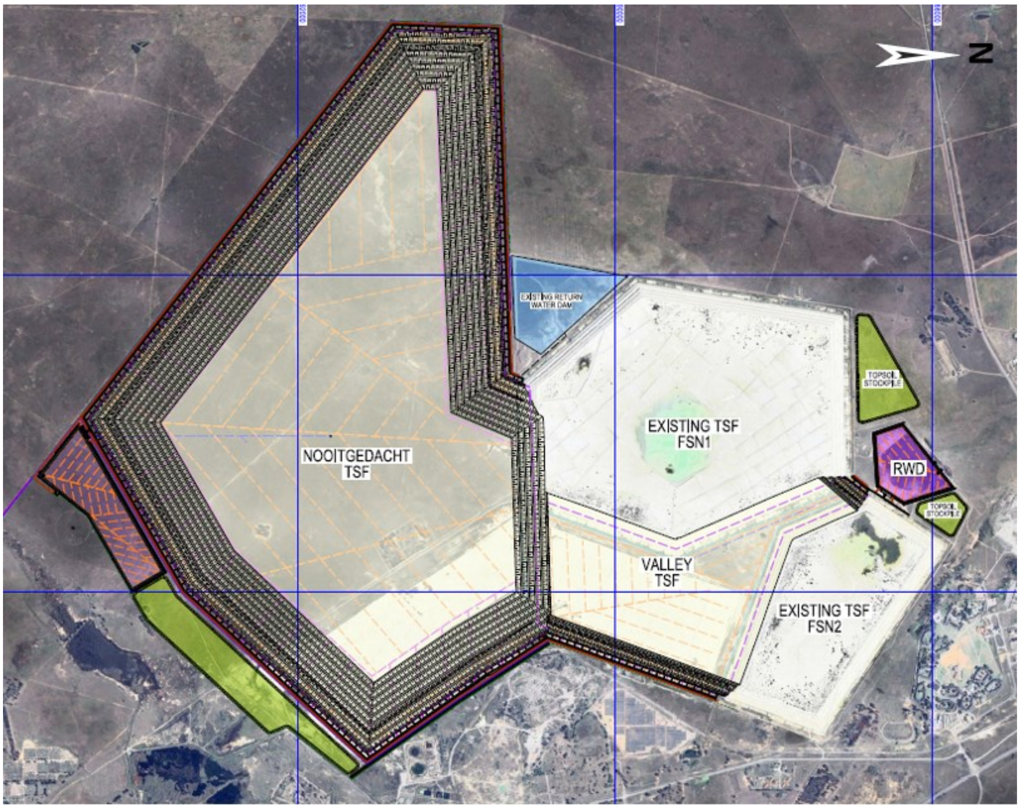
# HARMONY GOLD MINING COMPANY LIMITED (HARMONY GOLD)

GEOTHETA
CONSULTING ENGINEERS AND SCIENTISTS

# RE-DESIGN OF NOOITGEDACHT TAILINGS STORAGE FACILITY

# DESIGN REPORT

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2401265/R02 July 2024

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# Harmony Re-design of Nooitgedacht TSF Design Report

Report Reference Number: 2401265/R02

Revision date: July 2024

| COMPILED | | | | |
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| **TITLE** | **NAME AND SURNAME** | **REPORT REFERENCE/ REVISION** | **SIGNATURE** | **DATE** |
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| REVIEWED | | | | |
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| **TITLE** | **NAME AND SURNAME** | **REPORT REFERENCE/ REVISION** | **SIGNATURE** | **DATE** |
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**Data provided to Geotheta**

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**Data determined by Geotheta**

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## Executive Summary

Geotheta was appointed by Harmony Gold to re-design the Nooitgedacht Tailings Storage Facility (TSF) in Welkom, South Africa. The design is to include an amended barrier system.

Nooitgedacht TSF has a designed storage capacity of 804 million tonnes, making up 67% of Harmony Gold's required 1.2 billion tonnes of storage capacity in the Welkom area.

Key parameters of the Nooitgedacht TSF design are:

- Maximum final height: 93m
- Footprint area: 805 Ha
- Total capacity: 804 million tonnes
- Total deposition period at 2 000 000 tons per month: 34 years
- Maximum rate of rise (Basin): 3.77m/year
- Maximum rate of rise (Embankment): 2.89m/year
- Deposition method: Cyclone

The limiting factor for the facility's storage capacity is the freeboard requirement. At the maximum final height, due to the underflow/overflow cyclone splits, the freeboard will be 2m and the rate of rise of the basin will be higher than the rate of rise of the outer walls.

From GISTM, the Nooitgedacht TSF has an **Extreme Consequence Classification** rating.

From SANS 10286, the Nooitgedacht TSF has a **High Hazard Classification** rating.

Nooitgedacht TSF will have an overall outer slope of 1V:4H. Intermediate slopes between benches are 1V:3H. The inter-bench height is 10.5m and the benches are 10.5m wide.

The engineered toe wall embankment is 5m high with a 3m wide crest and an outer slope of 1V:1.5H and inner slope of 1V:2H.

The cyclone walls will be constructed 55m away from the toe wall, providing an elevated platform to allow for downstream overflow tailings deposition. The cyclone wall has a maximum height of 11m with a 5m wide crest, and outer and inner slopes 1V:2H. This transitions to a 1m nominal wall.

The minimum Factor of Safety against failure is 2.0 for drained conditions, 2.0 for undrained conditions, 1.1 for post seismic, post liquefaction or residual conditions and 1.2 for pseudo-static conditions. These Factors of Safety comply with local regulations and international slope stability standards.

The gold tailings material classified as a Type 3 waste. This necessitates a Class C barrier system. From an independent review by Legge and Associates, an 'inverted barrier' system is more practical and feasible. An 'inverted barrier' system will be used. The inverted barrier reduces seepage by changing the flow through the liner from Bernoulli flow at discontinuities to D'Arcian flow controlled by the tailings permeability at these points. The TSF stability is enhanced by omitting lower strength compacted clay layers and the geomembrane protection layers.

The Nooitgedacht TSF liner comprises two different sections, shown in Figure 1 below.

1. Liner system 1 - Over the existing FSN4 TSF footprint and outer edge, where high liner stresses are present, the liner system comprises (from top down), a 300mm thick layer

of tailings, 600 kN/m geogrid (or similar approved), a 300mm thick layer of tailings, 1.5mm thick double textured HDPE liner underlain by a 300mm ripped and recompacted layer of in-situ base preparation layer.

2. Liner system 2 - The liner system in the inner basin area comprises (from top down), 1.5mm thick double textured HDPE liner, underlain by a 300mm ripped and recompacted in-situ base preparation layer.

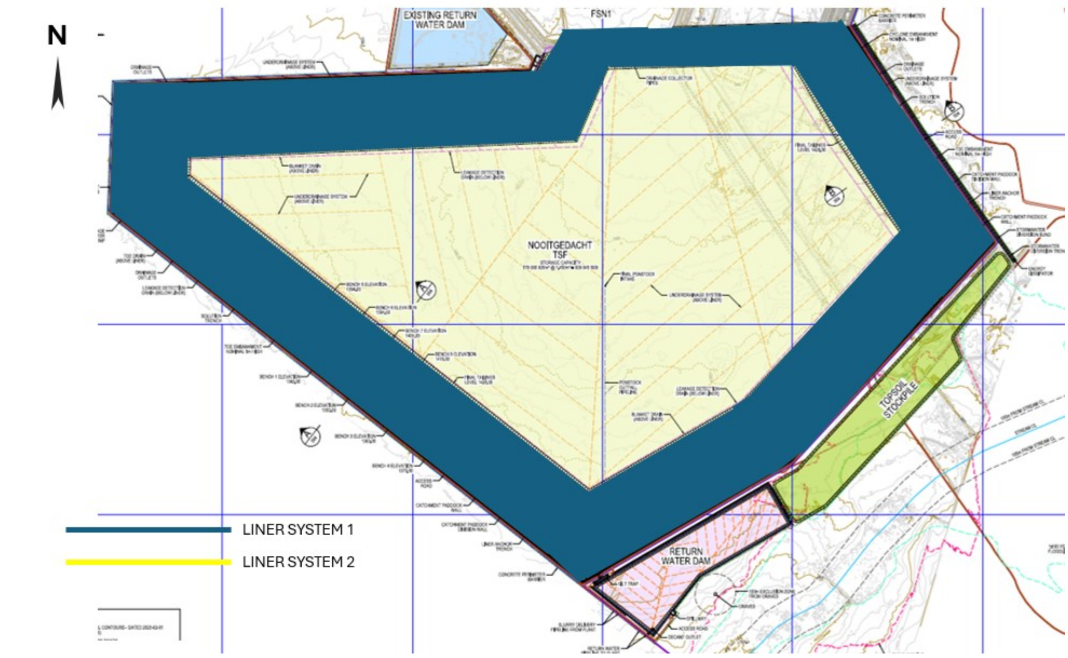


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**Figure 1: Liner systems present in Nooitgedacht TSF**

The TSF underdrainage system is provided above the liner to intercept seepage through the facility. The above liner drains lower the phreatic surface, thereby improving the overall stability of the facility. The above liner drains comprise toe drains, blanket drains and herringbone drains.

The above liner toe drain is a 160mm slotted HDPE pipe surrounded in 19mm stone overlain by a layer of 6mm stone, all enclosed in geofabric. The toe drain pipes discharge into the solution trench.

The above liner blanket drain is a 160mm slotted HDPE pipe surrounded in 19mm stone overlain by layers of 6mm stone and graded filter sand, all enclosed in a geofabric. The blanket drain pipes discharge into the solution trench.

The under-liner leakage detection drains are 160mm slotted Drainex HDPE pipes surrounded in 19mm stone, all enclosed in a geofabric. Similarly to the above-liner drains, the under-liner leakage detection drain outlet pipes discharge into the solution trench.

A 150mm thick reinforced concrete lined solution trench is provided along the perimeter of the TSF (except the northern flank where the TSF butts against the existing FSN1 TSF). The solution trench is 1m deep, base width 1m, side slopes 1V:1.5H. The solution trench discharges into the RWD and will accommodate the maximum peak penstock discharge of 2.87m$^3$/sec.

The climatic and meteorological data were assessed. From this the Return Water Dam (RWD), drainage collector sump and associated water infrastructure were sized.

The RWD total storage capacity is 606 500m$^3$, sufficient to ensure that it does not spill more than once every 50 years with the inflow from the penstock and underdrains.

The RWD liner system comprises 200mm high geocells (SW-356/200HD or similar approved) filled with 20Mpa concrete, underlain by a 1.5mm thick smooth HDPE liner and a 300mm in-situ base preparation layer.

The RWD leak detection drains comprise 160mm slotted HDPE pipes encased in 19mm washed stone, all wrapped in geofabric.

A RWD spillway is concrete lined to safely discharge excess water without overtopping of the RWD embankment walls. The spillway has a freeboard of 800mm and has capacity to discharge the 1:10 000 24-hour Probable Maximum Flood flow rate of 39.3m$^3$/sec.

A silt trap is installed upstream of the new RWD. The silt trap includes infrastructure to enable cleaning. This allows solids to settle out of the water before entering the RWD, minimising sedimentation in the RWD. The silt trap is a 2.25m deep, two-compartment, reinforced concrete water retaining structure with a concrete spillway to route de-silted water to the RWD. A sluice enables separate operation of each compartment. A sump is included in each compartment to enable water and slurry to be pumped out during operation, and before and after mechanical removal of silt as necessary.

Concrete poles with warning signs will be installed around the TSF. A 5m wide access road is provided around the facility for operational and monitoring requirements.

The facility is to be constructed and operated to ensure that the designed outer slope profile is achieved and to ensure the safe, efficient and environmentally responsible management of the Nooitgedacht TSF and associated infrastructure.

The recommended budget allocation for the Nooitgedacht TSF with an ‘inverted barrier’ is R3.3 billion (including 20% contingency and professional fees). The budget includes R400m for the 900NB steel delivery pipe and associated valves.

The construction timeline is estimated at 55 months (4.6 years). This extended construction period will require further rigorous time-line and deposition access planning which will need to be confirmed with the construction contractor(s).

## Table of Contents

## List of abbreviations

| | | |
|---|---|---|
| AASHTO | : | American Association of State Highway and Transportation Officials |
| ASTM | : | American Society for Testing and Materials |
| CBR | : | California Bearing Ratio |
| CPTu | : | Cone Penetration Test with pore water pressure measurement |
| CQA | : | Construction Quality Assurance |
| DBA | : | Dam Break analysis |
| DWS | : | Department of Water and Sanitation |
| FOS | : | Factor of Safety |
| GRI | : | Geosynthetic Research Institute |
| Geotheta | : | Geotheta (Pty) Limited |
| GISTM | : | Global Industry Standard on Tailings Management |
| GN | : | Government Notice |
| Ha | : | Hectare |
| HDPE | : | High Density Polyethylene |
| I&AP's | : | Interested and Affected Parties |
| kPa | : | Kilopascal |
| LC | : | Leachable Concentration |
| LCT | : | Leachable Concentration Threshold |
| MCE | : | Maximum Credible Earthquake |
| Mamsl | : | Meters above mean sea level |
| MAP | : | Mean Annual Precipitation |
| Mod | : | Modified |
| NEMWA | : | National Environmental Management: Waste Act No 59 of 2008 |
| NHRA | : | National Heritage Act |
| OMC | : | Optimum Moisture Content |
| PMC | : | Phalaborwa Mining Company |
| PMF | : | Probable Maximum Flood |
| RWD | : | Return Water Dam |
| SABS | : | South African Bureau of Standards |
| SANCOLD | : | South African National Committee on Large Dams |
| SANS | : | South African National Standards |
| SAWS | : | South African Weather Service |
| TLB | : | Tractor Loader Backhoe |
| TSF | : | Tailings Storage Facility |
| TC | : | Total Concentration |
| TCT | : | Total Concentration Threshold |
| UV | : | Ultraviolet |
| WULA | : | Water Usage Licence Application |
| ZOI | : | Zone of Influence |

## 1. Introduction

1.1 Geotheta was appointed by Harmony Gold to re-design the proposed Nooitgedacht Tailings Storage Facility (TSF) in Welkom, South Africa. The re-design includes an amended barrier system.

1.2 Harmony Gold presently requires a total of 1.2 billion tonnes of storage capacity from TSF'S in the Welkom area.

1.3 Nooitgedacht TSF has a total storage capacity of 804 million tonnes.

1.4 The Nooitgedacht TSF will be constructed south of the dormant FSN 1 TSF and overlaps a portion of the remined FSN 4 TSF.

## 2. Tailings Storage Facility location

2.1 The Nooitgedacht TSF is 6km north-west of Welkom in Free State, South Africa.

2.2 The site is located between the R34 roadway in the North, the R30 roadway in the East and the R710 roadway in the South.

2.3 The Nooitgedacht TSF location is shown in Figure 2 below.


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**Figure 2: Nooitgedacht TSF location**

# 3. Terms of reference

3.1 Harmony Gold submitted an invitation to tender for the feasibility level design of Nooitgedacht Tailings Storage Facility (TSF) on 19 October 2022, tender number CL202209(14)DG.

3.2 Geotheta submitted proposal reference 2210506 – Harmony – Nooitgedacht TSF Design – P01 on 05 November 2022.

3.3 A letter of award for the design of Harmony Nooitgedacht TSF (contract number: FG/23/01/0003) was issued to Geotheta on 26 May 2023.

3.4 Subsequent to the above submission, Geotheta was requested to submit a revised proposal to include an amended barrier system.

3.5 Geotheta submitted proposal reference 2401265 - Harmony – Re-design of Nooitgedacht TSF - P01 on 25 January 2024 and received confirmation of this order on 14 May 2024 (purchase order number: 309116 -CEN).

# 4. Scope of work

The agreed scope of works is:

## 4.1 Project kick-off

- Site visit to get an understanding of the general topography.
- Design criteria confirmation.

## 4.2 Geotechnical Work

- Review prior Jones and Wagner geotechnical reports.
- Identify additional geotechnical works required.
- Additional CPTu testing.

## 4.3 Nooitgedacht TSF deposition requirements

- Modelling and stage capacities.
- Assess cyclone and day wall paddock systems.
- Recommend and select deposition method.

## 4.4 Nooitgedacht TSF design and drawings

- Preparatory earthworks design.
- Dam break analysis to determine the zone of influence and consequence classification rating for the facility.
- Hydrology and meteorology, including climate change increases in rainfall and evaporation.
- Catchment paddock designs.
- Construction methodology.
- Seepage analyses.
- Barrier system design.
- Stability analyses.

- Underdrainage design.
- Penstock and catwalk design.
- Penstock outfall pipeline design.
- Slurry delivery piping design.
- Solution trench sizing.
- Storm diversion systems.
- Access roads.
- Closure and aftercare recommendations.

### 4.5 RWD design

- Stochiometric sizing to ensure the RWD does not spill more than once every 50 years.
- RWD modelling to determine the optimum construction works and costs.
- Earthworks design of walls, base, and trenches. This includes the silt trap sizing and detailing.
- Barrier system design.
- Decant design.

### 4.6 Drawings

- Drawings to "Issued for Information" level.

### 4.7 Construction requirements

- Preparation and costing of Bill of Quantities.
- Construction schedules.

### 4.8 Reports

- Dam break analysis report.
- Design report.
- Construction specifications.
- Liner Construction Quality Assurance (CQA).
- Operating, maintenance and surveillance manual.
- SCPTu report.

### 4.9 Additional scope of work required.

Additional CPTu testing on the Nooitgedacht TSF footprint was done.

## 5. Exclusions from the scope of work

The following is excluded from the scope of work:

- Ground survey work. A digital terrain model was provided by the client.
- A residue material characterisation report was provided by the client.
- Liaison or application for permissions/permits from government authorities.

- Environmental investigations or studies.
- Participation and consultation with I&AP's.
- Electrical and mechanical design is excluded.

## 6. Legislative requirements

6.1 The design, construction, operation and closure of mine residue facilities is controlled by local regulations. These are:

- National Environmental Management Waste Act (Act 59 of 2008) (NEMWA).
- Environmental Conservation Act (Act 25 of 1989).
- National Water Act, 1998 (Act 36 of 1998).
- Natural Environmental Management Act (Act 107 of 1998) (NEMA).
- National Heritage Resources Act (Act 25 of 1999) (NHRA).
- Mine Health and Safety Act No. 29 of 1996 and Regulations.

## 7. Applicable standards and guidelines

7.1 As agreed with the client as part of the design criteria:

- SANS 10286 Code of Practice for Mine Residue.
- Global Industry Standard on Tailings Management (GISTM).
- American Society for Testing and Materials (ASTM).
- South African National Standards (SANS) 1526 (2015).
- South African National Standards (SANS) 10409.
- South African National Standards (SANS) 1200.
- GN 636: National Norms and Standards for Disposal of Waste to Landfill.
- ICOLD Bulletin 194 of Sep 2022.
- Geosynthetic Research Institute (GRI) GM13.

## 8. GISTM Consequence classification

8.1 The GISTM consequence classification of the Nooitgedacht TSF was determined from the Dam Break Analysis (DBA) zone of influence.

8.2 The overall Zone of Influence is shown below in Figure 3.

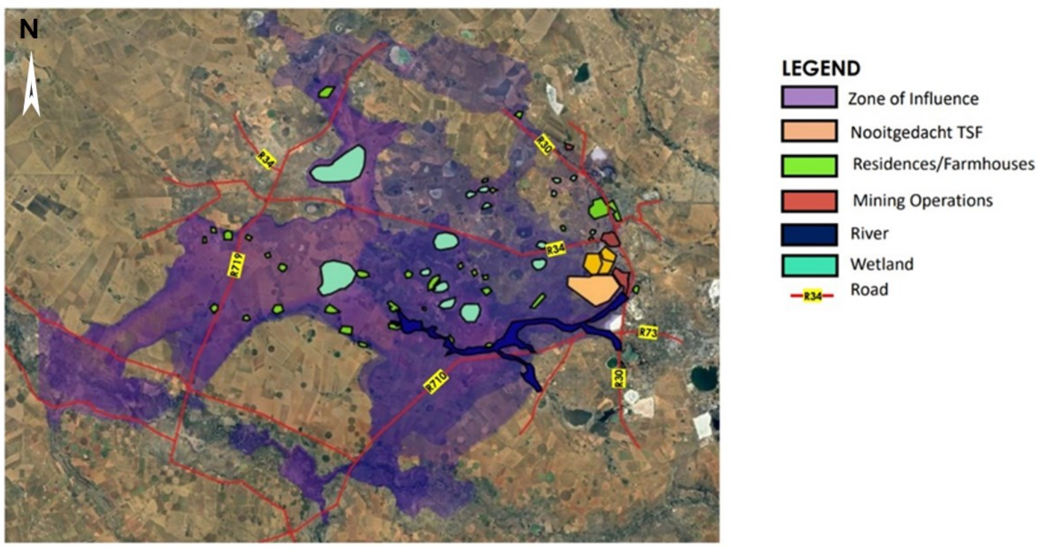


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**Figure 3: Zone of influence**

8.3 In the unlikely event of a dam break, high economic losses affecting infrastructure and recreational facilities are anticipated within the zone of influence of the facility. The affected infrastructure comprises the mine's own access road, solution trench, return water dam and the silt trap (all part of this design). Other infrastructure such as farmhouses and nearby mining operations will also be affected.

