Contract or not, which the Engineer may order or decide to be necessary as a result of the Contractor's de-watering or storm flow arrangements being negligent, inadequate or improper. The cost of all such rectification work will be at the Contractor's own expense.

## PSB.7 CONSERVATION OF TOPSOIL (SUB CLAUSE 5.2.1.2)

The following shall be an addition to Sub Clause 5.2.1.2:

Topsoil from the site, excavations and borrow pits shall be stripped by 300 mm or as indicated on the drawings. The material removed shall be transported to and disposed of at a suitable Site away from the Works, as directed by the Engineer. This is to be within the free haul distance of 2 km. Topsoil shall not be stockpiled to a height exceeding 2.5 m or as specified on Construction drawings.

The unit of measurement shall be the cubic metre of in-situ material removed. The rate must allow for the operation as described above and haulage to within 2 km of the Site area or as specified in the Bill of Quantities. The disposal area is to be left as described in Sub-Clause PSB.11.

## PSB.8 PREPARATION OF APPROVED SOIL BENEATH COMPACTED EMBANKMENTS AND ROADWAYS (SUB CLAUSE 5.2.1.4)

The following new Sub Clause 5.2.1.4 shall be added:

Prior to the commencement of construction of compacted embankments and roadways, the approved natural foundation soil beneath the base areas shall be broken up by ripping or other means to a minimum depth of 300 mm (or as stated in the Bill of Quantities) and compacted to the approval of the Engineer by not less than eight passes of an approved ten metric tonne roller.

The onus is placed on the Contractor to compact this layer to such a degree to ensure that the indicated densities or such lesser densities as may be specified by the Engineer can be achieved on subsequent layers. The unit of measurement for ripping and compacting the approved founding layer is the square metre.

## PSB.9 EXCAVATIONS FOR GENERAL EARTHWORKS AND FOR STRUCTURES (SUB CLAUSE 5.2.2.1)

The following shall be an addition to Sub Clause 5.2.2.1:

The Contractor shall excavate whatever materials are encountered to the depths, cross-sections and grades shown on the drawings. Excavated material not required or unsuitable for backfill and/or for embankment construction shall be transported to and disposed of at a suitable site away from the site of Works as directed by the Engineer. The unit of measurement for all excavation shall be the cubic metre of in-situ material excavated (measured **NETT**). It should be noted that when excavations are cut through embankments for the placing of drains, pipes, pipe encasements, puddle flanges etc., the payment for these excavations shall be based on **NETT** dimensions with the measurable depth of excavation limited to that of the maximum vertical dimension of the drain pipe or encasement structure at each particular cross-section. Similarly, the measurable width shall be the design width of each particular cross-section. All costs associated with the excavation greater than these dimensions (i.e. including backfilling with concrete or soil as required) shall not be considered for payment.

Material from excavations that are unsuitable for backfill and/or embankment construction shall be stockpiled to the dimensions and heights as instructed by the engineer and/or indicated on the Construction drawings.

The rates must allow for the operation as described above and haulage to within 2 km or as stated in the Bill of Quantities. The disposal area is to be left as described in Sub-Clause PSB.11.

## PSB.10 BORROW PITS (SUB CLAUSE 5.2.2.2)

The following shall be an addition to Sub Clause 5.2.2.2:

The Contractor shall be responsible for ensuring that materials obtained from borrow pits conform to the material requirements specified by the Engineer from time to time. These criteria include in brief terms, the material particle size distribution (i.e. grading envelope) minimum density and moisture content requirements.

To this end the Contractor will be required to excavate a reasonable number of trial pits at his own cost in order to prove the suitability of each borrow area location.

The Contractor, unless otherwise directed, shall obtain the required material by borrowing in these cuttings to such widths, lengths and depths as the Engineer may direct.

Borrow from borrow pits will normally be limited to material which can be loosened by the use of mechanical rippers having a minimum fly wheel power of 130 kW and operating weight of 23 000 kg (e.g. a Caterpillar D7, Komatsu D85) in good condition and driven by a competent operator.

All borrow pits shall be excavated to ensure free drainage of runoff resulting in no ponding and borrow areas are to be left in a safe and neat condition as directed by the Engineer at no extra cost.

Should stripping of unsuitable material overlying a borrow pit be required it shall be to such depths as determined by the Engineer. This unsuitable material shall be disposed of at a suitable site away from the site of Works as directed by the Engineer. The disposal area shall be within 2 km of the area from which it was removed.

The unit of measurement for unsuitable material removed shall be the cubic metre of in-situ material removed. The rate must allow for the operation as described above and haulage to within 2 km. The disposal area is to be left as described in Sub-Clause PSB.11.

Payment for the opening of borrow areas not allocated by the Engineer, will not be considered.

The unit of measurement for borrow material sourced shall be the cubic metre of in-situ material sourced to be used for construction. The rate must allow for the operation as described above and haulage to within 2 km. The disposal area is to be left as described in Sub-Clause PSB.11.

## PSB.11 DISPOSAL (SUB CLAUSE 5.2.2.3)

The following shall be an addition to Sub Clause 5.2.2.3:

Stockpile areas (which may include used borrow pits) shall be allocated for the disposal of all surplus material from clear site operations, excavations, removal of unsuitable material, and for topsoil stripped from the site. These areas shall be maintained in a neat condition and when completed, levelled off by grading to a given surface as directed by the Engineer. The rates must allow for all such levelling and trimming and for haulage to within 2 km of the site or as stated in the Bill of Quantities. These areas shall be specified by the Engineer.

## PSB.12 EXCAVATIONS OF UNSUITABLE MATERIAL BELOW COMPACTED WALLS/ROADWAYS (SUB CLAUSE 5.2.2.4)

The following new Sub Clause 5.2.2.4 shall be added:

Unsuitable natural soil below compacted walls and roadways shall be removed to such depths widths and lengths as the Engineer may determine after the completion of the site clearance activities. The material so removed shall be transported to and disposed of at a suitable site away from the site of Works or stockpiled for re-use as directed by the Engineer and/or as specified in the Construction drawings.

The unit of measurement for unsuitable material removal shall be the cubic metre of in-situ material removed (measured **NETT**). The rates must allow for the operation as described above and haulage to within 2 km or as stated in the Bill of Quantities. The disposal area is to be left as described in Sub-Clause PSB.11.

## PSB.13 UNAUTHORISED EXCAVATIONS (SUB CLAUSE 5.2.2.5)

The following new Sub Clause 5.2.2.5 shall be added:

The Contractor is prohibited from making Excavations other than those approved by the Engineer as necessary for the Works.

## PSB.14 BLASTING (SUB CLAUSE 5.2.2.6)

The following new Sub Clause 5.2.2.6 shall be added:

The purchase, storage, handling, transportation and use of explosives shall be strictly in accordance with the current Government regulations and to the requirements of the Government Inspector of Explosives.

From the time the explosives have been delivered to the Contractor until they are used in the Work, they shall be under the continuous control of a responsible person appointed for that purpose. The Contractor shall provide documentation in the form of training certificates / qualifications to the Engineer and/or Client as proof of competency to complete the task appointed to the responsible person to control all activities associated with the explosives delivered to site. Copies of the documentation shall be held on site and made available to the Engineer and/or Client for review as all times.

If required by the Government Inspector of Explosives, guards shall be provided by the Contractor at his own cost.

The Contractor shall acquaint himself with the requirements regarding the supply, delivery, storage etc., of blasting materials and shall make allowance in his rates for full compliance.

All blasting shall be carried out under proper control by licensed persons and the area to be blasted shall be adequately protected by rubber or steel mats and/or other approved methods if necessary.

The Contractor shall be responsible for any damage of any nature caused by such blasting to persons, animals, materials, existing services, etc., and shall adhere to all government and local regulations.

All blasting by specialist subcontractors: The Contractor shall still be held liable for any damages resulting from the use of explosives by the specialist subcontractor.

No blasting shall be permitted until all necessary precautions have been taken and permission obtained from the Engineer, who may prohibit the use of explosives in close proximity to buildings, pipelines, sewers, cables, roads, etc., and may restrict the size of the charge used. Such permission, however, shall not absolve the Contractor from his liability as stated above.

The Contractor is to measure and inspect all building prior to blasting, noting any existing damage to the structures. The Engineer shall be informed of the existing damages noted prior to blasting. Approval for blasting shall not be given without prior inspections of all structures that could be damaged.

Blasting within 500 m of any power lines shall be limited to single shots under cover. The unit of measurement for all blasting work shall be as specified for rock excavation in Sub-Clause PSB.1.

## PSB.15 OVERBREAK (SUB CLAUSE 5.2.2.7)

The following new Sub Clause 5.2.2.7 shall be added:

All excavation quantities throughout, in all classes of material will be measured **NETT**.

### PSB.15.1 EXCAVATION IN CLASS "B" MATERIAL (SUB CLAUSE 5.2.2.7.1)

The following new Sub Clause 5.2.2.7.1 shall be added:

Items measured in square metres, of extra for overbreak in Class "B" excavation material including filling with respective classes of concrete or back-shuttering and filling with selected earth filling and compacting in 300 mm layers (the Contractor is to provide a rate for both options) have been measured to the area of vertical concrete structure abutting against Class "B" excavation material for the respective classes of concrete. These items will be measured and paid for to all vertical faces of concrete structure abutting against Class "B" excavation material faces and the rate will apply irrespective of any discrepancy between the system (as above described) and the system used in construction.

Similarly, items measured in square metres of extra for overbreak in Class "B" excavation material including filling with respective classes of concrete have been measured to the area of horizontal or sloping concrete structure abutting against Class "B" excavation material.

These items will be measured and paid for over and above the concrete structure and blinding requirements of the drawings and no extra concrete in filling will be measured, no matter what extra depth may have been excavated and filled back. However, should the Engineer instruct that the excavation be carried out to depths greater than that required on the drawings, then the above-described square metre item will not be measured, but such excavation and backfilling shall be measured and paid for.

### PSB.15.2 EXCAVATION IN CLASS "A" MATERIAL (SUB CLAUSE 5.2.2.7.2)

The following new Sub Clause 5.2.2.7.2 shall be added:

- Where no Class "B" material as described is encountered in any one excavation, the excavation quantities will be measured NETT.
- Where Class "A" and "B" material as described are encountered in any one excavation, the excavation in Class "A", material will be measured only as stated in point above, irrespective of any over-excavation for any reason whatsoever, and the excavation in Class "B" material will be measured only as stated in PSB.15.1 previously, irrespective of any over-excavation for any reason whatsoever.

## PSB.16 EXCAVATIONS TO BE PASSED (SUB CLAUSE 5.2.2.8)

The following new Sub Clause 5.2.2.8 shall be added:

Before any concrete is poured, all foundation surfaces must be clean and generally prepared to receive it to the satisfaction of the Engineer. The cost of this work must be included in the rate for excavation and formwork.

In no case must concrete be placed in an excavation until the consent of the Engineer has been obtained.

## PSB.17 FALL IN OF GROUND / COLLAPSE OF EXCAVATION (SUB CLAUSE 5.2.2.9)

The following new Sub Clause 5.2.2.9 shall be added:

Should any ground or any of the excavations collapse, other than that required to be excavated owing to the omission or inefficiency of planking and strutting or any other cause, it must be dug out, and made good as outlined in Clause PSC.2.

These remedial measures will be carried out to the satisfaction of the Engineer at the Contractor's expense.

## PSB.18 EMBANKMENTS (SUB CLAUSE 5.2.3.1)

The following shall be an addition to Sub Clause 5.2.3.1:

Embankments and fills shall be constructed by obtaining selected material from excavations, approved borrow pits or stockpiles and forming it to the dimensions and elevations given on the drawings.

Material forming the embankment and fill shall be compacted in layers as detailed in Sub-Clause PSB.21.2 or PSB.22 to form durable embankments and fill of good, regular appearance with all cross-sections having the minimum sizes detailed on drawings and having side slopes not steeper than specified. The sides of the embankments and fill must be compacted to hard durable faces. Any spoil resulting from this operation is to be removed and disposed of at no extra cost.

The unit of measurement for embankment and fill construction shall be the design cubic metre of placed material after compaction, trimming and forming to the specified dimensions. Contractors will not be paid for embankments and fill constructed in excess of the dimensions specified. The Engineer will decide on acceptance or rejection of embankments and fill which are oversized.

The Contractor is to allow in his rate for forming and compacting an oversized embankment/fill, cutting back and compacting the sides of the embankment/fill to the correct size.

## PSB.19 BACKFILLING (SUB CLAUSE 5.2.3.2)

### PSB.19.1 BACKFILLING WHERE COMPACTION IS NOT REQUIRED

The following shall be an addition to Sub Clause 5.2.3.2:

The unit of measurement for all backfill shall be the **NETT** cubic metre of consolidated material placed.

### PSB.19.2 BACKFILLING WHERE COMPACTION IS REQUIRED

The following shall be an addition to Sub Clause 5.2.3.2:

Backfilling to foundations and trenches shall be paid for under the items provided in the Bill of Quantities and shall be carried out by replacing excavated material with, either:

- Selected excavated material in uncompacted 300 mm layers, each layer being thoroughly compacted, rammed and consolidated before the succeeding layer is placed or such other ways as may be directed by the Engineer. In areas where specified compaction densities are required for backfill then the identical testing and approval procedures as outlined in Sub-Clause PSB.21.2 and PSB.22 will be enforced. Only sand replacement testing may be done near concrete foundations.
- Selected material with the addition of 12% cement by mass and sufficient water to obtain a consistency to permit the compaction by means of concrete vibrating equipment (“soilcrete”)
- Loose selected material as shown on the drawings.

Any defects caused due to subsidence of the backfilling, as a result of improper workmanship shall be made good at the Contractor's expense. At the ground surface, the filling shall be banked to a height of about 100 mm above the level of the adjacent ground surface to allow for any settlements and before completion of the Works, and, if necessary, again before expiry of the maintenance period or at such other times as the Engineer may direct, all refilled excavations shall be examined and dressed and, where depressions have occurred, these shall be made good by refilling and ramming with suitable material at the Contractor's expense.

The unit of measurement for all backfill shall be the **NETT** cubic metre of compacted material placed.

# PSB.20 TRANSPORT OF EARTHWORKS (SUB CLAUSE 5.2.5)

The following shall be an addition to Sub Clause 5.2.5:

The Contractor shall at his own cost construct and maintain temporary haul roads as required along the route designated by the Engineer.

If the Contractor chooses, for reasons of his own, to transport material by a different route, the measurement of distance for transport will be along the routes designated by the Engineer.

In the case of borrow pits and stockpile areas, the Contractor shall be restricted to the routes designated by the Engineer.

Free haulage of material excavated from a borrow pit, excavation etc. or cutting shall be limited to a distance of one thousand meters or one kilometre.

Overhaul is that portion of the total haulage beyond the free haul limit and is measured separately.

The unit of measurement for overhaul in the case of compacted fill or placed material shall be the cubic metre - kilometre being the product of distance measured in kilometres to the nearest tenth of a kilometre and the cubic metres of compacted or placed (whichever is applicable) material transported. However, in the case of cut to spoil, or stockpile the unit of measurement for overhaul shall be the cubic metre-kilometre being the product of the distance measured in kilometres to the nearest tenth of a kilometre and the cubic metre of undisturbed in-situ material transported.

# PSB.21 TOLERANCES (CLAUSE 6)

## PSB.21.1 POSITION, DIMENSIONS, LEVELS, ETC. (SUB CLAUSE 6.1)

The following shall be an addition to Sub Clause 6.1:

All embankments, excavations, trenches, fill areas, channels etc. shall be neatly trimmed to the required widths, cross-sections and levels as specified on the drawings and specifications. Where not stated the tolerance is to be within + 25 mm (Degree of Accuracy I).

The width of the formation measured from the final staked centre line shall in no case be less than the specified dimension. The tolerance on the depth and location of soil replacement trenches shall be ± 150mm. The average depth shall not be less than the specified depth.

## PSB.21.2 MOISTURE CONTENT AND DENSITY (SUB CLAUSE 6.2)

The following shall replace Sub Clause 6.2 in its entirety:

### PSB.21.2.1 GENERAL

The standards of compaction required are shown on the drawings and the Contractor shall be entirely responsible for obtaining a density not less than the minimum specified Standard Proctor or Modified Proctor Maximum Dry Density whichever is applicable (hereinafter referred to as specified density).

All compacted fill material is to be placed in loose horizontal layers to a thickness that will ensure that after compaction has been completed the thickness of the compacted layer shall not be greater than 200 to 300 mm, to a density not less than the minimum specified density. It should further be noted that a uniform moisture content (as per specification) is to be achieved throughout the loose layer prior to compaction.

All compaction shall be carried out in a direction parallel to the centre line of the earthworks, working on a predetermined pattern which shall ensure that the whole area of the layer receives a uniform compaction.

The moisture content shall unless otherwise specified be in the range between one per cent below and two per cent above Standard Proctor optimum moisture content, (or any other range specified on the drawings) whichever is applicable. Compacted layers with moisture contents outside the specified range shall be deemed to have failed regardless of the densities achieved. The required moisture content shall be distributed uniformly throughout each layer of material.

Compaction shall be carried out by means of compaction equipment to be approved by the Engineer.

#### PSB.21.2.2 Compaction to a Performance Specification

If required and agreed with the Engineer, certain embankments and fills may be constructed by applying a performance specification to each placed layer (hereinafter referred to as normal or performance compaction). These embankments and fill shall be formed by compacting selected material in loose layers not exceeding 200 mm in thickness after compaction by applying a minimum number of passes, to be specified by the Engineer, by an approved roller. The minimum number of passes will be determined on site, jointly by the Contractor and the Engineer, and will be based on the number of passes required to obtain a compaction of 98% Standard Proctor Density (±2%) or any lesser density that the Engineer may specify. The Engineer reserves the right to re-execute these tests and to re-specify the minimum number of passes from time to time dependent on material variability, compactor type, moisture content, etc.

If necessary, during and/or prior to compaction, water shall be provided to bring the soil to the correct moisture contents as directed by the Engineer.

The Engineer reserves the right to stop and condemn all "performance" compaction work if, in his opinion, the Contractor is seen not to be executing the works as described above. All such remedial works shall be for the Contractor's account.

#### PSB.21.2.3 Preparation of Pipe Trench Floors

The floor of trenches shall be compacted to at least 95% Standard Proctor density at optimum moisture content or any other specified density and moisture content that the Engineer may authorise, to a minimum depth of 150 mm. The unit of measurement shall be the square metre of trench prepared.

#### PSB.21.2.4 Engineered Rock Fill and Compaction

The material shall be obtained from Tharisa’s Pit Operations as approved by the Engineer who may withdraw his approval of a source which he no longer considers to be satisfactory. The Engineered Rock Fill shall have a rock size as that indicated on the Construction Drawings or as indicated by the Engineer and shall not exceed 1000 mm. Any oversized rocks are to be removed from the wall and disposed of at the contractor's cost.

The material obtained from the Open Pit Operations is to be visually assessed and all fine material is to be placed on the upstream face of the wall, well graded material in the centre of the wall, with the coarse material being placed on the downstream face, as depicted in Figure 1, or as directed by the Engineer.

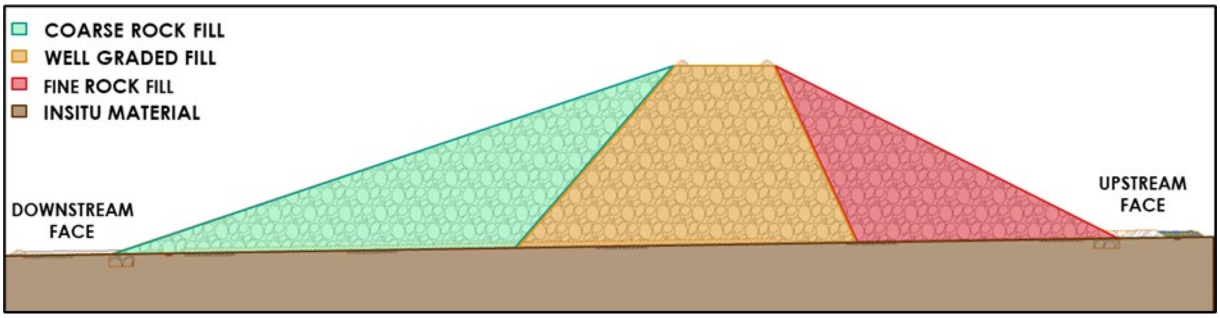


**Figure 1: Typical cross-section through the Rock Fill Wall depicting the placement of the different grades of material.**

The Engineered Rock Fill shall be constructed in layers not exceeding 2000 mm in thickness after compaction. The Engineered Rock Fill Embankment is to be dumped on the layer being constructed, 4000 mm from the edge and dozed into position to allow for mixing of the material as depicted in Figure 2.


**Figure 2: Operating methodology for dumping and dozing of Rock Fill Material**

The Engineered Rock Fill shall be spread so that a uniform layer thickness shall be obtained. The layer shall then be given not less than six passes of a twenty tonne (static weight) vibrating roller or an equivalent to be specified by the Engineer. A roller pass shall consist of rolling in a longitudinal direction over the whole width of the formation so that each roll laps half the width of the previous roll. The final layer is to be compacted and graded so as to ensure that the surface is trafficable in both transverse and longitudinal directions. No material is to be dozed off the side of the walls with the exception of topsoils.

The Engineered Rock Fill Embankment wall is to be surveyed after every lift (every 2m raise) to ensure that the wall is constructed in accordance with the drawings and adheres to the side slope and layer requirements. Construction of the subsequent wall lift may only continue and the placement of topsoil cladding to the walls may only commence once the survey has been approved by the Engineer. Failure to do so will result in the Engineer appointing an independent surveyor to undertake the survey, at the contractor's cost.

Compaction tests of the Engineered Rock Fill Embankment, as specified below, are to be carried out by the contractor as and when deemed necessary by the Engineer.

The unit of measurement shall be the design cubic metre of compacted material placed. Material penetrating into the in-situ material will not be measured and shall be deemed to be inclusive of the indicated rate.

The mining contractor will be responsible for loading, hauling, and placing of the rock. The Contractor is to co-ordinate retrieval of rock from the Open Pit Operations with the Mine.

The following tolerances are to be adhered to:

- Rock fill wall side slopes - within 250 mm.
- Rock fill wall lift raises - within 250 mm.

PSB.21.2.4.1 Test Fill Layout

The test fill shall be used to determine the required passes which will result in no or negligible settlement of the engineered rockfill material. This shall then be used as the specified number of passes required to compact the engineered rockfill material.

