HARMONY GOLD MINING COMPANY LIMITED (HARMONY GOLD)

VALLEY TSF - RETURN WATER DAM REDESIGN

DESIGN REPORT

GEOTHETA
CONSULTING ENGINEERS
AND SCIENTISTS

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Randfontein Office Park
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Randfontein
1759

2412469/R01R July 2025

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Report Reference Number: 2412469/R01R

Date: July 2025

COMPILED				
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Disclaimer

Data provided to Geotheta

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Data determined by Geotheta

Opinions presented in this report apply to the site conditions and features as they existed at the time of Geotheta's investigations, and those reasonably foreseeable. These opinions do not necessarily apply to conditions and features that may arise after the date of this report, about which Geotheta had no prior knowledge nor had the opportunity to evaluate.

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Neither Geotheta nor any of the authors of this report have any material present or contingent interest in the outcome of this report, nor do they have any pecuniary or other interest that could be reasonably regarded as can affect their independence or that of Geotheta.

Geotheta has no beneficial interest in the outcome of the technical assessment which can affect its independence.

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Geotheta assumes full professional liability for our designs. This may be limited per our professional liability insurance maximums, and also to ratios of professional fees per the professional appointment agreement.

Executive Summary

Geotheta (Pty) Ltd (Geotheta) was appointed by Harmony Gold Mining Company Ltd (Harmony) to redesign the Valley TSF decant, solution trench and return water dam (RWD) at the Free State Operations.

Geotheta previously did a design for the Valley TSF and its two return water dams in March 2024. The previous design included a new lined 'Valley Return Water Dam' to the north in the location of the existing FSN2 RWD and the unlined FSN1 RWD.

Harmony decided that lining two return water dams is not feasible. The previous design of the Valley TSF was therefore altered to only utilise and line the FSN1 RWD, which would then be known as the new Valley Return Water Dam.

The construction of the new Valley RWD will involve managing stormwater effluent from the dormant FSN1 TSF in the existing FSN1 RWD while the new Valley RWD is under construction.

This will be done by creating two compartments within the existing FSN1 RWD by utilizing the existing divisional wall. Each compartment will be isolated by extending the divisional wall to the perimeter embankments and the dam constructed sequentially on one compartment while the other will be used to collect stormwater from the FSN1 TSF.

Each compartment will need to accommodate 150 000 m^3 of stormwater while the other is constructed. The existing capacity of Compartment 2 is more than 150 000 m^3. Compartment 1 can therefore be constructed first.

The present capacity of compartment 1 will be confirmed once all the stored water is pumped to Dam 13. Construction can start on Compartment 2 if there is sufficient existing capacity to store 150 000 m^3 in Compartment 1.

During construction and extreme storms, water from the temporary storage compartment (1 or 2) will need to be pumped to Dam 13 at a rate of 16 500 m^3/day. This will prevent inundation of the works in the other compartment. The new Valley RWD construction must preferably take place during the dry season (April – October).

The new Valley RWD will have two compartments and a storage capacity of approximately 520 000 m^3 to accommodate stormwater from the FSN1 TSF and process water from the Valley TSF. The divisional wall retained from earlier construction separates the compartments. During extreme storms, return water is required to be pumped at a rate of 27 000 m^3/day. During normal operations return water is required to be pumped at a rate of 18 500 m^3/day.

In addition to the Valley TSF return water dam redesign, the TSF decant and solution trench were redesigned. The penstock was repositioned to the geometric centre of the TSF, and the access catwalk was positioned to the western flank. The penstock outfall pipe will be routed to the eastern solution trench.

The solution trench on the eastern and southern flanks of the Valley TSF will transport effluent from the penstock and drains to the new Valley RWD. Additionally, the northern solution trench will direct flow from the north down to the western flank of FSN1 TSF, conveying drain effluent to the new Valley RWD.

These solution trenches will be concrete lined. In addition, the solution trench surrounding the FSN2 TSF will be a regraded earth trench that will merge into the newly constructed concrete solution trenches.

The recommended budget allocation for the Valley TSF construction is R807 million (incl. contingency) over 2 years.

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List of abbreviations

AASHTO	:	American Association of State Highway and Transportation Officials
ASTM	:	American Society for Testing and Materials
CQA	:	Construction Quality Assurance
DWS	:	Department of Water and Sanitation
FoS	:	Factor of Safety
Geotheta	:	Geotheta (Pty) Limited
GISTM	:	Global Industry Standard on Tailings Management
GN	:	Government Notice
GRI	:	Geosynthetic Research Institute
Ha	:	Hectare
HDPE	:	High Density Polyethylene
kPa	:	kilo Pascal
mamsl	:	Meters above mean sea level
MAP	:	Mean Annual Precipitation
MCE	:	Maximum Credible Earthquake
Mod	:	Modified
NEMWA	:	National Environmental Management: Waste Act No 59 of 2008
NHRA	:	National Heritage Act
OMC	:	Optimum Moisture Content
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
SCPTu	:	Seismic Cone Penetration Test (with pore water pressure)
TSF	:	Tailings Storage Facility
UV	:	Ultraviolet
WULA	:	Water Usage Licence Application

1. Introduction

1.1 Geotheta was appointed by Harmony for the redesign of the Valley TSF infrastructure at the Harmony operations in the Free State.

1.2 The redesign includes a revised decant system, solution trench and a return water dam (RWD).

1.3 The existing RWD will be reconstructed while receiving stormwater effluent from the dormant FSN1 TSF.

2. Tailings storage facility location

2.1 The Valley TSF is located approximately 8 km north-west of Welkom Central in the Free State Province, South Africa.

2.2 The northern boundary of the site is demarcated by the R34 roadway. The R30 and the R710 roadways delineate the eastern and southern limits respectively. The Valley TSF location is shown in Figure 1.

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Figure 1: Valley TSF location

3. Terms of reference

3.1 Harmony issued an invitation to tender *CL202209(13) DG* for the design of the Valley TSF on 19 October 2022.

3.2 Geotheta submitted a proposal (reference: *2210513 - Harmony – Valley TSF Design - P01*) on the 05 November 2022.

3.3 A letter of award for the design of the Harmony Valley TSF (contract number: *FG/23/01/0003*) was issued to Geotheta on 31 May 2023.

3.4 Geotheta were requested to revise the design to utilize the inverted barrier system.

3.5 Geotheta submitted a proposal (reference: *2210513 - Harmony – Valley TSF Design - P02*) on the 06 December 2023 and received confirmation of this order on 12 December 2023.

3.6 Geotheta were requested on 8 January 2025 to submit a proposal for the redesign of the Valley TSF decant, solution trench and RWD.

3.7 Geotheta submitted a proposal (reference: *2412469 - Harmony – Valley TSF Design - P01*) on 09 January 2025 and received confirmation of this order on 14 April 2025.

4. Legislative requirements

4.1 The design, construction, operation and closure of mine residue facilities is controlled by the following legislation:

- National Water Act, 1998 (Act 36 of 1998).
- National Environmental Management Waste Act (Act 59 of 2008) (NEMWA).
- Natural Environmental Management Act (Act 107 of 1998) (NEMA).
- Mine Health and Safety Act No. 29 of 1996 and Regulations.
- Government Notice (GN) 636: National Norms and Standards for Disposal of Waste to Landfill.

5. Applicable standards and guidelines

5.1 The following standards and guidelines were used to develop the design criteria:

- South African National Standards (SANS) 10286 Code of Practice for Mine Residue.
- Global Industry Standard on Tailings Management (GISTM).
- American Society for Testing and Materials (ASTM).
- SANS 1526:2015 Edition 3 – Thermoplastics polyolefin sheeting for use as a geomembrane.
- SANS 10409: Design, selection and installation of geomembranes.
- Geosynthetic Research Institute (GRI) GM13.
- SANS 1200: Standardized Specification for Civil Engineering Construction.

6. Scope of work

6.1 The following work was done:

6.1.1 Site visit.

6.1.2 Repositioning of the penstock and access catwalk to the optimal position for the final height of the Valley TSF.

6.1.3 Redirecting the penstock outfall pipe to flow into the new Valley RWD.

6.1.4 Designing the solution trench from the north and down the west flank of FSN1 to the new Valley RWD.

6.1.5 Redirecting any existing underdrains from FSN1 TSF to decant into the new solution trench.

6.1.6 Designing the solution trench on the eastern and southern flanks of the Valley TSF, flowing into the new Valley RWD.

6.1.7 Time-step sizing and design of the new–lined Valley RWD.

6.1.8 A functional silt trap for the new Valley RWD.

6.1.9 A method statement on RWD construction for the diversion and control of existing water flow into the dam during construction.

6.1.10 Updated IFC drawings.

6.1.11 Updated priced Bill of Quantities.

6.1.12 Updated construction schedule.

6.1.13 Updated construction specifications.

6.1.14 Optimal position of the construction contractor's site.

7. Exclusions:

7.1 The following was not changed:

7.1.1 Stage capacity assessments and deposition requirements.

7.1.2 Preparatory earthworks design.

7.1.3 Dam Break Analysis (DBA).

7.1.4 Catchment paddock design.

7.1.5 Seepage analysis and underdrainage design.

7.1.6 Barrier design.

7.1.7 Geotechnical assessments and stability analysis.

7.1.8 Slurry delivery piping design.

7.1.9 Storm diversion systems.

7.1.10 Closure and aftercare recommendations.

7.2 The previous Valley TSF design report (report reference: *2210513 - Harmony - Valley TSF - R03RC*) covers the above scope of work. The report is included in Appendix A.

7.3 Further exclusions that are not covered in either design include:

7.3.1 Financial Tender adjudication. Geotheta will assist in the financial adjudication if requested to do so.

7.3.2 Permitting, licenses and similar applications - these will be done by the mine's environmental consultants or practitioners.

8. Design Criteria

8.1 The design criteria outlined in Table 1 was used in the design of the new Valley RWD.

Table 1: General design criteria

Criteria	Unit	Value
Rainfall station	-	Odendaalrus Station (SAWS station No. 0364322 X)
Evaporation data	-	Sand Vet Sentrum C4E009
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
1:10 000 year 24-hour rainfall	mm	269

9. Hydrotechnical assessment

9.1 Background

9.1.1 A hydrotechnical assessment was done to determine climatic and meteorological data for the site.

9.1.2 The data was used to complete the time-step water balance model.

9.2 Climate and meteorological data

9.2.1 The capacity of the RWD was based on the daily rainfall depth from the rainfall data obtained from the Odendaalrus Station (SAWS station No. 0364322 X rainfall station). The average monthly lake evaporation based on the Sand Vet Sentrum C4E009.

9.2.2 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.