8.4 Catastrophic loss of critical habitat or rare and endangered species within the zone of influence footprint area. Process water is likely to be toxic/impactful. A dam break and flow will inundate and cause deterioration of the surrounding environment.

8.5 There is a permanent identifiable population at risk within the zone of influence. These are the operating staff and the residential area. The potential population at risk is between 100 to 1000.

8.6 Refer to Table 1 of the GISTM consequence classification below. The Nooitgedacht TSF is categorised as an **Extreme Consequence Classification** facility according to the GISTM consequence classification criteria. This consequence has been determined by analysing the impact a failure would have on the life, environment and infrastructure in the overall inundation zone modelled during the dam break analysis.

**Table 1: GISTM consequence classification criteria**

| | Incremental Losses | | | | | |
|---|---|---|---|---|---|---|
| | **Potential Population at Risk** | **Potential Loss of Life** | **Environment** | **Health, Social & Cultural** | **Infrastructure & Economics** | **Livelihoods** |
| **Low** | None | None expected | Minimal short-term loss or deterioration of habitat or rare and endangered species. | Minimal effects and disruption of business. No measurable effect on human health. No disruption of heritage, recreation, community or cultural assets. | Low economic losses; area contains limited infrastructure or services. <US$1M | Up to 10 household livelihood systems disrupted and recoverable in the short term.<br>No long-term non-recoverable loss of livelihoods. |
| **Significant** | Temporary only | None Expected | No significant loss or deterioration of habitat. Potential contamination of livestock/fauna water supply with no health effects. Process water low potential toxicity. Tailings not potentially acid generating and have low neutral leaching potential. Restoration possible within 1 to 5 years | Significant disruption of business, service or social dislocation. Low likelihood of loss of regional heritage, recreation, community or cultural assets. Low likelihood of health effects. | Losses to recreational facilities, seasonal workplaces, and infrequently used transportation routes. <US$10M | Up to 10 household livelihood systems disrupted and recoverable in the longer-term: or<br>Up to 100 household livelihood systems disrupted and recoverable in the short-term. No long-term non-recoverable loss of livelihoods |
| **High** | 10-100 | 1-10 | Significant loss or deterioration of critical habitat or rare and endangered species. Potential contamination of livestock/fauna water supply with no health effects. Process water moderately toxic. Low potential for acid rock drainage or metal leaching effects of released tailings. Potential area of impact 10 km2 - 20 km2. Restoration possible but difficult and could take > 5 years | 500-1,000 people affected by disruption of business, services or social dislocation. Disruption of regional heritage, recreation, community or cultural assets. Potential for short term human health effects. | High economic losses affecting infrastructure, public transportation, and commercial facilities, or employment. Moderate relocation/compensation to communities. <US$100M | Up to 10 household livelihood systems lost and non-recoverable: or<br>Up to 50 household livelihood systems disrupted and recoverable over the longer-term: or<br>Up to 200 household livelihood systems disrupted and recoverable in the short term. |
| **Very High** | 100-1000 | 10 to 100 | Major loss or deterioration of critical habitat or rare and endangered species. Process water highly toxic. High potential for acid rock drainage or metal leaching effects from released tailings. Potential area of impact >20 km2. Restoration or compensation possible but very difficult and requires a long time (5 years to 20 years). | >1,000 people affected by disruption of business, services or social dislocation for more than one year. Significant loss of national heritage, community or cultural assets. Potential for significant longer-term human health effects. | Very high economic losses affecting important infrastructure or services (e.g., highway, industrial facility, storage facilities, for dangerous substances), or employment. High relocation/compensation to communities. <US$1B | Up to 50 household livelihood systems lost and non-recoverable: or<br>Up to 200 household livelihood systems disrupted and recoverable over the longer-term: or<br>Up to 500 household livelihood systems disrupted and recoverable in the short term. |
| **Extreme** | >1000 | More than 100 | Catastrophic loss of critical habitat or rare and endangered species. Process water highly toxic. Very high potential for acid rock drainage or metal leaching effects from released tailings. Potential area of impact > 20 km2. Restoration or compensation in kind impossible or requires a very long time (>20 years). | >5,000 people affected by disruption of business, services or social dislocation for years. Significant national heritage or community facilities or cultural asset destroyed. Potential for severe and/or longer-term human health effects. | Extreme economic losses affecting critical infrastructure or services, (e.g., hospital, major industrial complex, major storage facilities for dangerous substances) or employment. Very high relocation/compensation to communities and very high social readjustment costs. >US1B | More than 50 household livelihood systems lost and non-recoverable; or<br>More than 200 household livelihood systems disrupted and recoverable in the longer-term; or<br>More than 500 household livelihood systems disrupted and recoverable in the short term. |

## 9. Waste classification

9.1 Testing was done by Waterlab (Pty) Ltd (facilitated by Jones and Wagner) to determine the geochemical properties as well as the waste classification of the tailings material. Only the conclusions of the waste classification are discussed in this report. The detailed waste classification report prepared by Jones and Wagner is included in Appendix A.

9.2 The waste classification is determined by assessing the total concentration (TC) of a material and its leachable concentration (LC) to the guidelines provided in Regulation 635 of NEMWA.

9.3 The applicable leachable or total concentration thresholds are used to classify the waste into several categories as shown in Table 2.

**Table 2: Waste type classification by total and leachable concentration thresholds**

| Total Concentration Threshold (TCT) | Link between TCT and LCT | Leachable Concentration Threshold (LCT) | Waste Type | Barrier System |
|---|---|---|---|---|
| < TCT0 | and | < LCT0 | Type 4 | Class D |
| < TCT1 | and | < LCT1 | Type 3 | Class C |
| < TCT1 | and | < LCT2 | Type 2 | Class B |
| < TCT2 | or | < LCT3 | Type 1 | Class A |
| > TCT2 | or | > LCT3 | Type 0 | Not allowed |

9.4 The total concentration leachable concentration results were compared to the Total Concentration Threshold (TCT) and Leachable Concentration Threshold (LCT) prescribed in GN 635: National Norms and Standards for the Assessment of Waste for Landfill Disposal.

9.5 The gold tailings material classifies as a Type 3 waste (from the classification parameters set out by the National Environmental Management Waste Act (Act 59 of 2008)).

9.6 GN 636: National Norms and Standards for Disposal of Waste to Landfill requires a Class C barrier system for a Type 3 waste. A typical Class C barrier system is illustrated in Figure 4.

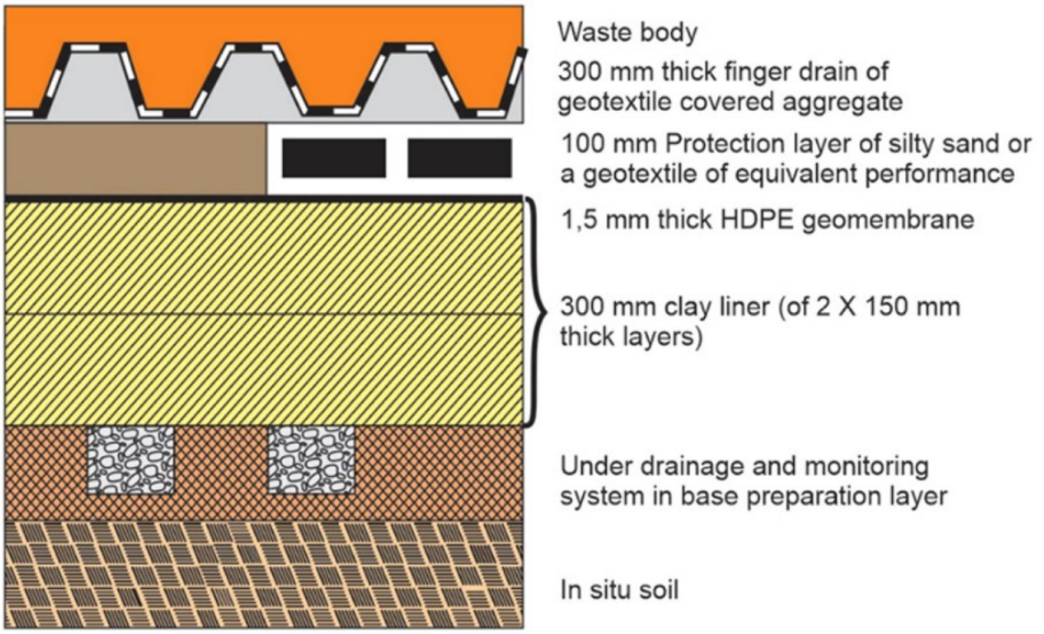


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**Figure 4: Typical Class C Liner**

9.7 An inverted barrier, recommended by Legge and Associates, is used in the design of the Nooitgedacht TSF.

9.8 The inverted barrier system has superior performance in terms of reducing seepage compared to the Class C barrier system. This is due to the tailings above the liner being in direct contact with the geomembrane thus the fine tailings particles clog holes or discontinuities and change the flow through the geomembrane from orifice flow (controlled by Bernoulli's equation) to Darcian flow.

9.9 The Legge and Associates report (reference: Harmony Geotheta Legislation on Source Pathway Receptor Risk Modelling) is included in Appendix L.

9.10 The TSF and RWD barrier systems are detailed in Sections 13 and 19 of this report.

## 10. Design Criteria

10.1 From the consequence classification determined above, the flood and seismic design criteria return period is 1:10 000 years. The magnitudes of each of these are provided below.

**Table 3: Flood and seismic design criteria for operation**

| Design 1:10 000 year flood event(determined by Geotheta) | Design Seismic Event (Source document: Seismic hazard analysis report by A Kijko) |
|---|---|
| 1 day: 200mm | 0.30g |

10.2 According to Hynes-Griffin (1984), half (50%) of the peak ground acceleration value should be used as the recommended horizontal seismic coefficient in a pseudo static equilibrium stability analysis. The expected peak horizontal acceleration in the design return period is 0.30g. The horizontal acceleration used in the pseudo static stability analyses was therefore 0.15g (=0.30g x 50%).

10.3 The agreed design criteria for slope stability are:

**Table 4: Slope stability design criteria**

| Criteria | Minimum FOS |
|---|---|
| Minimum required slope stability Factor of Safety – Drained conditions | 1.5 |
| Minimum required slope stability Factor of Safety – Undrained conditions (peak shear strengths) | 1.5 |
| Minimum required slope stability Factor of Safety – post seismic, post liquefaction or residual strength conditions | 1.1 |
| Minimum required slope stability Factor of Safety – Pseudo-static conditions | 1.1 |

10.4 Drained conditions represent the strength conditions applied in which soils may either drain or, because they are dense and dilate, lead to maintenance or a reduction in pore pressures during shearing. For this case, the effective strength parameters are used in the stability analyses.

10.5 Undrained conditions represent the strength conditions applied in which silty/clayey soils cannot drain during shearing. The loading initiates pore pressures and therefore undrained behaviour. For this case, the undrained strength parameters are used in the stability analyses.

10.6 Post seismic, post liquefaction or residual strength conditions represent the soil strength after liquefaction or significant shearing (deformation), which may be caused by seismic, static movements. This case would not include the horizontal driving forces of the earthquake or movement. For this case, the residual undrained strength parameters are used in the stability analyses.

10.7 Pseudo-static conditions represent the seismic loading that is modelled as a statically applied inertial force, the magnitude of which is a product of a seismic coefficient k and the weight of the potential sliding mass.

10.8 The following design criteria were established with Harmony Gold:

**Table 5: General design criteria**

| Criteria | Unit | Value |
|---|---|---|
| Tailings deposition period | years | 34 years |
| Tailings deposition rate | tons/month | 2 000 000 |
| Tailings in-situ dry density | tons/$m^3$ | 1.45 |
| Tailings slurry density | tons/$m^3$ | 1.35 |
| Tailings underflow mass split | % | 17 |
| Tailings overflow mass split | % | 83 |
| Maximum allowable rate of rise above starter walls | m/year | 3.7 |

| Criteria | Unit | Value |
|---|---|---|
| Maximum RWD spill frequency | frequency | Once every 50 years |
| Minimum RWD freeboard above spill level | mm | 800 |
| 1:50 year 24-hour rainfall | mm | 127 |
| 1:100 year 24-hour rainfall | mm | 142 |
| 1:10 000 year 24-hour rainfall | mm | 269 |
| Design pseudo static earthquake Peak Ground Acceleration (1:10 000 year return period) | g | 0.30 |
| Intermediate outer slope | - | 1V:3H |
| Outer slope bench width | m | 10.5 |
| Overall outer slope | - | 1V:4H |
| Waste type | - | Type 3 |
| Barrier system | - | Inverted barrier system |

10.9 To achieve maximum storage capacity, the Nooitgedacht TSF cyclone outer walls on the flanks will be developed at an intermediate outer slope of 1V:3H between benches.

10.10 At closure, the Nooitgedacht TSF cyclone outer wall slopes will have an overall slope of 1V:4H.

10.11 The overall outer slope will allow for establishing vegetation growth after topsoiling and to minimise erosion of the outer slopes after closure.

## 11. Hydrotechnical assessment

A hydrotechnical assessment was done to determine the climatic and meteorological data. This data was used to size the Return Water Dam, situated south-east of the TSF and associated water conveyance infrastructure.

### 11.1 Climate and meteorological data

11.1.1 The historical rainfall for the site was obtained from the Odendaalrus Station (SAWS station No. 0364322 X) and the average monthly lake evaporation was based on the Sand Vet Sentrum C4E009.

11.1.2 The Odendaalrus station was selected due to its long record length of 120 years, completeness of the data set, mean annual precipitation (MAP) of 504mm and location of the rainfall station with respect to the site.

11.1.3 Rainfall data collected from Odendaalrus Station started on 1 January 1898 and ended on 31 December 2018 (120 years).

11.1.4 The Odendaalrus rainfall station location in relation to the Nooitgedacht TSF is shown in Figure 5.

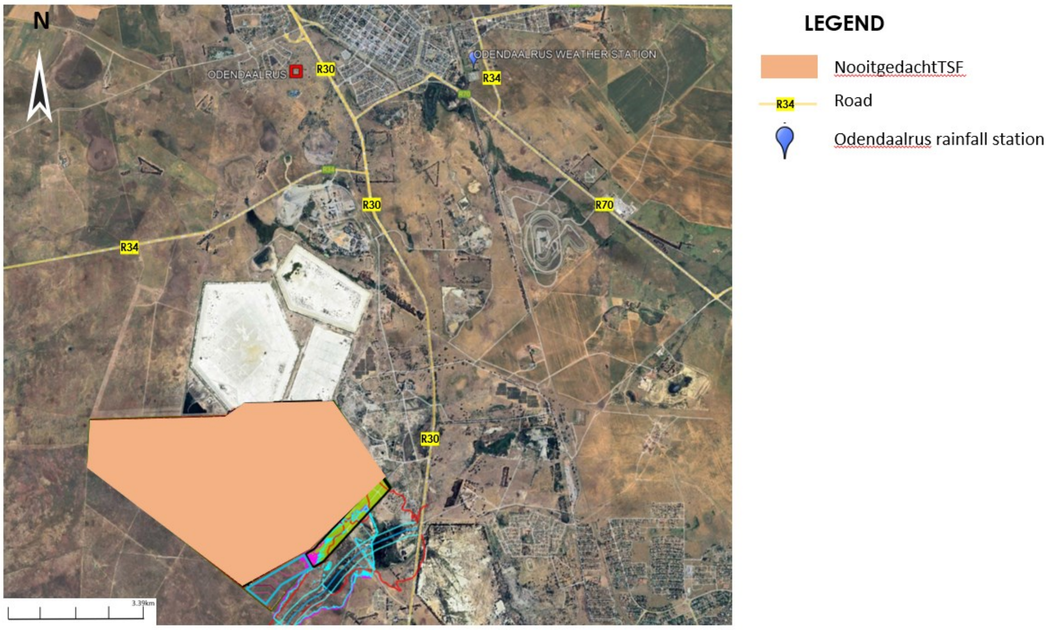


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**Figure 5: Odendaalrus rainfall station location**

11.1.5 Average monthly precipitation and evaporation data is shown in Table 6.

**Table 6: Average monthly rainfall and evaporation data**

| Month | Rainfall (mm) | Lake evaporation (mm) |
|---|---|---|
| January | 83.9 | 244.8 |
| February | 71.4 | 189.1 |
| March | 71.9 | 162.3 |
| April | 43.2 | 104.8 |
| May | 18.9 | 72.5 |
| June | 7.4 | 47.4 |
| July | 7.5 | 57.2 |
| August | 8.5 | 88.7 |
| September | 16.9 | 139.2 |
| October | 47.8 | 183.9 |
| November | 67.5 | 211.7 |
| December | 69.4 | 247.6 |

11.1.6 The storm rainfall depths were obtained from the design rainfall software (Smithers and Schulze, 2002). This provides rainfall depths for various durations up to a 1:200 year return period.

11.1.7 The maximum total rainfall depths for various return periods and storm durations are provided in Table 7 below.

**Table 7: Storm rainfall depths**

| Storm Duration | Rainfall Depth (mm) | | | | | | |
|---|---|---|---|---|---|---|---|
| (m/h) | 1:2 year | 1:5 year | 1:10 year | 1:20 year | 1:50 year | 1:100 year | 1:200 year |
| 5 m | 9 | 12 | 14 | 17 | 20 | 22 | 24 |
| 10 m | 13 | 18 | 21 | 25 | 29 | 32 | 36 |
| 15 m | 17 | 23 | 27 | 31 | 37 | 41 | 45 |
| 30 m | 21 | 29 | 34 | 39 | 46 | 52 | 57 |
| 45 m | 25 | 33 | 39 | 45 | 53 | 59 | 66 |
| 1 h | 27 | 37 | 43 | 50 | 59 | 65 | 73 |
| 1.5 h | 31 | 42 | 50 | 57 | 67 | 75 | 83 |
| 2 h | 34 | 46 | 55 | 63 | 74 | 83 | 92 |
| 4 h | 40 | 54 | 63 | 73 | 86 | 96 | 107 |
| 6 h | 43 | 59 | 69 | 80 | 94 | 105 | 117 |
| 8 h | 46 | 62 | 74 | 85 | 100 | 112 | 124 |
| 10 h | 49 | 66 | 77 | 89 | 105 | 117 | 130 |
| 12 h | 51 | 68 | 81 | 93 | 109 | 122 | 135 |
| 16 h | 54 | 73 | 86 | 99 | 116 | 130 | 144 |
| 20 h | 56 | 76 | 90 | 104 | 122 | 136 | 151 |
| 24 h | 59 | 79 | 94 | 108 | 127 | 142 | 157 |

11.1.8 The rainfall depths beyond a 1:200-year return period were determined using logarithmic extrapolation of the available rainfall data. This is shown in Figure 6 below.

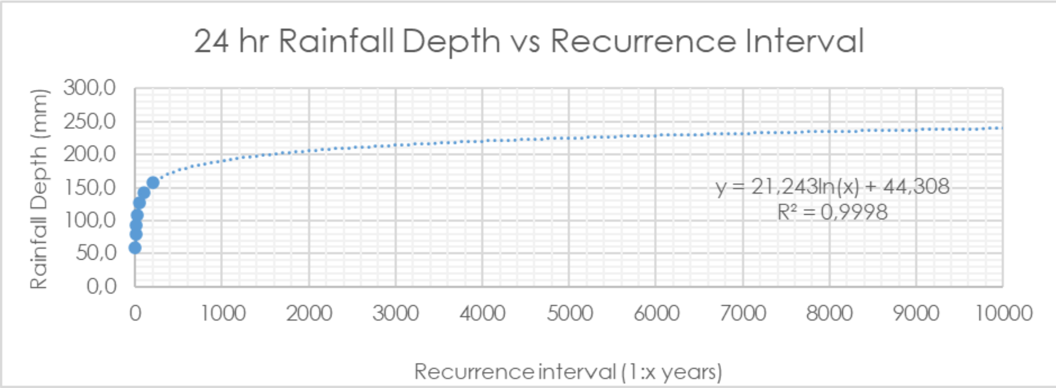


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**Figure 6: Determination of the PMF**

**Table 8: Extrapolated rainfall data.**

| **Input data** | |
|---|---|
| **Recurrence interval (years)** | **24 hr rainfall depth (mm)** |
| 2 | 59 |
| 5 | 79 |
| 10 | 94 |
| 20 | 108 |
| 50 | 127 |
| 100 | 1412 |
| 200 | 157 |
| **Output data** | |
| 1 000 | 191 |
| 2 475 | 235 |
| 5 000 | 252 |
| 10 000 | 269 |

11.1.9 Monthly temperatures were obtained from meteoblue.com. Average monthly temperatures and ranges are provided in Table 9 below.