The test fill should be located in a level and firm foundation area within or outside of the planned rockfill limits. The foundation area should be compacted by ten passes of the vibratory steel drum compactor or heavy rubber-tyred roller planned for use in the test fill to minimize the effect of subsequent roller pass settlements in the test fill subgrade.

A typical test fill layout for a vibratory compaction roller is shown on Figure 3. The test fill limits are determined by the size of the construction equipment and the number of lifts to be used for testing rockfill placement and compaction. The minimum width of the test fill subgrade area should generally be set at three times the width of the compaction roller and three times the height of the final test fill surface above the base level, as shown in Equation (1). The same test fill width is suggested for loaded haul trucks, due to the potential for lateral spreading of the rockfill along the exterior slopes of the test fill pad from the more concentrated and dynamic haul truck tyre loads.

Test Fill Minimum Base Width:

$$(W \times 3) + (N \times T \times 3) \qquad (1)$$

Where:

W = Roller drum width,

N = Number of lifts to be placed, and

T = Planned loose lift thickness.

PSB.21.2.4.2 Lift Thickness

A good rule of thumb for maximum rock size in the fill is typically set at two thirds of the loose lift thickness for ease in dozer levelling and compaction. For example, a rock borrow material with typically 0.45 m square mesh maximum rock fragment sizes with occasional rock fragment sizes greater than 0.45 m could be placed in 0.6 m  maximum loose lifts for test fill compaction by a fithteen ton (static drum weight) vibratory roller. The occasional rock fragment sizes above the 0.45 m mesh size in this example would be allowable within the lift, provided they do not protrude above the levelled lift surface to impede compaction. Dozer equipment spreading the loose lifts will sometimes track over the larger rocks to crush oversized rock fragments down to acceptable rockfill sizes or rake the oversized rock to the outside slope of the rockfill. The more rugged rockfill containing the larger oversized rock materials can be selectively placed in the downstream shell of a dam embankment with a transition to smaller sized rockfill materials in the interior next to the embankment filter and drain earth fills. The rockfill loose lift thickness is adjusted accordingly to suit the differing embankment zones of rockfill material sizes, as needed.

PSB.21.2.4.3 Lift Placement

Placement of a level rockfill lift close to the desired lift thickness is difficult to achieve by operators without some practice and adjustments in fill procedures. For rock haul truck operations, a load is end dumped in a pile and dozers spread the pile forward to the desired lift thickness. Careful control of the loose lift thickness is important for test fill evaluations. Toe stakes are generally set on both sides of the test fill limits as a visual guide. A person stands next to the test fill area with a stake marked with the planned loose lift height. The person indicates to the dozer operator to increase or decrease the lift with his dozer blade, as the loose rockfill material is being spread across the test fill area. Spreading operations by the dozer should be kept to the same amount of work accomplished on a regular fill operation. Excessive dozer traffic from spreading and levelling may distort the test fill results.

PSB.21.2.4.4 Roller Type

Experience indicates the most efficient rockfill compactors are large vibratory steel drum rollers. Test fill information and visual observations of rockfill test pits indicate the steel drum vibration range is most efficient at 1,200 to 1,500 vibrations per minute (vpm) at a roller speed of about 2 mph (3.2 km/h). This roller speed is equivalent to a casual walk by a person across level ground. The rockfill surface is generally not uniform in rock fragment distribution so that the natural resonance of the rockfill can be somewhat variable, when measured with a vibration meter.

The operating static weight for self-propelled single drum rollers may include the total weight of the roller equipment on level ground and not the weight of the roller drum itself. The single roller drum static weight is typically not more than 90 percent of the total operating weight. Double drum self-propelled compactors have each drum weight at 50 percent of the total static operating weight. The maximum dynamic or centrifugal drum force is generally achieved at high throttle with the vibrations in resonance with the fill surface.

Depending on the compactor, a lighter static drum weight with higher dynamic drum force can sometimes be more effective at compaction compared to a heavier static drum weight with lower dynamic force. As a general rule of thumb for loose rockfill lifts up to 0.5 m in thickness, the static drum weight should be at least 7.3 tonnes on level ground with a minimum dynamic drum force of 13.6 tonnes for a moistened and well compacted rockfill.

Heavy vibratory steel drum rollers of the order of 10 to 20 tons static drum weight and 20 tons minimum dynamic force have been used to compact thicker lifts. Variable densities occur in the thicker lifts, primarily because of a reduction in effective compaction with depth and some rock segregation for loose lifts approaching 1 m or more in thickness. The maximum effective compaction depth for the heavier vibratory compactor rollers is about 1.5 m for moderate rockfill compaction.

PSB.21.2.4.5 Roller Passes

After the loose lift is placed, an initial survey of the lift surface can be conducted by spray painting a cross pattern with a test point number at each control point to be surveyed. Occasional rock protrusions in the selected control point areas are removed and filled in with smaller rock or the fill surface is proof rolled by a single pass of the smooth drum roller without vibration to seat the rock for initial survey readings.

The technique selected for the test fill is dependent on the degree of surface roughness prior to compaction. The cross pattern is generally spray painted again following the first roller pass due to the initial movement and seating of surface rock materials. The control points are surveyed for elevation (settlement) readings versus roller passes using a conventional survey gun, rod, and minimum 0.3 m square plate having a cross pattern and centre mark. The cross pattern on the plate is lined up to match the control point cross pattern on the fill surface for consistent survey readings at the exact same location on the rocky surface. A minimum of five control points for each lift can be analysed for acceptable test fill control. The control points are laid out in a pattern for the central portion of the roller drum to pass over the control points with about 0.3 m of side overlap for each pass. For a roller drum width of 2.1 m, as an example, the control points would be spaced as shown on Figure 3.

An example format and test results for recording and plotting each elevation reading at increments of two passes by the compaction equipment are shown on Figures 4 and 5. Typically the survey control points for measuring settlement versus roller passes show the influence of additional dozer tracking in the direction of fill placement and dozer levelling with the leading edge of the test fill showing the most settlement. In the example test plot of surveyed test fill data shown on Figure 5, Control Points 1 and 2 were located on the leading edge of the test fill and showed more settlement compared to Control Points 4 and 5. Control Point 3, located in the centre of the test fill limits, showed measured settlement close to the overall average settlement of the 5 control points.

A total of eight passes in two-pass increments are made for each test fill lift to evaluate settlement versus roller passes and determine the required number of passes acceptable for rockfill placement. In general, the required number of passes is set at 80 percent of the total settlement in eight passes or a maximum of six passes. Excessive passes on rockfill with large or heavy roller equipment tend to pulverize and crush the surficial 0.15 to 0.3 m of rockfill without significantly improving the density of the lower portion of the lift.

PSB.21.2.4.6 Testing schedule for Rockfill Material

Test fills must be done on the engineered rockfill material that will be used. Tests to be conducted using a 20-ton vibratory steel drum roller. Tests on 2 000 mm; 2 500 mm and 3 000 mm thick lifts are to be conducted, with results recorded for every 2 roller passes of the 8 passes per test. The number of tests required per lift thickness to be confirmed on Site by the Engineer.

PSB.21.2.4.7 Summary

The primary purpose of large-scale test fills for compacted rockfills is to establish the lift thickness and compactive effort requirements to meet the intent of design. Rockfill moisture conditioning depends on the distribution and amount of earth fill soil particles contained within the rockfill fragment matrix and any rock fragments that weaken from wetting.

The large-scale test fill procedures for determining acceptable rockfill lift thickness and compactive effort depend on the available rock borrow source and planned selection and development as rockfill material. The geologic rock structure, degree of weathering, and natural fracture patterns of rock borrow sources often dictate the rock fragment sizes that can be produced from ripping or blasting for the test fill pad.

Test fill operations begin with rock borrow development. Rock borrow materials, selected as representative of the rockfill after blasting, ripping, or screening, are removed from the borrow area, placed in the test fill, and compacted using the same equipment and procedures as planned for the rockfill construction. This includes borrow development, loading, hauling, dumping, spreading, and compacting. Moisture conditioning, where required, can be done in the borrow area or on the fill.

Moisture conditioning of rockfill borrow materials is not as critical as for earth fill materials to achieve acceptable compaction density. Moisture conditioning is encouraged in the rock borrow areas as much as practical. However, rock borrow surface development is rugged and may restrict conventional water truck application to the fill areas.

Test fills are generally conducted in rockfills during construction to suit available rock borrow and site conditions. The test fills are conducted to determine specific acceptable procedures for placement and compaction including moisture conditioning, loose lift thickness, rock type and gradation, compaction equipment, and number of passes by the specified compactor. Some limitations are initially set during design concerning the specified rock types, maximum rock sizes, lift thickness, and compaction equipment requirements. The design specifications may be modified by the engineer to suit site specific conditions, based on the quality and quantity of available rock borrow materials and the test fill performance during construction.

The test fills are generally incorporated within the rockfill structure, because of the large quantities of rockfill materials required for single and multiple lifts and variations in loose lift placement in the test fills. Test fill performance is measured with surveyed control points (settlement versus roller passes) for each lift, as well as subsequent verification of compacted in-place density and gradation testing.

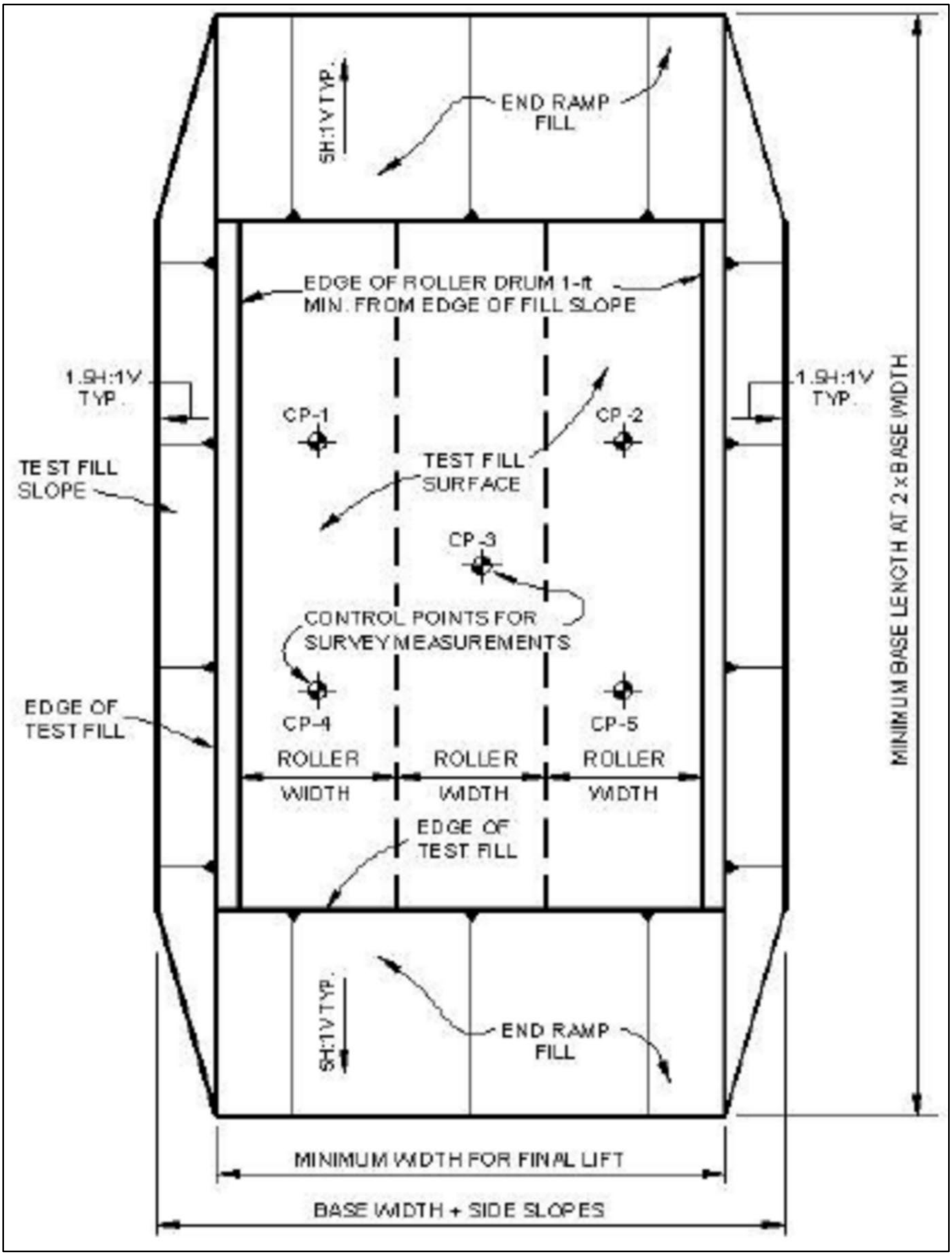


**Figure 3: Test Fill Layout Example**

TEST FILL #: ____________________ PROJECT NAME: ______________

LIFT #: ________________________ PROJECT #: ________________

LIFT THICKNESS: ________________ DATE: ____________________

ROLLER TYPE: __________________ BY: ______________________

ROLLER DRUM WIDTH **(m)** ______

ROLLER DRUM STATIC/DYNAMIC FORCE (TONS): _________ / _________

ROLLER SPEED **(Km/h):** __________

ROLLER VIBRATION (VPM): _________

PLACEMENT EQUIPMENT AND PROCEDURES: ________________________

____________________________________________________________

____________________________________________________________

____________________________________________________________

____________________________________________________________

| # OF ROLLER PASSES | CONTROL POINT # AND SETTLEMENT READINGS **(m)** | | | | | AVERAGE SETTLEMENT **(m)** |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | |
| 0 | | | | | | |
| 2 | | | | | | |
| 4 | | | | | | |
| 6 | | | | | | |
| 8 | | | | | | |
| 80% OF AVERAGE SETTLEMENT IN 8 ROLLER PASSES = | | | | | | |

**Figure 4: Engineered Rockfill versus Roller Pass Data Sheet**

| # OF ROLLER PASSES | CONTROL POINT # AND SETTLEMENT READINGS (m) | | | | | AVERAGE SETTLEMENT (m) |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | |
| | 100.50 | 100.40 | 100.50 | 100.60 | 100.50 | |
| 0 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.000 |
| | 100.73 | 100.58 | 100.66 | 100.71 | 100.62 | |
| 2 | 0.23 | 0.18 | 0.16 | 0.11 | 0.12 | 0.160 |
| | 100.80 | 100.63 | 100.70 | 100.75 | 100.67 | |
| 4 | 0.30 | 0.23 | 0.20 | 0.15 | 0.17 | 0.210 |
| | 100.83 | 100.66 | 100.73 | 100.78 | 100.69 | |
| 6 | 0.33 | 0.26 | 0.23 | 0.18 | 0.19 | 0.238 |
| | 100.84 | 100.67 | 100.74 | 100.78 | 100.70 | |
| 8 | 0.34 | 0.27 | 0.24 | 0.18 | 0.20 | 0.246 |
| 80% OF AVERAGE SETTLEMENT IN 8 ROLLER PASSES = | | | | | | 0.197 |

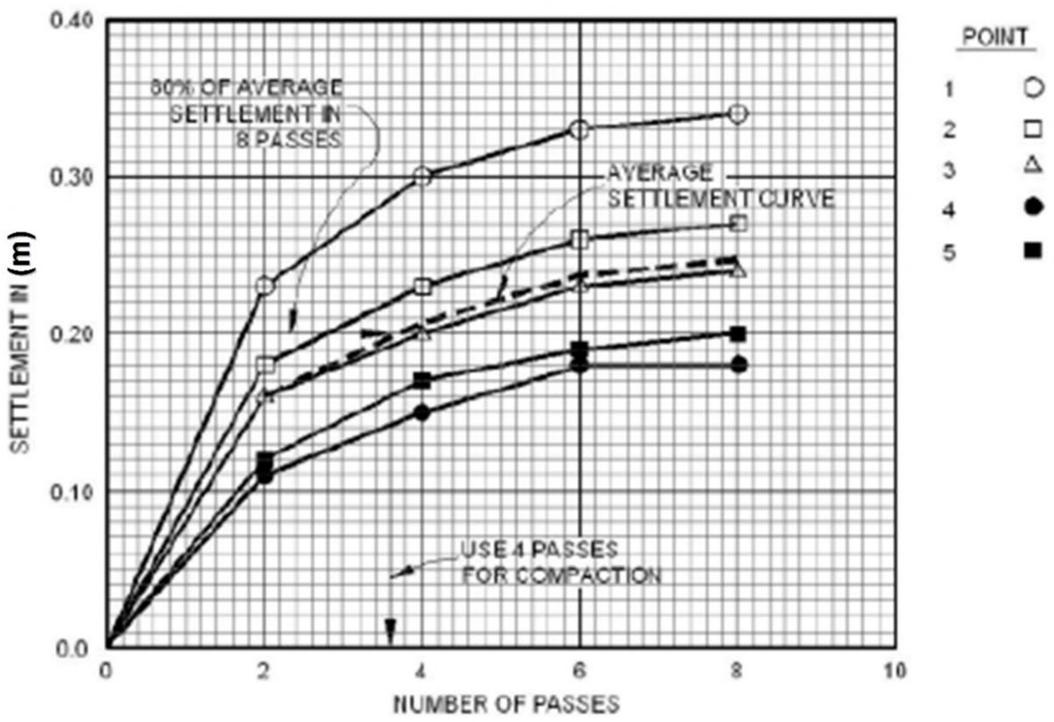


**Figure 5: Example Plot of Settlement versus Roller Pass Data**

## PSB.22 TESTING (CLAUSE 7)

## PSB.23 TAKING AND TESTING OF SAMPLES (SUB CLAUSE 7.2)

The following clause shall be and addition to Sub Clause 7.2:

### PSB.23.1 COMPACTION CONTROL

The Contractor shall provide an adequate SANAS accredited site laboratory, equipment, facilities and personnel for carrying out the required compaction tests. Should the Engineer at any time consider any of the above to be inadequate for this purpose, he shall instruct the Contractor to cease further work on compaction until such time as the Contractor has remedied the deficiency.

The onus shall be on the Contractor to ensure the following:

- That the state of the material when placed is such that the compaction as specified;
- That material selected for use in compacted embankments shall be approved by the Engineer on the basis of the maximum dry density (Standard Proctor, Modified Proctor, or Modified Proctor, whichever is applicable) being equal to or greater than a minimum density to be specified by the Engineer.
- Evaluate the test work on materials at regular intervals to confirm material properties.

Hence with the object of controlling the selection and compaction of all materials used in the various layers of fill the Contractor shall perform grading analyses, Standard Proctor, Modified Proctor, or Modified AASHTO density tests whichever is applicable on each type of material which he proposes to use, including mixed or blended materials.

In addition to the tests required for his own control the Contractor shall allow for at least two density checks per 200 square metre block of material compacted per layer or as specified by the Engineer. The recognised method of determining the density is the sand replacement test. However, the Radio Isotope or other approved method may be used (if approved by the Engineer) for density and moisture checks, provided suitable agreement is obtained between this method and the sand replacement method and provided the necessary calibration and specified tests to these instruments are undertaken at intervals as specified in applicable standards (e.g. for a nuclear density gauge SANS 3001 NG1 to NG5) or to be specified by the Engineer. If nuclear density measuring devices are used, they shall be calibrated against sand replacement tests.

If an alternative method of density determination is accepted, the sand replacement method shall be used to check every fourth density determination, and the moisture content of the sample shall be determined by oven drying as specified for the Modified AASHTO and Standard Proctor compaction methods.

To account for material variability, approved density tests will be accepted based on the following:

- Walls/Fill compacted to 100% Standard Proctor Density:
  - Two density tests per 200m$^2$ block is below 95% and not as specified, the entire block will be re-ripped, re-watered and re-compacted.

  - If any one or both of the two density tests per 200 $m^2$ block is between 95% and 98% then two more tests will be undertaken in the particular 200 m2 block. If the average of the four density tests is greater than or equal to 98% then the block will be passed. If the average is less than 98% then the entire block will be re-ripped, re-watered and re-compacted.
  - If both of the two density tests per 200 $m^2$ block lie between 98% and 102% then the block will be passed (i.e. a range of ± 2%). Tests achieving densities in excess of + 2% will not be accepted. In this case the block will have to be re-ripped, re-watered and re-compacted.
- Walls/Fill compacted to 98% Standard Proctor:
  - If any one of the two density tests per 200 $m^2$ block is below 98% then the entire block will be re-ripped, re-watered and re-compacted.
  - Any one density test will be deemed to have passed if a density of + 2% is achieved. Tests achieving densities in excess of + 2% will not be accepted and the entire block will be re-ripped, re-watered and re-compacted.
- Walls/Fill compacted to 95% Standard Proctor:
  - If any one of the two density tests per 200 $m^2$ block is below 93% then the entire block will be re-ripped, re-watered and re-compacted.
  - If any one or both the density tests per 200 $m^2$ block is between 93% and 95% then two or more tests will be undertaken in the particular 200 $m^2$ block. If the average of the four density tests is greater than or equal to 95% then the block will be passed. If the average is less than 95% then the entire block will be re-ripped, re-watered and re-compacted.
  - Any one density test will be deemed to have passed if a density of +2% is achieved. Tests achieving densities in excess of +2% will not be accepted and the entire block will be re-ripped, re-watered and re-compacted.
- Optimum moisture content of compacted walls/fills:
  - Should the tested block indicate density has been achieved, but the optimum moisture content of the tested block is below or +2% of the specified OMC, the layer shall be deemed to have failed the test and be re-ripped, re-watered or left to dry and re-compacted.

The compaction control tests shall be carried out as laid down in “South African National Standards – SANS 3001 - Civil Engineering Test Methods” published by the SANS Standards Division, Pretoria. Should no specification for a particular test be available within the SANS 3001 Civil Engineering Test Methods, the Contractor shall carry out compaction control tests as laid down in "Standard Methods of Testing Materials" published by the Department of Transport, Pretoria or as specified by the Engineer.

Field density and moisture content tests are to be carried out within twelve hours after the completion of each section of the layer. If such tests are not carried out by the Contractor within this period then the Engineer may fail a layer or section of the layer regardless of any test results which may then or subsequently be provided and this decision shall be final.

When the compaction of any section of any layer, for which a density and moisture content is specified, is completed, the Contractor shall supply to the Engineer copies of test results whether successful or otherwise within 6 hours of determination.

The Contractor is to note that no subsequent layer is to be placed until such time as the previous layer has been approved by the Engineer in writing.

The Contractor shall maintain updated, accurate records of all compaction control tests, i.e. test data, chainage, offset and layer elevation.

