OCEANA GOLD NZ LIMITED

FRASERS BACKFILL STAGE 2 DESIGN TO SUPPORT RESOURCE CONSENT APPLICATION

MACRAES GOLD MINE

March 2024

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TO SUPPORT RESOURCE CONSENT APPLICATION
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Abbreviations

Abbreviation / Term	Definition
AEP	Annual Exceedance Probability
FEWD	Frasers East Waste Dump
FF	Footwall Fault
FMEA	Failure modes and effects analysis
FoS	Factors of Safety
FRBF	Frasers Backfill embankment
FROP	Frasers open pit
FRUG	Frasers underground workings, accessed through the eastern Frasers open pit high wall
FSWRS	Frasers South Waste Rock Stack
FTSF	Frasers (pit) Tailings Storage Facility
GISTM	Global Industry Standard on Tailings Management
GPUG	Golden Point Underground
HMSZ	Hyde-Macraes Shear Zone
IDF	Inflow design flood
IMOP	Innes Mills open pit
k_y	Seismic displacement yield coefficient (g)
LOM	Life of Mine – current end date for active mining
LOMP	Life of Mine Plan
MGPG	Macraes Gold Project Grid
MP4	Macraes Phase 4 – Stage 3 Open pit extensions & FTSF Stage 2
Mt	Million tonnes
M_w	Earthquake mean magnitude
NCS	Normalised crest settlement
NSHM	National Seismic Hazard Model
NZDSG	New Zealand Dam Safety Guideline
OBE	Operating Basis Earthquake
OGNZL	OceanaGold (New Zealand) Limited
PAR	Population at risk
PGA	Peak Ground Acceleration
PIC	Potential Impact Classification

Abbreviation / Term	Definition
PLL	Potential loss of life
PMP	Probable maximum precipitation
PSHA	Probabilistic Seismic Hazard Analysis
$S_a(1.3T_s)$	Seismic displacement spectral acceleration (g)
SEE	Safety Evaluation Earthquake
T_s	Seismic displacement initial fundamental period $1.3T_s$ adopted as the degraded fundamental period
TSF	Tailings Storage Facility
TTTSF	Top Tipperary Tailings Storage Facility
V_s	Shear wave velocity
WD	Waste rock disposal feature
WRS	Waste rock stack

Executive summary

OceanaGold (New Zealand) Limited (OGNZL) are preparing to extend the Macraes operational mine plan until approximately 2030 as part of the Macraes Phase 4 Project(MP4) . MP4 proposes extensions at Innes Mills, Coronation and Golden Bar Open Pits, waste disposal as backfills and to waste rock stacks external to the pits, and the continuation of tailings disposal.

A new tailings storage facility (TSF) will be required for the Macraes operation as the tailings storage capacity of the existing Top Tipperary TSF (TTTSF) is forecast to run out in early 2025. The new TSF, called Frasers TSF (FTSF), is proposed to be located within the mined-out Frasers open pit (FROP). Tailings will be contained by the Frasers backfill embankment (FRBF) placed between FROP and the Innes Mills open pit (IMOP), constructed of waste rock from Innes Mills. FRBF and FTSF are to be consented in two stages to ensure continual tailings disposal throughout operations:

- Stage 1 FTSF design (WSP 2023) is subject to a separate consent application (Consent Continuity Project, lodged Dec 2023) and includes early disposal of 57 Mt of Innes Mills waste rock, to form FRBF to 450 mRL, and the deposition of 6 Mt tailings into FTSF
- Stage 2, designed herein, which includes the disposal of a further 23 Mt waste rock in the FRBF to 480m RL and 29.5 Mt tailings into the FTSF.

This report has been prepared for OGNZL to support the MP4 Open pit Extensions/FTSF resource consent application by providing an assessment of effects for FRBF Stage 2 as required under the Resource Management Act 1991. The FRBF Stage 2 design has been undertaken in accordance with the New Zealand Society on Large Dams (NZSOLD) Dam Safety Guidelines, 2015 (NZDSG) and includes analysis and assessment of the following:

- <u>Potential failure modes (PFMs)</u>: A total of 11 PFMs in operation and 12 PFMs in closure were identified through a Failure Modes and Effects Analysis (FMEA); however, none have been categorized as capable of resulting in catastrophic dam failure with the current design assumptions. In the context of this design, catastrophic failure would result in the significant release of contents from the FTSF into either a working area or the environment.
- <u>Potential Impact Classification (PIC)</u>: Assessed as Low during operations and closure. This rating is predominantly due to FTSF being confined within the pit shell, a forecast final tailings level significantly below crest elevation, limited mining activity downstream during operations, and no external loss of containment or persons at risk during closure as the pits fill with water. The PIC should be reassessed throughout the life of FTSF if key assumptions used to define the rating, such as those outlined above, change.
- <u>Geotechnical design of FRBF</u>: Included consideration of appropriate waste rock parameters and analysis of seepage, static stability, seismic stability, settlement and deformation. Results of these analyses demonstrate the FRBF ‘structure’ meets stability requirements of the NZDSG. It is acknowledged that, in closure, large deformations and downstream embankment failures may occur due to saturation of the backfill during SEE seismic loadings, but this would be inconsequential as the FRBF will be submerged (or partially submerged) and no release of contents outside of the Innes Mills pit could occur under any scenario.
- <u>Geotechnical pit wall risks</u>: Risks associated with stability of the FROP pit walls has been assessed by PSM (2024). This assessment indicates backfill and tailings placed in the pit will improve the stability of the west wall in comparison to end of mining, however ongoing creep of the west wall is expected and highwall movement on the east and west wall is anticipated under SEE seismic loadings. The main risks associated with highwall movement (sub-aqueous sliding resulting in potential seiche waves) can be managed throughout operations and after closure by the large projected freeboard between the top of the tailings, and later the pit lake, and the pit rim . OGNZL have previously demonstrated that highwall movement risks can be managed by a surveillance and monitoring programme that includes radar monitoring, visual inspections/mapping, activation of TARPs and remedial works as required on this basis.

- Tailings operating plan: The proposed tailings deposition operating plan consists of discharging the tailings slurry from one of three spigots set along the discharge pipeline, laid along benches on the upstream slope of the FRBF, with the supernatant water contained in the south-east corner of FROP. Floating pumping infrastructure will re-cycle the water back to the process plant for reuse through a series of staging ponds. The spigot pipeline will be lifted onto higher benches as the tailings inundate the lower benches.
- Tailings and backfill scheduling: Production schedules indicate deposition will commence during raising of FRBF, but there is no risk of overtopping the advancing crest as the rising tailings beach level will be significantly lower than the crest of the FRBF, providing in excess of 60 m operating freeboard. Deposition modelling that considers a 1% sub-aerial beach slope and 1.25 t/m^3 settled dry density indicates a final projected Stage 2 tailings level of 416.5 mRL relative to a final FRBF crest of 480 mRL.
- FTSF closure: The conceptual closure plan consists of a perpetual pit lake cover, maintained by rainfall, groundwater seepage and runoff from the surrounding catchments including from the rehabilitated TTTSF. Water balance modelling (GHD 2024) estimates the FTSF pit lake will reach the FRBF crest 65 years after closure, where it will commence overflowing into the rising IMOP pit lake. FRBF is forecast to be inundated by the combined FTSF and IMOP pit lake 95 years after closure. The pit lake reaches a long-term level that fluctuates between 486 and 494 mRL, due to anticipated short-term fluctuations due to storm events, seasonal fluctuations due to cyclic wet and dry periods, long-term fluctuations due to extended wet or dry periods and uncertainties in long term climate change behaviour. The maximum lake level is 20 m below the lowest pit rim level and is therefore always contained within the pit extent with no risk of overtopping.
- Project risks: Key risks throughout the intended FTSF lifecycle have been identified in this feasibility design report. A dam safety management system/programme, established within an Operations Maintenance and Surveillance (OMS) Manual, is proposed to ensure all dam safety requirements outlined in the NZDSG are addressed and actively managed during operations.

1 Introduction

OceanaGold (New Zealand) Limited (OGNZL), a subsidiary of OceanaGold Corporation, owns and operates the Macraes gold project (MGP) located approximately 60 km north of Dunedin, South Island, New Zealand.

OGNZL is preparing to extend the operational mine plan until the end of 2030 as part of the Macraes Phase 4 (MP4) extension. MP4 includes extensions at Innes Mills, Coronation and Golden Bar Open Pits, waste disposal as backfill in pits and to waste rock stacks external to the pits and the continuation of tailings disposal.