**Table 9: Temperature ranges**

| Month | Minimum temperature (° Celsius) | Maximum temperature (° Celsius) | Average temperature (° Celsius) |
|---|---|---|---|
| January | 16.0 | 32.0 | 24.0 |
| February | 15.0 | 31.0 | 23.0 |
| March | 13.0 | 29.0 | 21.0 |
| April | 9.0 | 26.0 | 17.5 |
| May | 5.0 | 22.0 | 13.5 |
| June | 1.0 | 19.0 | 10.0 |
| July | 0.0 | 19.0 | 9.5 |
| August | 2.0 | 22.0 | 12.0 |
| September | 7.0 | 27.0 | 17.0 |
| October | 11.0 | 29.0 | 20.0 |
| November | 13.0 | 30.0 | 21.5 |
| December | 16.0 | 31.0 | 23.5 |

11.1.10 The monthly climatic data summary is provided in Figure 7.

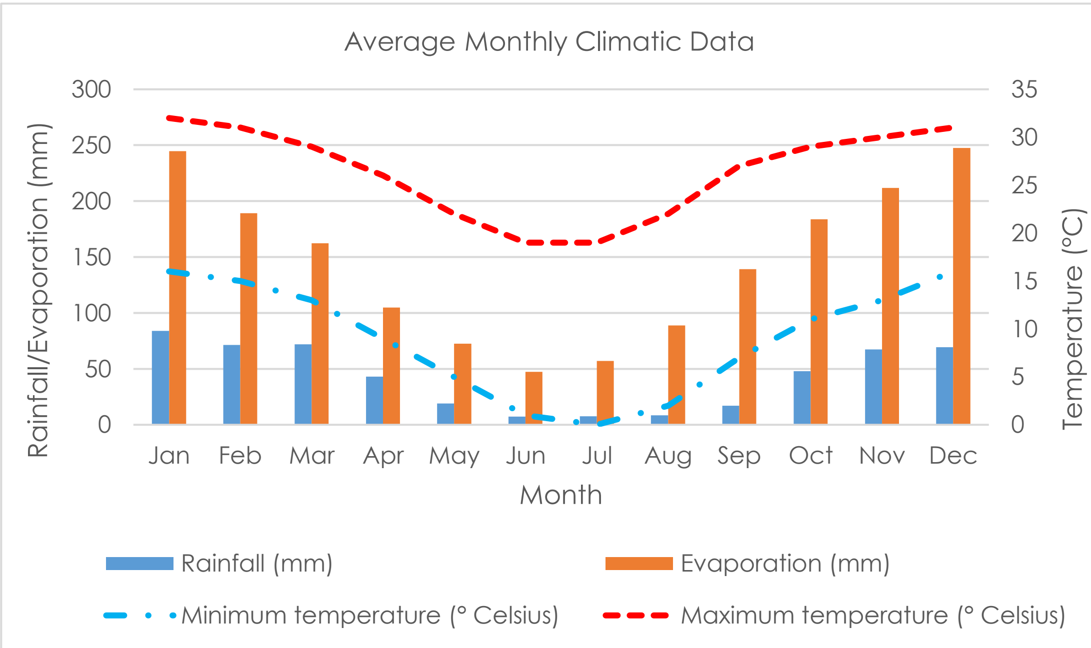


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**Figure 7: Monthly Climatic Data Summary**

# 12. Nooitgedacht TSF Design

Figure 8 shows the layout of the Nooitgedacht TSF below.

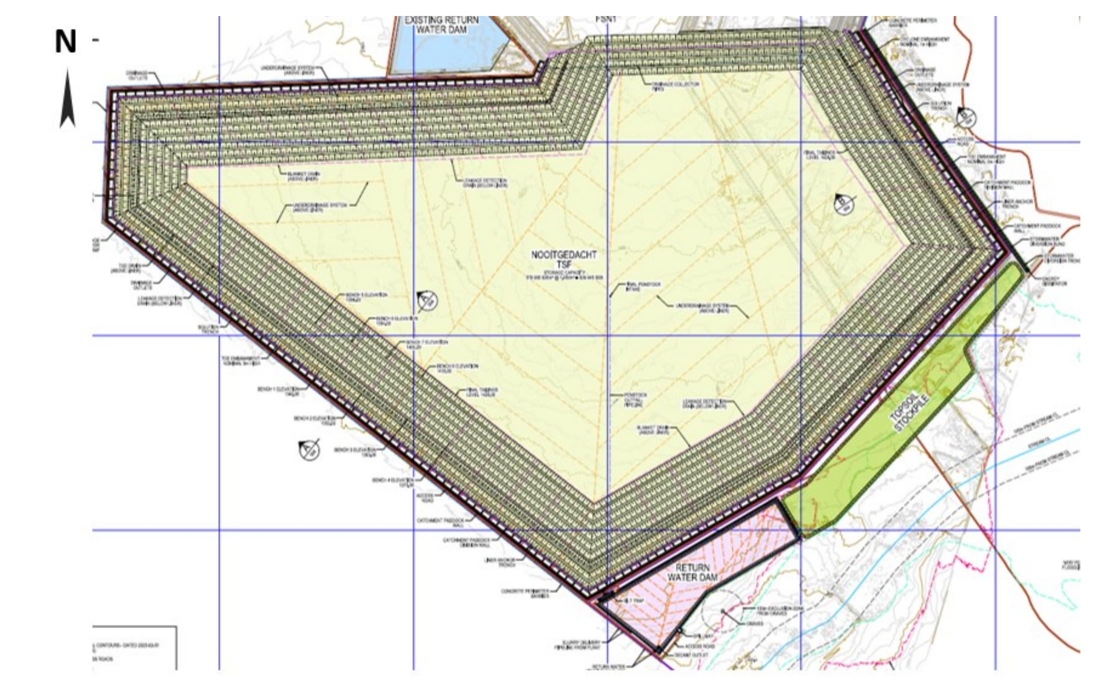


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**Figure 8: Layout of Nooitgedacht TSF**

## 12.1 TSF stage capacity assessment

12.1.1 The Nooitgedacht TSF will have a maximum height of 93m and a footprint area of 805Ha.

12.1.2 Stage capacities were developed for the Nooitgedacht TSF based on a tailings in-situ dry density of 1.45 tons/m$^3$ and a 17% underflow split. The designed outer profile comprises an overall outer slope of 1V:4H with 10.5m high intermediate slopes of 1V:3H between each 10.5m wide bench.

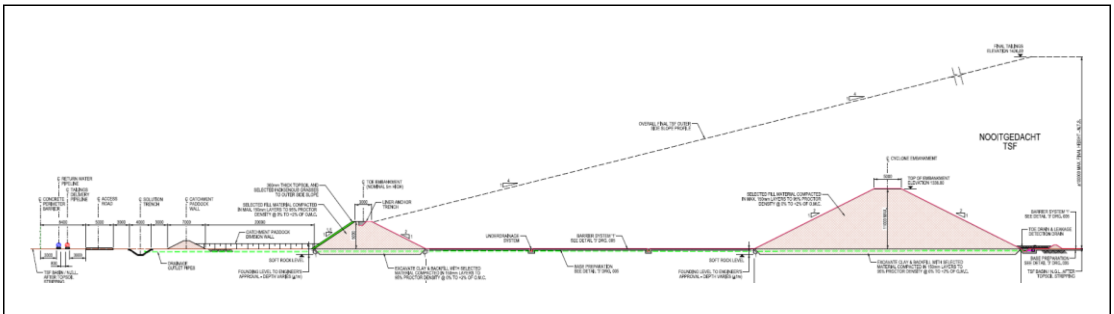


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**Figure 9: TSF outer profile configuration**

12.1.3 The Nooitgedacht TSF will for the first 27 months be constructed as a downstream cyclone facility. At elevation 1338 mamsl, the facility will be constructed as an upstream cyclone facility. The cyclone wall is sized to maintain freeboard.

12.1.4 The maximum rate of rise in the basin is 3.7m/year. This was calculated by comparing the basin and outer wall stage capacities. At the basin rate of rise of 3.7m/year, the freeboard will be 2m.

12.1.5 The rate of deposition over the over first 18 months is 650 000 tons/month, the rate of deposition over the next 35 months will be 1 500 000tons/month and the rate of deposition over the remaining life of the facility is 2 000 000tons/month.

12.1.6 The liner installation and deposition calculations are shown in Table 10 below. The monthly installation rate is 143 500m$^2$/month. These results are represented graphically in Figure 10.

**Table 10: Liner installation and deposition results**

| Liner elevation | Area | Liner installation time (months) | Liner installation time (years) | Time after construction start (months) | Pond elevation | Deposition time (months) | Cum. Max possible deposition (tons) | Max possible deposition rate (tons/month) | Limited deposition (tons/month) | Actual deposition (tons) | Cum. Actual deposition (tons) | Cumulative Maximum - Actual (tons) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1330.15 | 1 725 300 | 12.00 | 1.00 | 24.00 | 1329.15 | - | 2 964 492 | - | - | - | - | - |
| 1332.00 | 3 467 491 | 24.00 | 2.00 | 36.00 | 1331.00 | 12.00 | 9 736 934 | 811 411 | 650 000 | 7 800 000 | 9 736 934 | - |
| 1333.50 | 4 337 763 | 30.23 | 2.52 | 42.23 | 1 332.50 | 18.23 | 12 166 087 | 667 359 | 650 000 | 11 849 626 | 11 849 626 | 316 461 |
| 1337.00 | 6 750 624 | 47.05 | 3.92 | 59.05 | 1 336.00 | 35.05 | 41 109 788 | 1 721 261 | 1 500 000 | 25 223 113 | 37 072 739 | 4 037 049 |
| 1341.30 | 7 210 922 | 50.25 | 4.19 | 62.25 | 1 340.30 | 38.25 | 63 257 069 | 6 904 086 | 2 000 000 | 6 415 702 | 43 488 442 | 19 768 628 |

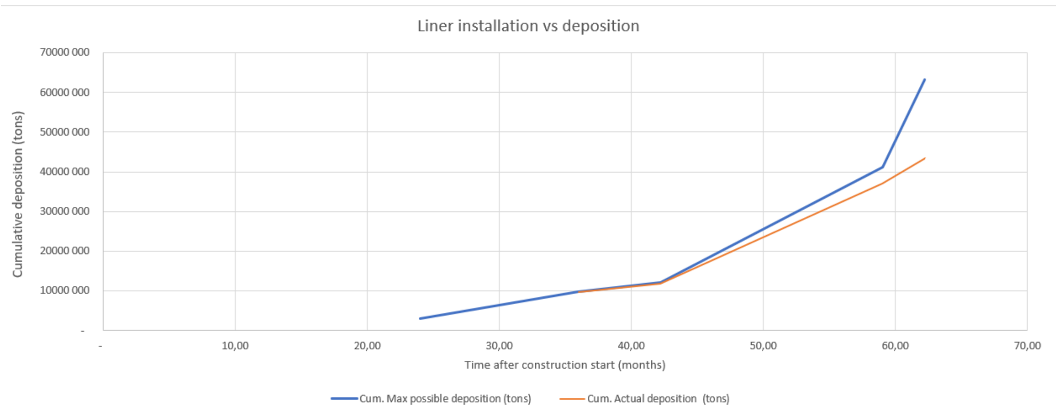


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**Figure 10: Liner installation vs deposition graph**

12.1.7 The staged development of the liner installation on the facility including limits and timelines are shown in the figures below.

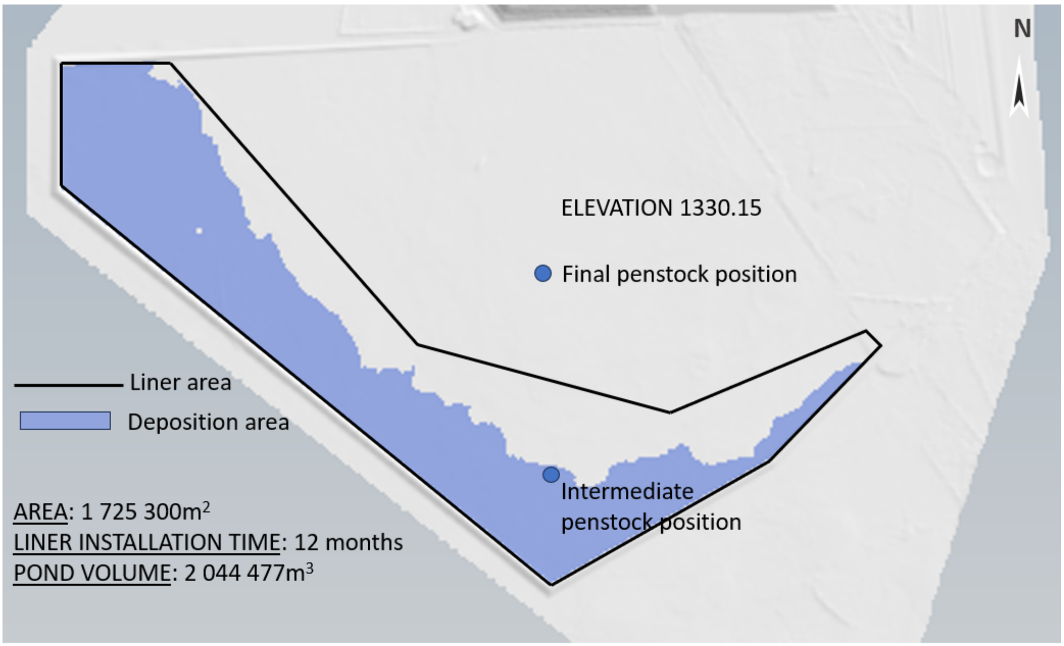


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**Figure 11: Liner installation diagram 1**

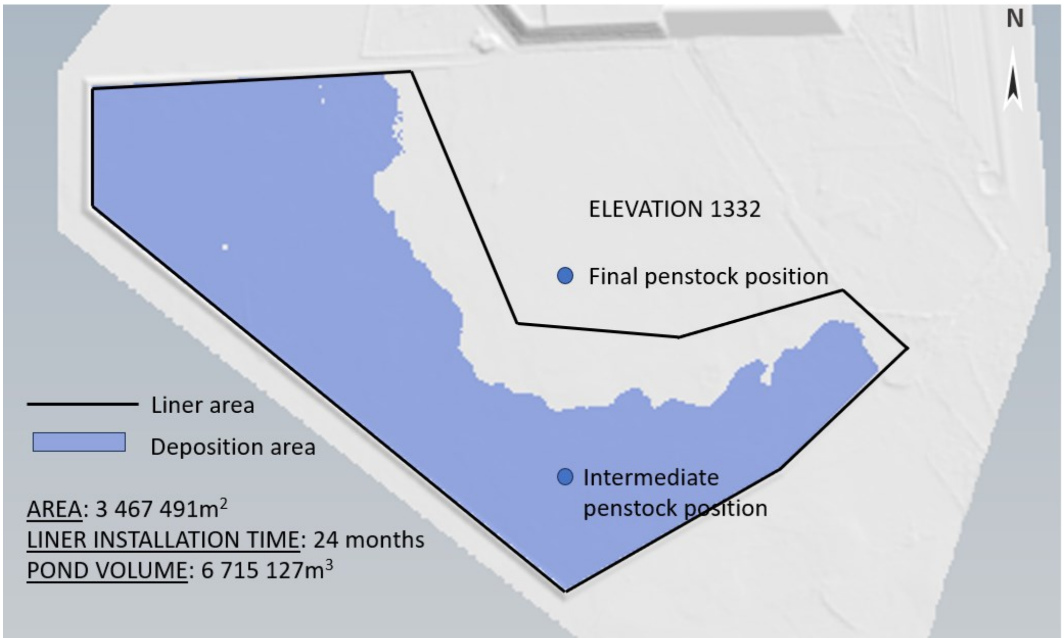


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**Figure 12: Liner installation diagram 2**

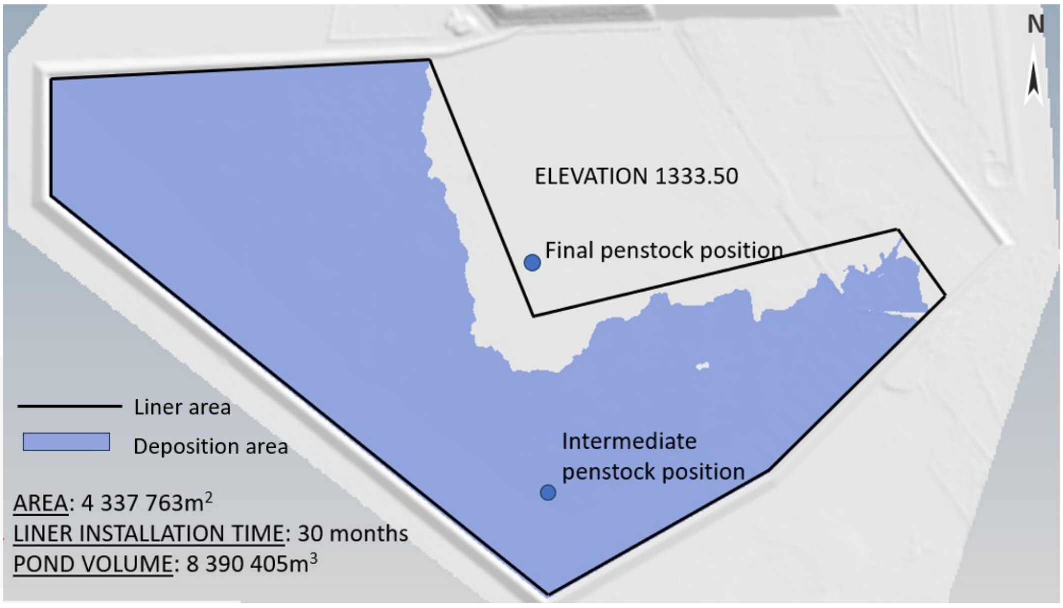


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**Figure 13: Liner installation diagram 3**

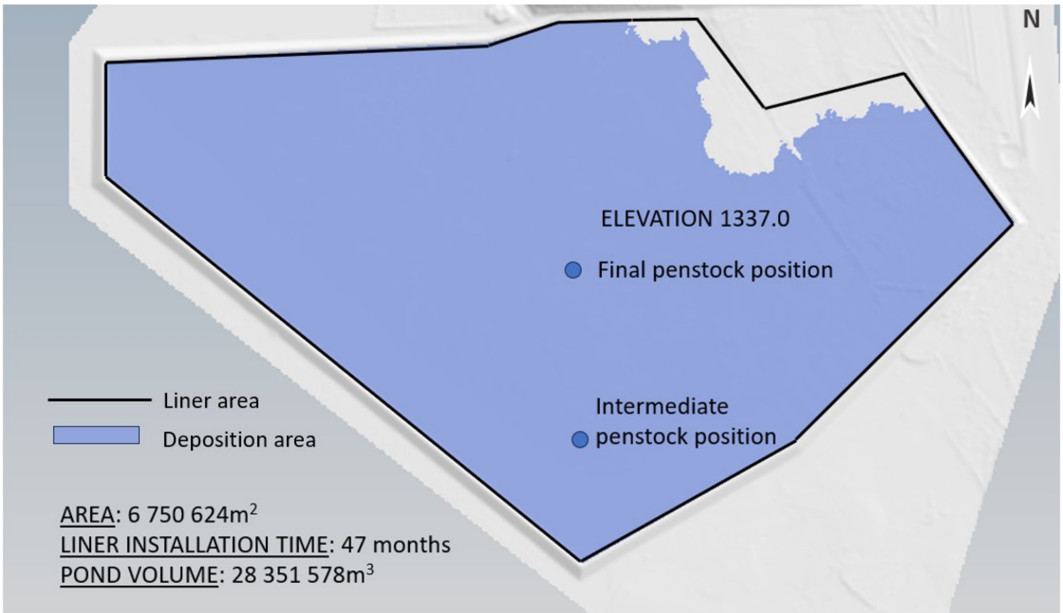


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**Figure 14: Liner installation diagram 4**

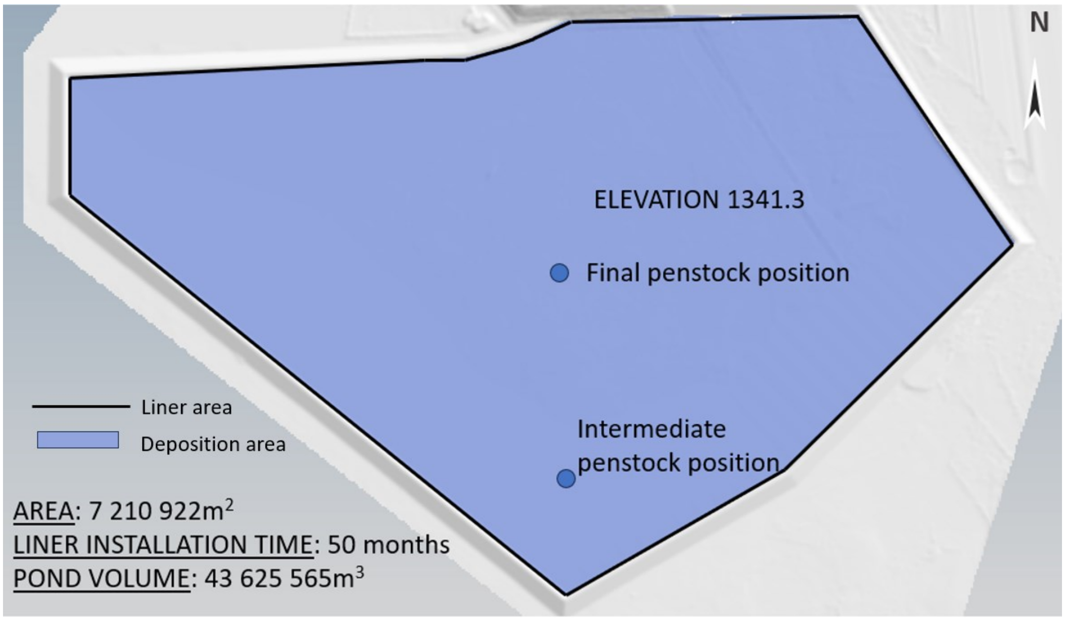


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**Figure 15: Liner installation diagram 5**