These records shall be available on site for inspection by the Engineer at all times.

Where tests reveal that the density or moisture content of any layer, at any depth, is not to specification, the Contractor shall rip, re-compact and re-water if necessary, such material. If the specified density cannot be obtained by further compaction of the material such material shall be removed and replaced by material capable of yielding the specified density.

All such testing and corrective work shall be undertaken at the Contractor's cost.

The Engineer may instruct the Contractor to carry out tests to check the density, moisture content and particle size distribution of the compacted material and/or to check the testing procedures of the Contractor as described above. The costs of these tests will be paid for by the Employer only if the results of the tests show that the specified density has been obtained.

The Contractor shall pay for all such tests where the results show that the specified density has not been obtained; also he shall pay for any further tests to check if the required density, moisture content and particle size distribution has been obtained after the specified corrective measures have been carried out.

# PSC SMALL EARTH DAMS (SANS 1200DE)

## PSC.1 RIP-RAP (CLAUSE 5.2.3.3)

The following shall be an addition to Sub Clause 5.2.3.3:

The Contractor shall supply and install as indicated on the Construction drawings broken hard rock having an average rock size $D_{50}$ of 200 mm. The rip-rap shall be well graded from a maximum size at least 1.5 times the average rock size to 30 mm spalls suitable to fill voids between rocks. Individual rock fragments shall be dense, sound and resistant to abrasion and shall be free from cracks, seams and other defects that would tend to increase unduly their destruction by wave action. The rip-rap need not be compacted but shall be placed to grade in a manner to insure that the larger rock fragments are uniformly distributed and the smaller rock fragments serve to fill the spaces between the larger rock fragments in such a manner as will result in well-keyed, densely placed, uniform layers of rip-rap of the specified thickness. Hand placing will be required only to the extent necessary to secure the results specified. All rip-rap material shall comply with the following requirements:

- Be hard, dense, durable rock that is free from weathering, cracks, seams and other defects that will cause rapid or excessive deterioration or degradation during service.
- Contain no more than 5% by mass in total impurities (undesirable material) such as individual pieces of rip-rap which do not meet the quality requirements as specified and which can be visually differentiated from satisfactory pieces, plus dirt, sand, clay, rock fines and material of low density.
- The specific gravity of the individual particles shall be greater than 2.55.
- The dry 10% Fines Aggregate Crushing Test (FACT) value determined in accordance with SANS 5842 shall be not less than 110 kN.
- The wet 10% FACT value determined in accordance with SANS 5842 shall be not less than 75% of the determined dry value.
- The loss after 5 cycles measured by the sodium sulphate soundness test shall not be greater than 10%.

The basic principles for determining the soundness of selected rip-rap material shall be in accordance with SANS 5839, adapted as stated below:

- Initially the sample shall be broken into an approximate uniform grading and shall be screened. The portion passing the 19 mm sieve but retained on the 13.2 mm sieve shall be used in the test.
- The test sample shall weight 1 000 grams ± 2% and shall be washed as described in SANS 5839.
- The procedure specified in Section 3 of SANS 5839 shall be followed for 5 cycles.
- The sample shall then be sieved using an 11.2 mm sieve as defined in table 3 of SANS 5839.
- The percentage loss shall be determined from the mass of the material retained on the sieve and mass of the original sample.

Rip-rap is to be selected from approved sources or the waste rock dumps either by locating pockets of coarse material with not more than 10% fines or by progressively pushing material from the top of the dump over the crest to facilitate gravitational sorting and thereafter systematically removing the above material from the toe. The area and final method of obtaining rip-rap will be indicated by the Employer. No undermining of waste rock dumps will be allowed in sourcing material for rip-rap.

The price for installing the rock material in the works will include all the costs of obtaining, loading, transporting the material from the approved source or dump to the works, complying with any security regulations or any arrangements the Plant may impose upon entering the area of the dump, or any other work necessary to obtain, supply and place the rock in the locations indicated on the drawings. **No overhaul will be paid for**. The Contractor is to allow in his rates for keeping the rock dump safe during loading periods. The Contractor is to obtain the Engineer's written approval regarding the safety of the dump on completion of the rock loading exercise.

The unit of measure shall be the design cubic metre of rock placed in the works or the works as specified.

## PSC.2 PERMEABLE MATERIAL (SUB CLAUSE 3.2.2)

The following shall be an addition to Sub Clause 3.2.2:

The Contractor’s attention is specifically drawn to the importance of obtaining consistent supplies of permeable drainage material in accordance with this specification. Each drainage layer is classed as a structural entity. Stringent quality control checks on the grading of the material, material thickness, and the dimensional correctness will be applied to ensure the integrity of each drainage layer.

The following quality control measures will be applied by the Contractor to all permeable materials at no additional cost.

Generally one grading analysis is to be carried out by the Contractor for every 100 $m^3$ of material brought to Site. However, if materials are observed to be variable, then the Engineer reserves the right to insist that one grading analysis per truck load be undertaken. The grading analyses are to be submitted to the Engineer for approval which must be obtained prior to placement of the permeable material. Any material which fails to meet with the specification will be rejected, removed from Site and replaced at the Contractor’s expense.

Stockpiles are to be formed on approved areas rendered free of vegetation and loose contaminant matter. Furthermore, in order to ensure an acceptable level of quality assurance and to minimise contamination, the number of stockpiles used and their location is to be approved by the Engineer.

Notwithstanding the criteria stipulated below, the Engineer reserves the right to approve the use of any materials proposed for the filter.

As a guide, he may work on the basis of the performances of the material in an actual flexible wall permeameter test (ASTM D5084-90).

Permeable material as used in the filter drains shall comply with the following:

### PSC.2.1 FILTER SAND

Filter sand shall be clean, washed sand free of all deleterious material and shall comply with the following general requirements:

D0 ........................................................................ between 0.065 mm and 0.300 mm

D5 ........................................................................ between 0.075 mm and 0.360 mm

D15 ........................................................................ between 0.100 mm and 0.500 mm

D50 ........................................................................ between 0.350 mm and 1.700 mm

D60 ........................................................................ between 0.50 mm and 2.500 mm

D85 ........................................................................ between 1.30 mm and 7.800 mm

D100 ........................................................................ between 2.20 mm and 21.00 mm

Drainage Criterium = $$5 < \frac{D_{15}(Filter)}{D_{15}(Soil)} < 40 \quad (2)$$

Erosion Criterium = $$\frac{D_{15}(Filter)}{D_{85}(Soil)} \leq 5 \quad (3)$$

Well Graded Material Criterium = $$\frac{D_{60}(Filter)}{D_{10}(Filter)} < 20 \quad (4)$$

The filter sand **SHALL NOT CONTAIN MORE THAN 5% PASSING 75µm**. The fines should also be cohesionless.

All grading analyses are to be carried out on a **WET SIEVE** according to methods described in SANS 3001 and/or TMH 1 Technical Methods for Highways.

In addition, the grain size curve of the filter sand should be roughly parallel to that of the surrounding material. The unit of measure shall be the cubic metre of approved filter sand in place in the drains.

### PSC.2.2 CRUSHED STONE

The stone shall be in accordance with SANS 1083:2018, except that the stone shall be thoroughly **cleaned and washed** and the grading requirements shall be as prescribed below:

#### PSC.2.2.1 INTERMEDIATE STONE

DO ........................................................................ between 1.00 mm and 2.60 mm

D5 ........................................................................ between 1.35 mm and 3.20 mm

D15 ........................................................................ between 2.00 mm and 4.80 mm

D50 ........................................................................ between 4.00 mm and 17.00 mm

D60 ........................................................................ between 4.80 mm and 25.00 mm

D85 ........................................................................ between 7.80 mm and 28.0 mm

D100 ........................................................................ between 10.0 mm and 75.0mm

#### PSC.2.2.2 COARSE STONE

DO ........................................................................ between 6.50 mm and 17.0 mm

D5 ........................................................................ between 7.00 mm and 21.0 mm

D15 ........................................ between 8.00 mm and 30.0 mm

D50 ........................................ between 13.0 mm and 42.00 mm

D60 ........................................ between 15.0 mm and 46.0 mm

D85 ........................................ between 18.0 mm and 58.0 mm

D100 ........................................ between 22.0 mm and 75.0 mm

(**Note**: grading envelopes are subject to change depending on the final approved filter material used and proposed during construction)

Hardness: When tested in accordance with SANS 3001: Part AG10, the aggregate crushing value shall **not exceed 21**.

Flakiness: The maximum flakiness index when testing in accordance with SANS 3001: Part AG4 shall be **25%**.

The unit of measurement shall be the design cubic metre of approved stone in place in the drains. The rate shall cover the cost of supply, delivery, wastage, placing and light compaction of the stone.

## PSC.3 UNDERDRAIN CONSTRUCTION (SUB CLAUSE 5.2.6)

The Following New Sub Clause 5.2.6 shall be added:

Underdrains shall be constructed as shown on the drawings.

Excavation for the underdrains shall be to the specified tolerances. The geotextiles as specified in Clause PD of this Specification shall be carefully and neatly laid on the ground and shall be pinned to the trench walls with 150 mm nails fitted with 30 mm diameter, 2 mm thick galvanised washers placed at approximately 1 000 mm centres. (The Contractor may propose other fixing methods to be approved by the Engineer).

Pipelines shall be laid to straight grades between vertical bends and shall be to the routes, levels and grades indicated on the drawings.

Before placing any permeable material over and adjacent to the pipes the Contractor is to obtain the approval of the Engineer.

The permeable materials shall be placed as shown on the drawings. The finished thickness of each layer of permeable material shall nowhere vary below the specified thickness. Care should be exercised when placing the permeable materials so as not to damage the subsurface drainage pipes.

The Contractor shall carry out tests from time to time to ensure that the permeable material conforms to the minimum requirements set out in Sub-Clause PSC.2. The Engineer may, at his discretion require further tests to be conducted to ensure the permeable material conforms to the minimum requirements set out in Sub Clause PSC.2.

Any material placed as permeable material not conforming to the minimum requirements as set out in Sub-Clause PSC.2 above shall, at the discretion of the Engineer, be removed and replaced with suitable material at the Contractor's expense.

At all junctions with outfall drains or at any other section where required by the Engineer, no permeable material shall be placed until the junction has been inspected and approved by the Engineer. The Contractor shall undertake the necessary rodding and/or water testing as required by the Engineer. All such costs shall be borne by the Contractor and be deemed to be included in the tendered rates.

### PSC.3.1 DUST SUPPRESSION (SUB CLAUSE 5.2.6.1)

The following new Sub Clause 5.2.6.1 shall be added:

Dust suppression is to be carried out to the Engineers satisfaction in the vicinity of the drain construction to ensure no contamination of the filter drains. All cost for dust suppression in the vicinity of the drain construction shall be borne by the Contractor and deemed to be included in the underdrainage construction tendered rates.

## PSC.4 EROSION CONTROL (SUB CLAUSE 5.2.7)

The following new Sub Clause 5.2.7 shall be added:

Any runnels or erosion channels greater than 50 mm deep which are formed during the construction period shall be backfilled and compacted and the surfaces returned to their original condition. This shall apply to outside embankment faces, embankment crests, inside slopes, berms and canals. During the rehabilitation process, should any erosion take place prior to vegetation being established, the Contractor shall reinstate the area as per Clause PA of this Specification, until such time as vegetation has been established and the maintenance period is completed.

The Contractor will receive no payment for repairing erosion damage as specified above and be deemed to be included in the tendered rates.

# PSD GABIONS AND PITCHING (SANS 1200DK)

## PSD.1 MATERIALS (SUB CLAUSE 3.1)

The following shall be an addition to Sub Clause 3.1:

The Contractor shall supply the relevant specification for the reno mattresses and/or gabion baskets from the supplier the Contractor intends to use for the works to the Engineer for approval. Failing this, the Engineer reserves the right to condemn any gabion baskets and/or reno mattresses installed on site and the Contractor shall at his own expense, replace the gabion baskets and/or reno mattresses to gabion baskets and/or reno mattresses as approved by the Engineer. Stone to be used in the gabion baskets shall be approved by the Engineer.

## PSD.2 CONSTRUCTION (SUB CLAUSE 5.4)

The following new Sub Clause 5.4 shall be added:

The Contractor submits a copy of the manufacturer’s installations guidelines (from supplier) to the Engineer for approval thereof.

# PSE CONCRETE (STRUCTURAL) (SANS 1200G)

## PSE.1 AGGREGATES (SUB CLAUSE 3.4.2)

The following shall replace Sub Clause 3.4.2 in its entirety:

"Plums" shall not be used.

## PSE.2 REINFORCEMENT (SUB CLAUSE 3.6)

The following shall be an addition to Sub Clause 3.6:

Reinforcement shall be as indicated on the Construction drawings.

## PSE.3 REINFRCEMENT FIXING (SUB CLAUSE 5.1.2)

The following shall be an addition to Sub Clause 5.1.2:

No welding of reinforcement shall be allowed. Where MESH reinforcement is to be used in the works, MESH shall be supplied welded from the supplier. No site welds on MESH reinforcing shall be allowed. MESH reinforcement with damaged welds shall not be used in the works without written approval of the Engineer.

## PSE.4 REINFORCEMENT COVER (SUB CLAUSE 5.1.3)

The following shall be an addition to Sub Clause 5.1.3:

The cover of concrete over reinforcement shall be as indicated on the Construction drawings and/or as specified by the Engineer.

## PSE.5 STRENGTH CONCRETE (SUB CLAUSE 5.5.1.7)

The following shall be an addition to Sub Clause 5.5.1.7:

All concrete in this contract shall be deemed strength concrete. The grade of concrete and position on the Works shall be shown on the drawings, and as described in the Bill of Quantities or as directed by the Engineer from time to time. The maximum nominal size of coarse aggregate shall be 19 mm. Ready mix concrete shall comply with the requirements set out in SANS 878:2012 - Ready-mixed Concrete.

## PSE.6 CONSTRUCTION JOINTS (SUB CLAUSE 5.5.7.3)

The following shall be an addition to Sub Clause 5.5.7.3:

The unit of measurement shall be the metre squared of concrete surface placed and prepared in accordance with SANS 1200G, as specified on the drawings or as directed by the Engineer. The Contractor shall submit details of the filler and sealant to be used in the construction joints to the Engineer for approval thereof. The Contractor shall inform the Engineer once a construction joint position is ready to receive the approved filler and sealant to allow the Engineer to inspect the joint prior to placement of the approved filler and sealant. The Engineer reserves the right to allow the Contractor to place approved filler and sealant without prior approval. It remains the Contractors responsibility to ensure all construction joints are completed to specification and Construction drawings supplied.

The Contractor shall supply the Engineer, on completion, an as-built drawing indicating the position of all construction joints. The drawing shall be supplied in AutoCad format.

The cost of all construction joints and works required to ensure construction joints are as per Specifications and Construction drawings are for the Contractors account and deemed to be included tendered rates for concrete.

## PSE.7 CONCRETE SURFACES (SUB CLAUSE 5.5.10.4)

The following new Sub Clause 5.5.10.4 shall be added:

Wood and steel float finishes will only be paid to the items listed in the Bill of Quantities. All other floating or striking off shall be deemed to be covered in the shutter and concrete rates.

## PSE.8 WATERTIGHT CONCRETE (SUB CLAUSE 5.5.11)

The following shall be an addition to Sub Clause 5.5.11:

All concrete structures in this Contract are to be watertight. Sealants that shall be used are to be agreed upon and approved by the Engineer, and are to be included in the concrete rates.

## PSE.9 WATERSTOPS (SUB CLAUSE 5.5.16)

The following new Sub Clause

Waterstops/ Waterbars shall be of adequate manufacture, of pattern and of material type and widths as specified in the Bill of Quantities and shown on the drawings. Polyvinyl Chloride (PVC) waterstops shall conform to USACE CRD-C572 and the specifications requirements set out in Table A 1-3.

All intersections between waterstops shall be prepared by mitring and welding intersection pieces in the factory according to the manufacturer's instructions and to the approval of the Engineer. Straight lengths of waterstops may only be field welded in accordance with the manufacturer's instructions.

Waterstops shall have eyelets in the outside edges to enable them to be attached firmly in position. Waterstops shall be supplied in lengths as long as possible consistent with means of transport and efficiency of handling so as to minimise jointing.

Adequate samples of each batch of waterstops that arrives on site shall be submitted to an accredited laboratory for testing in accordance with all the tests specified in Table A 1-3.

Water sellable 'Basic Polymer' hydrophilic waterstops shall be made from a preformed elastomeric strip free from rubber, bentonite or other inclusions. The waterstop shall have an unrestrained volumetric expansion of not less than 170%. It must not deteriorate under prolonged wet/dry cycling. It must be able to withstand a hydrostatic head of 50 metres.

The unit of measurement shall be the metre of waterstop in place.

**Table A 1-3: Polyvinyl Chloride Waterstop Requirements**

| PROPERTY | TEST METHOD | REQUIRED LIMIT |
|---|---|---|
| Water absorption | ASTM D 570 | 0.15% max. |
| Tear resistance | ASTM D 624 | 35 KN/m min. |
| Ultimate elongation | ASTM D 638 | 350% min. |
| Tensile strength | ASTM D 638 | 13.8 MPa min. |
| Low temperature brittleness | ASTM D 746 | No failure @ -37˚C |
| Stiffness in flexure | ASTM D 747 | 4.13 MPa min. |
| Specific gravity | ASTM D 792 | 1.45 max. |
| Hardness, Shore A | ASTM D2 240 | 79 ± 3 |
| Tensile strength after accelerated extraction | CRD-C572 | 11.0 MPa min. |
| Elongation after accelerated extraction | CRD-C572 | 300% |
| Effect of Alkalis after 7 days:<br>Weight change<br>Hardness change | CRD-C572 | <br>-0.10% <= +0.25%<br>± 5 points |

## PSE.10 TOLERANCES (SUB CLAUSE 6.1.1)

The following shall replace Sub Clause 6.1.1 in its entirety:

Degree of Accuracy II applicable.

## PSE.11 TEST (CLAUSE 7)

The following shall be an addition to Clause 7:

Concrete shall be cured and testing in accordance with SANS 1200G - Concrete (Structural).

Prior to commencement of concrete works on site the Contractor shall submit to the Engineer, mix designs and compression test results for the proposed mixes for each class of concrete specified together with the grading analysis reports of the aggregates used.

# PSF SEWERS (SANS 1200LD)

## PSF.1 MATERIALS (CLAUSE 3)

### PSF.1.1 UNDERDRAINAGE/ LEAKAGE DETECTION PIPES, FITTINGS AND PIPE JOINS (SUB CLAUSE 3.1.8)

The following new Sub Clause 3.1.8 shall be added:

Underdrainage/leakage detection pipes to be slotted drainex piping or similar approved unless otherwise specified on the Construction Drawings or by the Engineer. The diameter of the pipes shall be as specified in the Bill of Quantities and Construction Drawings. The unit of measure shall be the metre of pipe in place. The tendered price shall include the furnishing and placing of the pipes to the required grades and elevations and shall be inclusive of the joints and special make-up pieces.

### PSF.1.2 UNDERDRAINAGE / LEAKAGE DETECTION OUTLET PIPES, FITTINGS AND PIPE JOINTS (SUB CLAUSE 3.1.9)

The following new Sub Clause 3.1.9 shall be added:

All underdrainage outlet piping to be non-slotted drainex piping or similar approved unless otherwise specified in the Bill of Quantities and the Construction Drawings or as specified by the Engineer. The diameter of the pipes shall be as specified in the Bill of Quantities and Construction Drawings. The unit of measurement shall be the metre of pipe in place. The tendered price shall include furnishing and placing of the pipes to the required grades and elevations inclusive of joints and special make-up pieces.

# PARTICULAR SPECIFICATIONS

## PA SPECIFICATIONS FOR VEGETATION ESTABLISHMENT

## PA 1 VEGETATION ESTABLISHMENT

### PA 1.1 TOPSOIL HANDLING

All earth embankments and embankment crests that will be left exposed and will require re-vegetation are to be covered with a layer of topsoil at least 300 mm thick.

The topsoil layer is to be lightly compacted in order to minimise erosion prior to surface preparation for fertilising and seeding.

### PA 1.2 VEGETATION ESTABLISHMENT

The Contract is to supply the Engineer with a method statement for surface preparation and fertilisation of areas to be re-vegetated and a proposed seed mix for approval prior to starting the re-vegetation process.

### PA 1.3 MAINTENANCE

It may be necessary to continue watering the area planted during the establishment phase if conditions are very dry. This will be determined on Site by the Engineer. Such water can be applied from a water cart every second day for up to 3 months.

### PA 1.4 ACTIVITIES AND SCHEDULE

The Contractor is required to provide a schedule for completion of the activities listed below for approval by the Engineer.

- Place topsoil to a minimum depth of 300 mm.
- Prepare seedbed and scarify the surface to a depth of 20 mm to 30 mm.
- Apply Fertiliser.
- Hand plant vegetative species and water if necessary.
- Seed areas to be seeded and water if necessary.

### PA 1.5 PERFORMANCE GUARANTEES

The guarantees required are listed below.

- A minimum of 50% canopy cover of vegetation is sustained.
- No gaps in vegetation cover shall exceed 1000mm in any direction.
- Vegetation cover shall be maintained by the Contract for a twelve (12) month period following the establishment of acceptable vegetation cover.

- Any deterioration in, or failure of vegetation cover during the maintenance period shall be made good by the Contractor at no expense to the Employer.
- Payment shall be made to the Contractor in phases such that:
- 50% payment is provided on seeding and planting,
- 40% payment is provided on the successful establishment of acceptable vegetation cover at termination of construction period,
- 10% payment is provided after the twelve (12) month maintenance period, when satisfactory vegetation cover is evident, in line with retention money requirements.

The above guarantees and maintenance shall be covered by the rate.

### PA 1.6 UNIT OF PAYMENT

The unit of payment for vegetation establishment shall be square metres of area covered.

# PB SPECIFICATIONS FOR FENCING

## PB 1 SCOPE

This section covers the moving and re-erection of existing fences where necessary and the erection of new fences along the boundaries where so indicated on the drawings or as directed by the Engineer.

## PB 2 TYPES OF FENCING

No posts, corner posts, standards or droppers consisting of timber shall be used in the erection of fences. Stock-proof fences shall be erected in accordance with details shown on drawings with horizontal barbed fencing wire. Security fencing shall comply with the details on the drawings.