A new tailings storage facility (TSF) will be required for the Macraes operation, when storage capacity in the existing Top Tipperary Tailings Storage Facility (TTTSF) is forecast to run out in early 2025. The proposed new TSF is to be located within the mined-out Frasers pit and called Frasers TSF (FTSF).

The tailings will be contained by a waste rock embankment backfilled between the Frasers and the Innes Mills pits, called the Frasers Backfill (FRBF). Frasers and Innes Mills pits and the proposed FRBF and FTSF are shown in Figure 1.1.

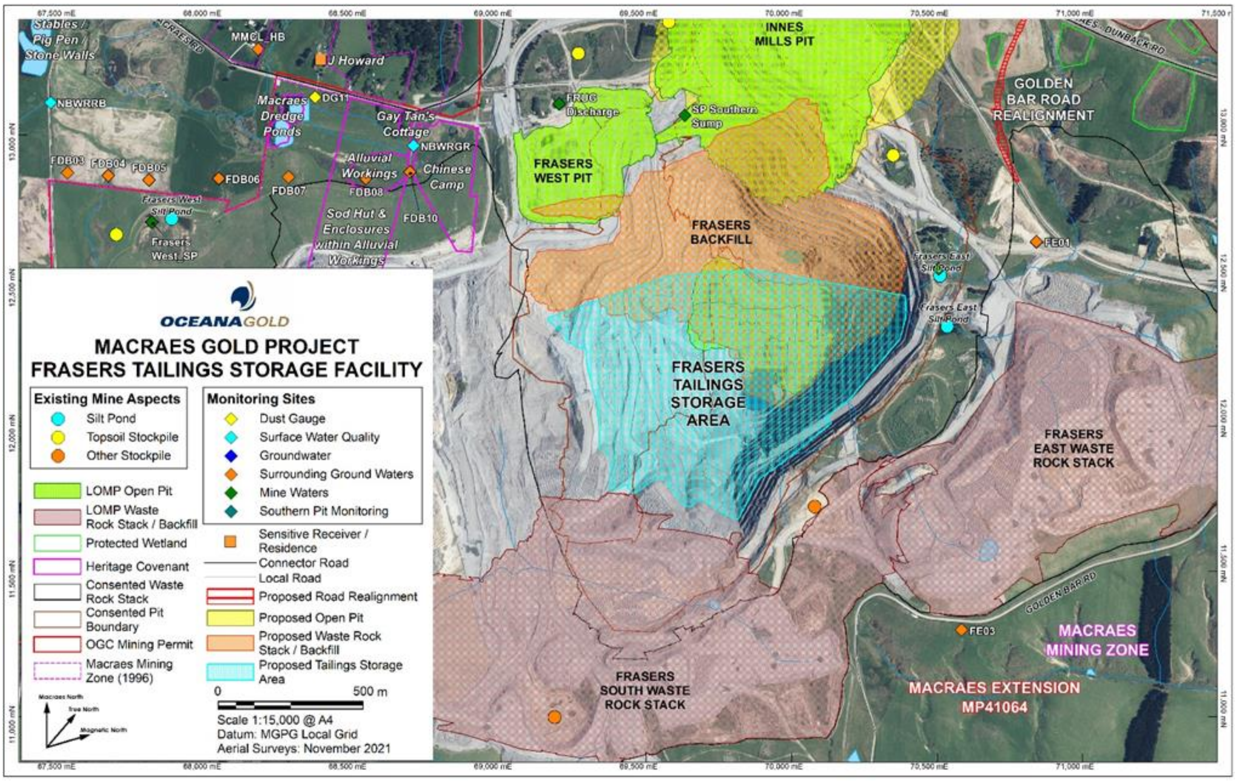

Figure 1.1 Frasers TSF proposed layout

FRBF and FTSF are being consented in two stages; Stage 1 and Stage 2, to ensure continual tailings disposal throughout the mine's operational life.

- Stage 1 provides continuity of mining operations until early 2026 and includes early disposal of 57 Mt waste rock and 6 Mt of slurried tailings discharged into Frasers Pit. The Stage 1 design to support consent application has been outlined separately by WSP (2023) and considers a FRBF crest elevation of 450 mRL and a maximum FTSF tailings elevation of 345 mRL.
- Stage 2 includes the disposal of a further 23 Mt waste rock, taking the FRBF to 480 m RL, and the deposition of a further 29.5 Mt of slurried tailings in FTSF to a maximum tailings elevation of approximately 417 mRL.