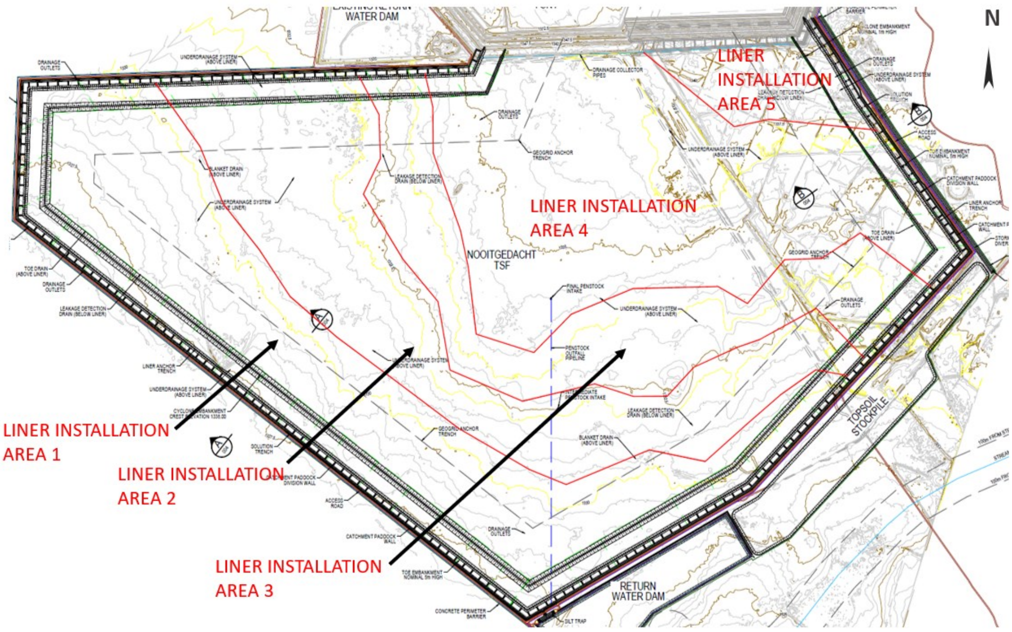


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**Figure 16: Liner installation sequence**

12.1.8 The facility provides storage of 804 million tons over 34 years at 2 000 000tpm.

**Table 11: Stage capacity results**

| Description | Unit | Value |
|---|---|---|
| Deposition rate | tons/month | 2 000 000 |
| Storage capacity | million tons | 804 |
| Max rate of rise (Outer Wall) | m/year | 2.89 |
| Max rate of rise (Basin) | m/year | 3.7 |
| Deposition period | years | 34 |

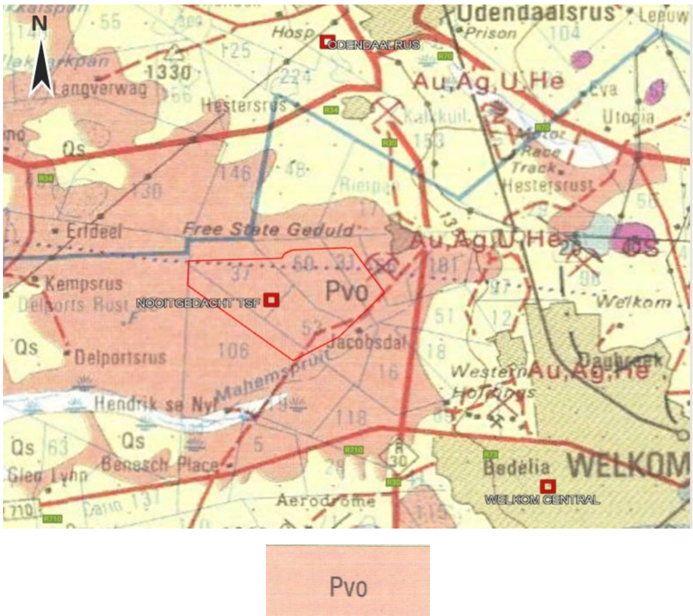
12.1.9 The detailed stage capacity graphs and outputs are included in Appendix C.

## 12.2 Engineering geology

12.2.1 The 1:250 000 2726 Kroonstad geological map indicates that the site consists of mudstone, siltstone and shale (Pvo) of the Volksrust Formation, Ecca Group, Karoo Supergroup.

12.2.2 The influence of climate on weathering is expressed by the N-value (H.H. Weinert 1980). The most important is where N=5. Where N is more than 5, disintegration is dominant, and where N is less than 5, decomposition is dominant.

12.2.3 The Weinert N-value is 4.0 for this region, indicating that decomposition is dominant.




Pvo = Mudstone, siltstone, shale

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**Figure 17: Regional geology**

12.2.4 Jones and Wagener investigated and evaluated the founding conditions for the Nooitgedacht TSF. This was done to characterise the soil profile, evaluate the geotechnical conditions and give founding recommendations for the subgrade preparations of the Nooitgedacht TSF.

12.2.5 Jones & Wagner did sampling and geotechnical testing of the materials at the Nooitgedacht TSF in October 2008 (JAWS report reference: JW150/08/B680 – Rev 0). This geotechnical report is in Appendix B.

12.3 **SCPTu testing and geotechnical investigation**

12.3.1 Additional SCPTu testing was done on the Nooitgedacht footprint to confirm and provide current founding conditions.

12.3.2 Twelve SCPTu tests around the site were done in June 2023. Depths were between 1.2m and 4.6m. The SCPTu test locations are indicated in Figure 18.


| | | |
|---|---|---|
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**Figure 18: SCPTu test locations**

12.3.3 The SCPTu results were analysed using P.K Robertson (2016). The SCPTu report is submitted as a separate report (report reference 2210506 – Harmony – Nooitgedacht TSF SCPTu Report – R07).

12.3.4 The table below shows a comparison of the soil profile determined by Jones & Wagener's geotechnical investigation and the SCPTu testing.

**Table 12: Soil profile correlations**

| | **Jones & Wagener** | **SCPTu testing** |
|---|---|---|
| Upper foundation | Moist, brown, loose, clay sand topsoil, pale brown, firm, clayey sand to sandy clay hillwash. | Clayey sand to sandy silt |
| Middle foundation | Slightly moist, olive mottled yellow-brown and grey, stiff, fissured, granular textured sandy clay reworked siltstone. | Very dense silty sand |
| Lower foundation | Slightly moist, olive blotched grey, stiff to very stiff clayey silt residual siltstone. | Silty clay |

12.4 **Engineering geotechnical parameters**

12.4.1 Geotechnical engineering parameters were developed based on correlations between the findings from the geotechnical site investigation, similarly classified material, and the analysis of the June 2023 SCPTu test results.

12.4.2 The geotechnical engineering parameters used for the designs are shown in Table 13.

**Table 13: Geotechnical parameters**

| | | | Mohr Coulomb | | SHANSEP (kPa) | | |
|---|---|---|---|---|---|---|---|
| **Material** | **Unit Weight (kN/m³)** | **Permeability (m/s)** | **Cohesion (kPa)** | **Phi (deg)** | **SHANSEP A** | **SHANSEP S** | **SHANSEP m** |
| Tailings | 14.5 | 8.0E-08 | 0 | 33 | | | |
| Tailings – undrained | 14.5 | 8.0E-08 | | | | 0.2 | |
| Tailings – residual | 14.5 | 8.0E-08 | | | | 0.05 | |
| Starter wall | 17.5 | 5.0E-07 | 8 | 32 | | | |
| Residual siltstone | 17.0 | 3.6E-08 | 0 | 30 | | | |
| Residual siltstone - undrained | 17.0 | 3.6E-08 | | | | 1.5 | |
| Residual siltstone – residual | 17.0 | 3.6E-08 | | | | 0.23 | |
| Dense silty sand | 19.0 | 7.2E-08 | 0 | 28 | | | |
| Clayey sand | 17.0 | 1.7E-09 | 0 | 34 | | | |
| Clayey sand – residual | 17.0 | 1.7E-09 | | | | 0.09 | |
| Cushion sand | 14.5 | 6.5E-06 | 0 | 33 | | | |
| HDPE Liner | 9.0 | 1.0E-011 | 0 | 18 | | | |

12.5 **Slope stability assessment**

12.5.1 Four cross sections were analysed. The cross-section locations are shown in Figure 19 and cover all open sides of the facility.

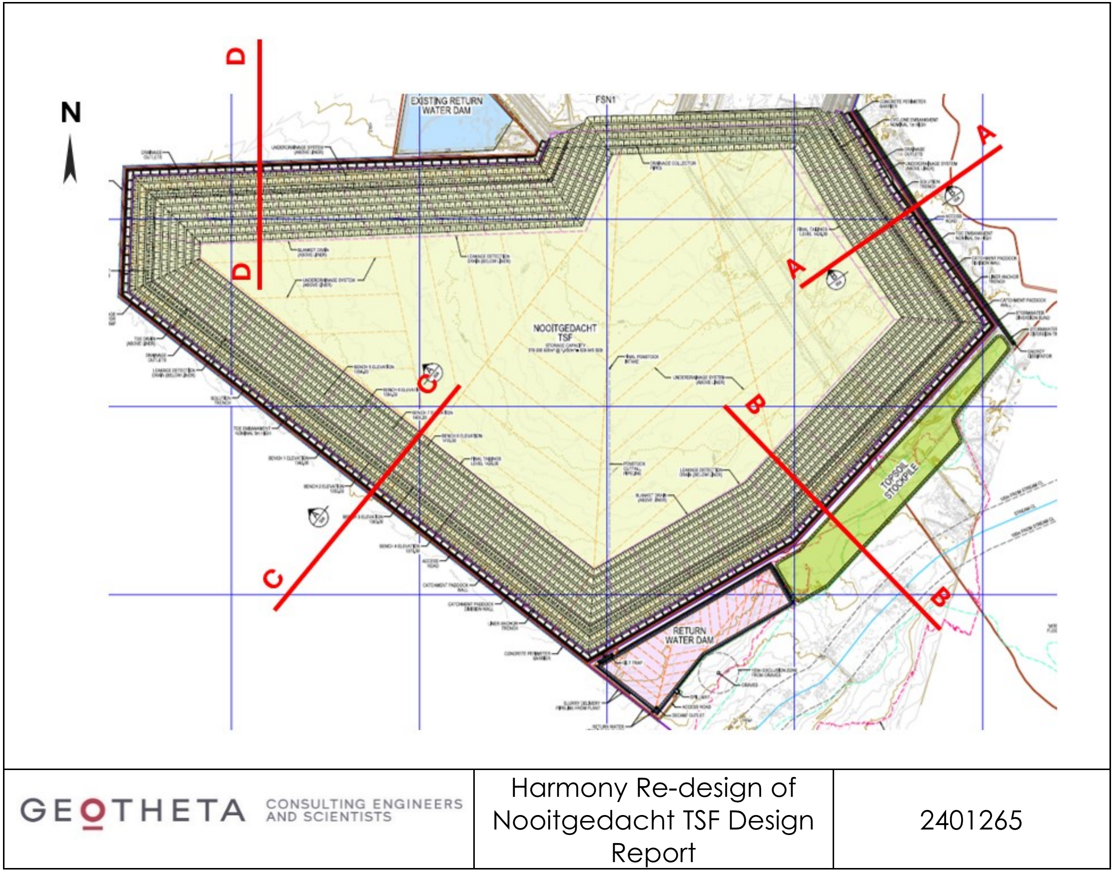


**Figure 19: Critical cross section location**

12.5.2 Slope stabilities were analysed using RocScience Slide 2 slope stability software using the Cuckoo failure path search method. This is a limit equilibrium stability assessment.

12.5.3 The TSF cross sections were analysed at final height for drained, undrained, residual (post seismic) strength conditions, and for pseudo static conditions.

12.5.4 Shallow (surficial) failure surfaces were not considered. Shallow failures mean that the outer face of the facility moves. This would be a localised surface failure which does not affect the overall stability of the facility. These can be relatively quickly and economically repaired to prevent any long-term instabilities and are solely in the area of operational inspections and repair as and when necessary.

12.5.5 A phreatic surface was modelled through the TSF embankment with hydrostatic pore water pressures below the phreatic surface.

12.5.6 The table below summarises the stability analyses results. Graphical slope stability outputs are included in Appendix D.

**Table 14: TSF Slope stability Factors of Safety**

| | Drained strength conditions | Undrained strength conditions | Post seismic, post liquefaction or residual strength conditions | Pseudo static conditions |
|---|---|---|---|---|
| Section A-A | 2.1 | 2.1 | 1.2 | 1.2 |
| Section B-B | 2.1 | 2.1 | 1.3 | 1.2 |
| Section C-C | 2.1 | 2.1 | 1.4 | 1.2 |
| Section D-D | 2.0 | 2.0 | 1.1 | 1.2 |

12.5.7 These Factors of Safety comply with the design criteria.

# 13. Liner system design – TSF

## 13.1 Barrier system

13.1.1 The Nooitgedacht site is underlain by clayey sand which provide suitable liner material for the tailings dam due to the low permeabilities. The clayey sand, together with the underdrains will minimise potential downward migration of contaminated water.

13.1.2 An independent review of the liner system on the adjacent proposed Valley TSF has been done by Legge and Associates. The review report recommended that an 'inverted barrier' system be used as opposed to a Class C barrier system. This inverted barrier system design of the Valley TSF is also used for the Nooitgedacht TSF design. A comparison of these two barrier systems is shown in Figure 20 below.

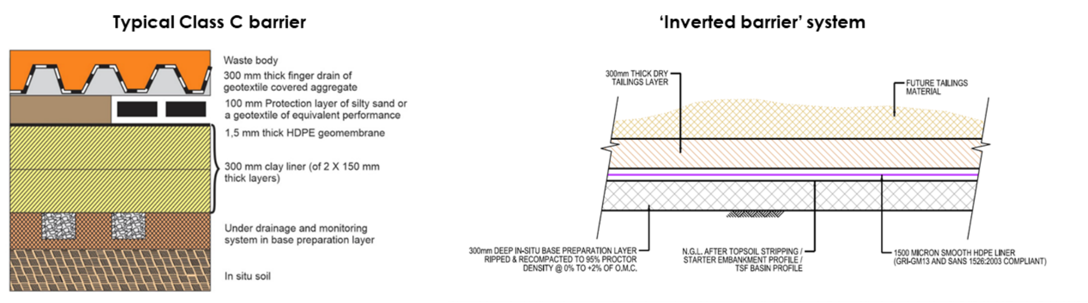


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**Figure 20: Comparison of typical Class C liner and inverted liner system**

13.1.3 The inverted barrier system has superior seepage reduction performance compared to the Class C barrier system, and equivalent performance in terms of service life. This is a more feasible option as it removes the need for a compacted clay liner (or alternative barriers) below the geomembrane. The stability of the TSF is also improved by omitting lower strength compacted clay layers and the geomembrane cushion layer (replaced by tailings).

13.1.4 The effectiveness of the proposed inverted liner system considers flow through the tailings due to the possible holes in the liner. With stringent construction quality control the liner system is assumed to have a maximum of 5 holes per hectare, with each hole being max 10mm in diameter. When a hole forms in the liner, the fine tailings will clog it, and Darcy's law is applied for seepage through the holes. The seepage through a typical 1.5mm HDPE liner with no holes used in landfill applications is negligible (R. Kerry Rowe, 2012).

13.1.5 Refer to Appendix L (report reference: Alternative Barrier System Layout to a Class C single composite barrier_Inverted Barrier) for further details.

13.1.6 The Nooitgedacht TSF liner comprises two different areas described below. The liner system layout is shown in Figure 21.

- Liner system 1 over the existing FSN4 TSF footprint and the outer edges, where high liner stresses are present.
- Liner system 2 in the inner basin area.

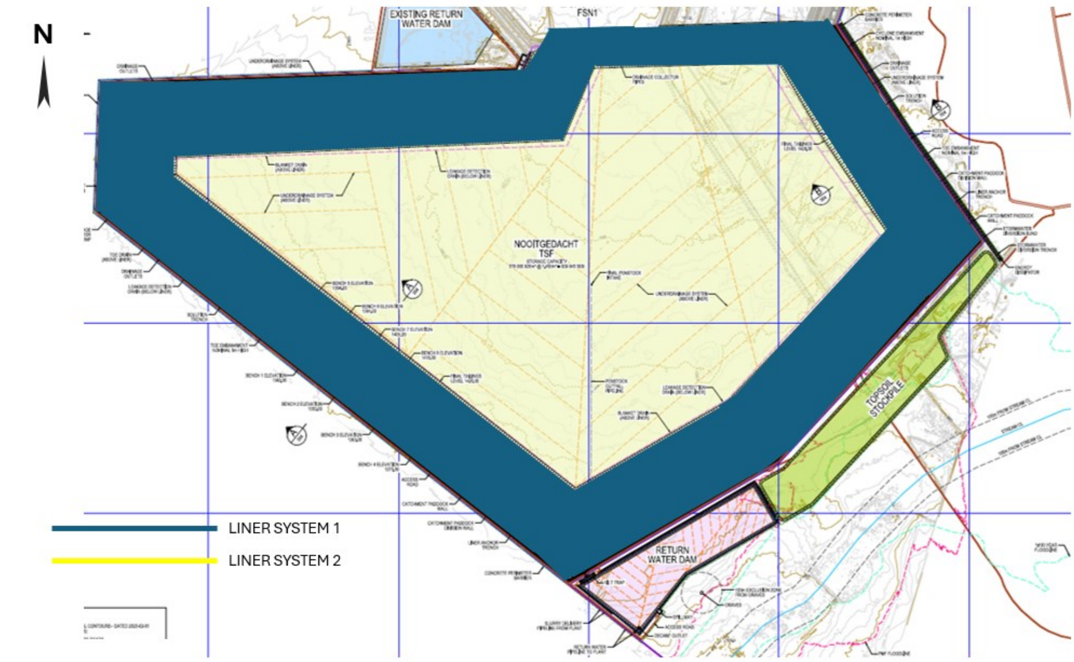


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**Figure 21: Liner systems layout**

13.1.7 The details of the proposed TSF barrier cross-sections are shown in Figures 22 and 23.

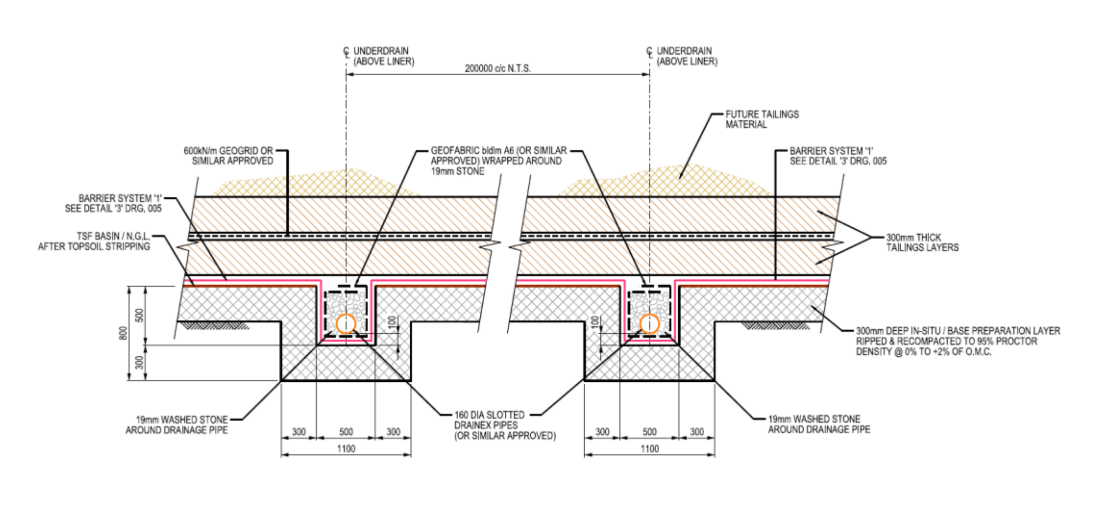


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**Figure 22: TSF liner system 1 – Outer wall area**

13.1.8 Liner system 1 where high liner stresses are present is shown in Figure 22 and comprises of the following layers (from top down):

- 300mm thick layer of tailings material.
- 600 kN/m geogrid or similar approved. The 600 kN/m geogrid is only to be placed 55m from the outer walls.
- 300mm thick layer of tailings material.
- Above liner drain comprising 160mm perforated HDPE pipes placed in a trapezoidal trench. The pipes will be encased in 19mm washed stone and wrapped in geofabric.
- 1.5mm thick double textured HDPE membrane (GRI-GM13 and SANS 1526:2003 compliant).
- Ripping and recompacting of the in-situ base preparation material 300mm deep to 95% Proctor density at a moisture content between 0% and +2% of optimum moisture content.
- Leakage detection system comprising 160mm perforated HDPE pipes placed in a 500mm by 500mm trench. The pipes will be encased in 19mm washed stone and wrapped in geofabric.