## PB 3 MATERIAL

### PB 3.1 STANDARD SPECIFICATIONS

The materials used in fencing shall comply in all respects with the following standard specification (where applicable), the latest revision of which shall be held to apply:

**Table B 3-1: Standard Specifications Applicable to Fencing Materials**

| SANS / SANS NUMBER | DESCRIPTION |
|---|---|
| SANS 675: 2011 | Zinc-coated fencing wire (plain and barbed) |
| SANS 32: 1997 | Internal and/or external protective coatings for steel tubes – Specification for hot dip galvanized coatings applied in automatic plants |
| SANS 121: 2011 | Hot dip galvanized coatings on fabricated iron and steel articles – Specifications and test methods |
| SANS 10244-2:2011 | Steel wire and wire products - Non-ferrous metallic coatings on steel wire - Part 2: Zinc or zinc alloy coatings |
| SANS 1024:2021 | Welded steel fabric for reinforcement of concrete |
| SANS 1200 G: 1982 | Concrete (Structural) |

Should the Contractor wish to submit for consideration by the Engineer, alternative fence materials or types of fencing, he shall submit full descriptions, specifications and particulars concerning their properties or manufacturing process to the Engineer.

Where the required materials are not covered by the above standard specifications, the Contractor shall use only materials supplied or manufactured by reputable companies. Full details must be submitted. The Contractor shall submit certificates from the manufacturer confirming quality of materials to the Engineer for review and approval.

The Engineer shall have the right to insist on approving samples of any such materials before orders are placed.

## PB 4 FENCING POSTS

All fencing posts shall be galvanised to SANS 32 and SANS 121 and manufactured as follows:

## PB 4.1 TUBULAR STEEL PIPING

Straining, corner and gate posts shall be 4 000 mm long for high and medium security fences and 1 200 mm long for boundary fences and shall be made from 100 mm diameter material with a wall thickness of 2.8 mm minimum.

Intermediate posts shall be 3 850 mm long for high and medium security fences and 1 050 mm long for boundary fences and shall be 75 mm in diameter and have a wall thickness of 2.8 mm minimum.

## PB 4.2 STAYS

Stays shall be tubular steel piping, galvanised to SANS 32 and SANS 121. They shall have a diameter of 50 mm and a minimum wall thickness of 2.0 mm. Before galvanising the top end of the stay shall be flattened and shaped to fit the posts, the bottom end to have a 150 x 150 x 4 mm plate welded on.

The length of the stays shall be as indicated on the drawings and shall be bolted to the straining, corner or gate post using 12 mm galvanised diameter bolts. After bolting a tack weld thread seal shall be applied to the bolt and nut to prevent subsequent removal. A cold galvanised corrosive protection of minimum thickness 50 microns shall be applied to this tack point.

## PB 4.3 WIRE

All wire shall be galvanised with a first class zinc coating to SANS 935 Class C Standard.

Smooth wire shall comply with the requirements of SANS 675 and shall be galvanised high tensile steel with a minimum diameter of 4 mm for straining wire and tying wire shall be galvanised mild steel with a minimum diameter of 2 mm.

Barbed wire shall comply with the requirements of SANS 675 and consist of mild steel grade 2 x 2.5 mm diameter double strand, uni-directional twist wire with barbs at a maximum spacing of 150 mm.

## PB 4.4 BARBED TAPE/RAZOR TAPE

Barbed tape shall be high tensile steel wire comprising of two 2.5 mm diameter strands or a single strand equivalent and with barbs or "razors" at a minimum spacing of 25 mm. A section shall consist of at least 55 coils and when stretched and fixed shall not span more than 13 metres.

The wire shall be galvanised to Class C zinc coating to SANS 10244-2:2011.

## PB 4.5 WELDED MESH FABRIC

Welded mesh fabric shall comply with SANS 1024, shall have fencing standard, pre-galvanised hard drawn wires of 2.5 mm diameter welded at spacing of 50 x 25 mm. The height shall be 2 400 mm and shall be galvanised with a Class C zinc coating to SANS 935. The 50 mm dimension shall be vertical. The minimum tensile strength of the wires shall be 460 $N/mm^2$.

## PB 4.6 GATES

All steelwork to gates is to be galvanised to SANS 32 and SANS 121.

### PB 4.6.1 Vehicle Access Gates

Vehicle access gates shall comprise of two 3 000 mm leaf gates for a bi-directional access road and single 3 000 mm for a single direction road. Should other opening sizes be required these will be indicated on the drawings.

The gates shall be fabricated with 50 mm galvanised tubular steel pipes 2 mm wall thickness and each gate leaf shall be 3 000 mm wide and 3 300 mm high for high and medium security fences and 1 000m high for boundary fences or as detailed on drawings.

The gate hinges shall be as detailed on drawings and shall consist of an eye bolt fabricated from 25 mm diameter mild steel, galvanised, the shaft being threaded sufficiently for two nuts and washers, one on each side of the gate post, to enable the gate to be adjusted for swing. A tack weld seal of the threads must be made after installation to ensure subsequent non-removal. A local cold galvanised corrosion seal to this tack weld area must be applied.

Each gate shall be fitted with a pipe and locking detail as indicated on the drawings. This locking device shall be hot dip galvanised with the gate.

Each gate of a double leaf gate shall also be fitted with a 20 mm diameter barrel bolt fitting, into a pipe set in concrete, to hold the gate firmly in the closed position.

Cladding of the gates shall match the fence and for high and medium security fencing a section of barbed tape or similar, shall be fitted to the top in such a manner that the gate can be opened without interference from the barbed tape of the security fence.

### PB 4.6.2 Pedestrian Gates

Pedestrian gates shall be fabricated from 40 mm tubular steel piping, galvanised, with a wall thickness of 2 mm. The gate shall be 1 200 mm wide and 2 400 mm high for high and medium security fences and 1 000 mm high for boundary fences, and shall be cladded to match the fence. A similar locking device to the vehicle gate shall be supplied as detailed on drawings.

### PB 4.7 CONCRETE

Concrete shall be to line and level as indicated on the drawings, shall have a minimum 28 day concrete cube strength of 15 MPa and generally comply with SANS 1200G. It is not intended that formwork be used to form the surface above ground level, but wood float to provide a projection of 75 mm minimum above existing ground level.

## PB 5 CONSTRUCTION

### PB 5.1 EQUIPMENT

The Contractor shall be responsible for providing all straining and other equipment required for the proper execution of the work described in this specification.

### PB 5.2 SETTING OUT

The Engineer will provide the setting out information for the fencing and the Contractor shall be responsible for the accurate setting out of all work.

### PB 5.3 CLEARING

The fence line shall be cleared over a width of at least 1.5 m, or as shown on the drawings, on each side of the centre line of the fence and surface irregularities shall be graded so that the fence will follow the general contour of the ground. Trees, stumps and other obstructions shall be removed and any depression shall be backfilled. The grass, shrubs, rocks, trees and structures which have been cleared shall be burnt or transported to suitable sites indicated by the Engineer.

### PB 5.4 INSTALLING FENCING POSTS

All posts and intermediate posts shall be planted firmly into natural ground be it soil, gravel or rock, at such depths that the correct clearance between the lowest wire and the ground can be maintained.

Straining posts shall be erected at all gates, ends, corners or bends in the line of the fence and at all functions with other fences, providing that the straining posts shall not be spaced further apart than 45 m and even spacings are required. The spacing of intermediate posts shall not be more than 15 m. The spacing of standards and/or droppers between intermediate and/or straining post shall not exceed 3m.

All posts and stays shall be cast into concrete by completely filling the hole dug with the post being no more than 100 mm from the bottom of the hole. Sizes of the holes shall be 750 x 600 x 600 mm for corner, gate and strain posts and 600 x 400 x 400 mm for intermediate posts.

Corner, end, gate and straining posts shall be braced by means of stays erected at a slope of 45°.

All posts shall be accurately aligned and set plumb.

### PB 5.5 WIRING

Fencing wire shall be carefully strung between end, corner, gate and straining posts, with true alignment. Care being exercised not to stretch the wire so tightly that it will break or that posts will be pulled up. The maximum force in fencing wire stretched between straining posts before it has been secured to the standards is 0.9 kN. (A fencing wire on horizontal terrain having a sag of 1200 mm when the ends are fixed 200 m apart will be subject to a force of approximately 0.9 kN).

All fencing wire shall be securely fastened in the correct position to each post with soft galvanised binding wire. The binding wire for each horizontal fence wire shall pass through a hole or notch in the post to prevent slipping of the fence wire in a vertical direction, while the ends of the wire shall be wound at least four times around the fencing wire to prevent it moving in a horizontal direction.

At end, corner, straining and gate posts the fencing wire shall be securely wrapped and anchored once about the post from inside and secured against slipping by tying the ends tightly to each other by means of at least six snug tight twists.

In the case of high tensile wire two long windings may first be made before the six tight twists, to prevent the wire from breaking at the first twist. When using smooth wire the loose end shall preferably be bent over and hooked into the notch between the fencing wire and the first winding.

Splices in the fencing wire will be permitted if made in the following manner using a splice tool; the end of each wire at the splice shall be carried at least 75 mm past the splice tool and wrapped snugly around the other wire for not less than 6 complete turns, the two separate wire ends being turned in opposite directions. After the splice tool is removed the space left by it in the spliced wire shall be closed by pulling the wire ends together. The unused ends of wire should be cut close so as to leave a neat splice.

The welded mesh fabric shall be stretched against the fence and securely tied to the 5 span wires at a maximum spacing of 600 mm along the wires.

The overlaps on the welded mesh shall be a minimum of 100 mm tied at 200 mm centres vertically down each panel end with galvanised crimping clips.

The barbed tape shall be hung from the top span wire and tied to it and the top span wire holding the welded mesh with binding wire at a maximum spacing of 450 mm.

Each barbed tape coil shall be stretched to a maximum length of 13 metres and shall lap with the following coil by a minimum of 150 mm the ends being tied together.

All straining posts, wires, stays, etc. shall be placed on the inside of the mesh fence.

### PB 5.6 INSTALLING GATES

Gates shall be installed at the places indicated by the Engineer. The gates shall be hung on gate fittings in accordance with the requirements shown on the drawings. Gates shall be so erected as to swing in a horizontal plane at right angles to the gate posts, clear of the ground in all positions. At pedestrian and security fences the double swing gates shall not leave a gap of more than 20 mm between them when closed and other gates shall not be further than 50 mm from the gate post when closed.

Gate posts shall be firmly tied to the straining posts by twisting 2 strands of 4 mm smooth wire until taut as detailed on the drawings.

### PB 5.7 CONCRETING

Concrete to kerbing and post bases is to be wood float formed to ensure minimum projection of 75 mm concrete above existing ground level. Where mesh is to be encased two castings of concrete to base posts may be required or a recess in the base post concrete provided.

### PB 5.8 TOLERANCES

The completed fence shall be plumb, taut, true to line and ground contour, with ad posts, intermediate and stays firmly set. The height of the lower fencing wire above the ground at posts and intermediate shall not vary from that shown on the drawings by more than 25 mm. Other fencing wires shall not vary by more than 10 mm from their prescribed relative vertical positions. Baggy welded mesh and posts and intermediates visibly out of line will be rejected.

Where existing fences are to be removed to allow the orderly execution of the work, the Contract shall arrange for new permanent or temporary fences to be erected or temporary gates to be installed without delay, if required by the Engineer.

Where temporary fences are erected they shall be firm and of sufficient height with a sufficient number of wires to prevent effectively the passage of stock.

### PB 5.9 TESTING

The Engineer shall have the right to conduct such tests on materials delivered to Site as he may deem necessary to satisfy himself regarding any item's compliance with this or the SANS specifications. Should the samples fail to comply with the appropriate standard, the Engineer shall have the right to reject the whole or part of the consignment from which the samples were taken.

### PB 5.10 MEASUREMENT AND PAYMENT

The unit of measurement for new fences is the metre long length of completed fence line and the price shall include for clearance, supply and installation of all materials as specified.

The price of new gates shall be for the number of new gates supplied and erected as outlined in the Bill of Quantities.

The unit of measurement for the re-erection of previously dismantled fence is the metre of re-erected fence including any replacement of materials damaged in dismantling. The unit of measurement for previously dismantled gates re-erected shall be the number so installed including any repair that may be necessary.

## PC SPECIFICATIONS OF SMOOTH LINING GEOMEMBRANE

### PC 1.1 SCOPE

The following geomembrane specification covers the technical requirements for the manufacturing and installation of the Smooth. Whichever is applicable, High Density Polyethylene (HDPE) geomembrane. All materials must meet or exceed the requirements of this specification, and all work will be performed in accordance with the procedures provided.

### PC 1.2 STANDARD SPECIFICATIONS

The materials used in manufacturing the lining geomembrane shall comply in all respects with the standard specification (where applicable) as shown in Table 2, the latest revision at date of issue of this specification document which shall be held to apply. Any contradictions between publications shall be submitted to the Engineer for decision.

- Project Technical Specifications.
- Project Construction Drawings.
- Project Construction Assurance Plan.

**Table 2: Standard Specifications Applicable to Lining Smooth Geomembrane Materials**

| PUBLISHER | REFERENCE NUMBER | DESCRIPTION |
|---|---|---|
| South African Bureau of Standards (SABS) | SANS 1526:2015 Edition 3 | Thermoplastics sheeting for use as a geomembrane |
| | SANS 10409:2005 Edition 1 | Design, selection and installation of geomembranes |
| American Society of Testing and Materials (ASTM) | D 638 | Standard test method for tensile properties of plastics |
| | D 792 | Standard test method for specific gravity and density of plastics by displacement |
| | D 1004 | Test method for initial tear resistance of plastic film and sheeting |
| | D 1238 | Standard test method for melt flow rates of thermoplastics by extrusion plastometer |
| | D 1505 | Test method for density of plastics by density-gradient technique |
| | D 1603 | Test method for carbon black in olefin plastics |
| | D 3895 | Standard test method for oxidative-induction time of polyolefins by differential scanning calorimetry |
| | D 4218 | Standard test method for determination of carbon black in polyethylene compounds |
| | D 4833 | Standard test method for index puncture resistance of geotextiles, geomembranes, and related products |
| | D 1599 | Standard test method for measuring nominal thickness of geotextiles and geomembranes |
| | D 5397 | Standard test method for evaluation of stress crack resistance of polyolefin geomembranes using notched constant tensile load test |
| | D 5596 | Standard test method for microscopic evaluation of dispersion of carbon black in polyolefin geosynthetics |
| American Society of Testing and Materials (ASTM) | D 5641 | Standard practice for geomembrane seam evaluation by vacuum chamber |
| | D 5820 | Standard practice for pressurized air channel evaluation of Dual seamed geomembranes |
| | D 5886 | Standard guide for selection of test methods for determining rate of fluid permeation through geomembranes for specific application |
| | D 5994 | Standard test method for measuring core thickness of textured geomembranes |
| | D 6392 | Standard test method for determining the integrity of non-reinforced geomembrane seams produced using thermos-fusion methods |
| | D 6693 | Standard test method for determining tensile properties of non-reinforced polyethylene and non-reinforced flexible polypropylene geomembranes |
| | D 7240 | Standard practise for leak location using geomembranes with an insulation layer in intimate contact with a conductive layer via electrical capacitance technique (Conductive geomembrane spark test) |

| PUBLISHER | REFERENCE NUMBER | DESCRIPTION |
|---|---|---|
| Geosynthetic Research Institute (GRI) | GRI GM 9 | Standard practise for cold weather seaming of geomembranes |
| | GRI GM 13 | Standard specification for test properties, testing frequency and recommended warranty for high density polyethylene (HDPE) smooth and textured geomembranes |
| | GRI GM 14 | Standard guide for selecting variable intervals for taking geomembrane destructive seam samples using the method of attributes |
| | GRI GM 17 | Standard specification for test properties, testing frequency and recommended warranty for linear low density polyethylene (LLDPE) smooth and textured geomembranes |
| | GRI GM 19 | Standard specification for seam strength and related properties of thermally bonded polyolefin geomembranes |

### PC 1.3 DEFINITIONS

The following definitions shall apply to this specification:

- **LOT**: A quantity of resin (usually the capacity of one rail car) used in the manufacture of geomembranes. Finished roll will be identified by a roll number traceable to the resin lot used.
- **Construction Quality Assurance Consultant (CONSULTANT)**: Party, independent from MANUFACTURER and INSTALLER that is responsible for observing and documenting activities related to quality assurance during the lining system construction.
- **ENGINEER**- The individual or firm responsible for the design and preparation of the project's Contract Drawings and Specifications.
- **Geomembrane Manufacturer (MANUFACTURER)**: The party responsible for manufacturing the geomembrane rolls.
- **Geosynthetic Quality Assurance Laboratory (TESTING LABORATORY)**: Party, independent from the OWNER, MANUFACTURER and INSTALLER, responsible for conducting laboratory tests on samples of geosynthetics obtained at the site or during manufacturing, usually under the direction of the OWNER.
- **INSTALLER**: Party responsible for field handling, transporting, storing, deploying, seaming and testing of the geomembrane seams.
- **PANEL**: Unit area of a geomembrane that will be seamed in the field that is larger than 9.3 $m^2$.
- **PATCH**: Unit area of a geomembrane that will be seamed in the field that is less than 9.3 $m^2$.

**SUBGRADE SURFACE**: Soil layer surface which immediately underlies the geosynthetic material(s).

# PC 2 Materials

## PC 2.1 LINER CHARACTERISTICS

Material shall be smooth geomembrane as shown on the drawings. Resin shall be new, first quality, containing no plasticizers, fillers or extenders, compounded and manufactured specifically for producing geomembrane. Recycled material shall not be accepted. Natural resin (without carbon black) shall meet the following requirements as shown in **TABLE 3**.

**TABLE 3: LINER - RAW MATERIAL PROPERTIES**

| PROPERTY | TEST METHOD | HDPE | FREQUENCY |
|---|---|---|---|
| **Density (g/cm³)** | ASTM D 1505 | ≥0.932 | 1 per lot |
| **Melt Flow Index (g/10 min)** | ASTM D 1238 (190/2.16) | ≤1.0 | 1 per lot |
| **OIT (minutes)** | ASTM D 3895 (1 atm/200⁰C) | ≥100 | 1 per lot |

Internal quality assurance testing shall be carried out by the geomembrane Manufacturer to demonstrate that the incoming resin meets this specification. The resin shall be virgin material with no more than 10% rework. If rework is used, it shall be of the same formulation as the parent material. No post-consumer resin of any type shall be added to the formulation.

A maximum of 3% total additives consisting of carbon black, anti-oxidants and heat stabilizers, with a maximum of 1% of additives other than carbon black, shall be permitted in the geomembranes. Geomembrane shall be free of holes, pinholes as verified by on-line electrical detection, bubbles, blisters, excessive contamination by foreign matter, and nicks and cuts on roll edges. Geomembrane material is to be supplied in roll form. Each roll is to be identified with labels indicating roll number, thickness, length, width and manufacturer.

All liner sheets produced at the factory shall be inspected prior to shipment for compliance with the physical property requirements listed **TABLE 4**. Sheets must be tested by an acceptable method of inspecting for pinholes. If pinholes are located, identified and indicated during manufacturing, these pinholes may be corrected during installation.

Extrusion rod or bead material shall be made from same type resin as the geomembrane. The additives shall be thoroughly dispersed and the materials shall be free of contamination by moisture or foreign matter.

The product shall meet the requirements as outlined below. Smooth geomembrane shall have good appearance qualities and shall be free from such defects that would affect the specified properties.

The design intent of the specified design parameters of the product is to meet the performance intent of the facility during the required service life.

In addition to the above, the product shall meet the following requirements:

- 2mm or 1.5mm HDPE smooth geomembrane

- Thickness to be Minimum not Nominal.
- Standard OIT to be greater than or equal to 100 minutes.
- High pressure OIT to be greater than or equal to 400 minutes.

**TABLE 4: SMOOTH LINING GEOMEMBRANE PROPERTIES FOR NON-EXPOSED APPLICATIONS**

| TESTED PROPERTY | UNIT | TEST METHOD | FREQUENCY | GEOMEMBRANE THICKNESS | | |
|---|---|---|---|---|---|---|
| | | | | 1.5MM | 2.0MM | 2.5MM |
| Thickness, (Minimum Average) | mm | ASTM D 5994 | Every Roll | 1.50 | 2.00 | 2.20 |
| Lowest Individual Readings | mm | | | 1.35 | 1.80 | 2.25 |
| Density (Minimum Average) | $g/cm^3$ | ASTM D 1505 | 90 000 kg | 0.940 | 0.940 | 0.94 |
| Tensile Properties (each direction) | | ASTM D 6693 Type IV | 9 000 kg | | | |
| Strength at Break | N/mm | Dumbbell,50 mm/min | | 16 | 53 | 67 |
| Strength at Yield | N/mm | | | 22 | 29 | 37 |
| Elongation at Break | % | G.L 50 mm | | 100 | 100 | 100 |
| Elongation at Yield | % | G.L 33 mm | | 12 | 12 | 12 |
| Tear Resistance | N | ASTM D 1004 | 20 000 kg | 187 | 249 | 311 |
| Puncture Resistance | N | ASTM D 4833 | 20 000 kg | 480 | 640 | 800 |
| Multi-axial Break Resistance | % | ASTM D 5617 | Per Formulation | 30 | 30 | 30 |
| Carbon Black Content | % Range | ASTM D1603*/4218 | 9 000 kg | 2.0 - 3.0 | 2.0 - 3.0 | 2.0 - 3.0 |
| Carbon Black Dispersion | | ASTM D 5596 | 20 000 kg | Note (1) | Note (1) | Note (1) |
| Notch Constant Tensile Load | Hr | ASTM D 5397, Appendix | 90 000 kg | 300 | 300 | 300 |
| Oxidative Induction Time | Min | ASTM D 3895, 200˚C, $O_2$, 1 atm | 90 000 kg | ≥100 | ≥100 | ≥100 |
| **GEOMEMBRANE ROLL DESCRIPTION** | | | | | | |
| Surface | Smooth | | | | | |

Notes:

1. Dispersion only applies to near spherical agglomerates. 9 of 10 views shall be Category 1 or 2. No more than 1 view from Category 3

## PC 2.2 ACCEPTED MATERIALS

GSE or similar approved as tested during design phase or based on Engineer approved alternative in line with project design and performance criteria.

## PC 2.3 TESTS

### PC 2.3.1 TESTING

The geomembrane material shall be tested by the manufacturer for compliance with the specifications listed in this specification or CQA plan by the test methods and frequencies indicated. The costs of these tests are to be included for in the contractor's price.

Conformance Testing shall be carried out as set out below to a third party external independent laboratory (MQA laboratory) not associated with the Manufacturer, earthworks or lining contractor or as directed by the Project Engineer.