9.2.3 Rainfall data collected from Odendaalrus Station started on 1 January 1898 and ended on 31 December 2018.

9.2.4 The Odendaalrus Station relative to the Valley TSF is shown in Figure 2.

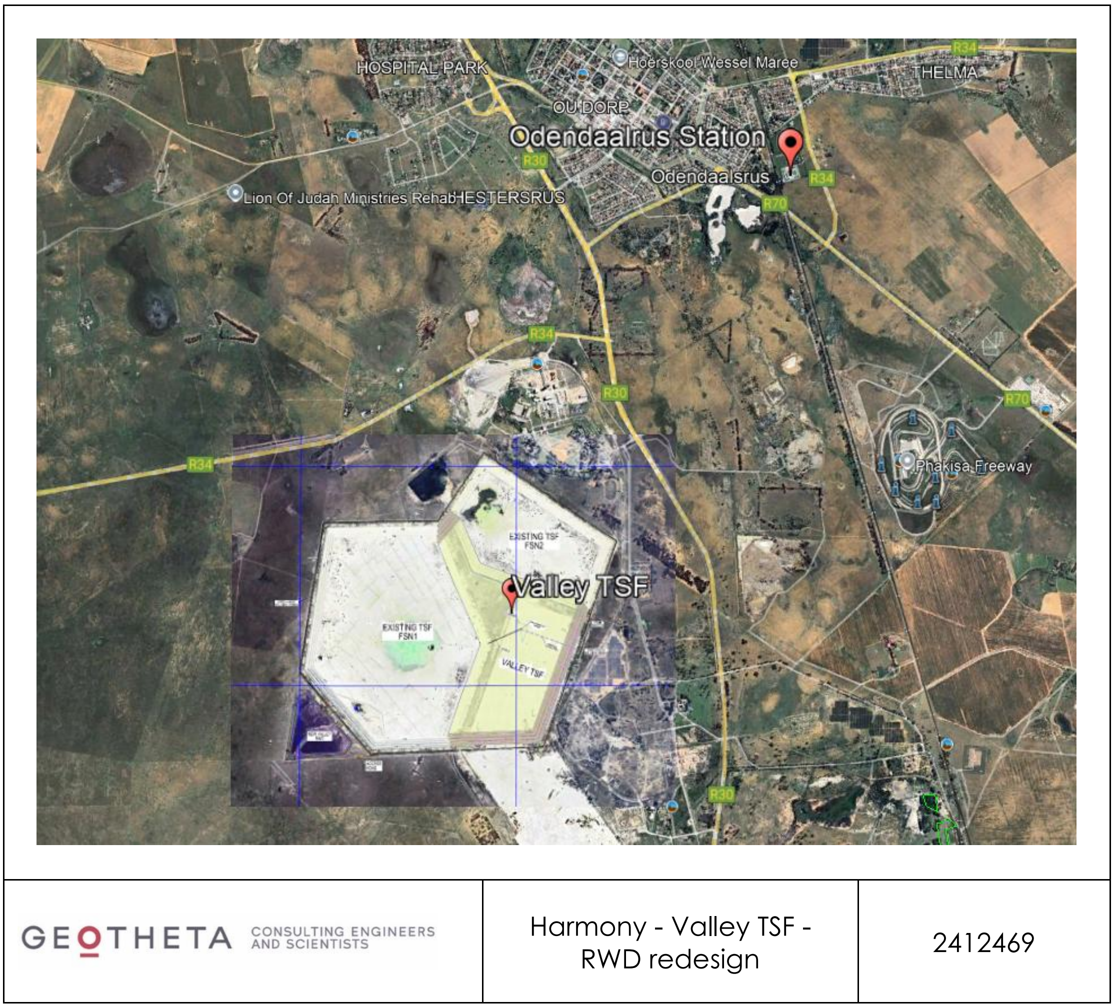

Figure 2: Odendaalrus Station relative to the Valley TSF

9.2.5 Monthly rainfall and evaporation data is provided in Table 2.

Table 2: 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
Annual total	**514.3**	**1749.2**

9.2.6 The rainfall depths per return period against the storm durations are shown in Table 3 . This data was obtained from design rainfall software (Smithers and Schulze, 2002).

Table 3: Storm rainfall depths

Duration	Rainfall Depth (mm)						
(m/h/d)	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

9.2.7 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 3 and Table 4 respectively.

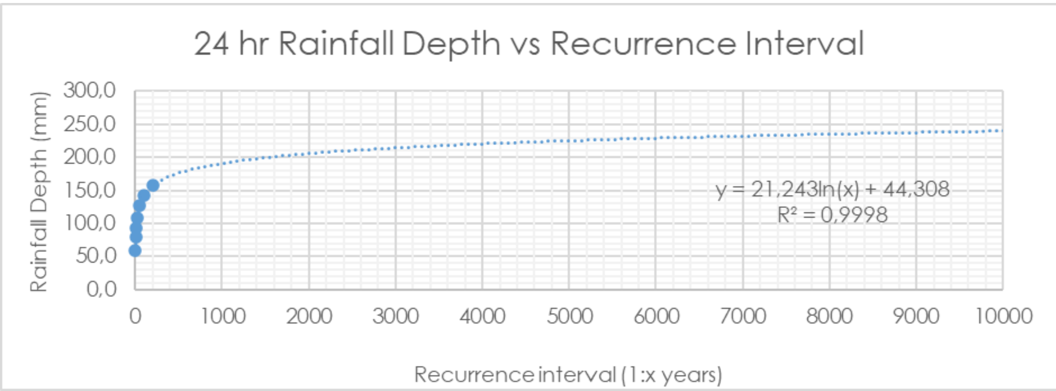

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Figure 3: Determination of the PMF

Table 4: Extrapolated rainfall data.

Input data	
Recurrence interval (years)	**24 hr rainfall depth (mm)**
2	59
5	79
10	94
20	108
50	127
100	141
200	157
Output data	
1 000	191
2 475	235
5 000	252
10 000	269

9.2.8 Monthly temperatures were obtained from website (www.meteoblue.com). Average monthly temperatures and ranges are provided in Table 5.

Table 5: 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

9.2.9 The summary of the monthly climatic data is provided in Figure 4.

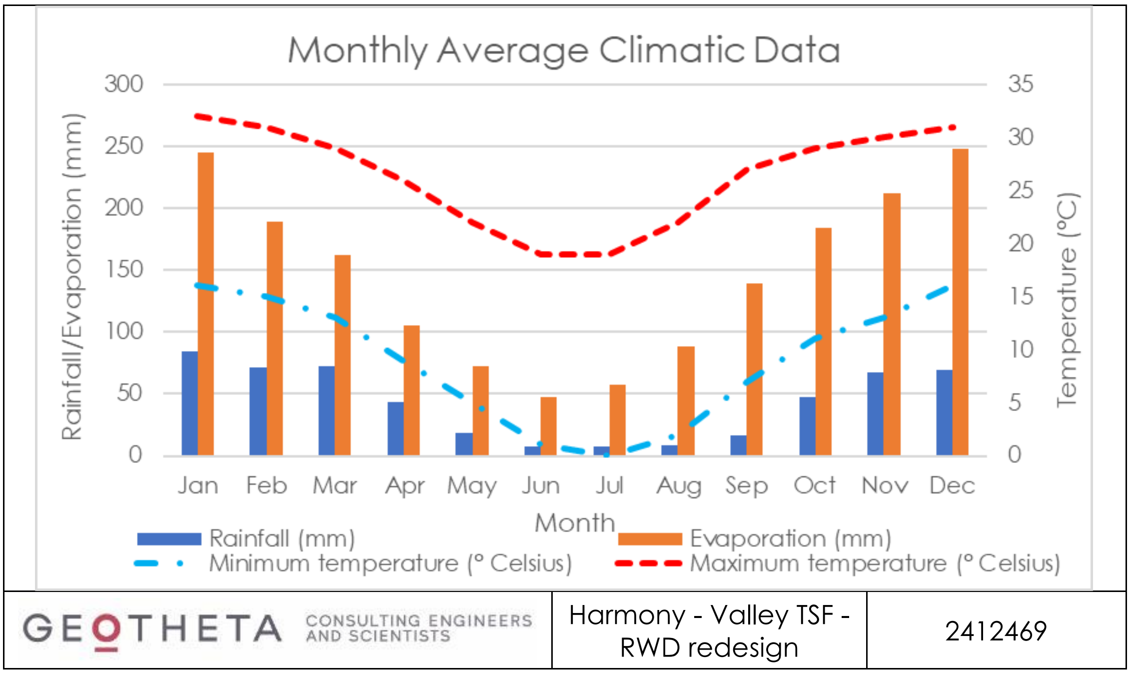

Figure 4: Monthly Climatic Data Summary

10. Return Water Dam (RWD) redesign

10.1 Background

10.1.1 For this report, the existing FSN1 RWD is known as the old RWD, and the redesigned RWD is known as the new Valley RWD. The old RWD will be redesigned, reconstructed and lined to become the new Valley RWD.

10.1.2 Two time-step water balance analyses were done. One for the old RWD handling stormwater run-off from the FSN1 TSF, and another for the new Valley RWD managing stormwater from FSN1 TSF, process water, and stormwater from Valley TSF.

10.1.3 The first water balance was done to allow the old RWD to be reconstructed into the new Valley RWD while receiving stormwater effluent from the dormant FSN1 TSF.

10.1.4 The second water balance was done to determine the required capacity of the new Valley RWD for the operation of the Valley TSF.

10.1.5 The capacity of the RWD was based on the daily rainfall depth from the rainfall data obtained from the Odendaalrus Station (SAWS station No. 0364322 X rainfall station). The average monthly lake evaporation based on the Sand Vet Sentrum C4E009.

10.1.6 The daily rainfall data and the 1:50 year storm is indicated in Figure 5.

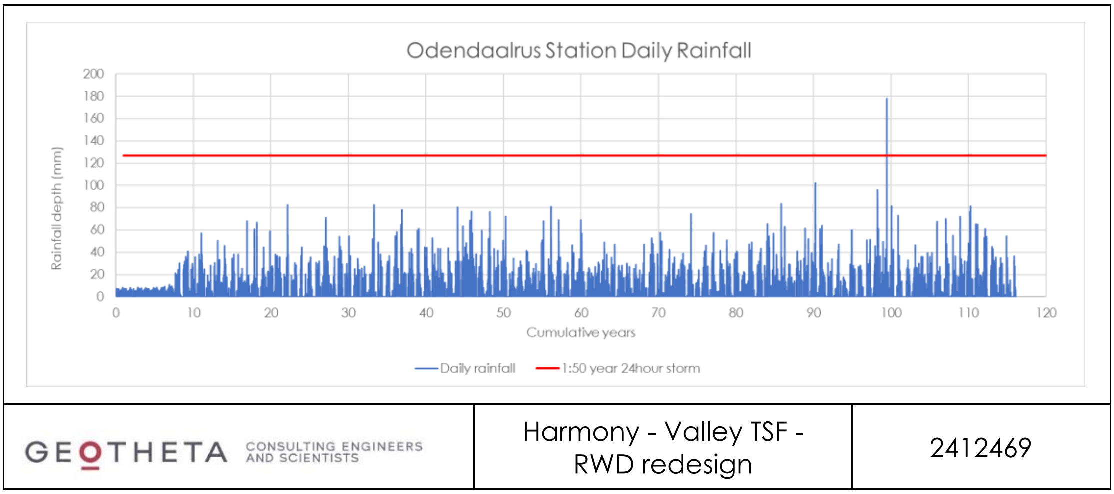

Figure 5: Daily rainfall record for Odendaalrus Rainfall Station (SAWS station No. 0364322 X)

10.1.7 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.