13.1.9 The flexible, high-strength geogrid is used to reinforce the tailings layer over the liner, thereby reducing tension stresses in the liner. The geogrid is made from materials that have extraordinary tensile strength enclosed in a protective coating for protection from installation damage and short term ultraviolet exposure. The geogrid will be placed on the outer edge only, where high tensile stresses are present.

13.1.10 The tailings layer can be initially sourced from the FSN 4 footprint prior to new deposition there. Alternative tailings sources can be sought (e.g. FSN 1 or 2), alternatively selected filter sand must be sourced. Tailings underflow can also be placed over the liner hydraulically but care will need to be taken to ensure that the exposed liner is not damaged or exposed for long periods.

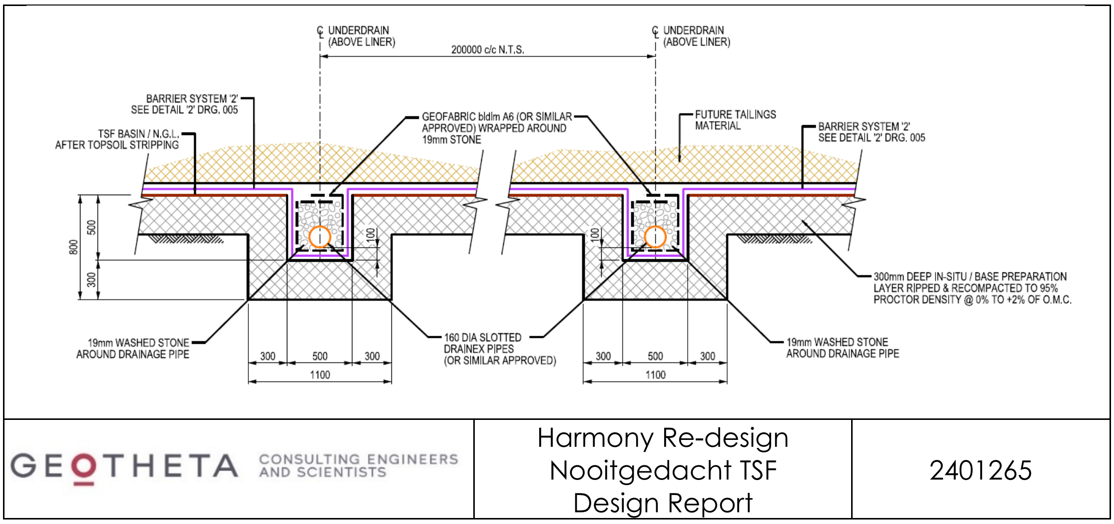


**Figure 23: TSF liner system 2 - basin area**

13.1.11 Liner system 2 in Figure 23 comprises the following layers (from top down):

- Above liner drain comprising 160mm perforated HDPE pipes placed in a trapezoidal trench. The pipes will be encased in 19mm washed stone and wrapped in geofabric.
- 1.5mm thick double textured HDPE membrane (GRI-GM13 and SANS 1526:2003 compliant).
- Ripping and recompacting of the in-situ base preparation material 300mm deep to 95% Proctor density at a moisture content between 0% and +2% of optimum moisture content.
- Leakage detection system comprising 160mm perforated HDPE pipes placed in a 500mm by 500mm trench. The pipes will be encased in 19mm washed stone and wrapped in geofabric.

## 13.2 **Seepage assessment**

13.2.1 The seepage through the liner system was quantified to evaluate the effectiveness of the proposed liner system.

13.2.2 The expected flow rate through the liner system was calculated using the Wissa and Fuleihan 1993 (W-F) equation. The reference document for the seepage calculation using the Wissa and Fuleihan 1993 (W-F) equation is *titled Short and Long-term Leakage through composite liners – The 7th Arthur Casagrande Lecture – R. Kerry Rowe*.

13.2.3 A geomembrane installed with good construction quality assurance (CQA) will have 2.5 – 5 holes per hectare (Giroud and Bonaparte 1989, 2001) and a typical hole diameter of approximately 10mm. The reference document for the number of holes per hectare and the typical hole diameter is titled *Leakage through Holes in Geomembranes below Saturated Tailings – R. Kerry Rowe*.

13.2.4 When a hole forms in the liner, the fine tailings will clog it, therefore the Wissa and Fuleihan 1993 (W-F) equation uses Darcy's Law to capture flow through the tailings contained within a 10mm diameter geomembrane hole. The seepage flow is calculated by the following equation.

$$Q = \frac{2khd}{1 + \frac{8}{\pi}\left(\frac{t}{d}\right)}$$

13.2.5 In the above equation, Q is the flow rate, *k* is the permeability of the tailings above the geomembrane, *h* is the head above the geomembrane, *t* is the geomembrane thickness and and *d* is the diameter of the hole in the geomembrane.

13.2.6 The calculated TSF seepage through the 'inverted barrier' is 46L/ha/day which is below the seepage rate for a Class C liner of 140L/ha/day.

13.2.7 The seepage flow rate through the tailings layer is low. Negligible impact to the underlying soils and groundwater is therefore expected.

13.2.8 The seepage through the liner was used to size the below liner drains.

13.2.9 The underdrainage system will be monitored as part of the operations, maintenance, and surveillance plan to determine and quantify any leakage through the liner system.

13.3 **Underdrainage system**

13.3.1 A TSF drainage system is provided above the liner system to intercept seepage through the facility and to reduce static water head on the liner . The underdrainage system lowers the phreatic surface, improving the overall stability of the facility.

13.3.2 The underdrainage system consists of toe drains, blanket drains and herringbone drains.

13.3.3 Herringbone drainage is provided between the cyclone wall and the toe wall to ensure that the outer cyclone underflow wall remains drained.

13.3.4 The above liner toe drains comprise 160mm slotted HDPE pipe surrounded in 19mm stone overlain by a layer of 6mm stone all enclosed in a geofabric. The toe drain outlet pipes also discharge into the solution trench.

13.3.5 The blanket drains comprise 160mm slotted Drainex HDPE pipes surrounded in 19mm stone overlain by a layer of 6mm stone and graded filter sand all enclosed in a geofabric. These drains intersect the starter wall with an HDPE pipe boot at the point of intersection with the liner.

13.3.6 The herringbone drainage pipes comprise 160mm slotted Drainex HDPE pipes surrounded in 19mm stone enclosed in a geofabric. The above-liner drains are spaced 200m apart.

13.3.7 The herringbone drainage east of the TSF will flow towards the main collector pipe which then discharges into the RWD situated south-east of the TSF. The herringbone drainage system west of the TSF will flow towards the collector pipe which flows into the 6.5m x 6.5m x 2.6m deep sump situated south-west of the TSF. The sump has been designed to accommodate a volume of 110 $m^3$. Water collected in the sump will then be pumped into the solution trench for discharge into the RWD south-east of the TSF. A 250 TV Multotec vertical spindle pump with a flow rate of 115l/s and a head of 3m is proposed. Electricity must be provided to the vertical spindle pump from the RWD electrical supply.

13.3.8 The TSF underdrainage details are shown in Drawing No. 2401265 – 006 SHT. 1 and 2401265 – 006 SHT. 2.

13.3.9 At the 36m height of the adjacent Valley TSF elevated drains will be installed on the Nooitgedacht TSF. The elevated drains will be designed just prior to installation based on actual measured tailings permeabilities at that time.

13.3.10 Nooitgedacht TSF will be constructed against the existing FSN 1 TSF and the Valley TSF. Underdrainage collecting seepage from the existing FSN1 and Valley TSF along the toe of the TSF comprises a 160mm slotted Drainex HDPE pipe and a 160mm unslotted Drainex HDPE collector pipe, joined by a 160mm double socket Y junction (45 degree). The 160mm pipes will be surrounded by 19mm stone overlain by a layer of 150mm washed river sand which is enclosed in a geofabric. These drainage collector pipes discharge into the solution trench.

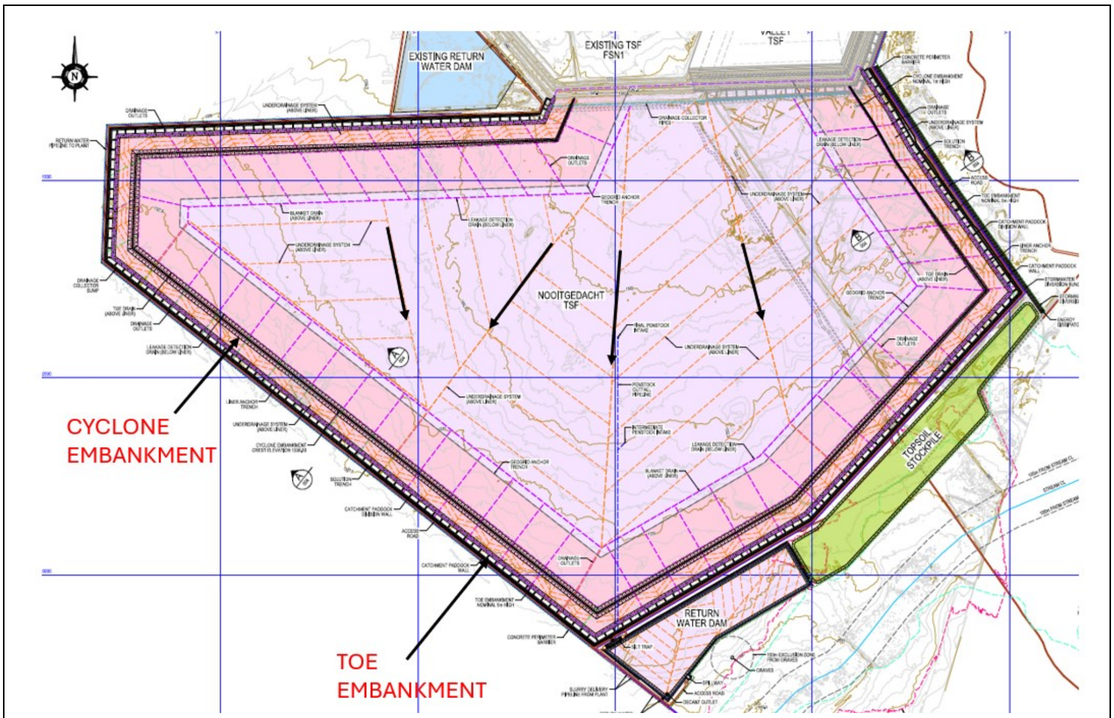


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**Figure 24: Underdrainage layout system flow direction (refer to Drawing No. 2401265-002)**

13.4 **Below liner leakage detection system**

13.4.1 The below liner leak detection drains will be monitored as part of the operations, maintenance, and surveillance plan to determine and quantify any leakage through the liner system. The below liner leakage detection was sized and spaced using the seepage rate through the liner.

13.4.2 The below liner leak detection system also alleviates any possible water pressure build-up beneath the liner from a potential rise of the groundwater table.

13.4.3 In the event of a leak, the drains serve to locate the area of the leak. Once the area of the leak is located, monitoring of the area and maintenance of the phreatic level is required or further action will need to be taken.

13.4.4 The below liner leakage detection drain comprises a 160mm slotted HDPE pipe surrounded in 19mm stone which is enclosed in a geofabric.

13.4.5 The below liner leakage detection outlet pipes discharge into the solution trench. All drain outlets will be clearly marked to distinguish between the underdrains, blanket drains and leakage detection drains.

13.4.6 The TSF underdrainage details are shown in Drawing No. 2401265 – 006 SHT. 1 and 2401265 – 006 SHT. 2.

## 13.5 Liner tension forces – TSF

13.5.1 Due to the foundation and height of the facility there are high tensile forces induced on the liner. Liner stresses induced by the slopes of the facility exceed the liner tensile strengths. To alleviate these stresses, geogrid has been designed.

13.5.2 The maximum shear stresses in the 600kN/m geogrid were determined.

13.5.3 The maximum shear stresses (and forces) have been analysed against the yield strength of the 600kN/m geogrid to determine the Factor of Safety against yield (failure) under drained, undrained, post seismic conditions and pseudo-static conditions.

13.5.4 Other remedial measures were considered to reduce the liner stresses. These included adjusting the intermediate slopes and foundation saw tooths equally spaced along the failure surface. These did not reduce the induced liner stresses, and the geogrid was designed.

13.5.5 A 600kN/m geogrid (or similar approved) has been specified.

13.5.6 The results from the analysis are shown in Table 15.

**Table 15: Forces in 600kN/m geogrid**

| Description | Drained conditions | Undrained conditions | Residual conditions | Pseudo-static conditions |
|---|---|---|---|---|
| Max shear stress along liner surface (kPa) | 264 | 64 | 359 | 387 |
| Max shear force per m width (kN/m) | 264 | 64 | 359 | 387 |
| Yield strength of 600kN/m geogrid (kN/m) | 600 | 600 | 600 | 600 |
| FOS against 600kN/m geogrid yield strength | 1.5 | 1.7 | 1.7 | 1.6 |

13.5.7 These Factor of Safety are satisfactory.

13.5.8 Liner tension forces were analysed at the liner anchor trenches. The detailed calculations are included in Appendix E.

13.5.9 The Factor of Safety at the TSF anchor trench is 1.5 which is adequate.

13.5.10 The total tensile strain in the geomembrane is less than 1%. This is due to minimal movement expected because of the engineered base, reinforcing geogrid, and cushion tailings protection layer of the inverted barrier system.

## 13.6 Liner service life assessment

13.6.1 The service life of a geomembrane is affected by various factors including UV exposure, temperature conditions and applied loading.

13.6.2 The deposition life of the Nooitgedacht TSF is 34 years, after which, pending future reclamation, it may exist as a dormant TSF for a very long time.

13.6.3 The main factors affecting the service life of a geomembrane is UV exposure and temperature. The geomembrane on the TSF will be covered during construction by tailings, therefore UV exposure will not have a detrimental effect on the service life of the geomembrane.

13.6.4 The geomembrane can alternatively be covered using tailings underflow, but installation timing and tailings beach advancement will need to be considered during liner installation and construction. Due to risk to the membrane, the placed tailings layer is recommended, and this has been costed in the budget estimates.

13.6.5 The average minimum and maximum ambient temperature of the site is 10°C and 25°C respectively. Based on research conducted by the Geosynthetics Institute in USA "Geomembrane Lifetime Prediction: Unexposed and Exposed Conditions" originally published in 2005 and later updated in 2011, it is reported that an unexposed geomembrane at 25°C will have a design life of more than 250 years.

13.6.6 It is noted that this time is for the geomembrane to reach the so called "half-life", meaning the antioxidant in the geomembrane have reached 50% of their original value.

13.6.7 Rowe (2005) discussed the effects of temperature on a geomembrane's service life. In the manufacturing process of geomembranes, antioxidants are added to the material to act as the sacrificial component in terms of oxidation. This means that for a certain time period the antioxidants prevent the geomembrane from being oxidised, which results in increasing the material's durability and service life.

13.6.8 The time required to deplete the antioxidants in the geomembrane depended on its exposure rate. The table below details the three stages of degradation and the service life of 1.5mm thick double textured HDPE geomembrane that meets the GRI GM13 specification.

13.6.9 The projected service life of a geomembrane at Nooitgedacht TSF is 2 775 years at 10°C and decreases to 608 years at a temperature of 25°C. The geomembrane service life is therefore considered acceptable

**Table 16: Estimated times for three stages of degradation and resulting service lives (Rowe, 2005)**

| (1) Temp: °C | (2) Stage 1: years Simulated | (3) Stage 2: years Base | (4) Stage 2: years Adjusted | (5) Stage 3: years Base | (6) Stage 3: years Adjusted | (7) Service life: years Unadjusted | (8) Service life: years Adjusted |
|---|---|---|---|---|---|---|---|
| 10 | 280 | 50 | 30 | 2445 | 1380 | 2775 | 1690 |
| 20 | 115 | 15 | 10 | 765 | 440 | 900 | 565 |
| 30 | 50 | 6 | 4 | 260 | 150 | 315 | 205 |
| 35 | 35 | 4 | 2 | 155 | 90 | 190 | 130 |
| 40 | 25 | 2 | 1 | 95 | 55 | 120 | 80 |
| 50 | 10 | 1 | 0.6 | 35 | 20 | 50 | 35 |
| 60 | 6 | 0.4 | 0.3 | 15 | 9 | 20 | 15 |

## 14. Dam Break Analysis

14.1 A feasibility dam break analysis was done by Geotheta in September 2023 using FLO-2D Overland Flood Modelling (report reference: 2210506 - Harmony – Nooitgedacht TSF Design - DBA - R02).

14.2 The following guidelines were used for the feasibility modelling and analysis to determine the GISTM Consequence Classification:

- Canadian Dam Association: Tailings Dam Breach Analysis (2021).
- ICOLD. Committee L Tailings Dams and Waste Lagoons. Technical Guidelines for Tailings Dam Safety Assessment and Design (2019).

14.3 Contours of the inundation area were used to develop a digital terrain model. These are accurate at 5m intervals which is considered sufficiently accurate for the purposes of establishing an indicative inundation zone. Given the range of possible failure scenarios, failure volumes and surface flow resistances that can occur, the contour intervals are therefore adequate for the purpose of this feasibility level study.

14.4 The proposed Nooitgedacht TSF is an **Extreme Consequence Classification** facility according to the Global Industry Standard on Tailings Management (GISTM) criteria. This is determined by analysing the impact a failure would have on life, the environment and infrastructure in the modelled inundation zone. The corresponding SANS 10286 hazard classification is **High**.

14.5 Note that this is the facility's "Consequence Classification", and it is not at all linked to the likelihood of failure. The dam break analyses merely address the consequence should the facility fail. The consequence classification leads to the design criteria to be used to ensure that the facility is adequately designed, operated, managed and closed so that the risk of failure is reduced to as low as reasonably practicable (ALARP).

14.6 The likelihood of failure would be addressed from further Failure Mode Effects Analyses, specifications, QA/QC aspects, etc. which do not form part of this scope.

14.7 The image below indicates the overall zone of influence and the delineated background flood.

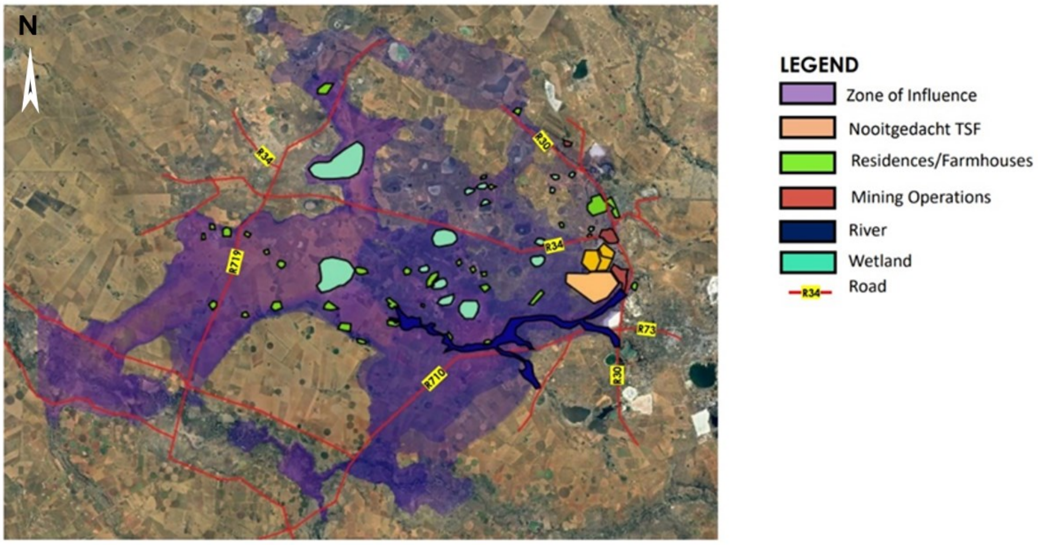


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**Figure 25: Overall zone of influence and the delineated background flood**

14.8 The analyses concluded that there would be extensive damage to both the natural environment and infrastructure within the inundation area.

14.9 Tailings flowing into the river south of the facility, will result in the loss of aquatic wildlife and decrease in water quality. It is likely that the pollution of the river and loss of aquatic wildlife would have adverse impacts on the ecosystem of the area and adversely affect users of the water.

14.10 The inundated area must be environmentally surveyed to identify the affected population, environment and infrastructure within the Zone of Influence.

14.11 The flood event would inundate households and associated infrastructure located near the facility and the populated area to the north-east of the Nooitgedacht TSF. The potential population at risk falls between 100 – 1 000, with the potential loss of life not exceeding 100.

14.12 The rainy day tailings flow of a breach on the north eastern flank will affect the residential area of Odendaalsrus to the north of the facility. This flow could be diverted away from the nearby residential area by constructing a (dump rock) bund approximately 1m high at the edge of the residential area. This can reduce the probability of loss of life to ranges of 1:10 000 or better. The bund must be designed to withstand flow erosion.

14.13 This is the dam break analysis of the Nooitgedacht TSF in isolation. An extensive dam break analysis can be done, as necessary, on the concurrent failure of FSN1, FSN2, Nooitgedacht and the future Valley TSFs to fully determine the additional extents of the impacted zone.