This report has been prepared for OGNZL to support the MP4 resource consent application by providing an assessment of effects for FRBF Stage 2 as required under the Resource Management Act 1991. The FRBF Stage 2 feasibility design has been undertaken in accordance with the New Zealand Dam Safety Guidelines (NZSOLD 2015).

2 Stage 2 description

This report presents the FRBF Stage 2 design in support of a consent application for the works that form part of the MP4 project. FRBF Stage 2 has been evaluated separately to the FRBF Stage 1 is, for the purposes of the application, considered an integrated continuously constructed structure to ensure there are no design or operational gaps between Stage 1 and Stage 2.

2.1 Frasers Backfill

Waste rock from Innes Mills stage 8 mining (IM8) will be backfilled into FROP to create FRBF Stage 1 and waste rock from mining stages 9 (IM9) and 10 (IM10) will be used to construct FRBF Stage 2 to a maximum elevation of 480 mRL. Construction of Stage 2 embankment will follow-on the completion of Stage 1, scheduled to be somewhere between early 2026 and November 2027.

The projected as-mined pit floor of the FROP and IMOP is shown in Figure 2.1, showing the extent of the IM9 and IM10 mining stages that contribute to waste rock fill for construction of the Stage 2 embankment. Figure 2.1 shows the pit floor of these two pits prior to construction of the FRBF embankment is started. Figure 2.2 presents a plan of the final FRBF Stage 2 at its final crest elevation of 480 mRL.