10.1.8 Rainfall data collected from Odendaalrus Station started on 1 January 1898 and ended on 31 December 2018.

10.1.9 Government Notice 704 of the National Water Act (Act No 36 of 1998) requires:

- Storage and spillage to be considered at each time step to determine the frequency of spillage.
- The RWD should not spill more than once every 50 years.

10.1.10 The variables used in the time-step water balance are shown in Table 6.

Table 6: Variables used in time-step 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

10.1.11 The water from the old RWD is pumped to Dam 13. However, there is presently a blockage on the route to Dam 13 that needs to be alleviated for the construction and operation of the new Valley RWD.

10.1.12 The daily water balance model has been developed by utilising a continuity equation (inflow – outflow = Δ storage) for each component. Storage capacity of Dam 13 and the plant was not considered in this assessment.

10.2 Old return water dam (existing FSN1 RWD) water balance

10.2.1 The water balance model comprises two main components (the dormant FSN1 TSF and the old RWD).

10.2.2 The average monthly water balance model (schematic) with the inputs and outputs for each component is shown in Figure 6.

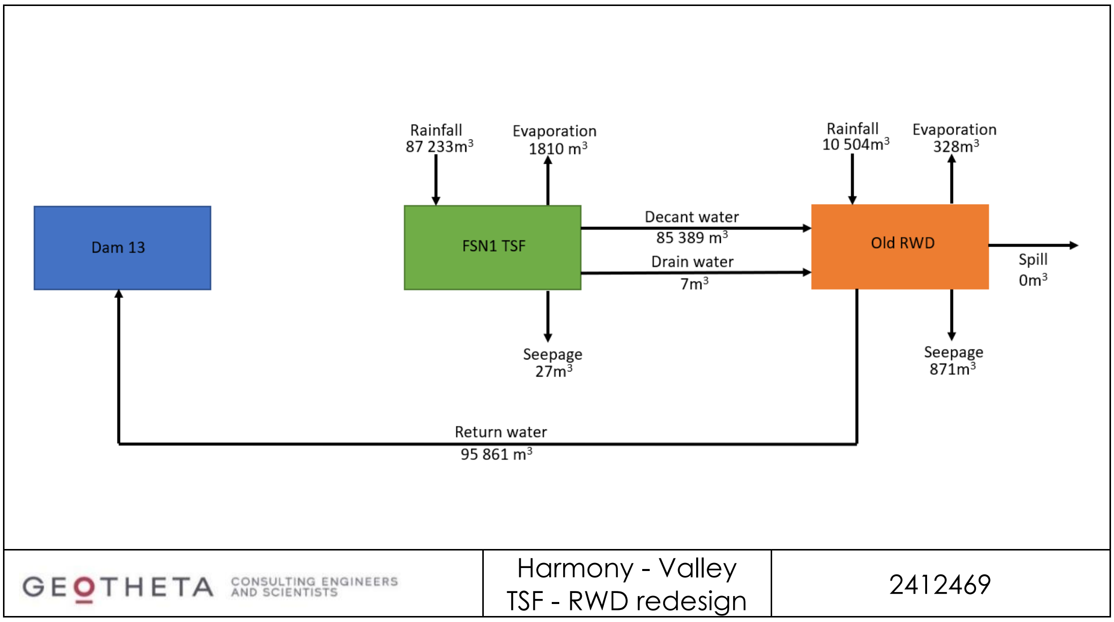

Figure 6: Old RWD Water balance model – monthly averages

10.2.3 The graphical plot showing the RWD volume with time is indicted in Figure 7.

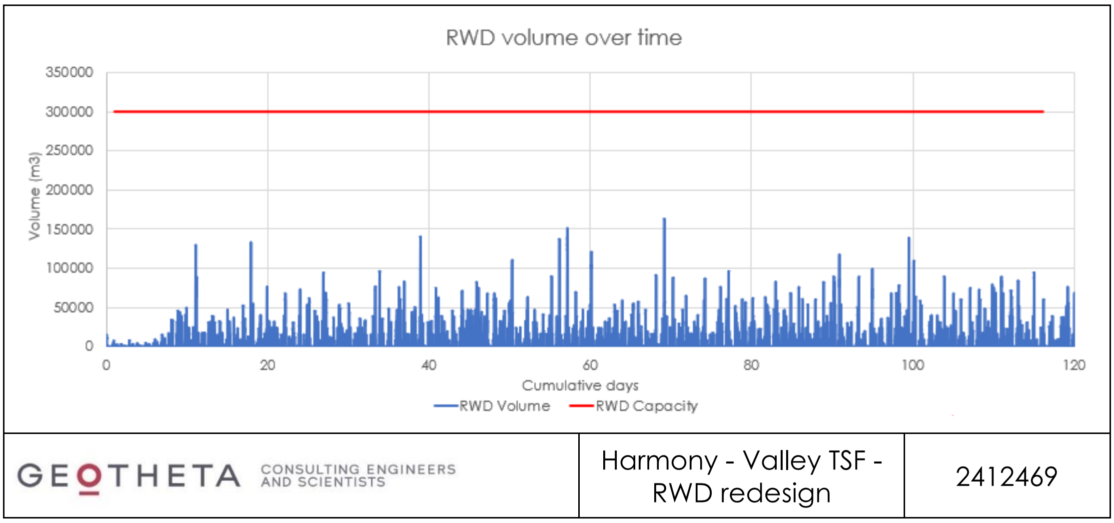

Figure 7: Old RWD volume over time

10.2.4 The old RWD has a storage capacity of approximately 300 000 m³.

10.2.5 During construction, the old RWD will be divided into two compartments by extending the existing divisional wall.

10.2.6 The RWD compartments can be seen in the post construction layout in Figure 8.

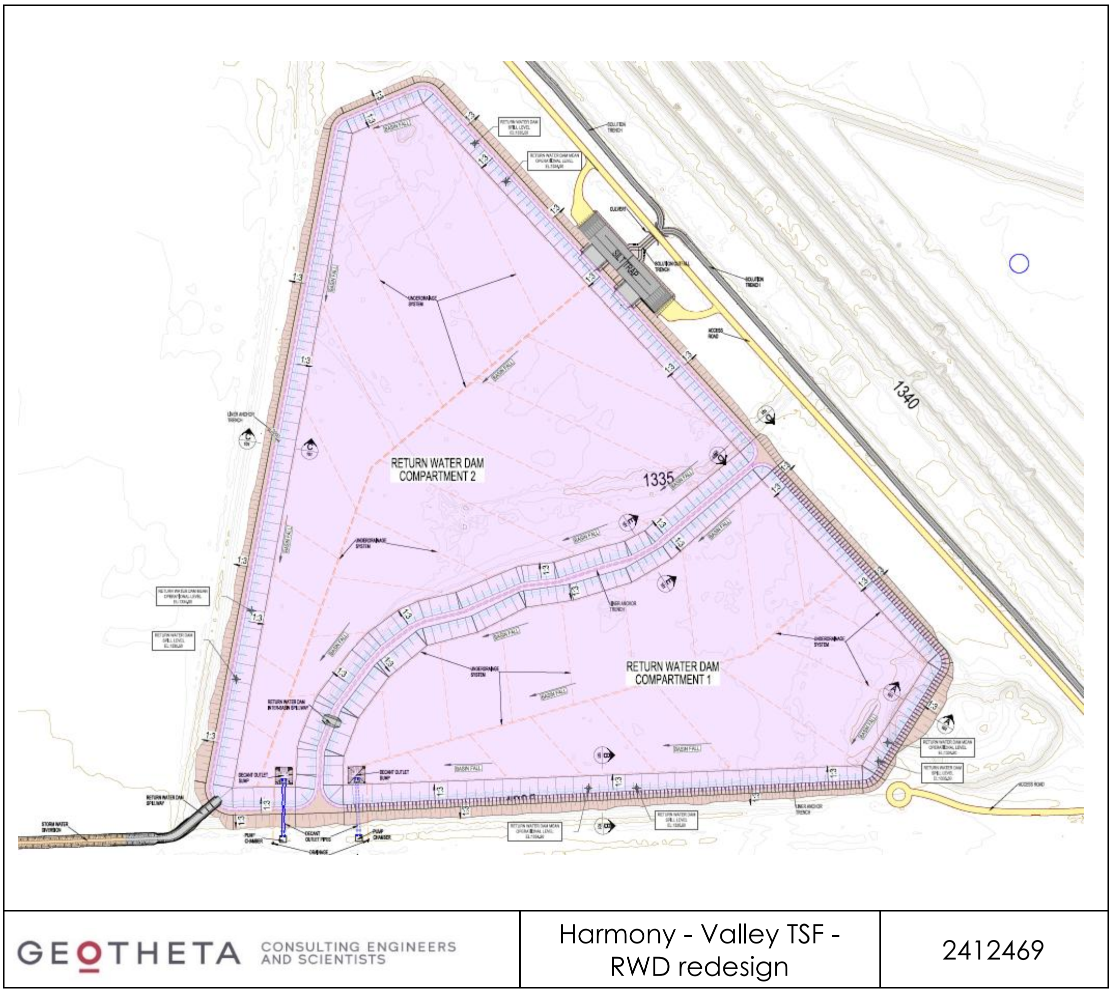

Figure 8: New Valley RWD layout

10.2.7 Each compartment will be able to accommodate 150 000 m3 while the other is constructed.

10.2.8 The existing capacity of Compartment 2 is more than 150 000m^3. Therefore, construction of Compartment 1 can commence while Compartment 2 stores effluent from the dormant FSN1 TSF.

10.2.9 The existing capacity of compartment 1 will be confirmed once all stored water is pumped to Dam 13. Construction can start on compartment 2 first if there is sufficient existing capacity to store 150 000 m^3 in Compartment 1.

10.2.10 During construction and extreme storms, water is required to be pumped to Dam 13 at a rate of 16 500 m^3/day. This is required to prevent the construction works from being inundated with stormwater.

10.3 New Valley return water dam (RWD) water balance

10.3.1 The water balance model comprises four main components (the Plant, the dormant FSN1, the Valley TSF and the new Valley RWD).

10.3.2 The average monthly water balance model (schematic) with the inputs and outputs for each component is shown in Figure 9.