Conformance testing is not an opportunity to reproduce the QC testing program. It is a check to provide confirmation that satisfactory material is delivered to the site. The testing frequency shall be at the discretion of the Engineer or as set out in the CQA plan, but the frequency as indicated in GRI-GM13 can be used as a guideline.

The name and address of the laboratory shall be approved by the Engineer. The Engineer has a right to reject any roll or production batch if the samples do not pass the conformance testing.

Conformance Testing including durability tests will be performed before material is shipped from the Manufacturer's plant so that it may be used immediately on arrival at the site as listed in **TABLE 5.**

Contractor to ensure he is familiar with the duration of conformance. The contractor shall submit a conformance testing schedule to the Project Engineer prior to the commencement of works and part of the overall project work breakdown schedule.

**TABLE 5 : CONFORMANCE TESTS BEFORE MATERIAL SHIPPING/TRANSPORT AND AS SPECIFIED IN THE CQA PLAN.**

| PARAMETER | METHOD |
|---|---|
| Thickness | ASTM D5994 |
| Density | ASTM D1505 |
| Carbon Black Content | ASTM D1603 |
| Carbon Black Dispersion | ASTM D5596 |
| Stress Crack Resistance | ASTM D5397 |
| Tensile Properties | ASTM D6693 |
| Oxidative Induction Time (OIT) - 3 layers | ASTM D3895 |
| High Pressure IT | ASTM D5885 |

OIT measurements during conformance testing shall be through the full thickness of the specimen (top, centre and bottom) therefore giving a broader perspective of the AO content throughout the full thickness of the geomembrane.

#### PC 2.3.1.1 DURABILITY TESTS

As these tests take a very long time to carry out. The manufacturer will be required to run the below tests once for every different masterbatch resin that the manufacturer uses. One set of results per lot of master batch used is expected for submission.

The following durability testing shall be performed and results provided to the Engineer for acceptance of products to be installed on the project site before the material is accepted and as part of CQA conformance tests. Shall be as per the relevant test methods in GRI - GM 13.

- Oven Aging at 85°C (ASTM D5721).
- Standard OIT 55% retained after 90 days (ASTM D3895).
- Oven Aging at 85°C (ASTM D5721).
- High Pressure OIT 80% retained after 90 days (ASTM D5885).
- UV Resistance High Pressure OIT 50% retained after 1600 hrs (ASTM D5885).

The above tests shall be done in additional to the CQA conformance test schedule during construction phase.

Some or all of the following listed tests may be performed on the samples by a recognised laboratory, to maintain quality control.

- Density.
- Carbon black content and dispersion.
- Tensile strength and elongation at break.
- Melt Flow Index (MFI) / Melt Flow Rate (MFR).
- Stress Cracking.
- Sheet Thickness.

All the above tests shall be completed as per the standard test method supplied in Sub-Clause PC 1.2 above.

### PC 2.4 ACCEPTANCE

The batch of sheets or rolls shall not be released for use in fabrication or installation unless the results for the above tests are within the set requirements.

Should the results fail another set of samples must be drawn and the tests repeated. If these results corroborate the first set of results the particular batch of sheeting will not be used.

Should this sample, however, show results that pass a third set of samples must be drawn and tested. The results, if pass leads to acceptance or, if fail, to rejection of the particular batch.

### PC 2.5 QUALIFICATIONS

#### PC 2.5.1 QUALIFICATION OF GEOMEMBRANE MANUFACTURER

The geomembrane shall be manufactured by the following:

- Reputable manufacturers, that meet all the technical and experience requirements as set out in the Project Specifications.
- Manufacturers whose product was tested and satisfied technical performance needs of the project during design phase.
- Details of the Manufacturer shall be provided by the Installer.
- The Manufacturer shall be approved by the Engineer and the Client.

### PC 2.5.2 QUALIFICATION OF LINER INSTALLER

The liner Installer must meet the following criteria, and supporting documents to the following criteria must be submitted to the Engineer for approval prior to the commencement of works:

- Be an accredited current member of the International Association of the Geosynthetics Installers (IAGI) association, and should have been a member in the previous 3 years consecutively without interruption in membership.
- Provide a list of their certified welders as examined by IAGI.
- Provide their maximum installation capacity per day and number of teams they are willing to mobilise to the project.
- Provide the relevant quality management system used in their work during liner installation i.e. SABS/ISO 9001.
- Should have a minimum experience of liner installation of 3,000,000 square meters.
- Provide workmanship warranty against defects in the installation and workmanship for final acceptance in line with project or Client requirements.
- Provide a minimum of two referee contacts of previous projects carried out in the last 15 months of similar size to the intended project. The details should include a contact name and number.

The following information is to be submitted at to the Engineer for approval prior to the commencement of works:

- Manufacturer name and track record in the South African and Democratic Republic of Congo markets listing completed successful projects for which the Manufacturer has manufactured geomembrane materials from the same type as that proposed to be used for this Contract.
- Manufacture capabilities:
  - Information on plant size, equipment, number of shifts per day, capacity per shift, quality control manual for manufacturing.
  - List of material properties, including certified test results.
- Manufacturer quality control manuals and related documentation.

- Long term service life information of the manufacturer's products in similar applications and tested post installation to be provided to Engineer. Of particular interest to the Engineer is the demonstration of longevity and performance of the geomembrane in the form of OIT measurements taken at periodic intervals post installation of Manufacturer's geomembrane.

Where materials, which have already been manufacturer and have been delivered to storage, the Engineer shall be furnished with the test results from an independent approved laboratory and the quality control certificates and will notify the Manufacturer in writing which geomembrane rolls are approved for shipping/transport from storage.

The Contractor/Installer shall obtain approval from the Engineer before the geomembrane material is loaded for shipping/transport.

## PC 2.6 GENERAL

The Contract shall be responsible to ensure that the manufacturer completes the required tests at place of manufacture and the Contractor completes regular testing in a laboratory to be established on Site.

Tests will be done on completed sheets prior to dispatch and on the welded sheets after installation, specifically to test the site welding. All pieces removed from the sheets for testing purposes will have to be repaired by the lining Contractor.

The responsibility for quality control of the raw material supplies will rest with the Contractor but the Engineer reserves the right to take samples for testing at any time.

## PC 2.7 MANUFACTURE

Manufacture shall be to the largest possible sheet size to minimise jointing. Adequate tests and controls must be performed to ensure a good quality of raw material for sheet production and the sheet production process shall be accurately monitored and shall be such as to insure homogeneous sheets, free from blisters, bubbles, pinholes and ragged edges.

The manufacturer shall submit a certificate stating that no recycled polymer and no more than 10% rework of the same type of material is added to the resin.

The Engineer may perform an audit of the manufacturing and quality control procedures used by the Manufacturer at the cost of the Contractor, specifically for the production of the geomembrane to be used for installation at the Client's facility. The Manufacturer shall give the Engineer at least one month's notice of the start of production of geomembranes for the project. Quality control test shall be performed as the geomembranes are manufactured.

The Manufacturer shall make available to the Engineer, Manufacturing Quality Control Manuals, which outline all quality procedures, to be implemented for the manufacturing of geomembranes.

The Engineer shall monitor production and testing of the geomembranes material allocated for this project. If material for this project has already been manufactured, the Engineer shall monitor production of the same type of geomembrane on the same production line to verify that manufacturing controls are in place. Additional tests by one independent approved accredited laboratory are also required before the material will be approved.

The Engineer shall review the quality control certificates and notify the Manufacturer in writing which geomembrane rolls are approved for shipping/transport. The Engineer shall be allowed to monitor the loading of the geomembranes for shipping/transport.

Production data and test reports of all tests done on each batch of material in accordance with the submitted quality control programme are to be kept and compiled in a Sheet Report and submitted to the Engineer with each delivery to Site.

The Engineer reserves the right to perform any test at any time on either the raw material or the manufactured sheet at a cost to the Contractor.

The following information must be delivered with every batch of sheet or rolls. This information must be presented in such a way as to allow identification of particular rolls at any time.

- Batch number and size.
- Sheet report for every sheet recording any visible defects due to physical damage.
- Product name and grade.
- Length and width of the roll.
- Total weight of roll.
- Production Lot number and individual roll number.

Sheets with manufacturing process defects shall not be delivered to Site. If any such sheets are delivered to Site, they shall be rejected forthwith, and all costs involved with such sheets shall be for the Contract's account.

## PC 2.8 ACCEPTANCE OF SHEET OR ROLLS

### PC 2.8.1 SUBMITTALS

The geomembrane Manufacturer shall issue Quality Control submissions to the Engineer for each delivery of material. The submissions shall include the following information:

Prior to shipment/transport of any geomembrane, the Manufacturer will provide the Engineer with the following:

- A certified properties sheet including, at a minimum, all specified properties, and test methods indicated in the Specifications.
- The internal MQC sampling procedures, frequencies of testing, and results of testing of material supplied to the project.

- The Engineer will verify that the property values certified by the Manufacturer are properly documented, the test methods used are acceptable and the geomembrane meets the Project Specifications.
- Geomembrane Manufacturer Tracking List - Cross referencing list delineating the corresponding resin used in the production of the rolls delivered.
- Manufacturing Quality Control Data - The manufacturing quality control test data indicating the actual test values.
- Physical Properties Sheet - The material specification for the geomembrane supplied in accordance with this Specification and that no plasticizers, fillers, or extenders were added during the manufacture of the resin, geomembrane and extrudate rods and beads.
- Letter of Certification - The letter indicating that the material is in conformance with the physical properties specified.

The Contractor shall carry out a visual inspection of the sheets or rolls on arrival at Site for possible transport damage. Sheets or rolls showing damage shall be singled out and clearly labelled as such.

A further inspection by the lining Contractor is required prior to fabrication or installation. Any faults not previously catalogued in the report must then be catalogued on the same.

The Engineer must be notified of any damage and damaged material shall be set aside until approval for repair and use is received from The Engineer.

### PC 2.8.2 TRANSPORTATION AND HANDLING OF MATERIALS

Geomembranes must be supported during the handling to ensure worker safety and to prevent damage to the product. Under no circumstances may the rolls be dragged, lifted from one end, lifted with only a fork of a lift truck or dropped on the ground from the delivery vehicle.

The Engineer shall verify that proper handling equipment exists which does not pose any danger to installation personnel or risk damage or deformation to the liner material itself. Suitable handling equipment is described below:

- **Carpet Spike** - A carpet Spike is a rigid pipe or rod with one end directly connected to a forklift or other handling equipment and the other end rounded off to allow easy insertion into roll material cores. If a carpet spike is used, it must be at least 3 m long and inserted to its full length into the roll core to prevent excessive bending of the roll when lifted.
- **Roller Cradles** - Roller Cradles consist of two large diameter rollers spaced approximately 75 mm apart, which both support the geomembrane roll and allow it to unroll freely. The use of roller cradles will be permitted if the rollers support the entire width of the geomembrane roll.

- **Spreader Bar Assembly** - A spreader bar assembly shall include a core pipe or bar and a spreader bar beam. The core pipe shall be used to uniformly support the roll when inserted through the geomembrane core while the spreader bar beam will prevent chains or straps from chafing the roll edges.
- **Straps** - Straps may be used to support the ends of spreader bars but are not recommended as the primary support mechanism. As straps may damage the geomembrane where wrapped around the roll and generally do not provide sufficient uniform support to prevent roll bending or deformation, great care must be exercised when this option is used.

### PC 2.8.3 Inspection Upon Delivery

Each roll shall be visually inspected when unloaded to determine if any packaging or material has been damaged during transit. Possible product conditions and actions are listed below:

- Rolls, including the roll cores, exhibiting damage shall be marked and set aside for closer examination during employment. Minor rips or tears in the plastic packaging shall be repaired with moisture resistant tape before being placed in storage to prevent moisture damage.
- The presence of free-flowing water within any roll packaging shall require that the roll is set aside for further examination to ascertain the extent of any damage.
- Geomembrane rolls delivered to the project site shall be those indicated on geomembrane manufacturing quality control certificates.
- Repairs to damaged geomembrane rolls shall be performed in accordance with PC 3.6 of this Specification.

The Engineer reserves the right to reject any roll at any stage prior to installation should it exhibit any of the above damages or non-conformance.

### PC 2.8.4 Storage

A designated storage area shall be established in a location such that on-site transportation and handling are minimised. The storage area should be protected from theft, vandalism, passage of vehicles, and be adjacent to the area to be lined. The geomembrane rolls shall be stored lying flat and continuously supported.

### PC 2.8.5 SAMPLING

When required by the Engineer sampling shall be taken as specified in the relevant test method and/or specifications.

The samples shall be labelled and numbered as to batch and roll or sheet number and handed to the Engineer for testing. The marking medium shall have no detrimental effect on the membrane.

Samples shall be taken as and when required by the Engineer.

Samples will be taken across the entire width of the roll and will not include the outer wrap of the roll. Unless otherwise specified, samples will be 500 mm long by the roll width. Specimens for testing will be taken across the full width of the sample.

If more than one resin type is used, each resin type shall be samples at the same frequency and tested. If roll numbers are very different and non-sequential, consideration should be given to testing each block or roll numbers at the same frequency.

The tests as set out in Sub-Clause **Error! Reference source not found.** shall be applicable to all samples.

### PC 2.8.6 PAYMENT FOR TESTING OF MATERIALS

The Contractor shall provide free of charge to the Engineer, samples required for testing at an accredited approved independent laboratory not associated with the Manufacturer. The costs associated with verifying material used in the manufacturing of the geomembrane shall be borne by the Contractor and deemed to be included in the construction rates.

## PC 3 INSTALLATION PROCEDURE OF GEOMEMBRANE

### PC 3.1 GENERAL

The Installer/Contractor must present to the Engineer a method statement prior to starting the works, providing information on how they intent to do the works. Along with the method statement, the Contractor must also provide the following:

- Certification stating that the resin meets the specification requirements.
- Statement certifying no recycled polymer and no more than 10% rework of the same type of material is added to the resin.
- Installer's Geosynthetic Field Installation Quality Assurance Plan.
- Installation and panel layout.

In preparing the panel layout, the Contractor shall take into account the construction schedule, access restrictions and the following limitations placed on seam locations:

- To the maximum extent possible, field seams shall be parallel to the slope.
- The number of transverse field seams on slopes steeper than 1V:6H shall be minimized, and in this case the location of such seams shall be approved by the Engineer.
- A minimum of 1 m shall be provided from the toe of any slope steeper than 1V:6H before providing any transverse seams.
- The field seams at inside and outside corners, odd-shaped geometric configurations, seam convergences, and small panels shall be avoided.

Upon completion, the Installer/Contractor must furnish the Engineer, within 14 days, with the following documents:

- Certificate stating the geomembrane has been installed in accordance with the Contract Documents.
- Material and installation warranties.
  - The Contractor shall request, and the geomembrane Manufacturer shall provide a warrant of the quality of the geomembrane material, and that the material will not fail due to ultraviolet degradation for a minimum period of 10 (ten) years from date of acceptance of installation. The warranty shall cover the cost of material, labour and equipment to replace the failed geomembrane.
- Red line drawings showing actual geomembrane placement and seams including typical anchor trench detail.

Irrespective of the liner system used, the membrane sheets shall be laid and welded down the slope and adequate arrangements must be made for anchoring at the top and bottom of the embankment.

**PC 3.2 PREPERATION BEFORE LAYING**

The entire basin area of the facility requiring a HDPE geomembrane lining system (i.e. floor and walls) shall be prepared in such a manner as to permit the laying of the chosen liner to the particular manufacturer's requirements.

The unit of measurement for this surface bed preparation where required shall be the square metre of prepared area.

The Installer/Contractor will be required to sweep the finished earthworks surface ahead of installing the liner to ensure that no particles remain that could damage the liner. No protruding sharp edged stones will be allowed. The surface shall be compacted with a smooth drum compactor and be clear of loose stones or protrusions in excess of 5 mm.

Agreement in writing must be done between the Contractor, Installer and the Engineer that the surface is suitable to place the liner. An example of the surface acceptance form can be found in SANS 10409.

**PC 3.3 ANCHOR TRENCH**

In some cases the geomembrane can be anchored in the same trench as any adjacent geosynthetic liner components (if used). Dimensions and location of the anchor trench shall be as indicated on the Construction drawings. The front edge of the trench is to be rounded, so as to prevent stress concentration on the geomembrane. Care should be taken to preserve the integrity of the sides of the trench during geotextile installation.

The geomembrane is to be placed in the trench such that it covers the entire trench area (Sides and floor) and extends no less than 50 mm outside the back edge of the trench. When the geomembrane is placed in position, the anchor trench must be temporarily loosely backfilled to a sufficient height to prevent movement or loaded with appropriate ballast to prevent movement until compaction commences. The anchor trench is to be backfilled and compacted with selected material in layers not exceeding 150 mm.

No pegs, (no penetrations allowed in the liner anchor trench) to be used for temporary anchorage in the liner.

### PC 3.4 PROCEDURE

The following points shall be observed in relation to geomembrane deployment:

- The geomembrane shall be installed on the approved areas shown on the Drawings and according to the approved panel layout, or as directed by the Engineer, using methods and procedures that ensure a minimum of handling and to minimize the formation of wrinkles, especially differential wrinkles between adjacent panels.
- Geomembrane deployment shall only proceed when ambient air temperatures measured are between 4 and 38 °C, unless approved by the Engineer.
- Geomembrane rolls shall be unrolled using a front end loader, a forklift or an excavator, with specially designed lifting apparatus attached to the bucket or forks of the equipment. This enables the panels to be placed in position without heavy equipment running on the material. Panels are deployed to allow a minimum overlap of ten centimetres. When possible, final overlap should be oriented to create a “shingle effect” in the downslope/grade direction.
- Should the contractor intend to use any deployment methods different to the above, he shall submit a method statement to the Project Engineer for approval and acceptance prior to moving equipment on site.
- The method used to unroll the geomembrane shall not cause scratches or crimps in the geomembrane and shall not damage the prepared subgrade or in-place geosynthetics. The geomembrane shall not be dragged over gravel, stones, debris or other material that could cause it damage. During deployment, the geomembrane shall be visually inspected by the CQC Contractor. Damaged, faulty or suspect areas shall be marked for testing and/or repair.

The geomembrane must be installed in accordance with the installation chart agreed with the Engineer.

Deployment of geomembrane panels shall be performed in a manner that will comply with the following guidelines:

- Each panel shall be assigned a panel number (i.e. P1, P2, P3, etc.);
- Panel numbers must be written on each panel and must be clearly visible;
- Panel numbers shall be recorded in a panel placement log book. This is to also include the respective roll number; and

- Should a partial roll of geomembrane remain after deployment, it remains imperative that the roll be clearly marked with its corresponding number so as to identify the roll after usage.

Furthermore:

- The surface on which the geomembrane is placed shall be properly inspected before deployment occurs.
- The pattern of sheets laid must be such that no more than three sheets shall lap at any place. This can be achieved by staggering adjacent strips of sheet forming T-joints instead of "+" joints. A full record of work done with respect to date and position must be kept and forwarded on a weekly basis to the Engineer.
- Unroll geomembrane using methods that will not damage the geomembrane and will protect underlying surface from damage (spreader bar, protected equipment bucket).
- Place ballast (commonly securely closed off sandbags with no loose items of sharp edges) on geomembrane which will not damage the geomembrane to prevent wind uplift.
- Personnel walking on geomembrane shall not engage in activities or wear shoes that could damage it. Smoking will not be permitted on the geomembrane.
- No vehicles of any kind shall be allowed onto the geomembrane.
- Sufficient material (slack) shall be provided to allow for thermal expansion and contraction of the material. This should consider the expected temperature of the tailings.
- The programme of construction shall be such as to minimise exposure of the sheets before the filling of the reservoir or placement of the material atop the geomembrane is commenced.
- The Contractor must ensure that no kinks or folds occur in the laid sheet. If any such kinks or folds develop the lining Contractor will be required to cut them out and repair the liner as described in Sub-Clause PC 3.6 at his own expense.
- The Contractor must ensure that sheets may not be installed transverse to the slope.

All joints must be prepared for welding by scraping the surface of the geomembrane over the full width and length of the joint and clearing the joint of all loose material and scrapings. Not more than 50 microns of the geomembrane thickness must be removed during this preparation procedure.

Where a joint runs transverse to the slope, the laps must be such that the higher sheet overlaps the lower sheet.

## PC 3.5 WELDING AND TESTING PROCEDURE

### PC 3.5.1 WELDING PROCEDURES

Seams shall meet the following requirements:

- To the maximum extent possible, orient seams parallel to line of slope (i.e. down and not across slope).
- Minimize number of field seams in corners, odd-shaped geometric locations and outside corners.
- Seams are welded with the fewest number of unmatched wrinkles or fish mouths.
- Slope seams (panels) shall extend a minimum of 1500 millimetres beyond the grade break into the flat area.
- Use a sequential seam numbering system compatible with panel numbering system that is agreeable to the Engineer and Installer/Contractor.
- Align seam overlaps consistent with the requirements of the welding equipment being used. A 152 mm overlap is commonly suggested.

During welding operations, the Installer/Contractor must provide at least one master seamer who shall provide direct supervision over other welders, as necessary. The master seamer shall have completed no less than 93 000 $m^2$ of geomembrane seaming using the type of seaming apparatus proposed for use in the Project. No welding technicians or welding apparatus shall be allowed to perform field seaming operations until the technicians and equipment have successfully completed prequalification and trial seams called for in this Specification.

All joints must be prepared for welding by scraping the surface of the geomembrane over the full length and width of the joint. No more than 50 microns of the geomembrane thickness may be removed during the preparation procedure.

During extrusion welding, hot-air tack adjacent pieces together using procedures that do not damage the geomembrane. Clean geomembrane surfaces by disc grinder or equivalent and Purge welding apparatus of heat-degraded extrude before welding.

Hot wedge welding must be done by a welding apparatus that is a self-propelled device equipped with an electronic controller which displays applicable temperatures. Prior to welding clean seam area of dust, mud, moisture and debris immediately ahead of hot wedge welder. Protect against moisture build-up between sheets.

Trial welds must be performed on geomembrane samples to verify that welding equipment is operating properly. The trial welds must be done under the same surface and environmental conditions as the production weld (i.e. in contact with subgrade and similar ambient temperature). A minimum of two trial welds must be done per day, per welding apparatus, one made prior to the start of work and one at mid-shift. Should a power shut-down occur, a trial weld should also be performed. Cut trail welds into four, 250 mm wide by 152 mm long test strips. Quantitatively test specimens for peel adhesion, and then for shear strength.