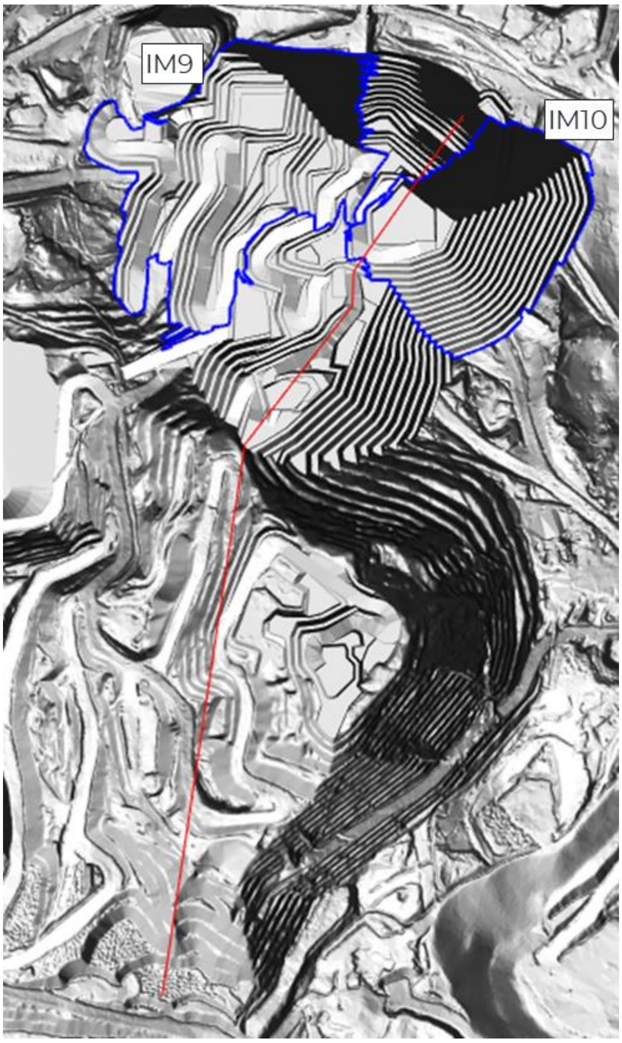

Figure 2.1 Projected final as-mined FROP & IMOP

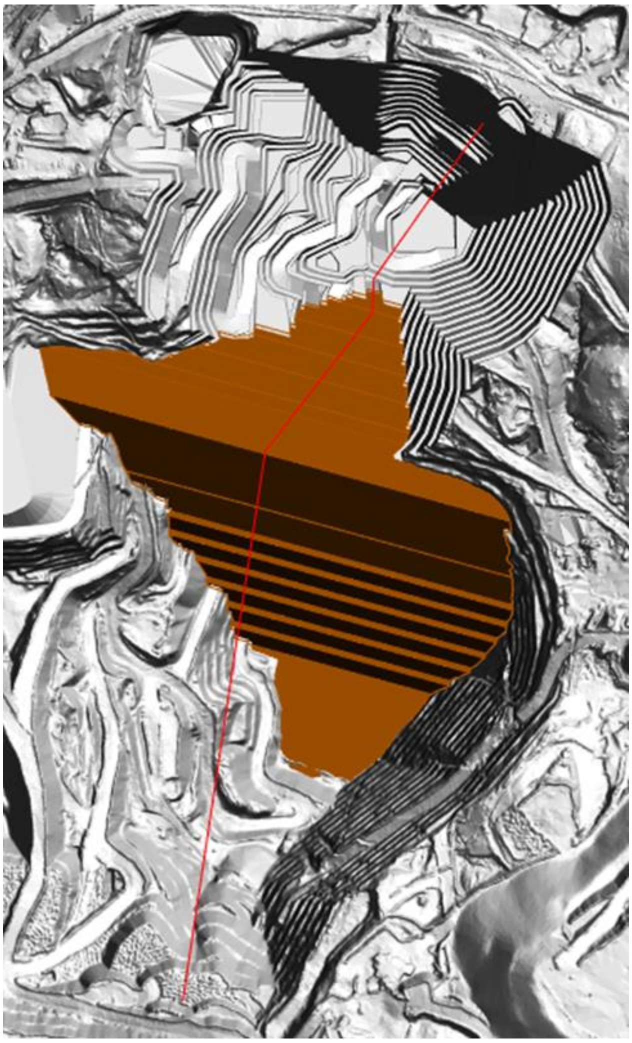

Figure 2.2 Plan of FRBF Stage 2 to 480 mRL

Figure 2.3 presents a long-section (the trace of the red line in Figure 2.1 and Figure 2.2) through the lowest pit floor pathway between the final projected as-mined FROP and IMOP. The highest pit floor elevation between the two pits, which represents the overtopping elevation between the two pits, is 380 mRL, at CH 1625 m (Figure 2.3).

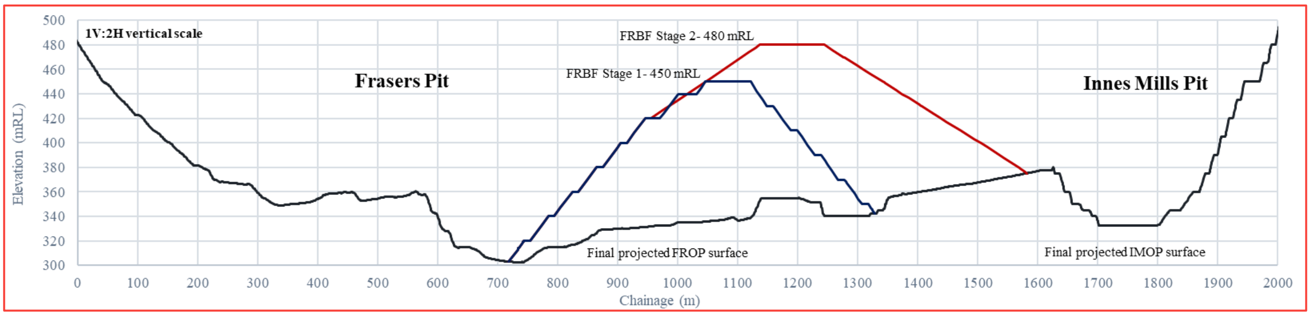

Figure 2.3 Cross-section though pits and FRBF, showing configuration of Stage 1 and 2 (1V:2H exaggeration)

The forecast waste rock delivery rate for the construction of the FRBF Stage 1 and Stage 2 is shown in Table 2.1.

Table 2.1 Waste rock delivery rate forecast for FRBF Stage 1 and Stage 2

Year	FRFB Stage	Waste rock tonnes (Mt)	Cumulative tonnes (Mt)	Dry Density (t/m^3)	Waste rock volume (Mm^3)	Cumulative volume (Mm^3)
2024 (*March - December*)	Stage 1	33.0	33.0	2.2	15.0	15.0
2025		23.5	56.5	2.2	10.7	25.7
2026	Stage 2	11.2	67.7	2.2	5.1	30.8
2027 (*January - November*)		13.8	81.5	2.2	6.3	37.0

2.2 Tailings Storage Facility

Tailings slurry will be pumped from the process plant to FROP and contained within the FTSF by FRBF. A total of 35.5 Mt of slurried tailings will be delivered to the FTSF between 2025 and 2030, with 6 Mt of tailings to be delivered during Stage 1 and 29.5 Mt during Stage 2, as indicated in the tailings production forecast shown in Table 2.2.