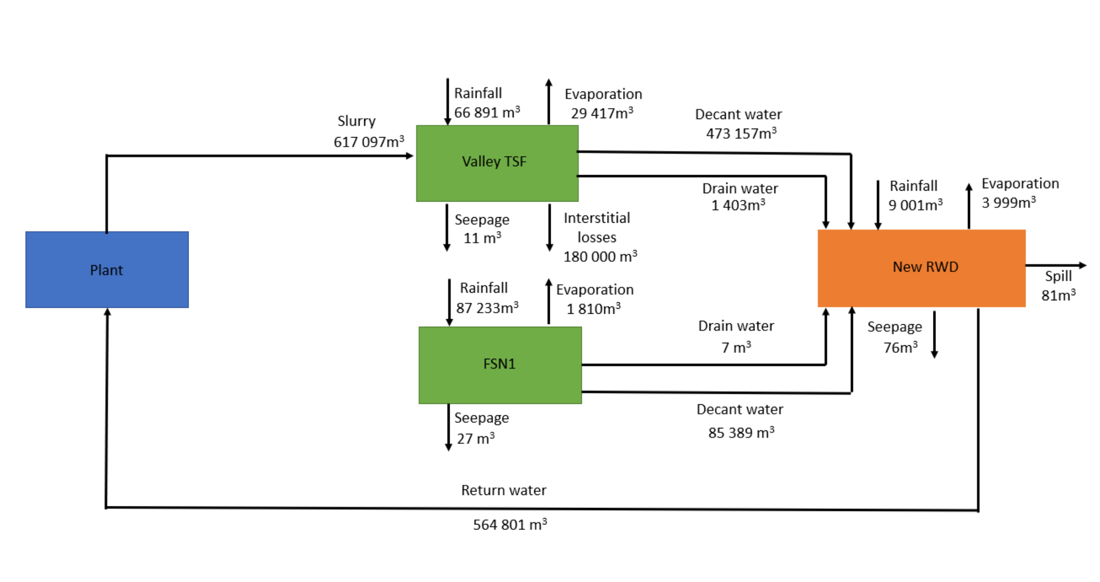

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Figure 9: New Valley RWD Water balance model – monthly averages

10.3.3 The graphical plot showing the new Valley RWD volume with time is indicted in Figure 10.

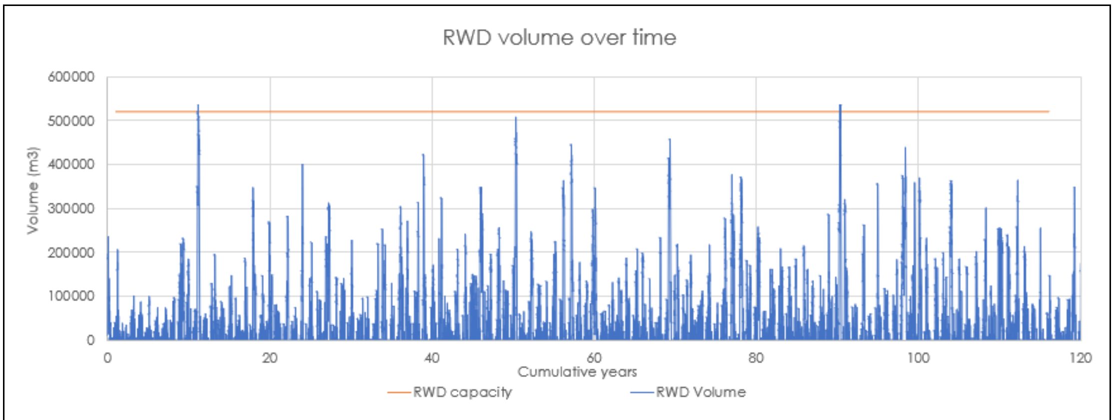

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Figure 10: New Valley RWD volume over time

10.3.4 The new Valley RWD will have a storage capacity of approximately 520 000 m³.

10.3.5 During extreme storms, return water must be pumped to Dam 13 at a rate of 27 000 m³/day. During normal operations, return water is required to be pumped at a rate of 18 500 m³/day.

10.4 New Valley return water dam (RWD) design

10.4.1 The new Valley RWD layout is shown in Figure 11.

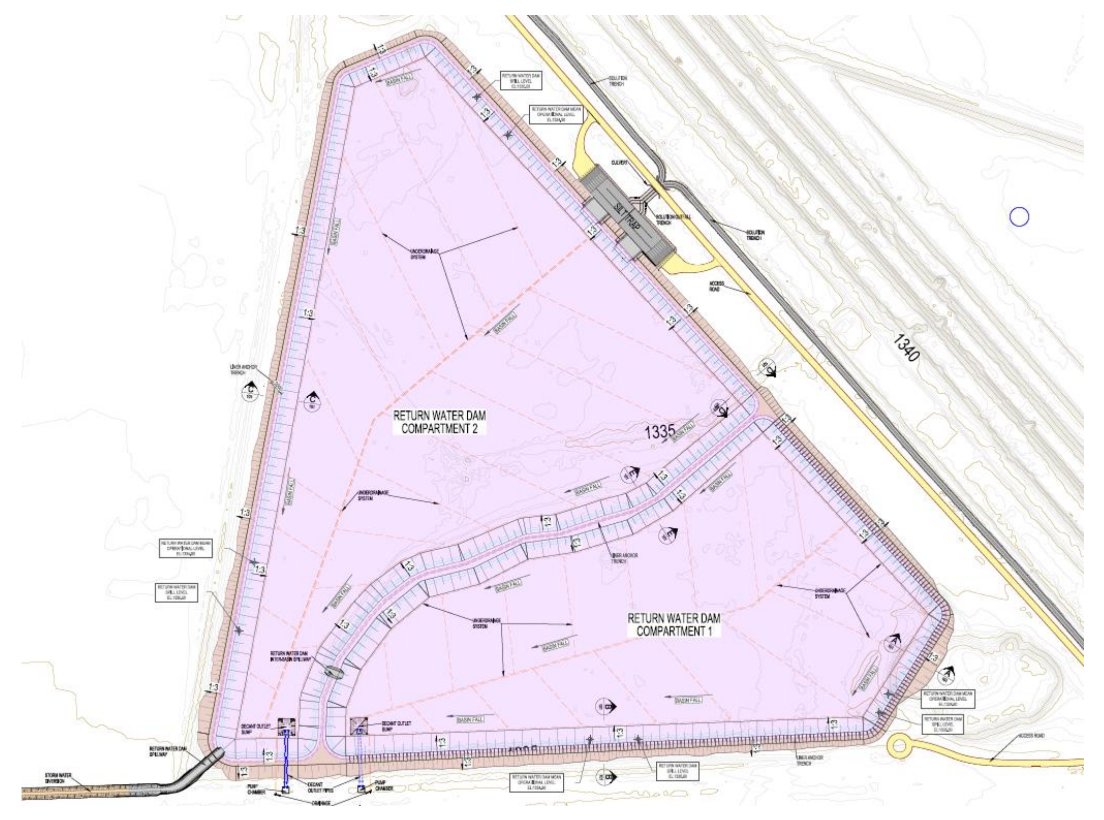

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Figure 11: New Valley RWD layout

10.4.2 The RWD will have two compartments separated by a divisional wall retained from earlier construction.

10.4.3 The RWD will have a freeboard of 800 mm. Water extraction from the RWD will be by means of a decant outlet sump and pump chamber.

10.4.4 Effluent from the solution trench enters the silt trap upstream of Compartment 2.

10.5 **Silt trap**

10.5.1 The silt trap layout is shown in Figure 12.

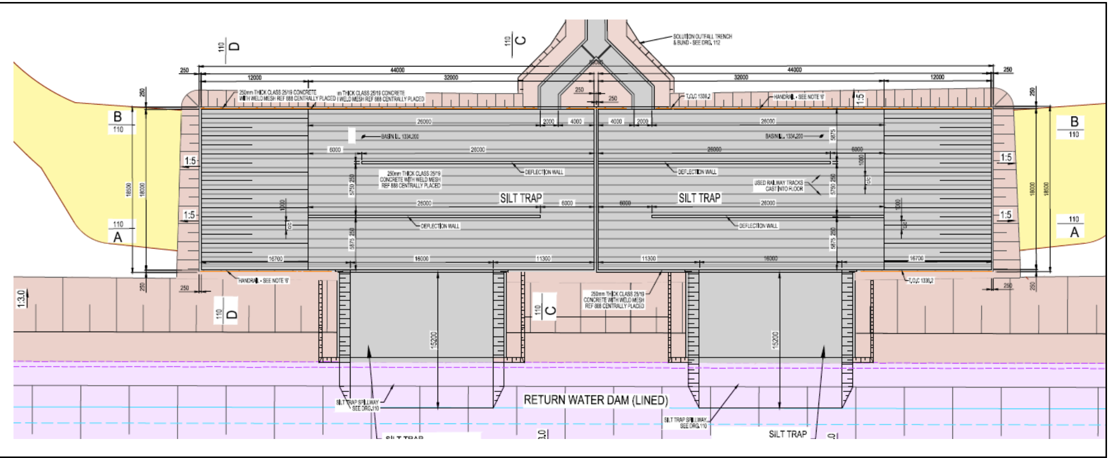

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Figure 12: Silt Trap

10.5.2 The silt trap ensures that solids are captured before entering the RWD, thereby minimising sedimentation in the RWD.

10.5.3 The silt trap comprises a 2.25 m deep reinforced concrete water retaining structure. An access ramp is provided to allow for a TLB (or similar) equipment to clean out the silt trap when required.

10.5.4 A sump has been included in each compartment of the silt trap to enable water to be pumped to the adjacent compartment prior to or after mechanical cleaning.

10.5.5 Sluice gates (2 m x 1 m Gereg specification or similar approved) at the solution trench split will close off flow into one silt trap compartment while cleaning and maintenance is in progress.

10.5.6 Used rail sections will be cast into the floor of the silt trap to prevent damage to the concrete surface during cleaning.

10.6 **Overflow channel**

10.6.1 An overflow channel is provided on the divisional wall to allow water to flow between the two compartments. The overflow channel is shown in Figure 13.