# 15. SANS 10286 TSF Classifications

## 15.1 TSF safety classification

15.1.1 The SANS 10286 Code of Practice for Mine Residue, requires that all mine residue deposits be classified into one or a combination of the following safety categories:

- High hazard
- Medium hazard
- Low hazard

15.1.2 The Nooitgedacht TSF SANS safety classification was determined by analysing the zone of influence and applying the safety classification criteria provided in the SANS 10286 Code of Practice for Mine Residue. The safety classification criteria are indicated in Table 17.

**Table 17: Safety classification criteria**

| No of residents in zone of influence | No of workers in zone of influence[1] | Value of third party property in zone of influence[2] | Depth to underground mined workings[3] | Classification |
|---|---|---|---|---|
| 0 | <10 | 0-R2 m | >200 m | Low hazard |
| 1-10 | 11-100 | R2 m-R20 m | 50 m-200 m | Medium hazard |
| >10 | >100 | >R20 m | <50 m | High hazard |

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

15.1.3 Based on SANS 10286, the Nooitgedacht TSF has a **High Hazard** classification rating.

## 15.2 TSF environmental classification

15.2.1 Table 18 below, outlines how the environmental classification is determined using SANS 10286.

15.2.2 The environmental classification of the TSF is a residue deposit with a **Significant** impact on any environmental component.

**Table 18: Environmental classification criteria**

| Aspect under consideration | Environmental classification | | |
|---|---|---|---|
| | Significant | Possibly significant | Not significant |
| Surface and groundwater | Deposit has potential to contaminate water that may be consumed by humans. | Deposit has potential to contaminate water that may be consumed by flora or fauna. | No contamination of water supplies likely. |

| Aspect under consideration | Environmental classification | | |
|---|---|---|---|
| | **Significant** | **Possibly significant** | **Not significant** |
| Land | Deposit has potential to permanently render surrounding land unsuitable for its pre-existing potential. | Release of residue from the deposit could have a long-term detrimental effect on land. | Release of residue from the deposit can be completely remediated. |
| Air | Deposit has potential to degrade air quality to a level that is detrimental to human health. | Deposit has potential to elevate dust nuisance (only) to an unacceptable level. | Deposit has negligible potential to adversely affect air quality. |
| Physical security | Residue has potential to cause injury on release as a result of structural failure. [1] | Residue has potential to cause injury as a result of structural failure [2] | Residue has negligible potential to cause harm through structural failure. |
| Business environment | Failure of Deposit has potential to result in business failure of operation. | Failure of Deposit has potential to result in significant economic loss. | Low potential for failure of Deposit to result in economic loss. |
| Social environment | Failure of Deposit could lead to severe adverse publicity, resulting in business failure and impairment of credibility. | Failure of Deposit could lead to adverse publicity, leading to regulatory intervention and/or financial loss. | Failure of Deposit is unlikely to lead to adverse publicity or indirect losses. |
| Government | Failure of deposits can lead to Harmony receiving directives/penalties. | Possibility of notice | None |

## 16. GISTM TSF classification

*Please note that GISTM is not a local regulation requirement but is reported here for Harmony Gold's internal requirements and review processes only.*

16.1 The GISTM, requires that all TSFs be classified into one of the following consequence classifications:

- Low
- Significant
- High
- Very High
- Extreme

16.2 The consequence classification of the Nooitgedacht TSF was determined by analysing the zone of influence and applying the consequence classification criteria provided in Table 1.

16.3 The Nooitgedacht TSF is categorised as an **Extreme Consequence Classification** facility due to the impact a failure of this facility would have on the life, environment and infrastructure in the inundation zone modelled during the dam break analysis. Refer to Section 8 for the consequence classification table.

# 17. Dam legal classifications

## 17.1 TSF legal classification

17.1.1 Regulation 139 of the of the National Water Act and South African National Committee on Large Dams (SANCOLD) regulations stipulates that a dam storing more than 50 000 $m^3$ **and** having an outer wall height of more than 5m should be registered as a dam with a safety risk.

17.1.2 A dam with a safety risk requires more stringent monitoring, inspection and controls by appropriately qualified persons registered in terms of the Act.

17.1.3 The Dam Safety Office originally only considered the amount of water stored on the facility when classifying dams with a safety risk. In this case the expected pool volume is less than the required 50 000$m^3$.

17.1.4 However, since the volume of flowable tailings in the event of a dam break is 346 800$m^3$, it is recommended to request an assessment by the Dam Safety Office of whether the facility should be categorised as a dam with a safety risk, or not.

# 18. Return Water Dam design

## 18.1 Layout

18.1.1 The layout of the Return Water Dam (RWD) is shown below.

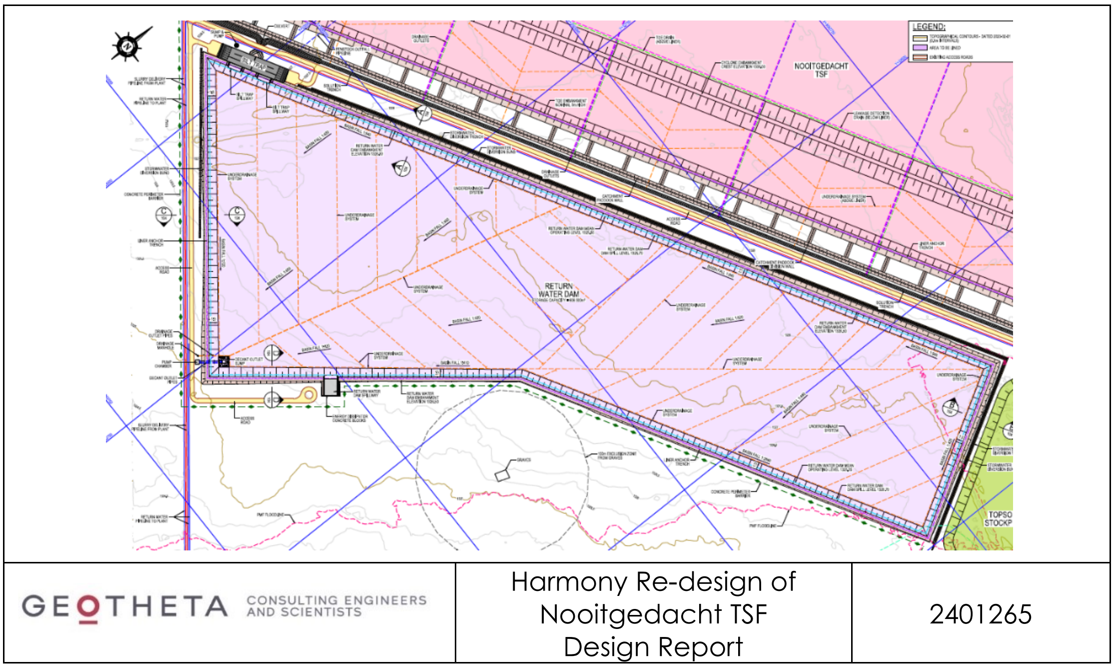


**Figure 26: RWD layout**

18.1.2 The lined RWD is situated south-east of the TSF.

18.1.3 The basin of the RWD is formed by excavation into the ground materials. The RWD has a total storage capacity of 606 500$m^3$. This provides adequate capacity to contain runoff from the TSF catchment area.

18.2 **RWD sizing**

18.2.1 A daily stochastic water balance of the TSF and associated infrastructure was modelled to determine the required capacity of the RWD. The capacity of the RWD was based on the daily rainfall depth data set.

18.2.2 The average monthly water balance model is shown in Figure 27. The average monthly water balance was done over the entire simulation period.

18.2.3 Storage and spillage have been considered at each time step to determine the frequency of spillage as required by Government Notice 704 of the National Water Act (Act No 36 of 1998).

18.2.4 The water balance model comprises three main components (the processing plant, the RWD and the TSF). Each component has various inputs and outputs.

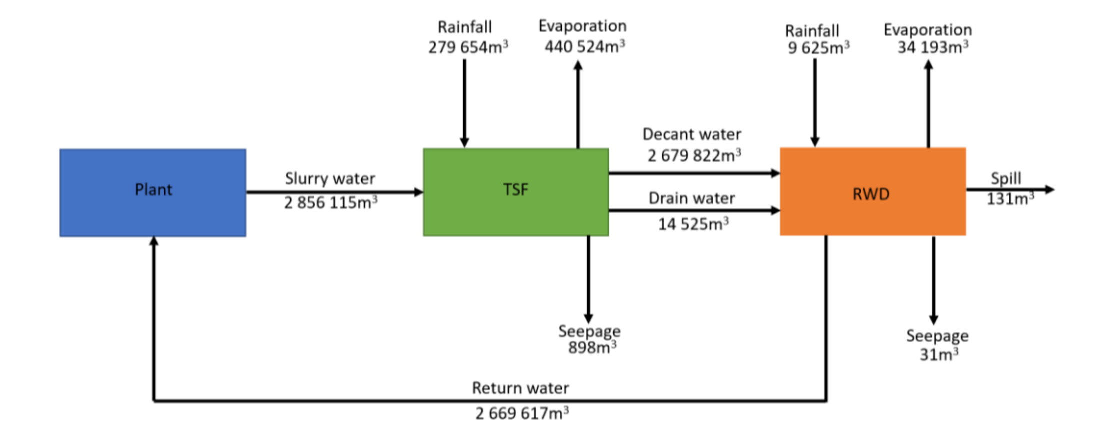


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**Figure 27: Water balance model – monthly averages**

18.2.5 The daily water balance model has been developed by utilising a continuity equation (inflow – outflow = Δ storage) for each component. Storage capacity in the plant is not considered.

18.2.6 TSF inputs are as follows:

- Direct rainfall onto the TSF.
- Slurry water from the plant.

18.2.7 TSF outputs are as follows:

- Evaporation from the TSF.
- Seepage from the leak detection drains through the liner routed to the RWD.
- Under drain flow to the RWD.
- Decant water to the RWD.

18.2.8 RWD inputs are as follows:

- Direct rainfall into the RWD basin.

- Decant water from the TSF.
- Under drain flow from the TSF.

18.2.9 RWD outputs are as follows:

- Evaporation from the RWD basin.
- Seepage into the underlying in-situ soils.
- Spill into the natural environment when the RWD capacity is exceeded.
- Return water which is pumped from the RWD to the plant for re-use.

18.2.10 The daily rainfall data needed for the RWD sizing was extracted from the Odendaalrus Station rain gauge (SAWS station No. 0364322 X). This station was selected due to its long record length of 120 years, completeness of the data set, mean annual precipitation (MAP) of 504mm and location of the rainfall station with respect to the site.

18.2.11 Rainfall data collected from Olivine Station started on 1 January 1898 and ended on 31 December 2018 (120 years).

18.2.12 The daily rainfall data is indicated in Figure 28 below.

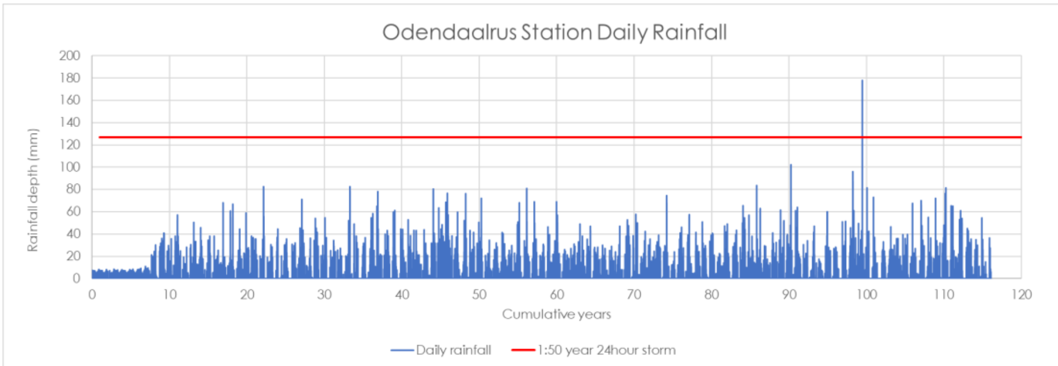


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**Figure 28: Daily rainfall record for Odendaalrus (0364322 X) rainfall station**

18.2.13 The graphical plot showing the RWD volume with time is indicted in Figure 29. The graph shows one spill event over a total simulation period of 120 years. This complies with the requirements to not spill more than once every 50 years.

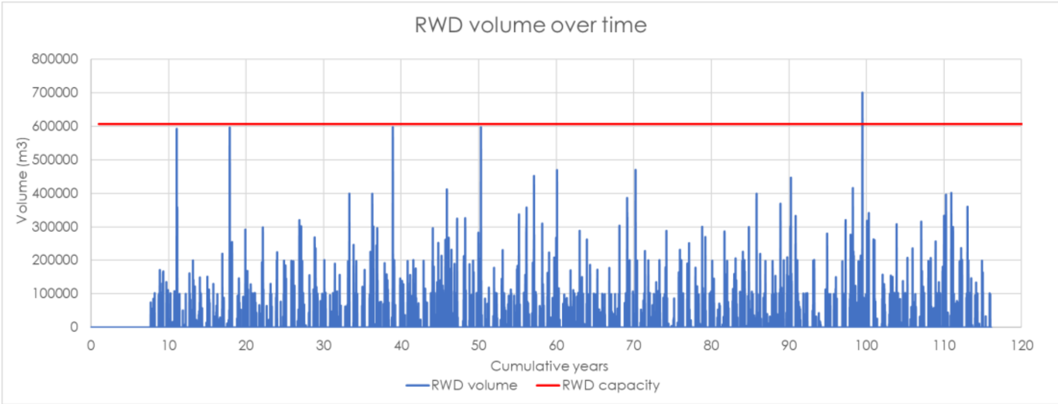


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**Figure 29: RWD volume over time**

18.2.14 The stochastic water balance analysis indicates that the required RWD storage capacity is 606 500 $m^3$. This ensures that the RWD does not spill more than once every 50 years as required by Government Notice 704 of the National Water Act (Act No 36 of 1998).

18.2.15 The RWD mean operating volume is 136 464$m^3$ at average 600mm deep. The mean operating volume was calculated by taking the volume of the fifth highest spill that is most likely to happen (470 036$m^3$ ), subtracted from the total storage capacity of the RWD (606 500$m^3$ ). The operating depth of 600mm is calculated by dividing the operating volume by the total area of the RWD. The depth of 600mm is recommended during the heavy rainfall seasons. This can be raised during the drier months.

18.2.16 The variables used in the stochastic water balance are shown in Table 19.

**Table 19: Variables used in stochastic water balance**

| | |
|---|---|
| Rainfall runoff from deposition beach factor | 0.9 |
| Wet beach evaporation factor | 0.7 |
| Wet beach area factor | 0.1 |
| Dry beach evaporation factor | 0.4 |
| Interstitial losses factor | 0.3 |

## 18.3 Water balance volumes

18.3.1 The average monthly water balance volumes are shown in Table 20.

**Table 20: Monthly water balance volumes**

| Facility | Inflow | | Outflow | |
|---|---|---|---|---|
| TSF | Rainfall | 279 654m$^3$ | Evaporation | 440 524m$^3$ |
| | Slurry water | 2 856 115m$^3$ | Drain water | 14 525m$^3$ |
| | | | Seepage | 898m$^3$ |
| | | | Decant water | 2 679 822m$^3$ |
| | **Total** | **3 135 769m$^3$** | **Total** | **3 135 769m$^3$** |
| RWD | Rainfall | 9 625m$^3$ | Return water | 2 669 617m$^3$ |
| | Decant water | 2 679 822m3 | Evaporation | 34 193 m$^3$ |
| | Drain water | 14 525m$^3$ | Seepage | 31m$^3$ |
| | | | Spill | 131m$^3$ |
| | **Total** | **2 703 972m$^3$** | **Total** | **2 703 972m$^3$** |

18.4 **RWD dam safety risk classification**

18.4.1 The total design capacity of the RWD is 606 500m$^3$ with a maximum above-ground wall height of 1.5m.

18.4.2 In terms of Regulation 139 of the of the National Water Act, for a dam to classify as a dam with a safety risk, the storage capacity must be greater than 50 000m$^3$ **and** the maximum wall height must be greater than 5m.

18.4.3 Although the storage capacity is greater than 50 000m$^3$, the maximum above-ground wall height (1.5m) is less than what is required for a dam to be classified as a dam with a safety risk (5.0m).

18.4.4 The RWD is not classified as a dam with a safety risk in terms of Regulation 139 of the of the National Water Act. The requirements for a dam with a safety risk as indicated in Regulation 139 of the of the National Water Act do not apply.

18.5 **Return Water Dam spillway design**

18.5.1 The RWD spillway is designed to accommodate the expected probable maximum flood (PMF), i.e. the 1:10 000 year 24-hour storm event, without overtopping of the RWD embankment.

18.5.2 Determination of rainfall depths beyond a 1:200 year return period was done by logarithmic extrapolation of the available rainfall data.

18.5.3 The RWD spillway was sized to have adequate capacity to safely discharge the PMF. The 1:10 000 year 24-hour storm event was calculated at 240mm. Determination of the PMF rainfall depth is indicated in Figure 6.

18.5.4 A concrete lined spillway is provided to safely discharge excess water without overtopping of the RWD embankment walls. The RWD spillway has a freeboard of 800mm and has been designed to discharge the 1:10 000 24-hour Probable Maximum Flood rate of 39.3m$^3$/sec over a 12-hour period. The RWD spillway details are shown in Drawing No. 2401265 – 105.

18.6 **Monitoring requirements**

18.6.1 The stormwater runoff water quality is to be monitored by the Mine's environmental consultants as and when required.

18.6.2 Drain water discharging from the Nooitgedacht TSF and RWD underdrainage outlet pipes are to be monitored by the Mine's environmental staff/consultants, at most annually.

18.7 **Silt trap**

18.7.1 A silt trap is provided upstream of the RWD. The silt trap includes cleaning infrastructure. The silt trap ensures that solids are captured before entering the RWD, thereby minimising sedimentation in the RWD. The silt trap details are shown in Drawing No. 2401265 -101 and 2401265 – 102.

18.7.2 The silt trap comprises a 2.25m deep reinforced concrete water retaining structure. An access ramp is provided to allow for a TLB (or similar) to clean out the silt trap when required. Sluice gates (2m x 1m Gereg specification or similar approved) at the solution trench split close off flow into one silt trap compartment while cleaning and maintenance is in progress. Used rail sections will be cast into the floor of the silt trap to prevent damage to the concrete surface during cleaning.

18.7.3 A sump has been included in each compartment of the silt trap to enable water and slurry to be pumped out to the TSF during operation, and prior to or after mechanical cleaning.

18.7.4 The settling velocity calculation used in the design of the silt trap is 0.00207m/s. The discharge from the penstock calculation assuming flow from penstock inlets with 400mm pool depth is 1.436$m^3$/sec. The entrainment velocity and tangential velocity is 0.13m/s and 0.12m/s respectively. The design of silt trap is therefore 89m in length and 18.5m wide.

18.8 **RWD slope stability assessment**

18.8.1 One cross section of the RWD was analysed for slope stability. The cross-section location is shown in Figure 30. This cross section of the RWD represent the critical scenario in terms of stability, which is the cross section with the maximum height on the RWD.

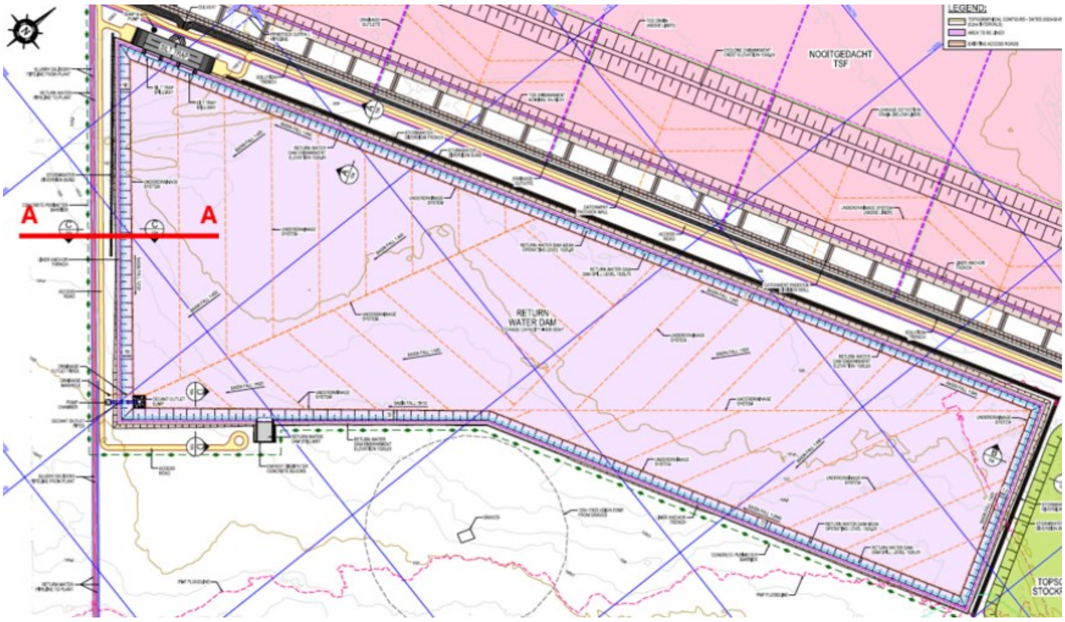


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**Figure 30: Critical cross section location**

18.8.2 The slope stabilities were analysed using RocScience Slide 2 slope stability software using the Cuckoo search method.