The trial weld specimens shall pass when the results of the tests pass the criteria shown in **TABLE 6**, when peel testing the break occurs in the linear material itself, not through peel separation and if the break is ductile.

**TABLE 6: MINIMUM WELD VALUES FOR SMOOTH AND TEXTURED HDPE GEOMEMBRANES (METRIC)**

| PROPERTY | TEST METHOD | 1.5 MM | 2.0 MM |
|---|---|---|---|
| **Hot Wedge Seams(1)** | | | |
| **Shear Strength(2), N/25 mm** | As Per GRI GM19 latest edition | 525 | 701 |
| **Shear Elongation at Break(3), %** | As Per GRI GM19 latest edition | 50 | 50 |
| **Peel Strength(2), N/25 mm** | As Per GRI GM19 latest edition | 398 | 530 |
| **Peel Separation, %** | As Per GRI GM19 latest edition | 25 | 25 |
| **Extrusion Fillet Seams** | | | |
| **Shear Strength(2), N/25 mm** | As Per GRI GM19 latest edition | 525 | 701 |
| **Shear Elongation at Break(3), %** | As Per GRI GM19 latest edition | 50 | 50 |
| **Peel Strength(2), N/25 mm** | As Per GRI GM19 latest edition | 340 | 455 |
| **Peel Separation, %** | As Per GRI GM19 latest edition | 25 | 25 |

If one trail weld fails in either the peel test or the shear test, then the trail weld test must be repeated in its entirety, no welding equipment or welder shall be allowed to preform production welds until equipment and welders have passed the trail weld tests. All data shall be logged in a trail welding log along with the speed and temperature of each welding machine.

Seaming shall not proceed when ambient air temperature or adverse weather conditions jeopardize the integrity of the liner installation. The Installer/Contractor shall demonstrate that acceptable seaming can be performed by completing acceptable trial welds.

Examine all seams and non-seam areas of the geomembrane for defects, holes, blisters, undispersed raw materials, and any sign of contamination by foreign matter. Repair and non-destructively test each suspect location in both seam and non-seam areas. Do not cover geomembrane at locations that have been repaired until test results with passing values are available.

### PC 3.5.2 SEAM PROPERTIES

All geomembrane seams subjected to laboratory testing shall conform to the properties as detailed in Table 1 of GRI Test method GM19.

### PC 3.5.3 WEATHER RESTRICTIONS

The Contractor shall take into account that rapid weather changes are possible at the Site, resulting in delays in production of field seams. Seaming shall only be undertaken under weather conditions allowing such work within the warranty limits imposed by the geomembrane manufacturer and which will not jeopardize the integrity of the geomembrane installation. Seaming shall not occur under adverse environmental conditions, including, but not limited to:

- Precipitation of any kind, including condensing fog.
- Areas of ponded water.
- Periods of excessive winds or dust.
- Extreme heat or cold, unless trial and field seams are shown to produce acceptable and consistent results.

The contractor shall submit to the Engineer prior to commencement of installation and upon agreement and approval of the Project Engineer what will be deemed and defined as adverse weather conditions in relation to project site weather conditions.

The contractor shall identify or provide for a weather measuring device including and not limited to temperature, humidity, rainfall, and a wind vane. If no allowance is made in the BOQ for this item it must be included in the installation rates.

In addition, should there be no weather station in close proximity to the project site, the contractor shall identify and obtain a 3 year historical record of weather data and not limited to (temperature, humidity, rainfall, and wind speed) of the project site area and plan his installation schedule according to historical weather data. The contractor shall submit a method statement indicating and outlining based on the weather historical data what will constitute normal installation weather.

Cognisance of the following testing procedure should be taken:

- Samples shall be allowed to cool down to room temperature prior to advancing with the testing.
- In extreme heat, samples should be cooled down with the aid of water or an insulated cooler.
- Visual inspection of the sample must be performed to identify the integrity of the material (i.e. squeeze-put, footprint, pressure and general appearance).
- Five samples must be tested in peel. In addition to the peel tests, shear tests must also be conducted.

### PC 3.5.4 FIELD SEAMS

All field seams shall be labelled by the Welding Technician according to the identification code on the panel layout, who shall record pertinent details relative to the weld, including:

- Welding Technician's initials.
- Welding apparatus identification number.
- Set temperature for fusion welders or nozzle temperature and preheat temperature for extrusion welders.
- Ambient temperature measured 150 mm above the geomembrane.
- Date and time welding of the seam commenced.

The QC Contractor shall monitor the pass/fail ratio of field seams with respect to geomembrane material, Welding Technician and welding apparatus, and the results shall be reported daily to the Engineer.

### PC 3.5.5 TESTING PROCEDURES

Non-destructive testing should be carried out as the seaming progresses or at completion of all field seaming. Vacuum testing shall be performed in accordance with ASTM D 5641. Air pressure testing shall be performed in accordance with ASTM D 5820. Spark testing shall be performed in accordance with ASTM D 7240.

#### PC 3.5.5.1 NON-DESTRUCTIVE SEAM TESTING

Inspections and non-destructive tests shall be performed on the full length of all seams and repairs using air pressure, vacuum, water, spark, or other approved method. Inter-seam air-pressure tests shall be performed to test continuity on seams with an enclosed air space. Vacuum testing shall be performed to test continuity on seams that cannot be tested with air pressure due to the absence of an enclosed air space. Hydrostatic or spark testing shall be conducted on seams used to make pipe boots and other prefabricated pieces. In locations where seams cannot be non-destructively tested, the area shall be capped, if possible, as instructed by the Engineer. Seams that are accessible for testing prior to final installation of the geomembrane or prefabricated piece shall be tested before final installation.

Non-destructive testing shall be performed by the QC Contractor as the seaming progresses, and in no case shall it be undertaken more than 24 hours after the seam was made. The QC Contractor shall monitor the pass/fail ratio of non-destructive tests with respect to test type, geomembrane material, Welding Technician and welding apparatus, and the results shall be reported daily to the Engineer.

The non-destructive testing program shall include:

- Observation

Visual observations shall be made routinely and shall include the following:

- Visually check of field seams for squeeze out, foot print, melt and overlap.
- Check machines for cleanness, temperature, and related items.
- Record details relative to the pressure test on the geomembrane at the test location or on a portion of the seam tested, including:
  - Tester's initials.
  - Date.
  - Initial pressure and time.
  - Final pressure and time.
  - Pass/fail designation.
  - After the test is completed and with the pressure still applied, the end of the seam furthest from the pressure gauge shall be cut open to observe the presence of escaping air which serves to confirm that the inter-seam channel

is continuous. Alternatively, pressure gauges may be used at both ends of the seam during the test. If air does not escape, the blockage in the channel shall be located, and a pressure test performed on the untested part of the seam.

    - Seal the penetration holes made by the pressure gauge/needle assembly by extrusion welding.

- Record details relative to the vacuum test on the geomembrane at the test location or on a portion of the seam tested, including:
    - Tester's initials.
    - Date and time of test.
    - Pass/fail designation.
- Record details relative to the spark test on the geomembrane at the test location or on a portion of the seam tested, including:
    - Tester's initials.
    - Date and time of test.
    - Voltage setting.
    - Pass/fail designation.
- Record details relative to the hydrostatic test in an area that will be visible after the piece is installed, including:
    - Tester's initials.
    - Date and time of test.
    - Pass/fail designation.

PC 3.5.5.2 **DESTRUCTIVE SEAM TESTING**

Destructive tests shall be performed on samples cut from trial and field seams.

Field seam samples shall be taken at a frequency not less than one sample per 100 metres, at locations identified by the Engineer. Destructive testing shall be performed by the QC Contractor as the seaming progresses, and in no case shall it be undertaken more than 24 hours after the test location has been marked by the Engineer.

The QC Contractor shall monitor the pass/fail ratio of non-destructive tests with respect to test type, geomembrane material, Welding Technician and welding apparatus, and the results shall be reported daily to the Engineer.

Destructive test samples shall be a minimum of 600 mm long by 300 mm wide, with the seam centred lengthwise. The sample shall be cut into two 300 mm long pieces, with one piece used by the QC Contractor (QC Sample) for destructive testing as described and the other piece retained by the Engineer. An additional 300 mm by 300 mm sample may be cut, if requested by the Engineer, for independent laboratory testing. The sample shall be marked with a sample identification number, the seam number, and date and time. The QC Contractor shall accurately mark the sample location and sample identification number on the panel layout drawing.

The destructive test shall be performed according to the following procedure:

- Cut 10 coupon specimens from the QC Contractor's sample using a coupon cutter and die.
- Test and examine 5 coupons for conformance to the shear requirements contained in Table 1 of GRI-GM19. If any of the test results for any of the coupons fail to conform, the seam shall fail. In the event of a failure, the procedure outlined below shall be followed.
- Test and examine 5 coupons for conformance to the peel requirements contained in GRI-GM19. Seams with enclosed air space shall have each weld tested in peel. If any of the test results for any of the coupons fail to conform, the seam shall fail. In the event of a failure, the procedure outlined below shall be followed.
- Record details relative to the destructive test on the geomembrane at the test location or on a portion of the seam tested, including:
  - Tester's initials.
  - Date and time sample taken.
  - Pass/fail designation.
- Repair the area where the sample was taken, as described in PC 3.6.

The procedure outlined below shall be followed when there is a destructive test failure:

- Perform two additional destructive seam tests according the procedure outlined above, one on each side of the failed test location, and at least 3 m from the failed test. If either of the additional tests fails, additional samples shall be taken in accordance with the above procedure until two passing tests are achieved to establish a zone in which the seam shall be repaired. In lieu of taking an excessive number of samples, with the approval of the Engineer, the entire seam may be repaired.
- Record details relative to the destructive test on the geomembrane at the test location or on a portion of the seam tested, including:
  - Tester's initials.
  - Date and time sample taken.
  - Pass/fail designation.

If the seam fails, Installer/Contractor shall follow one of two options:

- Reconstruct the seam between any two passed test locations.

- Trace the weld to intermediate location at least 3 m minimum or where the seam ends in both directions from the location of the failed test.
- The next seam welded using the same welding device is required to obtain an additional sample (i.e. if one side of the seam is less than 3 m long).

If sample passes, then the seam shall be reconstructed or capped between the test sample locations. If any sample fails, the process shall be repeated to establish the zone in which the seam shall be reconstructed.

#### PC 3.5.6 PRESENCE OF SCRATCHES ON LINER

The presence of scratches or marks on the geomembrane shall be limited at all times. Initial grinding depths from scratches should be targeted to less than 10% of sheet thickness. Areas where grinding depths are greater than 10% of sheet thickness, the Contractor will be liable to remove and re-line the area. The area relining will be at the discretion of the Engineer.

### PC 3.6 CORRECTIVE MEASURES

Remove damaged geomembrane and replace with acceptable geomembrane materials if damage cannot be satisfactorily repaired. Repair any portion of unsatisfactory geomembrane or seam area failing a destructive or non-destructive test. Installer/Contractor shall be responsible for repair of defective areas.

Any portion of the geomembrane or seam showing a defect, or having a failed destructive or non-destructive test shall be repaired. Reasons for requiring repairs to the geomembrane installation include, but are not limited to:

- A failed non-destructive seam test.
- A destructive seam test.
- Seam intersections.
- A hole, tear, or penetration, including holes in the seam for air pressure testing device.
- A scratch, gouge, or nick that penetrates more than 10 percent of the material thickness.
- A hard object underneath the geomembrane.
- A fish mouth or wrinkle at seam overlaps.
- Insufficient overlap.
- Bridging.
- Excessive scuffing.
- Geomembrane material defects.
- Large wrinkles.

Panels that require more than one repair per 25 $m^2$ shall, if instructed by the Engineer, be removed and replaced with new geomembrane at the Contractor's expense.

All repairs shall be labelled by the Welding Technician, who shall record pertinent details relative to the weld, including:

- Welding Technician's initials
- Welding apparatus identification number
- Set temperature for fusion welders or nozzle temperature and preheat temperature for extrusion welders
- Ambient temperature measured 150 mm above the geomembrane
- Date and time welding of the repair commenced

Agreement upon the appropriate repair method shall be decided between Engineer and Installer/Contractor by using one of the following repair methods:

- **Patching** - Used to repair large holes, tears, undispersed raw materials and contamination by foreign matter.
- **Abrading and Re-welding** - Used to repair short section of a seam.
- **Spot Welding** - Used to repair pinholes or other minor, localized flaws or where geomembrane thickness has been reduced.
- **Capping** - Used to repair long lengths of failed seams.
- **Flap Welding** - Used to extrusion weld the flap (excess outer portion) of a fusion weld in lieu of a full cap. Fusion welds must only be performed on samples of 1.0 m in length or longer.
- Remove the unacceptable seam and replace with new material.

The following procedures shall be observed when a repair method is used:

- All geomembrane surfaces shall be clean and dry at the time of repair.
- All seaming equipment utilised in the repairing procedures shall be qualified.
- Surfaces of the polyethylene which are to be repaired by extrusion welds shall be lightly abraded to assure cleanliness.
- Extend patches or caps at least 152 mm for extrusion welds and 102 mm for wedge welds beyond the edge of the defect, and around all corners of patch material.

Each patch repair shall be numbered and logged in a repair log book. Non-destructive tests shall be completed on each patch using method as specified in Sub-Clause PC 3.5.5. The position of each repair patch shall be indicated on a red line drawing and supplied to the Engineer along with the log book and completed test results.

All repair work of physical damage will be to the cost of the Contractor.

### PC 3.7 WELDING GEOMEMBRANE TO CAST IN ITEMS

The geomembrane shall be fastened and/or welded to the cast-in items where indicated on the drawings. Should the geomembrane be welded the weld width shall not be less than 10 mm and shall be tested according to one of the methods as stated in Sub-Clause PC 3.5.5.

## PC 3.8 PROTECTION DURING INSTALLATION

The Contract shall take adequate steps to ensure that the geomembrane is protected at all times from any damage. No vehicles of any kind shall be allowed to drive over the liner.

## PC 3.9 PLACING GEOMEMBRANE PROTECTION

In placing the geomembrane protection, the following precautionary measures shall be taken by the Contractor to minimise the risk of any damage to the liner.

a) All formwork laid in contact with the liner shall have all corners smoothed off and be so constructed as to maintain their position without the use of any other sharp objects.

b) All workmen shall wear soft soled shoes or gumboots.

c) Concrete protection shall be placed with tools with well rounded edges.

d) Spillage of concrete on the liner must be avoided. All spills must be immediately removed.

e) Anchoring of any geomembrane protection on the slope is necessary to avoid problems with sliding and slope stability failure possibilities.

Sand protection layer material shall be approved by Engineer prior to placement. The following properties shall be applicable to the Sand Protection layer:

- Sand material shall have a density of no less than 1 750 kg/m$^3$.
- Maximum particle size shall not exceed 4 750 µm (E.g. 90-100% passing 4.75 mm sieve).
- Shall not contain more than 5% passing 75 µm.
- Sand material shall be free of all deleterious materials.

The Contractor shall provide the Engineer grading analysis results for each 100 m$^3$ of sand material. The Engineer reserves the right to request additional grading analysis results should he deem it necessary. The cost of the grading analysis results is deemed to be included in the construction rates for the sand protection layer.

### PC 3.9.1 METHOD STATEMENT OF PLACEMENT OF SAND LAYER COVER/PROTECTION MATERIAL ON TOP OF GEOMEMBRANE

The Contractor is to provide a detailed method statement of placing any cover/protection onto the Geomembrane such as sand. Taking into account the following:

- Equipment allowance on top of sand cover layer as per project specification.
- Placement of a sacrificial cover layer which may be sand and/or similar approved material.

- Sequencing of cover layer placement to follow similar schedule to that of the liner panel placement.
- Management of wrinkles/folds during cover layer placement.

The commencement of cover/protection layer placement shall not proceed prior to the approval of the method statement by the Engineer in writing.

# PC 4 DAILY RECORD KEEPING

Standard reporting procedures shall include preparation of daily records that, at a minimum, will consist of:

- Field notes, including memoranda of meetings and/or discussions with the Contractor and Installer.
- Observation logs and testing data sheets.
- Construction problems and solutions data sheets.

This information must be regularly submitted to, and reviewed by the Engineer.

## PC 4.1 OBSERVATION LOGS AND TESTING DATA SHEETS

Observation logs and testing data sheets shall be prepared daily. At a minimum, these logs and data sheets shall include the following information:

- An identifying log/sheet number of cross-referencing and document control.
- Data on weather conditions.
- A site plan showing all active work areas and test locations.
- Descriptions and locations of on-going construction.
- Equipment and personnel in each work area, including those of all related sub-contractors.
- Description and specific locations of areas, or units, of work being tested and/or observed and documented.
- Locations where tests were undertaken and samples taken.
- A summary of test results.
- Calibrations of test equipment and actions taken as a result of any non-conformance.
- Off-site materials received, including quality verification documentation.
- Decisions made regarding acceptance of units of work and/or corrective actions to be taken in instances of non-conformance.
- Signatures of CQA officer and CQC monitor.

These logs must show all non-complying test results. A comprehensive set of QCA logs shall be as follows:

- Manufacturer/ Installer compliance agreement.
- Daily personnel attendance list.
- Material inventory.
- Conformance testing.
- Subgrade acceptance.
- Material deployment.
- Trail seaming.
- Production seaming.
- Repairs.
- Non-Destructive testing.
- Destructive testing.
- Laboratory test results.
- Problems and solutions.
- Soil cover placement.
- Daily report.

These documents shall provide fully traceable record of men, machines, machine settings, materials, and weather and test results, in the event of in-service problems. The QCA Officer shall incorporate all these logs in the CQA Final Report.

## PC 5 AS BUILT DRAWINGS

The geomembrane Installer/Contractor shall provide the Engineer with the following:

- Red line drawings once certain sections/areas are approved.
- Red line drawings indicating geomembrane panels and panel numbers as well as the last four digits of the roll number.
- Panel and roll numbers on the red line drawings are to correspond to the information logged in the panel placement log book.
- All destructive testing locations as well as repair locations shall be recorded on the red line drawings.

## PC 6 TOLERANCES

The works shall be finished to a Degree of Accuracy II as described in SANS 1200A Sub Clause 6.2.

Verification of Permissible Deviations (PDs) shall be as per Degree of accuracy II described in **TABLE 7** for finished levels: (Shall apply to liner subgrade and anchor trenches.)

**TABLE 7 : POSITIONS, DIMENSIONS, LEVELS ETC.**

| | | PERMISSIBLE DEVIATION (PD) | | |
|---|---|---|---|---|
| | | DEGREE OF ACCURACY | | |
| | | III | II | I |
| | | MM | MM | MM |
| 3) | Finished levels | | | |
| | PD from designated levels with reference to nearest transferred benchmark | | ± 25 | |

# PC 7 MEASUREMENT

The unit of measure for the installation of a suitable type of geomembrane by an approved Installer/Contractor, in accordance with the specifications as follows:

## PC 7.1 LENGTH

The measurement of length will be made along the centreline, adjusted for slope.

## PC 7.2 AREA

Unless geomembrane is deployed in simple geometric forms, area will be computed using a planimeter, survey methods, or other means as determined by the Engineer. The plan area measured will be adjusted for slope.

Measurement will not be made of geosynthetic waste, overlaps, patches, or scrap unless otherwise approved by the Engineer. Geosynthetics placed in trenches will be measured according to the embedded length shown on the Drawings multiplied by the length of the trench.

## PC 7.3 CUBIC METER

The sand protection layer shall be measure in cubic meters ($m^3$) of placed material. Measurement shall not be made for wastage.

## PC 7.4 PAYMENT

Items listed in the Bill of Quantities and Prices are deemed to cover all work indicated in the Drawings or detailed in the Contract. No additional items may be claimed by the Contractor and the Contractor must allow in the unit rates and prices for completing the Works in their entirety.

# PC 8 LISTED ITEMS IN BILL OF QUANTITIES

The quantities set out in the schedule of quantities at design stage have been determined from information available at the time of design. The final liability at construction phase shall rest entirely and solely with the Lining Contractor to verify the required types and quantities of the various materials required for the completion of the Works in accordance with the specifications and the drawings issued to the Earthworks Contractor for construction purposes.

Any reliance placed by the Lining Contractor on the estimated quantities stated in the Schedule of Quantities, or measurements made by the Lining Contractor from the drawings, shall be entirely at the Lining Contractor's risk and the Employer accepts no liability on this basis.

Any variations of data or information superseding what was provided at design stage shall be communicated to the lining contractor in writing by the Engineer.

### PC 8.1 Supply and Install Geomembrane ($m^2$)

Separate items will be listed for each structure or work area and for each geomembrane type and thickness. The rate shall cover the cost of material and consumables (such as welding rods/beads), delivery to and offloading at the Site. The area measured will be the net (i.e. exclusive of all joints and overlaps) shown on the drawings including area of geomembranes installed in anchor trenches. The rate shall cover the cost of storage, handling, and loading and transporting from the storage area to the work area, protecting the prepared subgrade, deployment, consumables (such as sandbags), and seaming. Furthermore, no payment will be made until each section is approved by the Engineer.

### PC 8.2 Install Wear Sheet ($m^2$)

Separate items will be listed for each structure or work area and for each geomembrane type and thickness. The rate shall cover the cost of deployment, seaming, and tack welding to underlying geomembrane.

### PC 8.3 Fabricate and Install Pipe Boots (No.)

Separate items will be listed for each structure or work area and for each geomembrane type and thickness, and pipe diameter. The rate shall cover the cost of fabrication and installation, including clamps, bands, gaskets, etc.

### PC 8.4 CQA Conformance Testing (No.)

The contractor shall allow for conformance testing as set out in the project CQA plan. These costs shall include shipping of material, and testing with report addressed to the Project Engineer.

### PC 8.5 Sand Protection Layer Supply and Install

The rate shall include for the source, supply, delivery to site, offloading, temporary stockpiling, placing, spreading, compaction as required and the grading analysis tests as described in this specification. No payment shall be made for wastage.

## PC 9 GEOMEMBRANCE ACCEPTANCE

The contractor shall retain all ownership and responsibility for the geomembrane until final commissioning. Owner will accept the geomembrane installation when the installation is complete and verification of the adequacy of all field seams and repairs, including associated testing, is complete.

# PD SPECIFICATIONS FOR GEOTEXTILES

## PD 1 GENERAL

### PD 1.1 SCOPE

The following geotextile specification covers the technical requirements for the manufacturing and installation of the geotextiles to be used for leachate collection/detection works, separation and geotextiles to perform hydraulic and mechanical roles as filter, drainage separation materials.