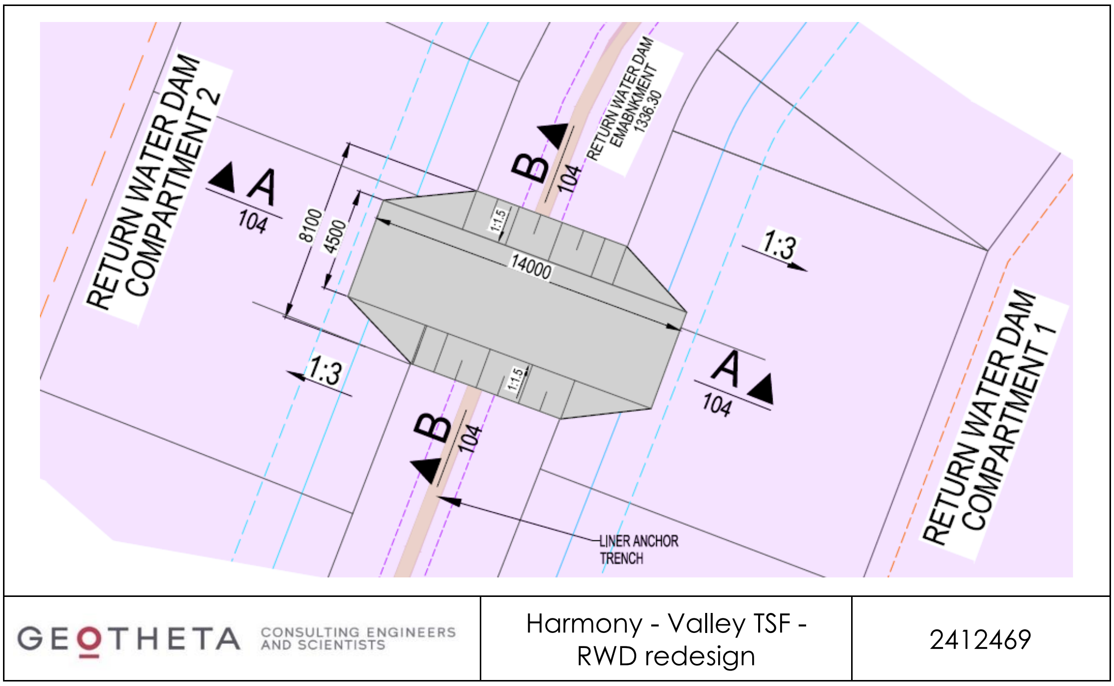

Figure 13: Overflow Channel

10.7 **Spillway**

10.7.1 A concrete lined spillway is provided to safely discharge excess water without overtopping of the RWD embankment walls.

10.7.2 The RWD spillway is designed to accommodate the expected probable maximum flood (PMF), i.e. the 1:10 000 year 24-hour storm event.

10.7.3 The layout of the spillway is shown in Figure 14.

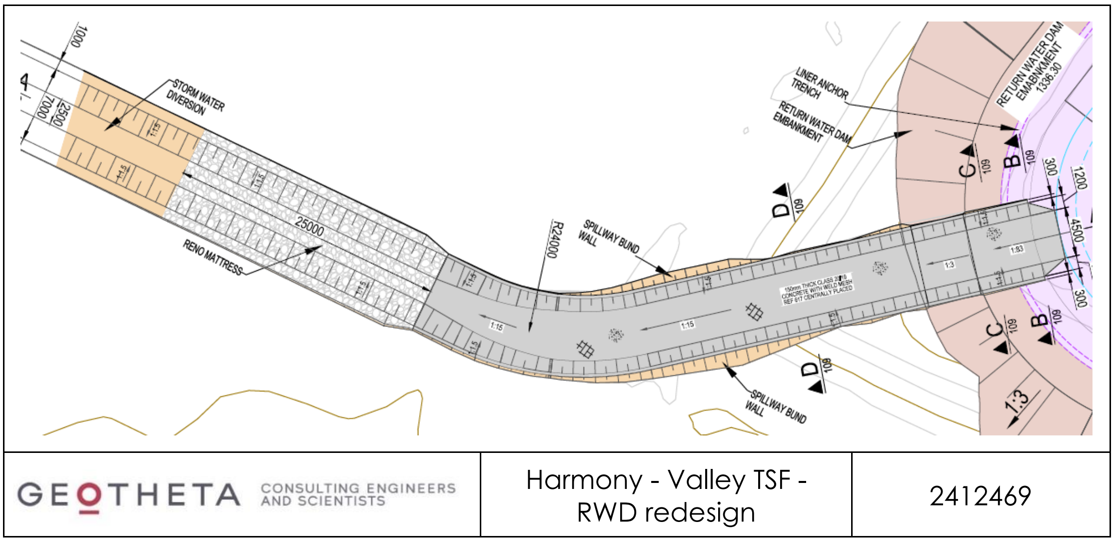

Figure 14: Spillway

10.7.4 The spill will discharge into the northwestern Nooitgedacht TSF stormwater diversion trench.

10.8 **Slope stability assessment**

10.8.1 The critical cross section (maximum height) stability of the RWD was analysed. The cross-section location is shown in Figure 15.

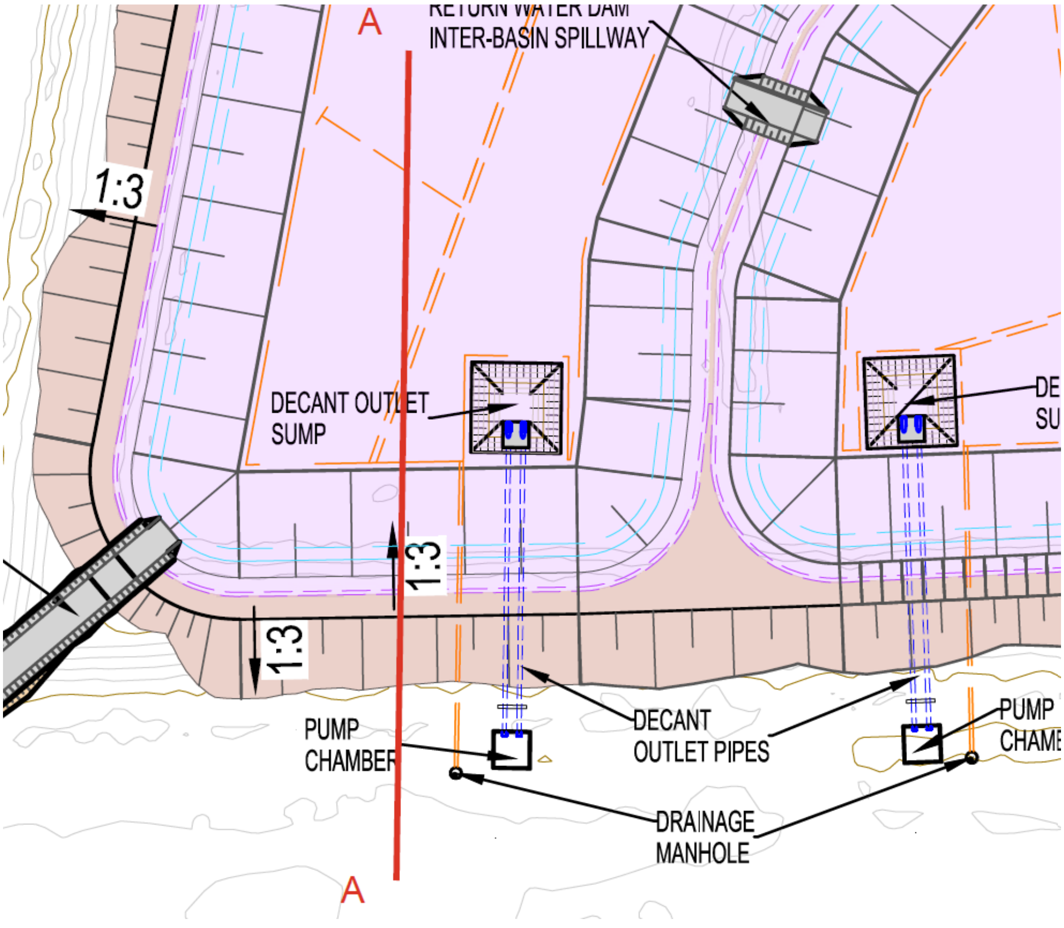

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Figure 15: Critical cross section location

10.8.2 The slope stability was analysed using RocScience RS2 Finite Element Analysis (FEA) software.

10.8.3 The stability results are shown in Table 7. Graphical slope stability outputs are included in Appendix B.

Table 7: Slope stability Factors of Safety

Scenario	Drained	Seismic
RWD inner slope - Empty	1.6	1.1

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

10.9 **Barrier system**

10.9.1 The RWD barrier system is indicated in Figure 16.

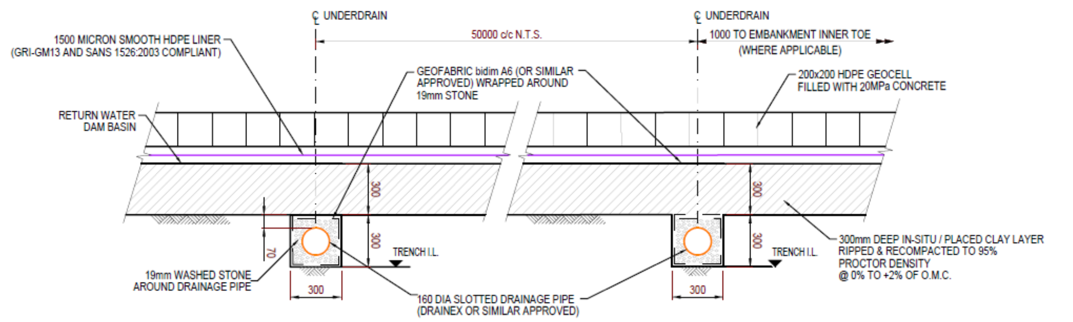

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Figure 16: RWD liner system and underdrainage

10.9.2 The barrier system in the RWD comprises, from top down:

- A 200 mm high perforated HDPE geocells filled with 20 MPa concrete.
- 1.5 mm thick smooth HDPE membrane liner.
- Ripped and recompacted 300 mm base preparation layer compacted to 95% Proctor density at a moisture content between 0% and +2% of optimum moisture content.
- Underdrainage system comprising of 160mm perforated HDPE pipes placed in a 300 mm by 300 mm trench. The pipes will be encased in 19 mm washed stone and wrapped in geofabric.

10.9.3 The geomembrane requires a protection layer to prevent damage and to ensure intimate contact between the liner and the underlying in-situ layer to ensure overall composite barrier functionality.

10.9.4 The concrete filled geocells provides durable protection to the liner against UV degradation and equipment and machine damage during cleaning. The geocells allows for minor differential settlement.

10.9.5 A typical image of the HDPE geocell is shown in Figure 17 below.

10.10 Liner tension forces

10.10.1 No tension forces are expected to be induced on the liner as the liner will be overlain by a rigid layer of concrete filled geocells.

10.10.2 Any shear stresses will be transferred to the concrete and not reach the liner.

10.10.3 Typical construction of concrete filled HDPE geocells is shown in Figure 17.

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Figure 17: Construction of concrete filled HDPE geocells

10.11 **Underdrainage system.**

10.11.1 The underdrainage system alleviates any water pressure build-up beneath the liner caused by a potential rise of the groundwater table. The underdrainage system may also be used to collect seepage.