18.8.3 Table 21 summarises the stability analyses results. Graphical slope stability outputs are included in Appendix D.

**Table 21: Slope stability Factors of Safety**

| Scenario | Drained | Seismic |
|---|---|---|
| RWD inner slope - Empty | 2.0 | 1.3 |
| RWD inner slope - Full | 2.0 | 1.3 |

18.8.4 These Factors of Safety comply with the local regulation and international slope stability standards.

## 19. Liner system design - RWD

### 19.1 Barrier system

19.1.1 The liner system (from top down) comprises:

- 200mm high perforated HDPE Geocells (SW-356/200HD or similar approved) filled with 20Mpa concrete.
- 1.5mm thick smooth HDPE membrane (GRI-GM13 and SANS 1526:2003 compliant).
- Ripping and recompacting 300mm of the in-situ base preparation material to 95% Proctor density at a moisture content between 0% and +2% of optimum moisture content.

- Underdrainage/leakage detection system comprising 160mm perforated HDPE pipes placed in a 300mm by 300mm trench. The pipes will be encased in 19mm washed stone and wrapped in geofabric.

19.1.2 The RWD liner system is indicated in Figure 31.

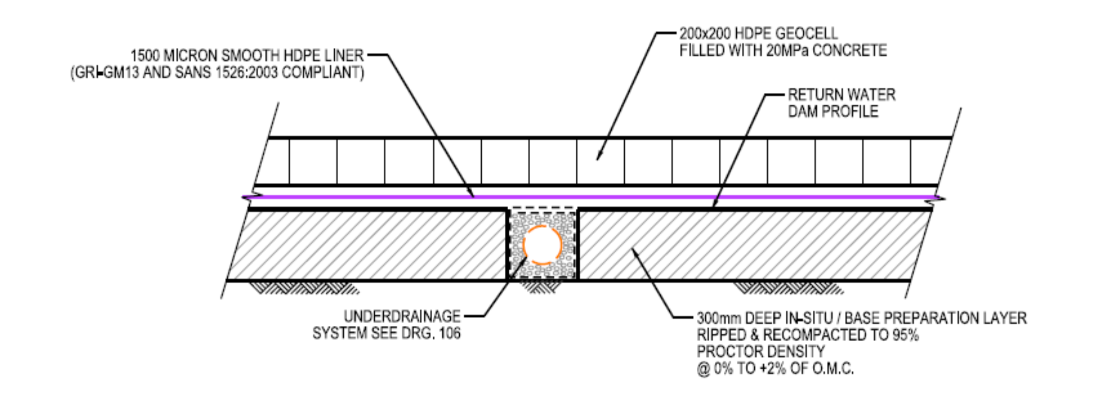


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**Figure 31: RWD liner system**

19.1.3 The use of a geomembrane requires a protection layer to achieve intimate contact between the liner and the underlying clay to ensure overall liner functionality.

19.1.4 The protection layer also provides durable protection to the liner against UV degradation and (possible) equipment and machine damage.

19.1.5 The protection layer will be 200mm high concrete filled perforated geocells. These will provide superior and long life protection compared to other options evaluated.

19.1.6 The geocells are perforated to prevent the blocks from acting independently and, if trafficked by maintenance or cleaning equipment, puncturing through the HDPE geomembrane. A typical image of the HDPE geocell is shown in Figure 32 below.

| | | |
|---|---|---|
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**Figure 32: Typical HDPE geocell**

19.2 **Seepage assessment**

19.2.1 The seepage through the liner system was quantified to evaluate the effectiveness of the proposed liner system.

19.2.2 The expected flow rate through the liner system was calculated using the Wissa and Fuleihan 1993 (W-F) equation. This equation uses Darcy's Law to capture flow through the concrete filled geocells taking into consideration the discontinuity of the geocell. The seepage flow is calculated by the following equation.

$$Q = \frac{2khd}{1 + \frac{8}{\pi}\left(\frac{t}{d}\right)}$$

19.2.3 In the above equation, *Q* is the flow rate, *k* is the permeability of the concrete filled geocells above the geomembrane, *h* is the head above the geomembrane, *t* is the geomembrane thickness and and *d* is the diameter of the hole in the geomembrane.

19.2.4 The calculated RWD seepage is 1.4 x $10^{-4}$ L/ha/day.

19.3 **Underdrainage system.**

19.3.1 An underdrainage system is provided beneath the RWD basin area. The underdrainage system acts as a leakage detection. The underdrainage system also alleviates any possible water pressure build-up beneath the liner caused by a potential rise of the groundwater table. The RWD underdrainage details are shown in Drawing No. 2401265 – 106. The RWD underdrainage layout is shown in Figure 33.

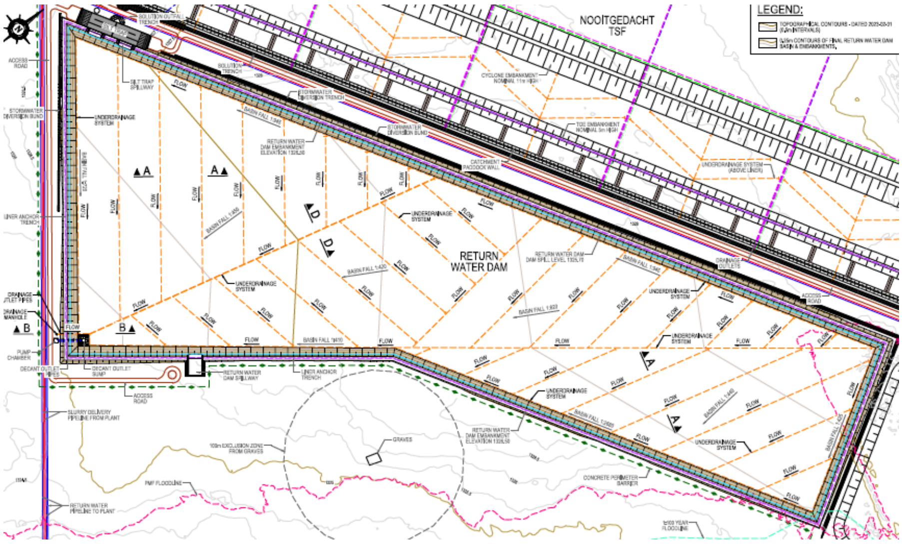


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**Figure 33: RWD underdrainage layout**

19.3.2 The underdrains comprise 160mm slotted HDPE pipes encased in 19mm washed stone. The stone will be wrapped in geofabric to prevent fines from entering the drains.

19.3.3 The underdrains from the RWD basin lead to collection manholes located on the perimeter of the RWD. The manholes provide access to monitor under-liner seepage.

19.3.4 The underdrainage system will be monitored as part of the operations, maintenance, and surveillance plan to determine and quantify any leakage through the liner system.

19.3.5 Water extraction from the RWD will be by means of a decant outlet sump and pump chamber. The pump specification should be sized as a 400L centrifugal pump. The maximum operating flow rate in the pumping system is 155 000m$^3$/day. The pumping system can run for an average of 14 hours per day. The RWD decant structure and details are shown on Drawing No. 2401265 – 107.

## 19.4 Liner tension forces – Return Water Dam

19.4.1 The slope stability models were used to determine the maximum shear stresses in the 1.5mm thick smooth HDPE liner.

19.4.2 The maximum shear stresses (and forces) have been analysed against the yield strength of the 1.5mm thick smooth HDPE liner to determine the Factor of Safety against yield (failure) of the HDPE liner.

19.4.3 The results from the analysis are shown in Table 22.

**Table 22: Forces in HDPE liner at the RWD**

| Description | RWD empty – Drained | RWD full – Drained | RWD full - Seismic | RWD empty - Seismic |
|---|---|---|---|---|
| Max shear stress along liner surface (kPa) | 5.5 | 5.09 | 7.7 | 7.9 |
| Max shear force per m width (kN/m) | 5.5 | 5.09 | 7.7 | 7.9 |
| Yield strength of 1.5mm HDPE Liner (kN/m) | 22 | 22 | 22 | 22 |
| FOS against yield | 4.0 | 4.3 | 2.9 | 2.8 |

19.4.4 The minimum FOS against yield (failure) of the 1.5mm thick smooth HDPE liner is 2.8. See Table 22 above.

19.4.5 The results show that the liner stresses were not exceeded.

19.4.6 The liner forces were also analysed at the liner anchor trenches. Shear stresses develop at the interface between the anchor trench surface and the liner. The detailed calculations are included in Appendix E.

19.4.7 The Factor of Safety at the RWD anchor trench is 1.5. This indicates that the liner can withstand the shear stresses developed at the anchor trenches.

19.4.8 The total tensile strain in the geomembrane is less than 1%. This is due to minimal movement expected because of the engineered base and concrete filled geocell protection layer in the inverted barrier system.

### 19.5 Liner service life assessment

19.5.1 Refer to Section 13.6 for Liner service life assessment.

## 20. TSF engineering features

### 20.1 Topsoil stripping and stockpiling

20.1.1 Stripped topsoil will be stored at the areas shown, as well as in the Valley TSF area.

### 20.2 Water management structures

20.2.1 A 150mm thick reinforced concrete lined solution trench is provided at the perimeter of the Nooitgedacht TSF except the northern flank which is butt up against existing FSN1 TSF. The trapezoidal solution trench is 1m deep with side slopes of 1V:1.5H and a base width of 1m.

20.2.2 The solution trench conveys effluent from the drain outlets as well as other contaminated water from the facility to the silt trap of the RWD. The solution trench of the Nooitgedacht TSF will accommodate the maximum peak discharge from the penstock of 2.87$m^3$/sec.

20.2.3 A concrete lined solution trench will be installed since the effluent is contaminated dirty water. This will prevent seepage of the drain effluent into the underlying soils. It also provides a durable surface for cleaning and maintenance. An HDPE liner can be considered; however the liner is exposed and therefore deteriorates over time. Cleaning and maintenance will need to be done by hand and any damage caused to the liner will need to be repaired immediately.

20.2.4 The drainage collector sump is situated to the south-west of the TSF. The sump has been designed to accommodate a volume of 110 $m^3$. Water collected in the sump will be pumped by a vertical spindle pump into the solution trench to the east of the sump and flow to the RWD.

## 20.3 Access control

20.3.1 A perimeter fence will not be installed around the TSF complex as the fence is prone to theft. Perimeter barrier warning signs will be installed around the perimeter of the TSF complex as an alternative. The signs will be installed during construction. All signs are to comply with the Harmony Gold Mine standards.

20.3.2 A 5m wide all weather access road is provided around the facility to all key infrastructure for operational and monitoring requirements.

## 20.4 Tailings slurry delivery system

20.4.1 Slurry will be delivered from the One Plant to the TSF site via an overland Cement Mortar Lined (CML) flanged steel pipe up to the perimeter of the TSF.

20.4.2 Slurry will be distributed to cyclones via a 900NB steel delivery pipeline around the TSF perimeter. The flange specification is SABS 1123:2500/3. A 900NB pinch valve (or similar approved) will be used at every cyclone. Refer to drawing 2401265 - 014 and 2401265 – 015 for details on the steel delivery pipeline.

20.4.3 Tailings delivery stations are provided every 30m along the starter wall crests to convey tailings slurry from the ring main pipeline to the cyclones. As the facility is raised with tailings, the cyclones will be raised to the new crest elevation. The ring main will be lifted onto new berms as required.

## 20.5 Toe and cyclone walls

20.5.1 The toe walls are constructed at the outer edge of the Nooitgedacht TSF and demarcate the extent of tailings underflow deposition.

20.5.2 A toe wall embankment is specified to accommodate tailings during initial deposition. The toe wall has a height of 5m with a 3m wide crest, outer slope of 1V:1.5H and 1V:2H inner slope. The toe wall embankment will be constructed in 150mm layers to 95% Proctor density at 0% to +2% O.M.C. The toe wall material will be won from borrow pits in the basin of the facility. The starter wall embankment is key cut 1.2m into the foundation.

20.5.3 A cyclone wall will be constructed 55m away from the toe wall. These cyclone walls will provide an elevated platform level to allow for upstream overflow tailings deposition. The cyclone wall has a maximum height of 11m with a 5m wide crest, outer slope of 1V:1.5H and 1V:2H inner slope. This transitions to a 1m nominal wall.

20.5.4 Figure 34 below shows the positions of the toe and cyclone embankments respectively. The details of the toe and cyclone walls are indicated in Drawing No. 2401265 - 002.

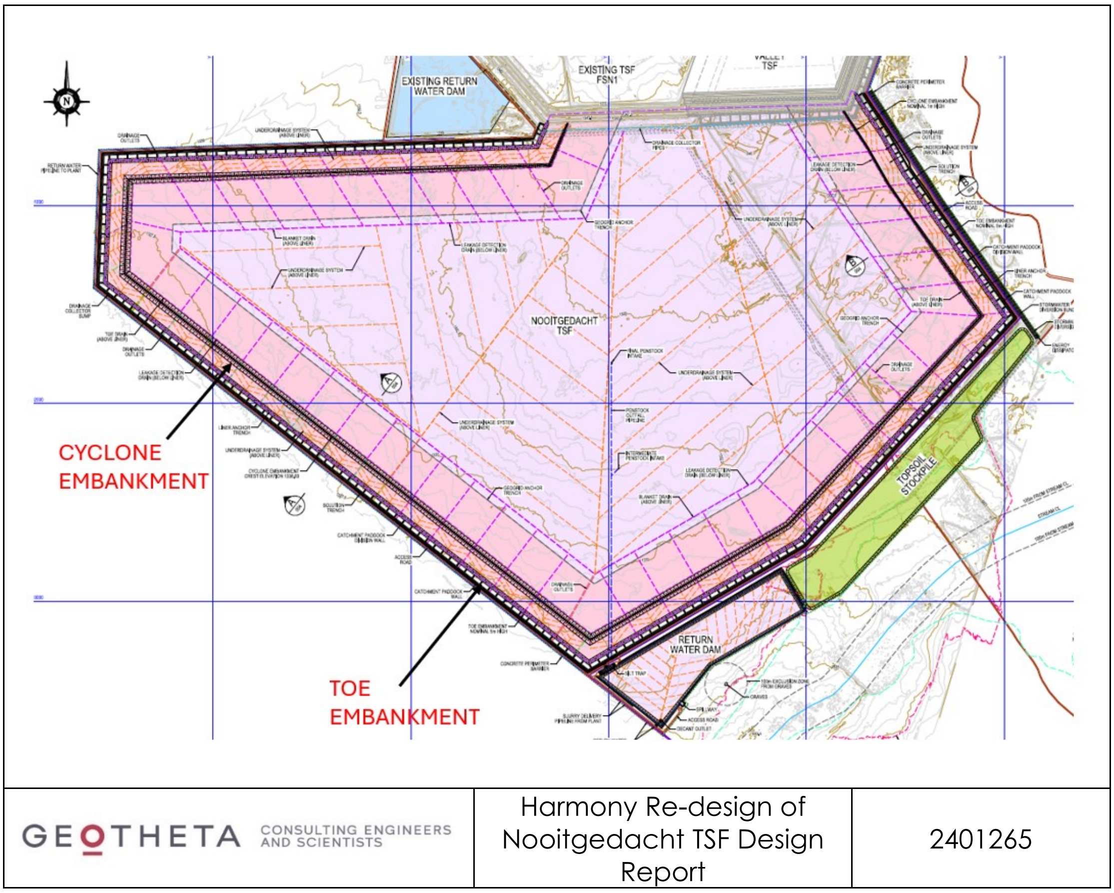


**Figure 34: Toe and cyclone embankment position**

20.6 **Decant system**

20.6.1 The initial decant system comprises a gravity decant and a 900mm HDPE outfall pipe.

20.6.2 Intermediate penstock intake structures are each a reinforced concrete base with one 510mm precast concrete penstock ring intake.

20.6.3 The final penstock intake structure is a reinforced concrete base with four 510mm precast concrete penstock ring intakes.

20.6.4 As the facility rises the penstock intakes will be raised by stacking standard precast concrete penstock rings. The penstock intake structure is located centrally within the TSF basin.

20.6.5 The intermediate and final penstock concrete bases will be located on concrete piles driven to refusal.

20.6.6 Based on previous experience on similar projects, the 900mm HDPE pipe will provide sufficient usage for approximately 10 years, thereafter the pipe may be susceptible to long term creep failure. Due to the pipes being susceptible to creep failure, the 900mm HDPE pipes will be concrete encased. The pipe creep calculations are included in Appendix F.

20.6.7 The configuration of the penstock pipes are shown on drawing No. 2401265 – 009 Sheet. 1 and 2401265 – 009 Sheet. 2. Figure 35 and 36 below show the plan views of the intermediate and final penstock.

20.6.8 The final penstock outfall pipe comprises two 900mm OD PN10 PE100 HDPE pipes encased in concrete. In an event of one of the HDPE pipes being defective, the second HDPE pipe will be functional. The main outfall pipe will flow towards the Return Water Dam (RWD).

20.6.9 Once sufficient head is obtained between 20-25m high, the decant system will change to a syphon system.

20.6.10 A syphon system consists of a syphon head and floating catwalk. The syphon head consists of a fibreglass structure that is airtight and watertight to create buoyancy. A fibreglass outfall pipe which is cut out to accommodate the pan is placed below. Due to the buoyant force, the pan floats on top of the pool of water below the outfall pipe. Water then collects into the pan which then flows into the outfall pipe. To overcome the difference in height between the basin and the wall, a vacuum pump is needed to overcome the head. Once the head is overcome a natural syphon occurs.

20.6.11 The syphon system was initially in use as a decant system on the Kareerand TSF, but this frequently blocked due to not being centralised and then eventually being on the beach area of the facility. If the pool depth is maintained, and the syphon system position is centralised, this then remains the most efficient permanent decant solution.

20.6.12 The detailed syphon system and floating catwalk will be designed just prior to being required based on the operating conditions at that time. The system will be required 9 years after deposition begins.

Once the syphon is in operation, the existing 900mm HDPE outfall pipes will become redundant and will be sealed off.

20.6.13 The syphon system is currently successfully used as a decant system at the PMC (Phalaborwa Mining Company) TSF in Phalaborwa.

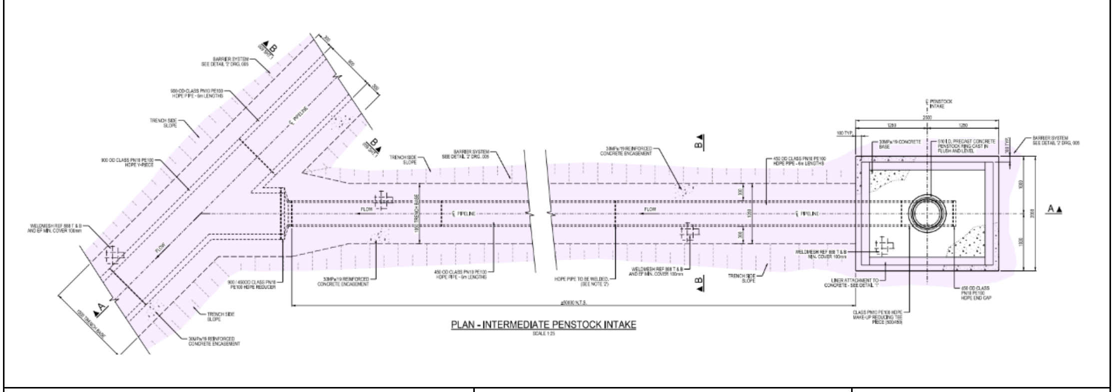


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**Figure 35: Intermediate penstock**

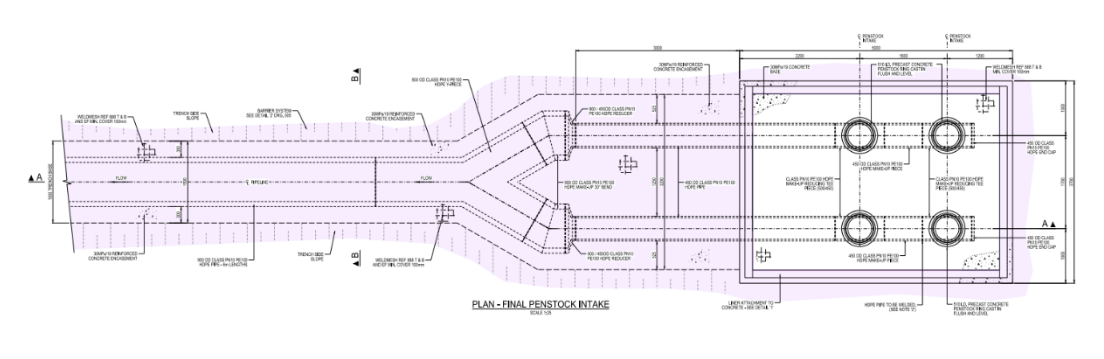


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**Figure 36: Final penstock**

## 21. Maintenance Plan

21.1 An operating, maintenance and surveillance manual has been prepared for the Nooitgedacht TSF and is submitted as a separate report (report reference 2401265 – Harmony – Re-design of Nooitgedacht TSF OMS Manual - R05).