Table 2.2 Tailings forecast to be discharged into FTSF

Year	Tailings (dry Mt)	Cumulative tonnes (dry Mt)	Settled dry density (t/m^3)	Volume (Mm^3)	Cumulative volume (Mm^3)
2025 (Stage 1)	6.5	6.5	1.25	5.2	5.2
2026	6.5	13.0	1.25	5.2	10.4
2027	6.5	19.5	1.25	5.2	15.6
2028	6.5	26.0	1.25	5.2	20.8
2029	6.5	32.5	1.25	5.2	26.0
2030	3.0	35.5	1.25	2.4	28.4

The Stage 2 tailings beach is expected to reach a final elevation of 416.5 mRL at an estimated average settled dry density of 1.25 t/m^2 (based on historically achieved densities in the Macraes TSFs). The final tailings beach will be 63.5 m below the crest of the FRBF, as indicated in section in Figure 2.4 and plan in Figure 2.5.

Tailings will be discharged from the embankment to form a beach sloping at 1% to the south (Figure 2.5). The tailings supernatant (water released from the tailings on first settling after deposition) will form a return water decant pond in the southern area of FTSF. The return water will be pumped back to the process plant for reuse, using a floating pump arrangement in the decant pond and a series of staging ponds and pumps along the route as shown on Figure 12.3.

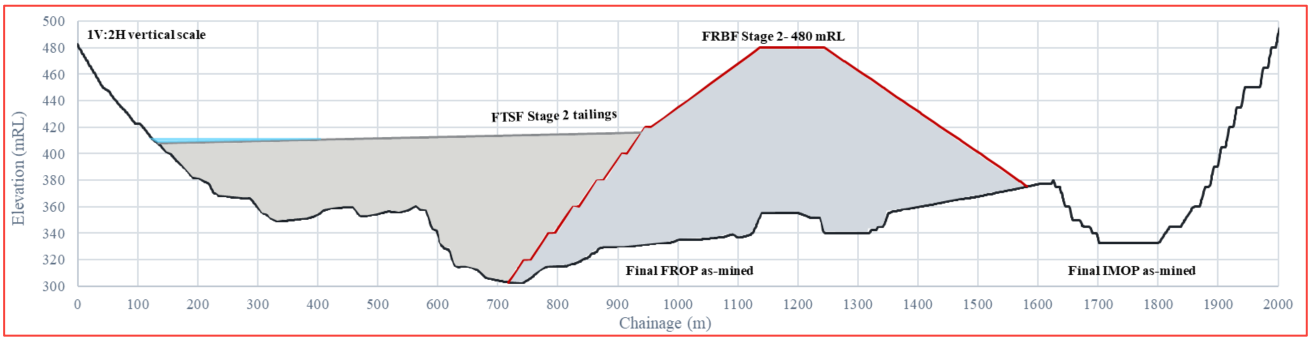

Figure 2.4 Cross-section though pits and FRBF, showing elevation of final FTSF tailings (1V:2H exaggeration)