All materials must meet or exceed the requirements of this specification, and all work will be performed in accordance with the procedures provided.

### PD 1.2 STANDARD SPECIFICATIONS

The materials used in manufacturing the geotextile shall comply in all respects with the standard specification (where applicable) as shown in TABLE D 1-1, the latest revision at date of issue of tender enquiry/specification or bid close which shall be held to apply. Any contradictions between publications shall be submitted to the Engineer for decision.

- Project Technical Specifications.
- Project Construction Drawings.
- Project Construction Assurance Plan.

**Table D 1-1: Standard Specifications Applicable to Geotextile Materials**

| PUBLISHER | REFERENCE NUMBER | DESCRIPTION |
|---|---|---|
| South African Bureau of Standards (SANS) | SANS 1525:2013 | Geosynthetics - Wide-width tensile test |
| | SANS 9862:2013 | Geosynthetics - Sampling and preparation of test specimens |
| | SANS 9863-1:2013 | Geosynthetics - Determination of thickness at specified pressure Part 1: Single layers |
| | SANS 12236:2013 | Geosynthetics - Static puncture test (CBR test) |
| | SANS 11058:2013 | Geotextiles and geotextile-related products - Determination of water permeability characteristics normal to the plane, without load |
| | SANS 12958:2014 | Geotextiles and geotextile-related products - Determination of water flow capacity in their plane |
| | SANS 13433:2013 | Geosynthetics - Dynamic perforation test (Cone drop test) |
| | SANS 12956:2013 | Geotextiles and geotextile-related products - Determination of the characteristic opening size |
| International Organization | 10319:2008 | Geosynthetics - Wide-width tensile test |
| | 9862:2005 | Geosynthetics - Sampling and preparation of test specimens |

| PUBLISHER | REFERENCE NUMBER | DESCRIPTION |
|---|---|---|
| for Standards (ISO) | 9863-1:2005 | Geosynthetics - Determination of thickness at specified pressures, Single layers |
| | 12236:2006 | Geosynthetics - Static puncture test (CBR test) |
| | 13433:2006 | Geosynthetics - Dynamic perforation test (Cone drop test) |
| | 11058:2010 | Geotextiles and geotextile-related products - Determination of water permeability characteristics normal to the plane, without load |
| | 12958:2010 | Geotextiles and geotextile-related products - Determination of water flow capacity in their plane |
| International Organization for Standards (ISO) | 12956:2010 | Geotextiles and geotextile-related products - Determination of the characteristic opening size |
| American Society of Testing and Materials (ASTM) | D 4632 | Standard test method for grab breaking load and elongation of geotextiles |
| | D 4533 | Standard test method trapezoidal tearing strength of geotextiles |
| | D 4354 | Practice for Sampling of Geosynthetics for Testing |
| | D 4355 | Test Method for Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus) |
| | D 4439 | Terminology for Geotextiles |
| | D 4491 | Test Methods for Water Permeability of Geotextiles by Permittivity |
| | D 4595 | Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method |
| | D 4751 | Test Method for Determining Apparent Opening Size of a Geotextile |
| | D 4759 | Practice for Determining the Specification Conformance of Geosynthetics |
| | D 4833 | Test Method for Index Puncture Resistance of Geotextiles and Related Products |
| | D 4873 | Guide for Identification, Storage, and Handling of Geotextiles |
| | D 5261 | Test Method for Measuring Mass per Unit Area of Geotextiles |
| | D 6241 | Test Method for Static Puncture Strength of Geotextiles and Geotextile Related Product Using a 50-mm Probe |
| Geosynthetic Research Institute (GRI) | GRI GT 7 | Standard practise for determining long term design strength of geotextiles |
| | GRI GT 12(a) | Standard Specification for test methods and properties for nonwoven geotextiles used as protection (or cushioning) materials |
| | GRI GT 12(b) - ISO Version | Standard specification for test methods and properties for nonwoven geotextiles used as protection (or cushioning) materials |

| PUBLISHER | REFERENCE NUMBER | DESCRIPTION |
|---|---|---|
| | GRI GT 13 | Standard specification for test methods and properties for geotextiles used as separation between subgrade soil and aggregate |
| | GRI GT 13(a) ASTM Version | Standard specification for test methods and properties for geotextiles used as separation between subgrade soil and aggregate |
| | GRI GT 13(b) ISO Version | Standard specification for test methods and properties of geotextiles used as separation between subgrade soil and aggregate |
| AASHTO Standards | M288-96 | Geotextile Specification for Highway Applications |

## PD 2 APPLICATION

Geotextiles shall consist of a synthetic polymer material manufactures in a continuous homogeneous sheet. The synthetic polymers used during the manufacturing process may be one or more of the following:

- Polyester.
- Polypropylene.

The geotextile material is specified in three categories, Type A, B and C.

- 1) Type A – Separation, sediment or erosion control application
- 2) Type B – Stabilization, sediment or erosion control applications
- 3) Type C – Reinforcement applications

This specification covers non-woven needle punched polyester or polyprop geotextile test properties (Type A) for subsequent use as protection (or cushioning) materials.

This specification covers geotextile test methods properties for subsequent use as separation between subgrade soil and aggregate predominantly in pavement systems.

## PD 3 DEFINITIONS

For the purposes of this specification, the definitions given in the Contract and the following definitions shall apply:

- “According to ASTM D4439, a Geotextile” is a permeable geosynthetic comprised solely of textiles. Geotextiles are used with foundation, soil, rock, earth, or any other geotechnical engineering-related material as an integral part of a human made product, structure, or system.
- "Minimum Average Roll Value (MARV)" is the property value calculated as Typical Roll Value minus two standard deviations. Statistically, it yields a 97.7 percent degree of confidence that any sample taken during quality assurance testing will exceed the Minimum Average Roll Value.
- Separation, the placement of a flexible porous geosynthetic between dissimilar materials so the integrity and functioning of both materials can remain intact or be improved.

# PD 4 MATERIALS

## PD 4.1 QUALIFICATIONS

### PD 4.1.1 QUALIFICATION OF GEOTEXTILE MANUFACTURER

The geotextile shall be manufactured by the following:

- Reputable manufacturers, that meet all the technical and experience requirements as set out in the Project Specifications.
- Manufacturers whose product was tested and satisfied technical performance needs of the project during design phase.
- Details of the Manufacturer shall be provided by the Installer.
- The Manufacturer shall be approved by the Engineer and the Client.

### PD 4.1.2 QUALIFICATION OF GEOTEXTILE INSTALLER

The geotextile Installer must meet the following criteria, and supporting documents to the following criteria must be submitted at tender enquiry:

- Be an accredited current member of the International Association of the Geosynthetics Installers (IAGI) association, and should have been a member in the previous 3 years consecutively without interruption in membership.
- Provide their maximum installation capacity per day and number of teams they are willing to mobilise to the project.
- Should have a minimum experience of geotextile installation of 3,000,000 square meters.
- Provide workmanship warranty against defects in the installation and workmanship for 1 year commencing with the date of final acceptance or in line with project or Client requirements.
- Provide a minimum of two referee contacts of previous projects carried out in the last 15 months of similar size to the intended project. The details should include a contact name and number.

The following information is to be submitted at tender stage together with the contractor bid:

- Manufacturer name and track record in South Africa market listing completed successful projects for which the Manufacturer has manufactured geotextile materials from the same type as that proposed to be used for this Contract.
- Manufacture capabilities:
- Information on plant size, equipment, number of shifts per day, capacity per shift, quality control manual for manufacturing.
- List of material properties, including certified test results.
- Manufacturer quality control manuals and related documentation.

- Long term service life information in the cases where the geotextile is to be used in an exposed application of the manufacturer's products in similar applications and tested post installation to be provided to Engineer.

### PD 4.2 MANUFACTURING PROCESS

Manufacturing of the geotextile shall be to the largest possible sheet size to minimise jointing. Adequate tests and controls must be performed to ensure a good quality of raw material for sheet production and the sheet production process shall be accurately monitored and shall be such as to insure homogeneous sheets.

The Engineer may perform an audit of the manufacturing and quality control procedures used by the Manufacturer at the cost of the Contractor, specifically for the production of the geotextile to be used for installation at the Client's facility. The Manufacturer shall give the Engineer at least one month's notice of the start of production of geotextile for the project. Quality control test shall be performed as the geotextiles are manufactured.

The Manufacturer shall make available to the Engineer, Manufacturing Quality Control Manuals, which outline all quality procedures, to be implemented for the manufacturing of geotextiles.

The Engineer shall monitor production and testing of the geotextiles material allocated for this project. If material for this project has already been manufactured, the Engineer shall monitor production of the same type of geotextile on the same production line to verify that manufacturing controls are in place. Additional tests by one independent approved accredited laboratory are also required before the material will be approved.

The Engineer shall review the quality control certificates and notify the Manufacturer in writing which geotextile rolls are approved for shipping/transport. The Engineer shall be allowed to monitor the loading of the geotextiles for shipping/transport.

Production data and test reports of all tests done on each batch of material in accordance with the submitted quality control programme are to be kept and compiled in a Sheet Report and submitted to the Engineer with each delivery to Site.

The Engineer reserves the right to perform any test at any time on either the raw material or the manufactured sheet at a cost to the Contractor.

The following information must be delivered with every batch of sheet or rolls. This information must be presented in such a way as to allow identification of particular rolls at any time.

### PD 4.3 SUBMITTALS

The following shall be submitted to the Engineer and QA Officer. The submissions shall include the following information:

9. Certification: The contractor shall provide to the Engineer a certificate stating the name of the manufacturer, product name, chemical composition of the filaments or yarns and other pertinent information to fully describe the geotextile.

10. The Certification shall state that the furnished geotextile meets MARV requirements of the specification as evaluated under the Manufacturer's quality control program.
11. The QA Officer/Engineer will verify that:
12. The property values certified by the Manufacturer are properly documented, the test methods used are acceptable and the geotextile meets the Project Specifications.
13. The manufacturer's certificate shall state that the finished geotextile meets the requirements of the specification as evaluated under the manufacturer's quality control program. A person having legal authority to bind the manufacturer shall attest to the certificate.

Where materials, which have already been manufactured and have been delivered to storage, the Engineer shall be furnished with the test results from an independent approved laboratory and the quality control certificates and will notify the Manufacturer in writing which geotextile rolls are approved for shipping/transport from storage.

The Contractor/Installer shall obtain approval from the Engineer before the geotextile material is loaded for shipping/transport.

## PD 4.4 SHIPMENT AND LABELLING

Geotextile labelling, shipment, and storage shall follow ASTM D 4873. Product labels shall clearly show the manufacturer or supplier name, style, and roll number.

Each shipping document shall include a notation certifying that the material is in accordance with the manufacturer's certificate.

Each geotextile roll shall be wrapped with a material that will protect the geotextile, including the ends of the roll, from damage due to shipment, water, sunlight and contaminants. The protective wrapping shall be maintained during periods of shipment and storage.

Sheets with manufacturing process defects shall not be delivered to Site. If any such sheets are delivered to Site, they shall be rejected forthwith and all costs involved with such sheets shall be for the Contract's account.

## PD 4.5 STORAGE

The geotextile shall be stored under cover and out of direct sunlight at all times. To this end the Contractor is to satisfy the Engineer of suitable covering facilities, e.g. shed or adequate canvas covers etc. The manufacturer's wrappings shall not be removed until just prior to installation.

During storage, geotextile rolls shall be elevated off the ground and adequately covered to protect them from the following: site construction damage, precipitation, extended ultraviolet radiation including sunlight, chemicals that are strong acids or strong bases, flames including welding sparks, temperatures in excess of 160°F (71°C), and any other environmental condition that may damage the property values of the geotextile.

## PD 4.6 ULTRA-VIOLET, CHEMICAL AND BOILOGICAL PROPERTIES

All geotextiles shall be root-proof and shall be resistant to bacteria, algae and fungi. All geotextiles shall maintain at least 70% of the original tensile strength after direct exposure to sunlight for 1000 hours as specified in ASTM D 4355.

The geotextile shall be resistant to the effects of elevated temperatures and leachates generated from waste materials. The geotextiles shall not be attractive to rodents and termites.

The Contractor shall be responsible to ensure all the geotextiles intended for use in the works shall comply with all the above requirements.

## PD 4.7 CLASSIFICATION

### PD 4.7.1 GEOTEXTILES

Geotextiles shall be classified according to a few of its typical usages, namely:

- Geotextiles used for the separation between the subgrade soil and aggregates;
- Stabilisation purposes; and
- Filtration and drainage purposes.

## PD 4.8 MATERIAL SPECIFICATION

### PD 4.8.1 SEPARATION BETWEEN SUBGRADE SOIL AND AGGREGATES

For the intended purpose, the geotextile can be classified as a class 2 or 3 as defined in the AASHTO Standards: M288-96 - Geotextile Specification for Highway Applications.

- Class 1: For severe or harsh survivability conditions where there is greater potential for geotextile damage.
- Class 2: For typical survivability conditions; this is the default classification to be used in the absence of site specific information.
- Class 3: For mild survivability conditions where there is little or no potential for geotextile damage.

In accordance with ASTM D4632, the non-woven needle punched polyester or polyprop geotextile must fail at elongation (strains) greater than 50% and shall comply with the following material specifications as a separation application when placed on firm strength sub grades.

**Table D 4-1: Geotextile Properties Class 1 (High Survivability)**

| PROPERTY | TEST METHODS | UNITS | ELONGATION < 50% | ELONGATION > 50% |
|---|---|---|---|---|
| Grab strength | ASTM D 4632 | N | 1400 | 900 |
| Trapezoid Tear Strength | ASTM D 4533 | N | 500 | 350 |

| | | | | |
|---|---|---|---|---|
| CBR Puncture Strength | ASTM D 6241 | N | 2800 | 2000 |
| Permittivity | ASTM D 4491 | $Sec^{-1}$ | 0.02 | 0.02 |
| Apparent Opening Size | ASTM D 4751 | Mm | 0.60 | 0.60 |
| Ultraviolet stability | ASTM D 4738 | % Str. Ret. @ 500 lt. hrs. | 50 | 50 |

Notes:

1. All Values are minimum average roll values (MARV) except apparent opening size which is a maximum average roll value (MaxARV) and UV stability which is a minimum average value.
2. Evaluation to be on 50mm strip tensile specimens after 500 hours exposure.

**Table D 4-2: Geotextile Properties Class 2 (Moderate Survivability)**

| PROPERTY | TEST METHODS | UNITS | ELONGATION < 50% | ELONGATION > 50% |
|---|---|---|---|---|
| Grab strength | ASTM D 4632 | N | 1100 | 700 |
| Trapezoid Tear Strength | ASTM D 4533 | N | 400 | 250 |
| CBR Puncture Strength | ASTM D 6241 | N | 2250 | 1400 |
| Permittivity | ASTM D 4491 | $Sec^{-1}$ | 0.02 | 0.02 |
| Apparent Opening Size | ASTM D 4751 | Mm | 0.60 | 0.60 |
| Ultraviolet stability | ASTM D 4738 | % Str. Ret. @ 500 lt. hrs. | 50 | 50 |

Notes:

1. All Values are minimum average roll values (MARV) except apparent opening size which is a maximum average roll value (MaxARV) and UV stability which is a minimum average value.
2. Evaluation to be on 50mm strip tensile specimens after 500 hours exposure.

**Table D 4-3: Geotextile Properties Class 3 (Low Survivability)**

| PROPERTY | TEST METHODS | UNITS | ELONGATION < 50% | ELONGATION > 50% |
|---|---|---|---|---|
| Grab strength | ASTM D 4632 | N | 800 | 500 |
| Trapezoid Tear Strength | ASTM D 4533 | N | 300 | 180 |
| CBR Puncture Strength | ASTM D 6241 | N | 1700 | 1000 |
| Permittivity | ASTM D 4491 | $Sec^{-1}$ | 0.02 | 0.20 |
| Apparent Opening Size | ASTM D 4751 | Mm | 0.60 | 0.60 |
| Ultraviolet stability | ASTM D 4738 | % Str. Ret. @ 500 lt. hrs. | 50 | 50 |

Notes:

1. All Values are minimum average roll values (MARV) except apparent opening size which is a maximum average roll value (MaxARV) and UV stability which is a minimum average value.
2. Evaluation to be on 50mm strip tensile specimens after 500 hours exposure.

The various classes of the corresponding typical usage above shall be regarded as a guideline only. The actual class of geotextile to be used on the works will be as shown on the Construction drawings and stated in the Bill of Quantities.

## PD 4.9 ACCEPTANCE OF SHEET OR ROLLS

The type of geotextiles to be used shall be as indicated on the Construction drawings or and approved equivalent. The Engineer reserves the right to approve the make and grade of any alternative type of geotextiles considered.

The Contractor shall carry out a visual inspection of the sheets or rolls on arrival at Site for possible transport damage. Sheets or rolls showing damage shall be singled out and clearly labelled as such.

The Engineer must be notified of any damage and damaged material shall be set aside until approval for repair and use is received from the Engineer.

## PD 4.10 TESTS

The geotextile material shall be tested by the manufacturer for compliance with the specifications listed in this specification or CQA plan by the test methods and frequencies indicated. The costs of these tests are to be included for in the contractor's tendered price.

Conformance Testing shall be carried out as set out below to a third party external independent laboratory (MQA laboratory) not associated with the Manufacturer or earthworks contractor or as directed by the Project Engineer.

Conformance testing is not an opportunity to reproduce the QC testing program. It is a check to provide confirmation that satisfactory material is delivered to the site. The testing frequency shall be at the discretion of the Engineer or as set out in the CQA plan.

The name and address of the laboratory shall be approved by the Engineer. The Engineer has a right to reject any roll or production batch if the samples do not pass the conformance testing.

Conformance Testing will be performed before material is shipped from the Manufacturer's plant so that it may be used immediately on arrival at the site as listed below.

Contractor to ensure he is familiar with the duration of conformance. The contractor shall submit a conformance testing schedule to the Project Engineer during tender phase and part of the overall project work breakdown schedule.

The following listed tests will be performed on the samples by an accredited laboratory, to maintain quality control.

- Thickness.
- Grab strength.
- Sewn seam strength.
- Trapezoidal tear strength.
- Tensile strength.
- Static puncture strength.
- Puncture resistance.
- Normal through flow.

- Permeability.
- In-plane through flow.
- Pore Size.

All the above tests shall be completed as per the standard test method supplied in Sub-Clause PD 1.2 above.

The Contractor shall include in his rate the cost of verifying the material as per CQA plan, for samples required for testing at an accredited approved independent laboratory not associated with the Manufacturer. The costs associated with verifying material used in the manufacturing of the geeotextile shall be borne by the Contractor and deemed to be included in the tendered rates.

#### PD 4.10.1 ACCEPTANCE

The batch of sheets or rolls shall not be released for use in fabrication or installation unless the results for the above tests are within the project specification requirements.

Should the results fail another set of samples must be drawn and the tests repeated. If these results corroborate the first set of results the particular batch of sheeting will not be used.

Should this sample, however, show results that pass a third set of samples must be drawn and tested. The results, if pass leads to acceptance or, if fail, to rejection of the particular batch.

## PD 5 INSTALLATION OF GEOTEXTILES

### PD 5.1 GENERAL

Only approved geotextiles as per project specifications shall be used. Only approved Installers/Contractors shall install the geotextiles. The Engineer reserves the right to allow the Contractor to install geotextiles where drainage is the applicable application of the material.

The Installer must present to the Engineer a method statement prior to starting the works, providing information on how they intent to do the works. Along with the method statement, the Contractor must also provide the following:

- Installer's Geosynthetic Field Installation Quality Assurance Plan.
- Storage methodology of the geotextiles once they arrive on site.
- Panel installation layout plan.

Upon completion, the Installer must furnish the Engineer, within 14 days, with the following documents:

- Certificate stating the geotextile has been installed in accordance with the project specifications and requirements.
- Material and installation warranties as requested in project specifications
- Red line drawings showing actual geotextiles placement and seams including typical anchor trench detail.

The geotextile shall not be exposed to direct sunlight for prolonged periods, and shall be protected from mechanical damage and contamination during the installation and construction.

The geotextile material shall be overlapped both longitudinally and transversely. The longitudinal overlaps shall be in the direction of flow. Geotextile overlapping shall comply with the properties as shown in Table D 5-1.

**Table D 5-1: Geotextile Overlapping Requirements**

| APPLICATION | SOIL STRENGTH (CBR) | OVERLAP UNSEWN (MM) | OVERLAP SEWN (MM) |
|---|---|---|---|
| Filtration and Drainage | 1 - 3 | 200 | 25 |
| Separation and Stabilisation | < 1 | Not Recommended | 225 |
| | 1 - 2 | 950 | 200 |
| | 2 - 3 | 750 | 75 |
| | > 3 | 400 | 25 |

## PD 5.2 PREPERATION BEFORE LAYING

Unless otherwise specified, the surface area shall be trimmed to provide a uniform surface prior to placing any geotextiles.

The Installer/Contractor will be required to sweep the finished earthworks surface ahead of installing the geotextile to ensure that no particles remain that could damage the geotextile. No protruding sharp edged stones will be allowed.

## PD 5.3 PROCEDURE

The geotextiles must be installed in accordance with the installation panel layout plan agreed with the Engineer. Deployment of geotextiles panels shall be performed in a manner that will comply with the following guidelines:

- Each panel shall be assigned a panel number (i.e. GT1, GT2, GT3, etc.);
- Panel numbers shall be recorded in a panel placement log book. This is to also include the respective roll number; and
- Should a partial roll of geotextile remain after deployment, it remains imperative that the roll be clearly marked with its corresponding number so as to identify the roll after usage.
- The surface on which the geotextile is placed shall be properly inspected before deployment occurs.
- The pattern of sheets laid must be such that no more than three sheets shall lap at any place. This can be achieved by staggering adjacent strips of sheet forming T-joints instead of "+" joints. A full record of work done with respect to date and position must be kept and forwarded on a weekly basis to the Engineer.
- Unroll geotextile using methods that will not damage the geotextile and will protect underlying surface from damage (spreader bar, protected equipment bucket).

- The geotextile shall be held in place with sandbags to prevent wind uplift. Should the geotextile be displaced by wind or any other force, the Engineer shall inspect the geotextile for damage and can instruct the installer to remove the damaged geotextile and deploy a new roll at the Installer's own cost
- Personnel walking on geotextile shall not engage in activities or wear shoes that could damage it.
- Smoking will not be permitted on the geotextile.
- No vehicles of any kind shall be allowed on the geotextile.
- Protection of geotextiles in areas where heavy traffic occurs, by placing protective cover over the geotextile.
- The programme of construction shall be such as to minimise exposure of the sheets before placement of material atop the geotextile is commenced.