21.2 The objective of the manual is to provide a methodology for the safe, efficient and environmentally responsible management of the TSF and associated infrastructure.

21.3 Adherence to the guidelines provided in the operating, maintenance and surveillance manual will result in continued safe operations of the TSF for the design life.

## 22. Emergency management plan

22.1 Emergency management is addressed in the TSF operating, maintenance and surveillance manual (report reference 2401265 – Harmony – Re-design of Nooitgedacht TSF OMS Manual - R05).

22.2 Emergency management encompasses the following aspects:

- Prevention of emergencies
- Awareness and training
- Continuous monitoring
- On-going assessment of risk
- Emergency response procedures

22.3 A Trigger Action Response Plan (TARP) and Emergency Response Plan (ERP) will be developed by Harmony.

## 23. Operation and development

### 23.1 Method of tailings deposition

23.1.1 Tailings will be cyclone deposited on the eastern, western and southern flanks of the Nooitgedacht TSF.

23.1.2 No cyclone deposition will take place on the outer wall of FSN1 TSF which butts up against the Nooitgedacht TSF. Spigot deposition will be done from FSN1 for pool control only when required. Delivery piping will be placed on the dormant facilities as required. Upstream cyclone deposition will commence when the TSF is at the FSN 1 height of 36m.

23.1.3 During cyclone tailings deposition, the total tailings stream is split into a coarse fraction (underflow) and fine fraction (overflow) by centrifugal separation.

23.1.4 The coarse underflow is usually discharged as a flare or spray in the shape of an inverted cone (spray discharge). A continuous discharge with the appearance of a rope (roping discharge) must be avoided. The optimum split of underflow is usually achieved when the underflow is spraying, but just at the point between spraying and roping. An underflow : overflow mass split of 17 : 83 was used in the stage capacity calculations.

23.1.5 The cyclones are supported on customised steel stands placed in such a manner that an underflow cone of about 1.2m high will be deposited. The cyclone and stand are then moved to an adjacent position to deposit another underflow cone. The cyclone should also be moved to fill in low spots between underflow cones to ensure an even horizontal surface along the top of the outer wall.

23.1.6 The fine overflow will be discharged into the basin through an overflow pipe connected to the cyclone. The end of the overflow pipe discharging into the basin should always be at a lower elevation than the cyclone vortex finder. During commissioning the overflow pipes must be long enough to discharge overflow directly into the basin area beyond the toe drains.

23.1.7 Overflow must be discharged well beyond the coarse underflow zone and must not be discharged directly over the exposed toe or blanket drains during commissioning.

23.1.8 Deposition of the tailings material must be done according to the deposition plan. The deposition plan must ensure that the rate of rise of the cyclone underflow is greater than the rate of rise of the basin.

23.1.9 The deposition position into the basin is to be selected based upon managing the height of solids around the TSF perimeter and the shape of the pool. The deposition locations are to be rotated around the facility to ensure adequate beach formation and favourable pool location and size.

## 23.2 Method of embankment construction

23.2.1 Nooitgedacht TSF will be built in two stages. The first stage will consist of coarse underflow tailings being filled between the toe wall and cyclone wall, by downstreaming from the cyclone wall.

23.2.2 The cyclone wall was sized for freeboard requirements and the toe wall was sized for slope stability requirements.

23.2.3 Upstream deposition will commence once the area between the toe wall and the cyclone wall has been filled with cyclone underflow material. This will be at elevation 1338 mamsl.

23.2.4 When the upstream method of embankment construction is employed, the facility is raised using the underflow material. Tailings material is then placed on previously deposited tailings which has consolidated sufficiently and is safe to access. This is shown in Figure 37.

23.2.5 The upstream deposition cycle must allow for the previous layer of deposition to dry before the next layer is deposited.

23.2.6 The two stage deposition methods as described above has been implemented and is operational on the Elikhulu Upper and Lower compartments.

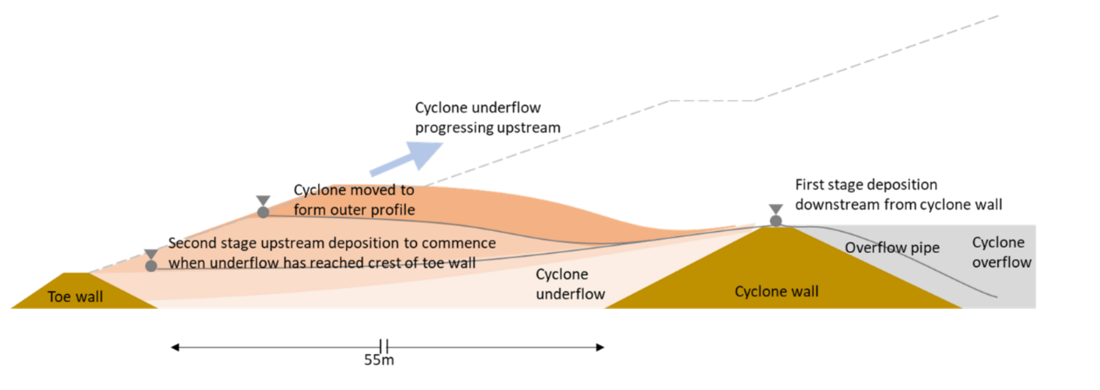


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**Figure 37: Typical two-stage cyclone embankment construction**

### 23.3 Freeboard and pool control

23.3.1 Freeboard is defined as the vertical distance between the operating pool level and the lowest point on the top of the outer wall. The minimum freeboard must be equal to the water level rise that is caused by a 1:50 year 24-hour storm event plus 800 mm [Regulation 704 of the Water Act - Act 36 of 1998]. The minimum freeboard requirement is illustrated in Figure 38 below.

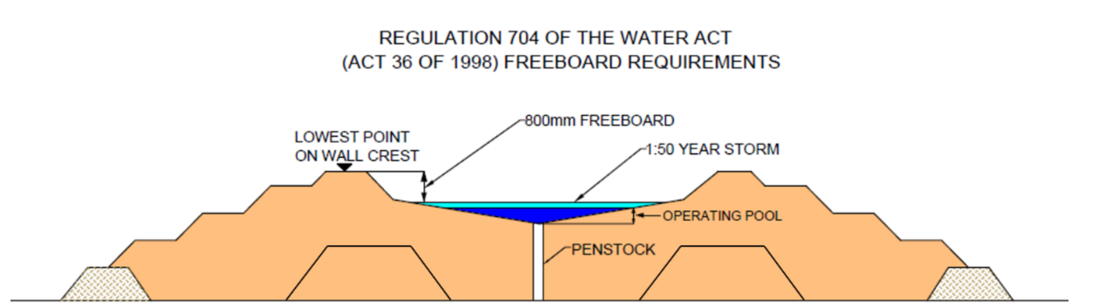


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**Figure 38: Freeboard requirement**

23.3.2 The facility must be operated so that it can always contain the 1:50 year 24-hour storm event on top of the normal operating pool level whilst maintaining 800mm freeboard on the normal operating pool level whilst maintaining 500mm freeboard.

## 24. Closure plan

### 24.1 Closure objectives

24.1.1 The objectives of the closure and rehabilitation procedures will be:

- To establish a self-sustaining eco-system solution that minimises the need of continuous maintenance.
- To minimise the potential impact to the surrounding environment.
- To create safe and stable landforms.
- To return the site to beneficial land use.

24.1.2 In achieving these objectives, the closure and rehabilitation procedures must comply with the relevant legislation and conform to acceptable international practice.

24.2 **Closure considerations**

24.2.1 The TSF is to be constructed and operated towards final closure.

24.2.2 A detailed closure plan will be developed during the life of the TSF.

24.2.3 The objectives for the closure and rehabilitation of the TSF is to prevent pollution to the surrounding environment and ensure a stable facility is maintained.

24.2.4 The final surface of the facility will be the same configuration as the operating dam with inter-bench slopes of 1V:4H.

24.2.5 The outer surface, the benches and the shape top surface should be covered with a 300 mm thick layer of stripped and stockpiled topsoil (retained from earlier construction removal). The topsoil will be grassed and vegetated to form a self-sufficient eco-system. (The vegetation design will be done by others).

24.3 **Final geometry**

24.3.1 It is intended that the upper surface of the facility will be shaped to divert rainfall off the facility.

24.3.2 The outer slopes of the facility ensures structural stability with limited erosion damage.

24.4 **Water control**

24.4.1 Stormwater around the facility will be gravity-drained away from the Nooitgedacht TSF. Vehicle and equipment access ramps will double as water run-off increases.

24.4.2 The run-off from the side slopes of the TSF wall will be attenuated by the vegetation cover established at closure.

24.4.3 A trapezoidal stormwater diversion trench and bund are provided along the upstream flank of the TSF to divert clean stormwater away from the TSF site. This ensures that clean and dirty water systems are kept separate.

24.4.4 A bund wall will be constructed on the outer edge of the access road to prevent flow of water on the access road. The compacted diversion bund embankment is 2.5m high and has a 2.5m wide crest with outer slopes of 1V:1.5H. The diversion trench is 2.5m deep with side slopes of 1V:1.5H and a base width of 2.5m.

24.4.5 Dirty runoff water within the Nooitgedacht TSF catchment area is routed to the RWD via the concrete lined solution trench.

### 24.5 Vegetation

24.5.1 Vegetation on the surface and outer slopes of the facility will reduce erosion and dust generation.

24.5.2 Vegetation on all the outer side slopes is to be established at closure. The vegetation establishment and maintenance, and the associated irrigation systems, will be designed by others.

## 25. Drawings

25.1 Issued for Construction drawings are included in Appendix G.

## 26. Bill of quantities

26.1 A Bill of Quantities has been prepared and is included in Appendix H. The Bill of Quantities is issued separately for use by Harmony for tender purposes.

## 27. Price estimates and construction timelines

27.1 In September 2023, rates and costs for the Nooitgedacht TSF construction were provided by:

- Stefanutti Stocks Inland (SSI)
- Intasol
- Wilson Bayly Holmes Ovcon (WBHO)

27.2 A priced Bill of Quantities from each contractor is included in Appendix I. P's and G's at 17% of the total construction cost are added.

27.3 A summary of the estimated capital costs from each contractor is provided in Table 23 below.

**Table 23: Budget capital costs (Rands excluding VAT)**

| | INTASOL | WBHO | SSI |
|---|---|---|---|
| Preliminary and general | 406 313 422 | 415 010 539 | 393 635 951 |
| Site clearance | 130 392 233 | 104 101 603 | 121 828 851 |
| Earthworks | 541 678 190 | 684 521 491 | 618 540 133 |
| Small earth dams | 806 977 | 816 077 | 787 194 |
| Earthworks (roads, subgrade) | 2 672 841 | 2 076 157 | 1 460 334 |
| Concrete (structural) | 145 878 877 | 143 224 394 | 140 609 721 |
| Medium pressure pipelines | 443 767 044 | 404 343 561 | 426 469 664 |
| Sewers | 12 178 758 | 13 410 762 | 13 434 192 |
| Stormwater drainage, fence | 569 473 | 532 784 | 466 564 |
| Geosynthetics | 1073 460 853 | 1026 608 622 | 960 574 921 |
| Timber (structural) | 3 588 264 | 4 456 224 | 4 045 146 |
| Cyclones | 35 085 444 | 57 146 790 | 27 288 871 |
| Sub-total | **2 796 392 376** | **2 856 249 004** | **2 709 141 544** |
| Estimated professional fees | 100 000 000 | 100 000 000 | 100 000 000 |
| Sub-total | **2 896 392 376** | **2 956 249 004** | **2 809 141 544** |
| Construction contingency | 559 278 475 | 571 249 801 | 541 828 309 |
| **TOTAL BUDGET PRICE** | **3 455 670 851** | **3 527 498 804** | **3 350 969 852** |

27.4 The recommended budget allocation for the Nooitgedacht TSF construction is R3.3 billion (incl. contingency). The price includes R100 million professional fees and a R400 million steel delivery pipe.

27.5 The construction timeline is estimated to be 55 months (4.6 years).

27.6 The budget cash flow and schedule are included in Appendix J and Appendix K respectively.

## 28. Quality assurance and quality control

28.1 The construction of the Nooitgedacht TSF and associated infrastructure will be done according to strict quality assurance and quality control requirements.

28.2 The Liner CQA report is submitted separately under reference 2401265 - Harmony – Re-design of Nooitgedacht TSF - CQA - R04.

28.3 The civil works will be done according to SANS 1200, subject to Particular Specifications for certain aspects.

## 29. Report references

29.1 The report references for the Nooitgedacht TSF and associated infrastructure are listed below:

- Design basis memorandum - 2401265 – Harmony – Re-design of Nooitgedacht TSF – DBM - R01.

- Dam break analysis report - 2210506 – Harmony – Nooitgedacht TSF Design - R02.
- Nooitgedacht TSF Design report - 2401265 – Harmony – Re-design of Nooitgedacht TSF - R02.
- Construction specifications - 2401265 – Harmony – Re-design of Nooitgedacht TSF – CS - R03.
- Liner Construction Quality Assurance (CQA) - 2401265 – Harmony – Re-design of Nooitgedacht TSF – CQA - R04.
- Operating, maintenance and surveillance manual - 2401265 – Harmony – Re-design of Nooitgedacht TSF – OMS - R05
- SCPTu report - 2210506 – Harmony – Nooitgedacht TSF Design – SCPTu - R07.

## 30. Conclusions and recommendations

Based on the detailed design of the new Nooitgedacht TSF, the following conclusions and recommendations can be drawn:

30.1 Safe operating systems and procedures are to be implemented during operation of the facility.

30.2 Key parameters of the Nooitgedacht TSF design are:

- Maximum final height: 93m
- Footprint area of facility: 805 Ha
- Total capacity: 804 million tons
- Total deposition period at 2 000 000 tons per month: 34 years
- Maximum rate of rise (Basin): 3.77m/year
- Maximum rate of rise (Embankment): 2.89m/year
- Deposition method: Cyclone

30.3 The limiting factor for the facility's storage capacity is the freeboard requirement. At the maximum final height, the freeboard will be 2m and the rate of rise of the basin will be higher than the rate of rise of the outer walls.

30.4 According GISTM, the Nooitgedacht TSF has an **Extreme Consequence Classification** rating.

30.5 Based on SANS 10286, the Nooitgedacht TSF has a **High hazard classification** rating.

30.6 Nooitgedacht TSF will be developed with an intermediate outer slope of 1V:3H between benches. The overall slope of the facility is 1V:4H. The inter-bench height is 10.5m and the benches are 10.5m wide.

30.7 The engineered toe wall embankment is 5m high with a 3m wide crest and an outer slope of 1V:1.5H and inner slope of 1V:2H. The toe wall embankment will be constructed in 150mm layers to 95% Proctor density at optimum moisture content.

30.8 The cyclone walls will be constructed 55m away from the toe wall, providing an elevated platform to allow for downstream overflow tailings deposition. The cyclone wall has a maximum height of 11m with a 5m wide crest, and outer and inner slopes 1V:2H. This transitions to a 1m nominal wall.

30.9 The minimum Factor of Safety against failure is 2.0 under drained conditions, 2.0 under undrained conditions, 1.1 under post seismic, post liquefaction or residual conditions and 1.2 under pseudo-static conditions. The slope Factors of Safety comply with local regulations and international and international slope stability standards.

30.10 The gold tailings material classified as a Type 3 waste. This necessitates a Class C barrier system. From an independent review by Legge and Associates, an 'inverted barrier' system is more practical and feasible. The inverted barrier reduces seepage by changing the flow through the liner from Bernoulli flow at discontinuities to D'Arcian flow controlled by the tailings permeability at these points. The TSF stability is enhanced by omitting lower strength compacted clay layers and the geomembrane protection layers. This 'inverted barrier' system is used in the Nooitgedacht barrier system.

30.11 The TSF liner system comprises two different sections. These are shown in Figure 1 in the Executive Summary.

- Liner system 1 - Over the existing FSN4 TSF footprint and the outer edge wall, where high liner stresses are present, the liner system comprises (from top down), a 300mm thick layer of tailings, 600kN/m geogrid (or similar approved), a 300mm thick layer of tailings, 1.5mm thick double textured HDPE liner underlain by a 300mm ripped and recompacted layer of in-situ base preparation material.
- Liner system 2 - The liner system in the inner basin area comprises (from top down), 1.5mm thick double textured HDPE liner underlain by a 300mm ripped and recompacted layer of in-situ base material.

30.12 The under-liner leakage detection drains are 160mm slotted Drainex HDPE pipes surrounded in 19mm stone which is enclosed in a geofabric. The leakage detection drain outlet pipes discharge into the solution trench.

30.13 The above-liner toe drain is a 160mm slotted HDPE pipe surrounded in 19mm stone overlain by a layer of 6mm stone all enclosed in a geofabric. The toe drain outlet pipes discharge into the solution trench.

30.14 The above liner blanket drain is a 160mm slotted HDPE pipe surrounded in 19mm stone overlain by layers of 6mm stone and graded filter sand, enclosed in a geofabric. The blanket drain outlet pipes discharge into the solution trench.

30.15 A 150mm thick reinforced concrete lined solution trench is provided along the perimeter of the TSF (except the northern flank where the TSF butts against the existing FSN1 TSF). The solution trench is 1m deep, base width 1m, side slopes 1V:1.5H. The solution trench discharges into the RWD and will accommodate the maximum peak penstock discharge of 2.87m$^3$/sec.

30.16 A hydrotechnical assessment was done to determine the climatic and meteorological data. The Return Water Dam (RWD), drainage collector sump and associated water infrastructure were then sized.

30.17 The RWD total storage capacity is 606 500m$^3$, ensuring spill frequencies are less than once every 50 years.

30.18 The RWD has a concrete lined spillway to discharge excess water without overtopping of the RWD embankment walls with 800mm freeboard. The RWD spillway is designed to discharge the 1:10 000 24-hour Probable Maximum Flood volume of 39.3m$^3$/sec.

30.19 A silt trap is installed upstream of the RWD. The silt trap includes infrastructure to enable cleaning. This allows solids to settle out of the water before entering the RWD, minimising sedimentation in the RWD. The silt trap is a 2.25m deep, two-compartment, reinforced concrete water retaining structure with a concrete spillway to route de-silted water to the RWD. A sluice enables separate operation of each compartment. A sump has been included in each compartment of the silt trap to enable water to be pumped out prior to mechanical removal of silt.

30.20 The RWD liner system (from top down) comprises 200mm thick 20Mpa concrete filled geocells (SW-356/200HD or similar approved) as a wearing surface, a 1.5mm thick smooth HDPE liner, underlain by 300mm in-situ base preparation layer.

30.21 The RWD under drains comprise 160mm slotted HDPE pipes encased in 19mm washed stone. The stone is wrapped in geofabric.

30.22 Concrete poles with warning signs will be installed around the TSF. A 5m wide access road is provided around the facility for operational and monitoring requirements.

30.23 The facility is to be constructed and operated to ensure that the designed outer slope profile is achieved, and that operations are safe and environmentally responsible.

30.24 Safe operating systems and procedures are to be implemented during operation of the facility.

30.25 Monitoring of the facility is to be undertaken as outlined in the Operating, Maintenance and Surveillance Manual.

30.26 The preliminary BOQ pricing returns are:

| | |
|---|---|
| **SSI** | |
| Construction cost (with inverted barrier): | R 2.8 billion |
| Add contingency at 20%: | R 541 million |
| **Total excluding VAT** | **R 3.35 billion** |
| **INTASOL** | |
| Construction cost (with inverted barrier): | R 2.8 billion |
| Add contingency at 20%: | R 559 million |
| **Total excluding VAT** | **R 3.45 billion** |
| **WBHO** | |
| Construction cost (with inverted barrier): | R 2.9 billion |
| Add contingency at 20%: | R 571 million |
| **Total excluding VAT** | **R 3.52 billion** |

30.27 The recommended budget allocation for the Nooitgedacht TSF construction is R3.3 billion (incl. contingency). The price includes R100m professional fees and a R400m steel delivery pipe.

30.28 The construction timeline is estimated to be 55 months (4.6 years).

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In terms of Geotheta Quality Policy, this report has been reviewed, product corrected and certified okay for distribution and use**.**

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# APPENDIX A: WASTE CLASSIFICATION REPORT

# APPENDIX B: GEOTECHNICAL INVESTIGATION REPORT

# APPENDIX C: STAGE CAPACITY

# APPENDIX D: SLOPE STABILITY OUTPUTS

# APPENDIX E: LINER CALCULATIONS

# APPENDIX F: PENSTOCK OUTFALL PIPE CREEP CALCULATIONS

# APPENDIX G: DRAWINGS

# APPENDIX H: BOQ (UNPRICED)

# APPENDIX I: BOQ (PRICED)

# APPENDIX J: BUDGET CASH FLOW

# APPENDIX K: BUDGET SCHEDULE

# APPENDIX L: LEGGE AND ASSOCIATES REVIEW REPORTS

# Geotheta Report Distribution Record

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| Report No. | 2401265/R02 |
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