10.11.2 The layout of the underdrainage system is shown in Figure 18.

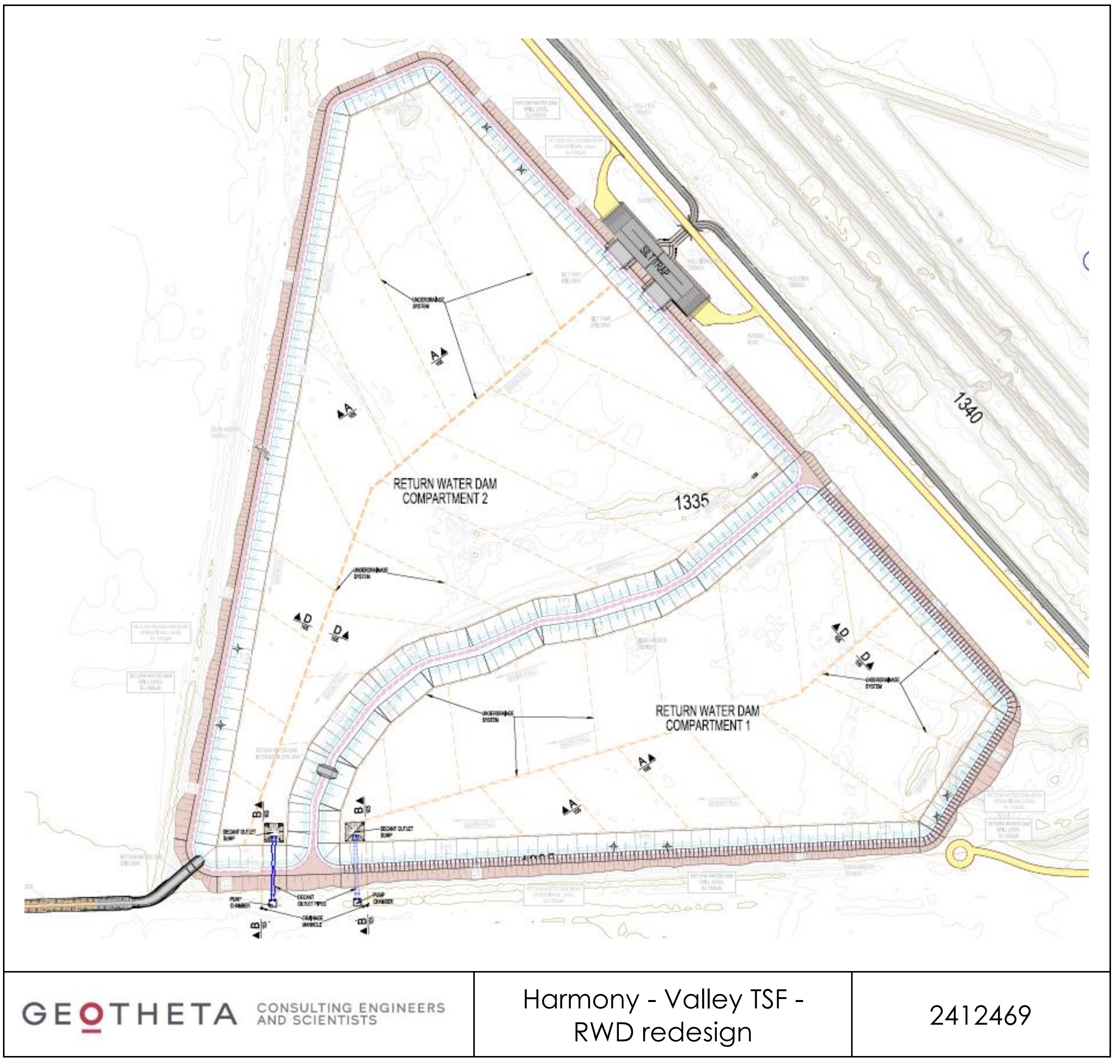

Figure 18: RWD underdrainage layout

10.11.3 A cross section through the underdrainage is shown Figure 19. The underdrains comprise 160 mm slotted HDPE pipes encased in 19 mm washed stone. The stone will be wrapped in geofabric.

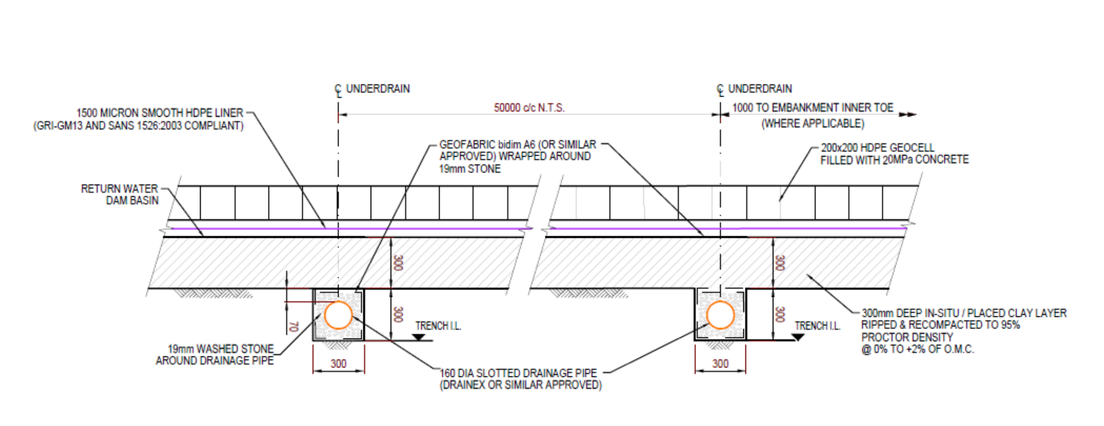

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Figure 19: RWD underdrainage section

10.11.4 The underdrains lead to collection manholes located on the southern perimeter of the RWD. The manholes provide access to store and monitor seepage.

10.12 Liner service life

10.12.1 The main factors that affect the service life of a geomembrane are UV exposure and temperature.

10.12.2 The HDPE liner in the RWD is fully covered by concrete-filled geocells and remains under ponded water throughout its service life. Based on site climatic data and literature values for covered liners (Rowe and Islam, 2009), the average liner temperature is estimated at 20-25°C throughout its service life. Therefore, UV exposure will not have a detrimental effect on the service life of the geomembrane at the New Valley RWD.

10.12.3 The average ambient temperatures of the site range between 10°C and 25°C. During construction, the liner should not be left exposed to direct sunlight over extended periods of time.

10.12.4 Based on research conducted by the Geosynthetics Institute in the 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 20-25°C will have a design life of more than 565-385 years.

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

10.12.6 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 for oxidation. This means that for a certain period the antioxidants prevent the geomembrane from being oxidised, which results in the increase of the material’s durability and service life.

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

Table 8: 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

10.13 Classification of the RWD as a dam safety risk

10.13.1 The total design storage capacity of the RWD is approximately 520 000 m^3 with a maximum above-ground wall height of 3 m.

10.13.2 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 50 000 m^3 and the maximum wall height must be greater than 5 m.

10.13.3 Although the storage capacity of the new Valley RWD is greater than 50 000 m^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 m).

10.13.4 The new Valley RWD is therefore not classified as a dam with a safety risk in terms of Regulation 139 of the of the National Water Act.

10.13.5 The requirements for a dam with a safety risk as indicated in Regulation 139 of the of the National Water Act do not apply to the new Valley RWD.

11. Construction method statement

11.1 Overiew

11.1.1 The new Valley RWD will be constructed while it receives stormwater effluent from FSN 1 TSF. A high-level construction method statement was prepared to demonstrate the procedure to follow when constructing the new Vally RWD.

11.1.2 Construction of the new Valley RWD will be done in 2 steps.

11.2 Step 1: Site preparation

11.2.1 Pump out all the water in the existing RWD. A pumping system is required to dewater the dam during construction as well.

11.2.2 Baseline survey of the RWD to be done. The baseline survey must be submitted to the Engineer prior to the construction work below. If the baseline survey finds that compartment 1 does not have sufficient capacity (150 000m^3), discharge water from the TSF must be routed return water to compartment 2 and construction will begin on compartment 1.

11.2.3 Preliminary works for compartment the first compartment to be constructed:

- Prepare the site for stormwater management.
- Clear vegetation in the dam and surrounding area to make access.
- Create safe access roads and ramps for deliveries and machines working.
- Clear and grub.
- Remove tree stumps.
- Strip and stockpile topsoil.
- Remove unsuitable material and stockpile.
- Rip and recompact insitu base preparation.

11.2.4 Peg setting out coordinates and levels for the divisional wall.

11.2.5 Construct the divisional wall: Compacted embankment to 95% Standard Proctor density at a moisture content of 0% to +2% of OMC.

11.3 Step 2: Construction of compartments

11.3.1 Begin construction of the first compartment (baseline survey dependent).

11.3.2 Excavate to design levels as shown on the drawings layer.

11.3.3 Rip and recompact insitu base preparation.

11.3.4 Fill and compact the basin in layers to design level.

11.3.5 Fill and compact divisional wall side slope.

11.3.6 Drain construction:

- Set out drain lines and levels.
- Excavate drains to drawing specifications and haul spoiled material to stockpile for later use.
- Rip and recompact trench base area.
- Place bidim A4 or similar approved Geotextile as per drawing specification.
- Place the collection drain pipes (slotted/solid) on the bidim. Surveyor to survey the top of pipe levels and submit to the Engineer for verification.
- Place and level 19 mm stone to 500 mm depth or as specified in the construction drawings. Surveyor to survey the top of 19 mm stone and submit to the Engineer for verification.
- Wrap the 19 mm stones with bidim and overlap.

11.3.7 Excavate liner anchor trench.

11.3.8 Install HDPE liner.

11.3.9 Back fill and nominally compact liner anchor trenches backfill.

11.3.10 Place geocells.

11.3.11 Concrete fill geocells. Allow 28 days for concrete curing.

11.3.12 Divert stormwater into the newly constructed silt trap.

11.3.13 Repeat the above process for the next compartment (site preparation preliminary works to be included).

12. Valley TSF redesign

12.1 Background

12.1.1 The redesign of the Valley TSF was limited to the solution trenches, decant and drainage systems.

12.1.2 The redesigned RWD is discussed in section 10.

12.2 Revised decant system

12.2.1 The Valley, FSN1 and FSN2 TSFs will not be combined to form one facility.

12.2.2 The final penstock for the Valley TSF was repositioned to the geometric centre of the facility.

12.2.3 The access catwalk will be located west of the Valley TSF and is the shortest path to the penstock.

12.2.4 The penstock outfall pipe will be routed to the eastern solution trench and is the shortest path to the solution trench.