### PD 5.4 WELDING/STICTHING PROCEDURE

The method used to weld/stitch the various geotextile sheets together shall be presented to the Engineer for approval prior to commencement. The procedure to be followed shall be clearly defined and the Contractor shall provide the Engineer details on Quality Assurance Procedure that will be followed to ensure the welding/stitching procedure is successfully completed.

### PD 5.5 CORRECTIVE MEASURES

Any damage caused to the geotextile during installation or during the placement of filter material and/or rip-rap material shall render it unsuitable for use. Should the damage be localized, the Engineer may direct the Installer/Contractor to repair the damaged geotextile. This shall occur only once the Engineer has given permission.

Damaged geotextiles shall be removed and replaced with acceptable geotextile materials if damage cannot be satisfactorily repaired. Any portion of unsatisfactory geotextile or welding/stitching area shall be repaired. Installer/Contractor shall be responsible for repair of defective areas.

Agreement upon the appropriate repair method shall be decided between Engineer and Installer/Contractor by approved methods

Each repair shall be numbered and logged in a repair log book. The position of each repair shall be indicated on a red line drawing and supplied to the Engineer along with the log book as well as a certificate stating repair has been completed as per approved methods. All repair work of physical damage will be to the cost of the Contractor.

### PD 5.6 PROTECTION DURING INSTALLATION

The Contract shall take adequate steps to ensure that the geotextiles are protected at all times from any damage. No vehicles of any kind shall be allowed to drive over the geotextiles. Installed geotextiles shall be covered as soon as possible after installation to ensure that no prolonged exposure to direct sunlight occurs.

### PD 5.7 TOLERANCES

The works shall be finished to a Degree of Accuracy II as described in SANS 1200A Sub Clause 6.2.

Verification of Permissible Deviations (PDs) shall be as per Degree of accuracy II described in Table D 5-2 for finished levels:

**Table D 5-2: Positions, Dimensions, Levels Etc.**

| | | PERMISSIBLE DEVIATION (PD) | | |
|---|---|---|---|---|
| | | DEGREE OF ACCURACY | | |
| | | III | II | I |
| | | MM | MM | MM |
| 1) | Finished levels | | | |
| | PD from designated levels with reference to nearest transferred benchmark | | ± 25 | |

## PD 6 AS BUILT DRAWINGS

The geotextile Installer shall provide the Engineer with the following:

- Red line drawings once certain sections/areas are approved.
- Red line drawings indicating geotextile panels and panel numbers as well as the last four digits of the roll number.
- Panel and roll numbers on the red line drawings are to correspond to the information logged in the panel placement log book.
- All repair locations shall be recorded on the red line drawings.

## PD 7 MEASUREMENT

The tendered rate for the supply of the geotextile shall include full compensation for all materials, plan, labour and other incidentals required to manufacture, purchase, transport, deliver, storing the material on and/or off site, test or comply with all manufacturing and construction quality assurance and controlled requirement in full accordance with the relevant specifications, irrespective of the source of point of manufacture. Waste allowance, overlap etc. shall be deemed to be included in the tendered rate. The quantity measured for payment will be the net area placed.

The costs of freight, duty landing charges and rates of exchange shall be included in the tendered rate as well as an allowance for waste and overlap. Variations in these costs are dealt with under special materials (if applicable).

## PD 8 TOLERANCES

The works shall be finished to a Degree of Accuracy II as described in SANS 1200A Sub Clause 6.2.

Verification of Permissible Deviations (PDs) shall be as per Degree of accuracy II described in Table D **8-1** for finished levels:

**Table D 8-1 : Positions, Dimensions, Levels Etc.**

| | | Permissible deviation (PD) | | |
|---|---|---|---|---|
| | | Degree of accuracy | | |
| | | III | II | I |
| | | MM | MM | MM |
| 3) | Finished levels | | | |
| | PD from designated levels with reference to nearest transferred benchmark | | ± 25 | |

## PD 9 DOCUMENTATION

The Engineer will ensure that all quality assurance requirements have been addressed and satisfied.

### PD 9.1 DAILY RECORD KEEPING

Standard reporting procedures shall include preparation of daily reports that, at a minimum, will consist of:

- Field notes, including memoranda of meetings and/or discussions with the Contractor and GSM Installer.
- Observation logs and testing data sheets.
- Construction problem and solution data sheets.

This information must be regularly submitted to, and reviewed by the Engineer.

### PD 9.2 OBSERVATION LOGS AND TESTING DATA SHEETS

Observation logs and testing data sheets shall be prepared daily. At a minimum, these logs and data sheets shall include the following information:

- An identifying log/sheet number of cross-referencing and document control
- Date, client name, project name, location and other identification
- Data on weather conditions
- A site plan showing all active work areas and test locations
- Descriptions and locations of on-going construction
- Equipment and personnel in each work area, including those of all related subcontractors
- Description and specific locations of areas, or units, of work being tested and/or observed and documented
- Locations where tests were undertaken and samples taken
- A summary of test results
- Calibrations of test equipment and actions taken as a result of any non-conformance
- Off-site materials received, including quality verification documentation

- Decisions made regarding acceptance of units of work and/or corrective actions to be taken in instances of non-conformance
- Signatures of CQA officer and CQC monitor
  - These logs must show all non-complying test results.
  - A comprehensive set of CQA logs shall be as follows:
- Daily personnel attendance list
- Material and equipment inventory
- Conformance testing and results
- Subgrade acceptance and sign offs
- A photographic record of construction
- Material deployment
- Production seaming
- Repairs
- Problems and Solutions
- Soil Cover placement
- Daily report

These documents shall provide fully traceable record of men, machines, machine settings, materials, and weather and test results, in the event of in-service operational problems. The CQA Officer shall incorporate all these logs in the CQA Final Report.

## PD 10 AS BUILT DRAWINGS

The Installer/Contractor shall provide the Engineer with the following:

- As-built drawings once certain sections/areas are approved.
- Panel and roll numbers on the as-built drawings are to correspond to the information logged in the panel placement log book.
- All repair locations shall be recorded on the as-built drawings.
- Construction details that differ from as-designed details

# PE SPECIFICATIONS FOR PENSTOCK PIPELINE

## PE 1 CONSTRUCTION

### PE 1.1 GENERAL

This part of the specification covers the minimum requirements regarding construction for Civil and Structural Works pertaining to the earthworks and concrete works for the penstock pipeline and shall be read in conjunction with the drawings.

## PE 2 EARTHWORKS

### PE 2.1 TERRACING

Terrace material shall be placed at optimum moisture content in layers not exceeding 150 mm thick to the specified density. The Contractor shall provide suitable plant, tools and methods of compaction to achieve the specified density in uniform layers.

### PE 2.2 EXCAVATIONS

A Box Cut Excavation approximately along the axis of the Penstock pipeline shall be dug to 2 m in depth below natural ground level. Overlying transported Slicken-sided Clay and residual Norites are deemed compressible and potentially collapsible and are unsuitable as a founding horizon for any structures.

Any exposed rock surface shall be brushed clean in preparation for the construction of an Engineered Soil Raft.

#### PE 2.2.1 BOX CUT

A Box Cut Excavation approximately along the axis of the Penstock pipeline shall be taken down to expose the existing Rock Norite layer located at depths between 0 and 3.0m below Natural ground level. Overlying transported Slicken-sided Clay and residual Norites are deemed compressible and potentially collapsible and are unsuitable as a founding horizon for any structures.

Footings shall be founded on material having an allowable bearing capacity in excess of 300 kPa U.N.O. (competent norite rock). Where difficulty in reaching the required bearing capacity is experienced, the designer shall be contacted for further direction.

The contractor is to engage a qualified geotechnical engineer to verify the founding horizon and bearing capacity of the foundations prior to placement of the blinding layer.

All loose material and water shall be cleaned out of the foundation. Formwork shall be used where the sides of the excavation are not stable or exceed 1500 mm in depth . Where excavations are greater than 1500 mm deep the excavation shall be shored and propped or benched/battered at an angle determined by the geotechnical engineer.

### PE 2.2.2 EXPOSED ROCK SURFACES

The exposed rock surface shall be brushed clean in preparation for the construction of an Engineered Founding Layer.

### PE 2.3 BACKFILLING OF EXCAVATIONS

A local Excavation for the Penstock Pipeline is to be cut into the in-situ material to the neat concrete dimensions shown on the drawings. Care shall be taken to ensure that the founding layer of the Penstock trench is prepared as per section PSB.16 of this document. The sides of the excavation shall be neatly trimmed to receive concrete and as no working space or shuttering of the vertical sides is permitted.

Excavations up to 1 500 mm deep require to be shored where there is a risk of collapse or as directed by the Consulting Engineers. Failure of the Engineer to order propping shall not relieve the Contractor of his obligation to do this of his own accord. All excavations in excess of 1 500 mm deep require to be shored in accordance with the Code of Practice on Lateral Support and in compliance with statutory requirements noted therein.

Excavations in close proximity to foundations or structures shall be undertaken with all necessary precautions to prevent damage, settlement or collapse of the works.

The Contractor shall deal with and dispose of groundwater and storm water to keep excavations dry and shall cut such drainage trenches or install drain pipes as are necessary to relieve the build-up of water in the foundation works and shall build berms to divert water from entering the excavations.

### PE 2.3.1 ENGINEER FILL MATERIAL

Material to be used for the construction of the Engineered fill shall be selected from the open cast pit or the Waste Rock Dump or suitable stockpiles, to comply with the G6 grading and specification. Material shall be free from organic matter and boulders greater than 100mm in diameter shall be removed by hand picking prior to compacting. In the event of material for filling obtained from the open pit or Waste Rock Dump being unsuitable or in insufficient quantity, the Contractor shall supply, deliver, and place additional material from his own sources to the approval of the Consulting Engineers, at the cost of the Client, but subject to prior agreement thereon.

Selected G6 material to be placed in 150mm thick layers (max) and compacted to a density of 95% MOD AASHTO at OMC.

### PE 2.3.2 ENGINEERED FOUNDATION LAYER

The Box cut excavation shall be filled by the Engineered Founding layer up to the founding level of the pipeline blinding layer, with selected waste rock material in 300mm thick layers (max) and compacted to a density of 95% MOD AASHTO at OMC. Material shall be free from organic matter and boulders greater than 200mm in diameter shall be removed by hand picking prior to compacting. The material is to be compacted in 300mm layers with an impact roller until no further settlement is observed. The layer is to be wetted after every second pass and fines are to be added to the layer where necessary to fill voids. The contractor shall take particular care to monitor and record the number of compaction passes to determine optimum compaction. Should the crushing of the rock be observed, this indicated too many passes.

### PE 2.3.3 PENSTOCK TRENCH EXCAVATION

A local excavation for the Penstock Pipeline is to be cut into the completed engineered fill to the neat concrete dimensions shown on the drawings. Care shall be taken to ensure that the founding layer of the Penstock trench is to remain undisturbed during the excavation of the trench. The sides of the excavation shall be neatly trimmed to receive concrete and as no working space or shuttering of the vertical sides is permitted.

### PE 2.3.4 DEEP EXCAVATIONS

Excavations up to 1 500 mm deep require to be shored where there is a risk of collapse or as directed by the Consulting Engineers. Failure of the Engineer to order propping shall not relieve the Contractor of his obligation to do this of his own accord. All excavations in excess of 1 500 mm deep require to be shored in accordance with the Code of Practice on Lateral Support and in compliance with statutory requirements noted therein.

### PE 2.3.5 EXCAVATION PRECAUTION

Excavations in close proximity to foundations or structures shall be undertaken with all necessary precautions to prevent damage, settlement or collapse of the works.

### PE 2.3.6 PROTECTION OF EXCAVATION

The Contractor shall deal with and dispose of groundwater and storm water to keep excavations dry and shall cut such drainage trenches or install drain pipes as are necessary to relieve the build-up of water in the foundation works and shall build berms to divert water from entering the excavations.

### PE 2.3.7 BURIED PIPE SERVICES

Backfilling for buried pipe services shall in addition to the requirements of PD 2.2.2 include a granular bedding cradle (Class B – SABS 1200D) to the underside of the pipe service.

## PE 2.4 TOLERANCES, TESTS AND MATERIALS

### PE 2.4.1 TOLERANCE

The contractor shall be responsible for ensuring that sufficient tolerances are provided and integrated throughout all the elements of the works.

Surfaces of cut or fill to form compacted terraces shall be finished to the levels and grades specified on the drawings to within plus or minus 20 mm.

#### PE 2.4.2 TESTS

The Contractor shall employ an independent Soils Testing Laboratory to establish the compaction properties of (blended) filling material available on site or from off-site sources, and shall carry out regular field tests on compaction layers during progress of the works. All results shall be made available to the Consulting Engineers, immediately they become available.

In-situ Density tests are to be conducted on each of the 300 mm thick layer to ensure the required 95% Standard Proctor Maximum Dry Density at Optimum Moisture Content. Plate bearing tests are to be conducted in addition to in-situ tests to ensure that the compacted layer has a stiffness (Young's Modulus) of not less than 50 MPa.

## PE 3 CONCRETE, REINFORCEMENT AND FORMWORK

Concrete work shall be carried out in accordance with the requirements of SANS 10100:2000 – The Structural Use of Concrete, Materials and Execution of the Work and as detailed in the CONCRETE SPECIFICATION (C22013/SP01) produced by Carlisle & Associates.

Where there is conflict between SANS 1200 and the Specifications brought forward by Carlisle & Associates, the Particular Specifications for Concrete, Reinforcement and Formwork shall rule.

### PE 3.1 CONCRETE

#### PE 3.1.1 STANDARDS

Concrete work shall be carried out in accordance with the requirements of SANS 10100 and SANS 1200G.

#### PE 3.1.2 SUPERVISION

Supervision during concreting and mixing operations shall be undertaken by a suitably qualified technician on behalf of the Contractor.

#### PE 3.1.3 GENERAL

Construction joints shall be properly formed and used only where shown on the design drawings or specifically approved by the designer. Construction joints where not shown on the drawings shall be located as approved of the designer.

Thicknesses shown are minimum structural requirements, no reduction in thickness due to falls or topping is permitted.

The face of all concrete against which new concrete is to be cast shall be thoroughly mechanically scabbled, fully exposing the aggregate matrix, prior to commencing the next concrete pour. U.O.N.

Holes, chases, or embedment of pipes other than shown on the drawings shall not be made without the prior approval of the designer.

External and exposed corners of concrete members shall have a 20 x 20 chamfer.

Vertical pour breaks shall be formed using expamet "hy-rib" or an approved equivalent.

Dimensions shall not be scaled from drawings. Should necessary dimensions be missing from the drawings. The engineer shall be notified without delay where prescribed on the drawings. Dimensions shall be checked on site and any material discrepancy brought to the attention of the engineer prior to proceeding with any construction activity which may be affected.

After casting, exposed concrete surfaces shall be kept moist and protected by proprietary curing agents, plastic sheeting, damp sand or alternative approved means, for a minimum period of 7 days.

Concrete which appears honeycombed or otherwise defective after stripping shall not be repaired until inspected by the engineer and agreement has been reached on the means of repair. The Engineer may order concrete that has been repaired prior to his inspection to be demolished.

The concrete encasement should be cast in no more than 24 m sections.

### PE 3.1.4 Structural Concrete

The characteristic compressive strength of cube (fcu) at 28 days of in place concrete is noted in Table 25 below :

**Table 2: Concrete Strength Requirements**

| Element | Concrete Strength | Clear cover to reinforcement (mm) | | |
|---|---|---|---|---|
| | | Exposed | Against Forms | Against Ground |
| Blinding | 15MPa / 13mm | N/A | N/A | N/A |
| Mass Concrete | 30MPa / 19mm | N/A | N/A | N/A |
| Other Concrete | 30MPa / 19mm | 50 | 50 | 50 |

The characteristic strength is denoted by strength followed by maximum aggregate size, e.g. 25 MPa/19mm refers grade 25 mix with 19mm aggregate.

Unless noted otherwise, clear concrete cover (mm) to reinforcement will comply with the table above.

Ready mixed concrete shall comply with SABS 878-1970 – Standard Specification for Ready Mixed Concrete.

Column base plate grout shall be an approved high strength, cementitious non-shrink pourable type unless noted otherwise. Dry pack grout shall not be used.

No admixtures shall be used without approval.

All concrete shall be vibrated.

All concrete shall be cured in accordance with the specification SANS 5861, 5862, 5863

All concrete shall be sampled and tested in accordance with SABS 0100-2 and the project specification.

All formwork shall comply with SANS 0100-2.

### PE 3.1.5 LEVELS

Levels indicated on drawings of Structural Works correspond to top of concrete.

## PE 3.2 REINFORCEMENT

### PE 3.2.1 ABBREVIATIONS:

| | |
|---|---|
| T | Top |
| B | Bottom |
| EF | Each Face |
| IF | Inside Face |
| OF | Outside Face |
| NF | Near Face |
| FF | Far Face |
| | |
| B1 | Bottommost Layer |
| B2 | Second layer of bottom reinforcing |
| T1 | Topmost layer |
| T2 | Second layer of top reinforcing |
| STAG | Bars Staggered |
| ALT STAG | Bars Alternately Staggered |
| ABR | Alternate Bar Reversed |
| ABRS | Alternate Bar Reversed Staggered |

### PE 3.2.2 COVER

Cover to reinforcement unless otherwise stated shall be:

- Foundations and buried concrete — 75 mm
- Slabs on grade — 50 mm from top surface
- All concrete above grade — 50 mm

Concrete cover noted is measured from the formwork or ground face to the outermost reinforcement bar. i.e., In columns and beams to the outside of ties or stirrups.

Cover shall be maintained during pouring by the use of plastic chairs or plastic tipped metal chairs.

Porous materials shall not to be used.

### PE 3.2.3 REINFORCING OVERLAP/SPLICING

Reinforcement spacing noted on drawings is to assist scheduler and steel fixer to assess total number of bars required. where bars placed in accordance with spacing nominated foul with other structural requirements, preference shall be given to relocating bars by locally adjusting spacing to enable assembly of reinforcement to be completed. The designer shall be contacted in the event that reinforcement is needed to be cut on site prior to continuing.

Splices in reinforcement drawings shall be made only in the positions shown on the drawings, unless written approval is obtained from the designer. where splices are shown, these may be substituted by a continuous bar of the larger diameter.

Welding of reinforcement bars shall not be permitted.

Laps to reinforcement shall be a minimum of 50 times the bar nominal diameter.

### PE 3.2.4 REINFORCEMENT DETAILS

For details of reinforcement refer to the Bending Schedules.

### PE 3.3 FORMWORK AND FINISHES

All formwork shall comply with SANS 0100-2.

### PE 3.3.1 CONCRETE FINISHES

Concrete which requires to receive finishes shall have a roughened texture suitable for bonding onto the specified finishing application.

### PE 3.3.2 BURIED CONCRETE

Buried concrete may be cast against rough formwork or against neatly trimmed excavations where this is practical.

### PE 3.3.3 FORMWORK REMOVAL

Formwork shall not be removed before the concrete has attained sufficient strength to support its own weight and any loads that may be imposed on it.

### PE 3.3.4 SURFACE FINISHES

Surface finish to un-shuttered concrete shall be achieved with a smooth wooden trowel and, only where indicated on the drawings, shall exposed horizontal surfaces be finished to a slight uniform slope to assist with surface water drainage.

## PE 3.4 TOLERANCE

### PE 3.4.1 CONSTRUCTION TOLERANCE

Construction tolerance on all concrete work shall be in accordance with Accuracy Class II as specified in SABS 1200GB unless otherwise noted on the drawings.

### PE 3.4.2 SLUMP

Slump for ordinary concrete vibrated into the works shall be 80 mm ± 15mm. Slump for concrete to be pumped shall fall in the range 100 mm ± 15mm.

## PE 3.5 TESTS

### PE 3.5.1 CURING AND TESTING

Concrete shall be cured and tested in accordance with SABS 1200GB – Concrete.

### PE 3.5.2 PROPOSED MIX DESIGNS

Prior to commencement of concrete work on site the Contractor shall submit to the Consulting Engineers, mix designs and compression test results for the proposed mixes for each class of concrete specified together with the grading analysis reports for the aggregates used.

## PE 3.6 MATERIALS

### PE 3.6.1 AGGREGATES

Fine and coarse aggregate for use in concrete shall comply with SABS 1083-1994 – Aggregates from Natural Sources – Aggregates for Concrete.

### PE 3.6.2 CEMENT

Cement used in concrete shall comply with the following in accordance with SABS ENV 197:

- CEM I 32,5 or CEM I 32,5R (Ordinary Portland Cement)
- CEM II/A-S 32,5 or CEM/II A-S 32,5R (Portland Cement blend with 15% slag)
- CEM/A-S 42,5 (Portland Cement blend with 15% slag)

### PE 3.6.3 REINFORCING STEEL

Steel used for reinforcement shall comply with:

- Mild steel plain round bars : SANS 0920 grade 250
- High strength deformed bar: SANS 0920 grade 450

Reinforcing material is designated on the drawings as follows:

- Grade 450 - Deformed bar
- Grade 250 - Plain bar

**Annexure 1**

# 4 BILL OF QUANTITIES

**PREAMBLE TO BILL OF QUANTITIES**

These Bill of Quantities form part of the Contract Documents and are to be read in conjunction with the General Conditions of Contract, Particular Conditions of Contract, Construction Specifications and Drawings.

A price or rate is to be entered against each item in each Bill of Quantities, whether quantities are stated or not. Items which are not priced shall be considered as covered by other prices or rates in the Bill of Quantities. All rates are to be submitted as dry rates. All rates are deemed to be fixed for the duration of the Contract.

The Quantities are to be regarded as approximate and not necessarily the actual amount of work to be done.

The Contract Amount for the completed Contract shall be computed from the actual quantities of work done and valued at the unit rates and prices tendered against the respective items in the Bill of Quantities.

The prices and rates to be inserted in the Bill of Quantities, are to be the full inclusive values of the work described under the items, including all costs and expenses which may be required in and for the construction of the work described, together with all general risks, liabilities and obligations set forth or implied in the documents on which the tender is based. The tendered unit prices will be deemed to apply to any changes in quantity that may be necessary.

General directions and description of work and material given in the Specifications are not necessarily repeated in the Bill of Quantities. Reference is to be made to the Specifications, General Conditions of Contract, and Drawings for this information.

Appendix 2

# IN-SITU SOILS LABORATORY TEST RESULTS

**Appendix 3**

# CONSTRUCTION DRAWINGS