12.2.5 The revised positions of the penstock and access catwalk is shown in Figure 20.

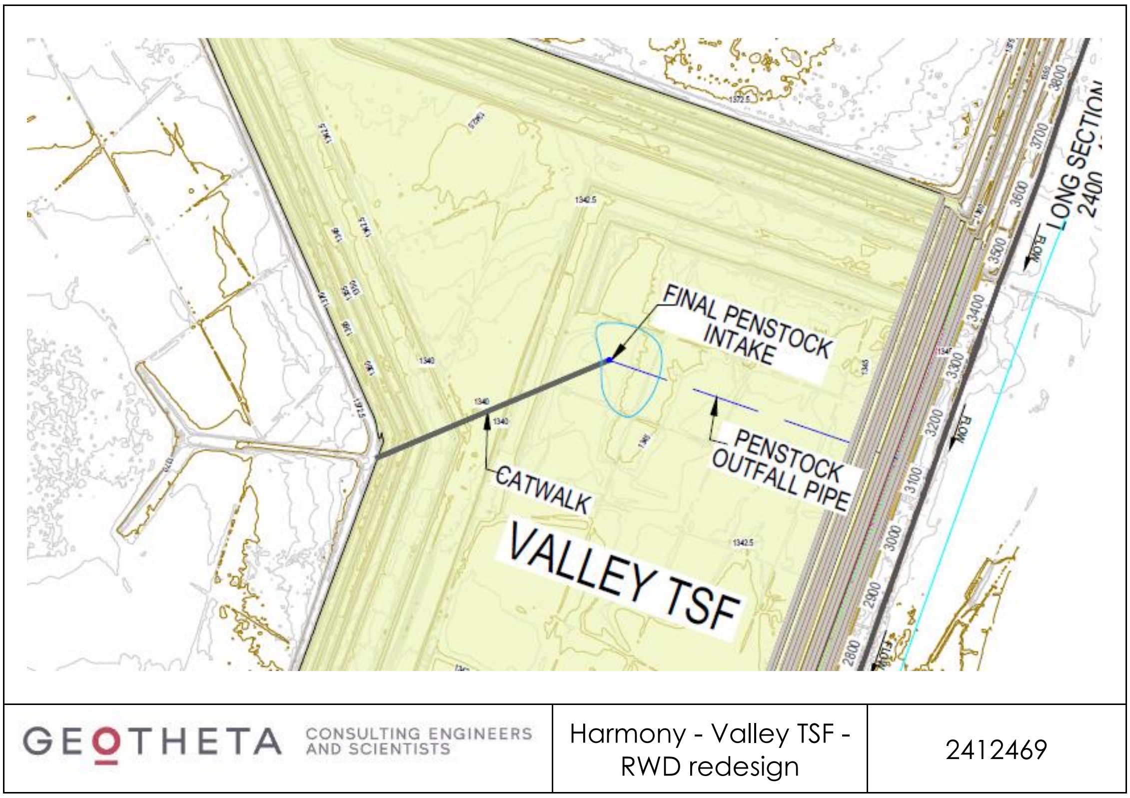

Figure 20: Revised penstock and catwalk positions

12.2.6 The Valley TSF footprint (after the tailings have been cleared from the remined footprints) has a relatively flat terrain. The Valley TSF will therefore have a final penstock only. Supernatant water at the start of operations will need to be pumped to the solution trenches or to the final penstock intake.

12.2.7 The final penstock will be decommissioned once the TSF reaches an elevation of 1365 mamsl (approximately 5.5 – 6 years after the start of deposition).

12.2.8 For the last 5 – 7m lift, a Turret Pumping System (or similar) may be used to decant supernatant water off the TSF. Pumping will take place for approximately 1.5 – 2 years.

12.2.9 The final penstock intakes will be founded on a reinforced concrete base with 4 x 510 mm precast concrete penstock ring intakes. The plan of the final penstock is shown in Figure 21.

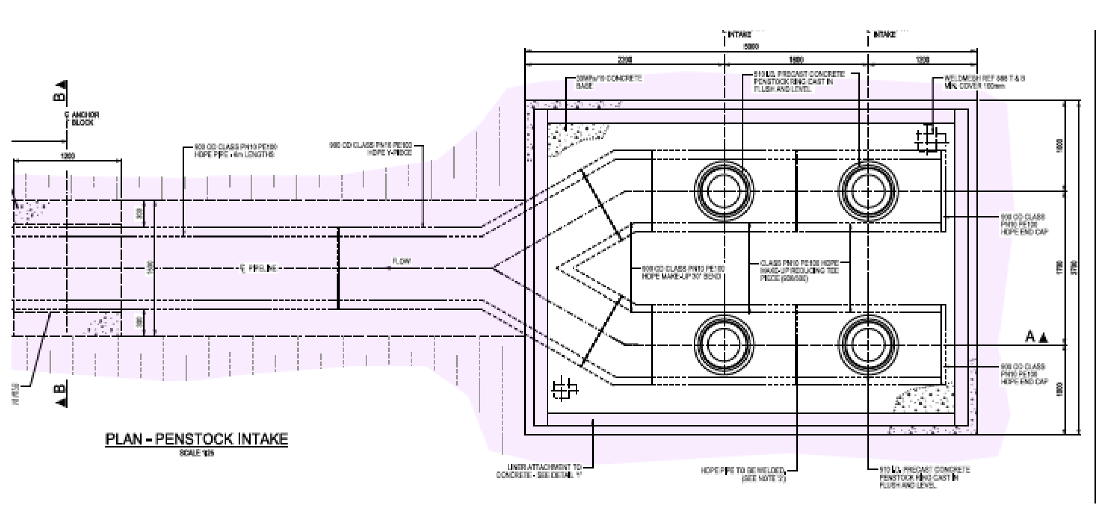

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Figure 21: Plan on final penstock

12.2.10 As the facility rises the penstock intakes will be raised by stacking the standard precast concrete penstock rings.

12.2.11 The typical section through the final penstock base is shown in Figure 22.

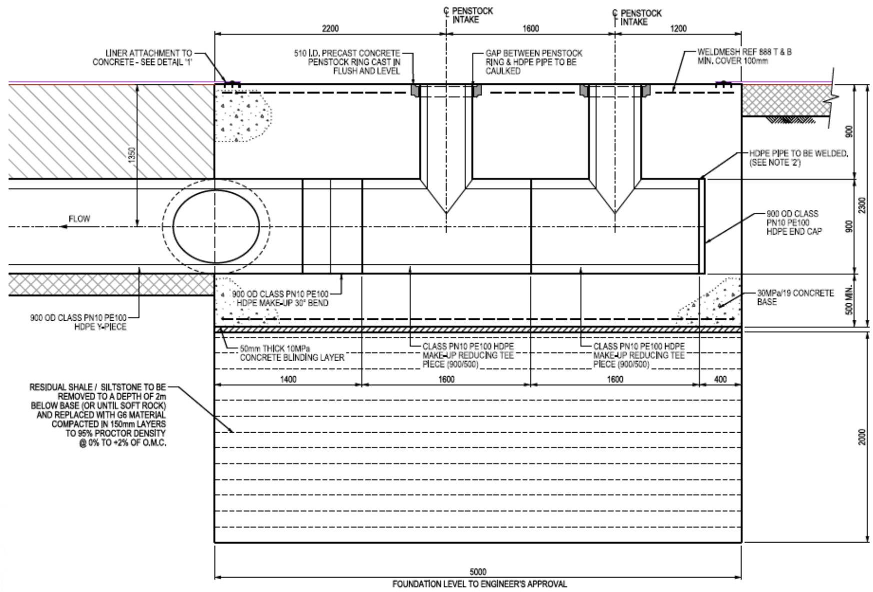

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Figure 22: Cross section through the final penstock

12.2.12 The unsuitable material beneath the final penstock base is to be removed to a depth of 2m or until the soft rock level and replaced with a G6 material. The G6 material will be compacted in 150 mm thick layers to 95% Mod AASHTO density @ 0% to +2% of O.M.C. The founding level will be agreed with Resident Engineer (RE).

12.2.13 The final penstocks will decant into a 900mm Class 10 PE100 OD HDPE outfall pipe.

12.2.14 A section through the outfall pipes (at the anchor block) is shown in Figure 23.

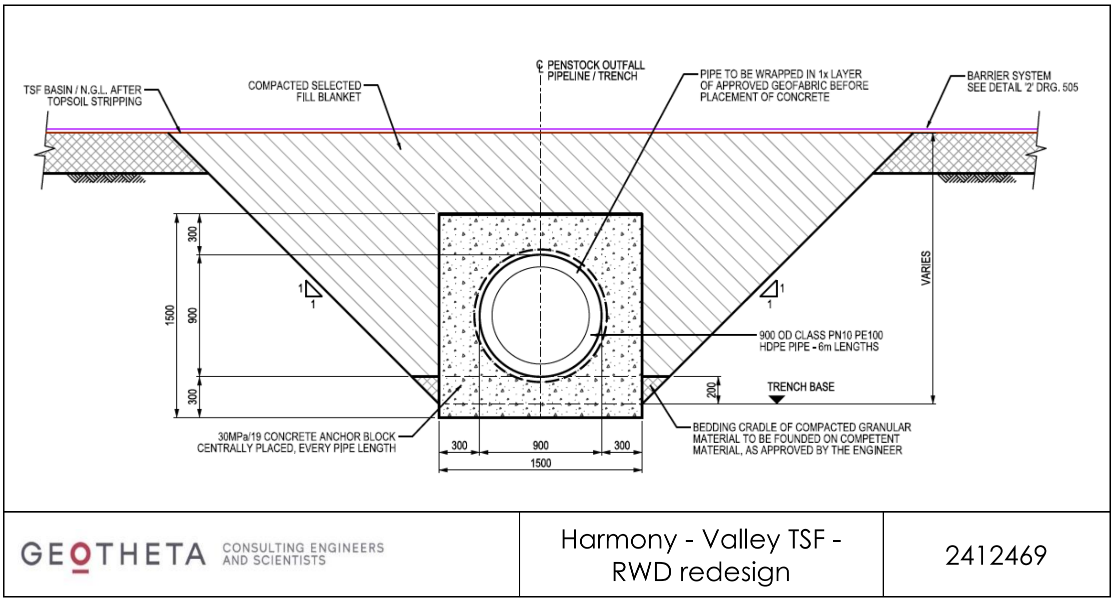

Figure 23: Section through the outfall pipes

12.2.15 When the pumping system is in operation, the existing final penstocks outfall pipes will be isolated by sealing.

12.3 Solution trench

12.3.1 The solution trench on the eastern and southern flanks of the Valley TSF will convey effluent from the penstock and drains to the new RWD. The solution trench will be concrete lined.

12.3.2 The northern solution trench will flow from the north and down to the west flank of FSN1 TSF. This solution trench will convey drain effluent to the new RWD. The solution trench will be concrete lined.

12.3.3 The solution trench around FSN2 will be a regraded earth trench and will to merge to the new concrete solution trenches.

12.3.4 All solution trenches will be regraded and merged into the new Valley TSF solution trenches.

12.3.5 The layout of the solution trench and flow direction is shown in Figure 24.

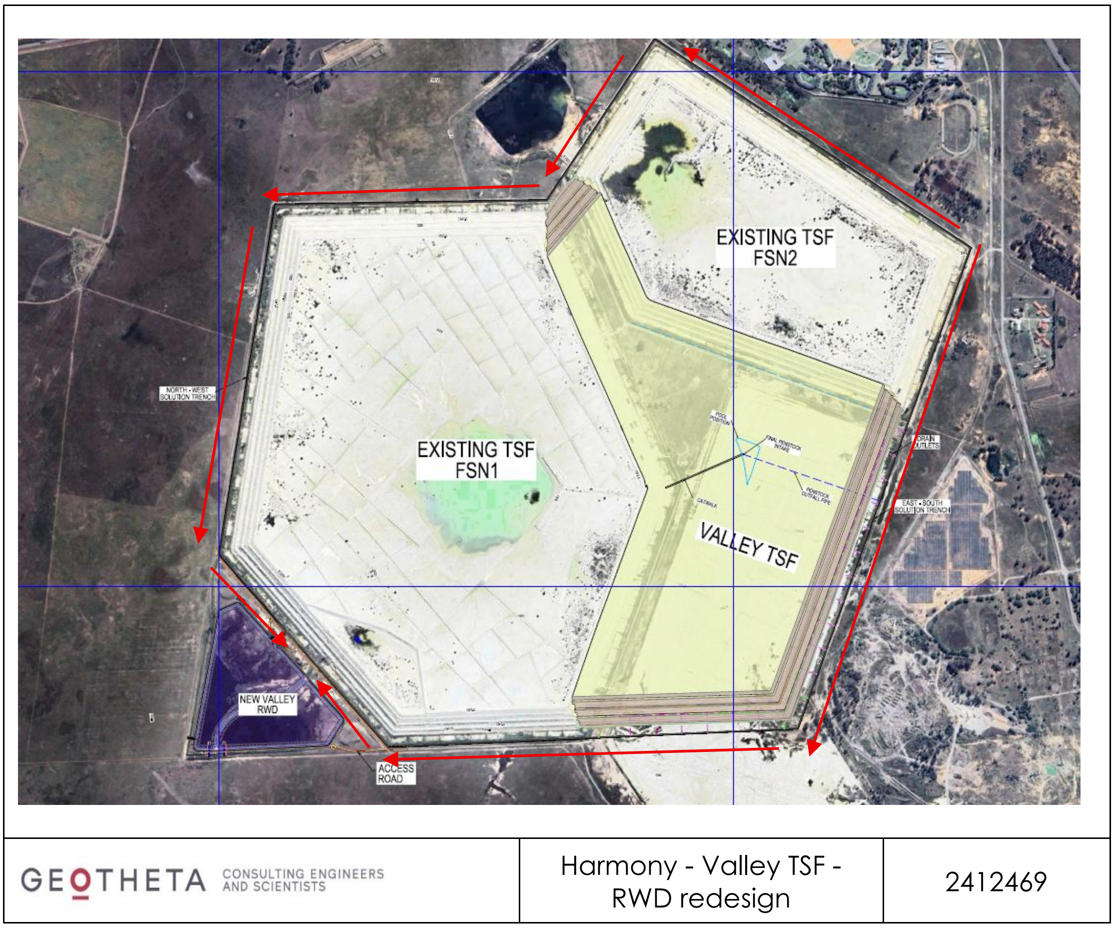

Figure 24: Solution trench flow direction

12.3.6 The long sections for the solution trenches are shown in drawing no. 2412469-113.

12.3.7 The typical section of the concrete lined solution trenches is shown in Figure 25.

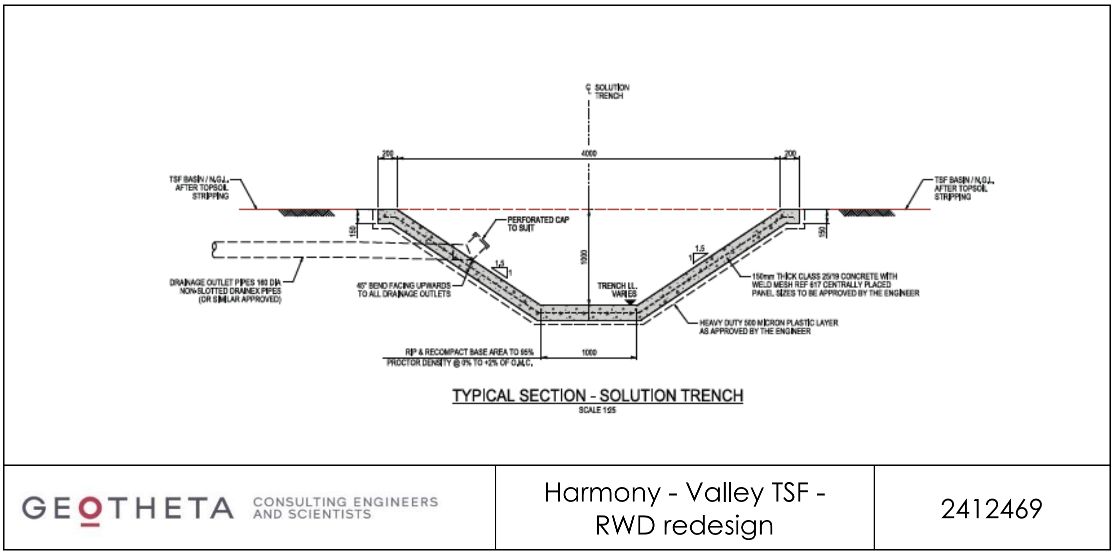

Figure 25: Typical section through the solution trench

12.3.8 The trapezoidal solution trench is 150 mm thick reinforced concrete. The trench is 1 m deep with side slopes of 1V:1.5H and a base width of 1 m.

12.3.9 A concrete lined solution trench prevents seepage from new contaminated water and provides a durable surface for cleaning and maintenance.

12.3.10 The eastern FSN2 TSF regraded earth trench will not be in constant operation and minimal flows are expected. The trench will convey old, contaminated water from the dormant FSN2 TSF therefore it is not required to be lined.

12.3.11 The solution trenches convey effluent from the drain outlets and penstock to the silt trap of the RWD.

13. Drawings

13.1 Drawings of the Valley TSF and the RWD are included in Appendix C.

14. Bill of Quantities

14.1 Rates were obtained from three Civil Engineering Contractors. These were used to compile the construction Capital Expenditure (CAPEX) for the project.

14.2 The summary of the cost estimates is shown in Table 9.

Table 9: Construction CAPEX

			Contractor 1	Contractor 2	Contractor 3
SECTION	**DESCRIPTION**		**AMOUNT Excl VAT**	**AMOUNT Excl VAT**	**AMOUNT Excl VAT**
	PART 1: GENERAL				
A	PART A: PRELIMINARY AND GENERAL	R	122 808 783	126 722 257	118 486 550
B	PART B: SITE CLEARANCE	R	57 257 398	36 156 614	50 266 039
C	PART C: EARTHWORKS	R	104 921 559	157 139 216	128 993 224
D	PART D: SMALL EARTH DAMS	R	413 303	864 437	410 731
E	PART E: EARTHWORKS (ROADS, SUBGRADE)	R	1 375 229	1 467 655	751 370
F	PART F: CONCRETE (STRUCTURAL)	R	149 587 502	123 185 195	143 749 585
G	PART G: MEDIUM PRESSURE PIPELINES	R	13 563 604	9 860 127	11 400 732
H	PART H: SEWERS	R	3 553 708	24 043 180	3 847 548
I	PART I: STORMWATER DRAINAGE	R	176 541	145 309	75 517
J	PART J: GEOSYNTHETICS	R	193 506 586	174 121 299	166 975 106
K	PART K: TIMBER (STRUCTURAL)	R	1 702 625	2 069 659	1 954 601
L	PART L: CYCLONES	R	7 893 178	21 913 645	6 734 461
	TOTAL CONSTRUCTION EXCLUDING VAT	R	**656,760,015**	**677,688,594**	**633,645,463**
	ESTIMATED PROFESSIONAL FEES	**R**	**19,702,800**	**20,330,658**	**19,009,364**
	CONSTRUCTION CONTINGENCY	**R**	**131,352,003**	**135,537,719**	**126,729,093**
	BUDGET PRICE	**R**	**807,814,819**	**833,556,971**	**779,383,920**

14.3 The priced BoQ using rates from Contractors is included in Appendix D. P&G's are estimated at 23% of the total construction cost. The unpriced BOQ is included in Appendix E.

14.4 The recommended budget allocation for the Valley TSF redesign project construction is R 807 million (incl. 20% contingency).

14.5 The construction CAPEX for the Valley TSF redesign project is expected to be spread over 2 years. The construction schedule is attached in Appendix F.

15. Conclusions and recommendations

15.1 Geotheta was appointed by Harmony for the redesign of the Vally TSF in Welkom, South Africa. The redesign includes a revised decant system, solution trench and RWD.

15.2 The final penstock was repositioned to the geometric centre of the Valley TSF and according to the deposition beach slope from the Valley TSF deposition.

15.3 The access catwalk will be located west of the Valley TSF and is the shortest path to the penstock.

15.4 The concrete encased penstock outfall pipe will be routed to the eastern solution trench and is the shortest path to the solution trench.

15.5 The final penstocks will be decommissioned after the TSF is raised by 20m to 25m and sufficient head is available to switch to a syphon system.

15.6 The solution trench on the eastern and southern flanks of the Valley TSF will convey effluent from the penstock and drains to the new RWD. The solution trench will be concrete lined.

15.7 The northern solution trench will flow from the north and down to the west flank of FSN1 TSF. This solution trench will convey drain effluent to the new RWD. The solution trench will be concrete lined.

15.8 The solution trench around FSN2 will be a regraded earth trench and will to merge to the new concrete solution trenches.

15.9 All solution trenches will be regraded and merged into the new Valley TSF solution trenches.

15.10 The eastern FSN2 TSF regraded earth trench will not be in constant operation and minimal flows are expected. The trench will convey old, contaminated water from the dormant FSN2 TSF therefore it is not required to be lined.

15.11 The old RWD has a storage capacity of approximately 300 000m^3.

15.12 The old RWD will be separated into two compartments during construction via the reworked divisional wall.

15.13 Each compartment will accommodate 150 000m^3 each. During extreme storms, return water is required to be pumped to Dam 13 at a rate of 16 500m^3/day.

15.14 The new RWD will have a storage capacity of approximately 520 000m^3. During extreme storms, return water is required to be pumped to Dam 13 at a rate of 27 000m^3/day. On average return water is required to be pumped at a rate of 18 500 m^3/day.

15.15 The new RWD will have two compartments separated by a divisional wall retained from earlier construction. A channel is provided downstream of the RWD to allow water to flow over into compartment 1 from compartment 2.

15.16 The recommended budget allocation for the Valley TSF redesign project construction is R 807 million (incl. 20% contingency). The construction CAPEX for the Valley TSF redesign project is expected to be spread over 2 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.

Reviewed by:

Ian Hammond Pr Eng
CEO: Geotheta (Pty) Limited

APPENDIX A: VALLEY TSF DESIGN REPORT

APPENDIX B: RWD STABILITY

APPENDIX C: IFC DRAWINGS

APPENDIX D: PRICED BOQ

APPENDIX E: UNPRICED BOQ

APPENDIX F: CONSTRUCTION SCHEDULE

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