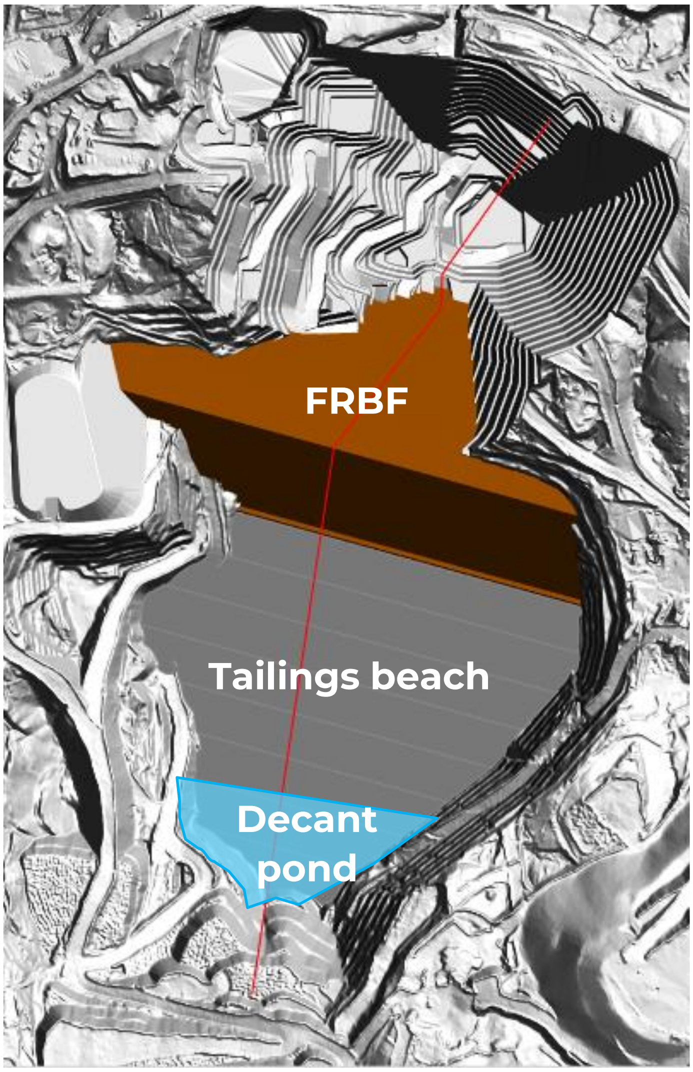

Figure 2.5 Plan of final tailings beaching against FRBF Stage 2

2.3 TSF closure plan

The closure plan for FTSF has the following two stages:

2.3.1 *Immediately after cessation of mining*

A water cover will be maintained by the mine over the tailings to prevent dust generation immediately after cessation of mining and hence tailings deposition. This water cover will have a minimum depth of 1.0 m against the FRBF to allow for seasonal changes in the pond extent. There may be a need to install a ±25 m width of waste rock across the tailings beach against the FRBF to account for the seasonal variation of the water cover depth in the short-term.

2.3.2 *Long-term*

In the long-term the FROP and IMOP will fill with water from catchment runoff and seepage infiltration, forming pit lakes that will eventually submerge the FRBF and connect to form a single pit lake (Figure 2.6). Flow would occur over the width of the FRBF crest if one pit lake fills faster than the other, until such time that the water level in both pits is the same. Limited and inconsequential erosional damage is to be expected on the downstream slope of the FRBF due to expected low rate of such overflows.

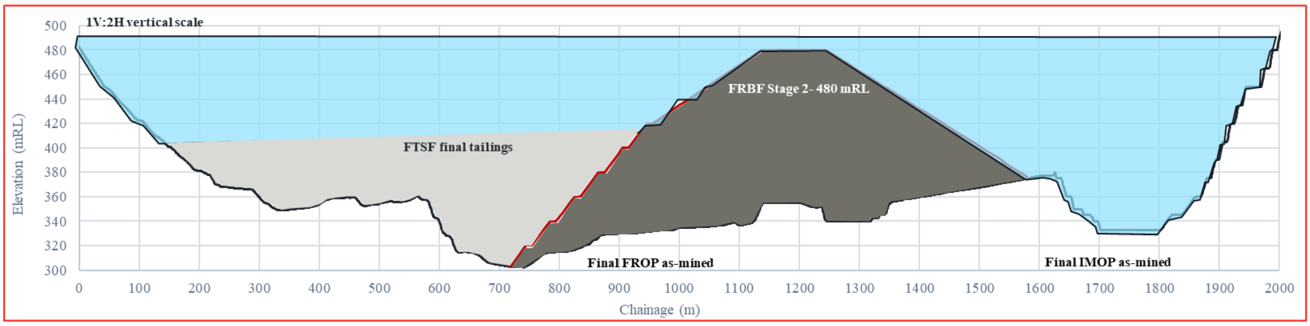

Figure 2.6 Cross-section though pits and FRBF, showing long-term pit lake elevation

GHD (2024) has undertaken long-term (300 year) water balance modelling for the closure of Stage 2 to estimate the rate that the pit lakes in FROP and IMOP develop and the long-term water level. The result of this modelling (Figure 2.7) indicate a positive overall water balance and rising lake water level as follows:

- FROP pit lake rises ahead of IMOP and reaches the FRBF crest (480 mRL) after 65 years, after which excess water will flow across the crest of FRBF into IMOP. Equilibrium between the FROP and IMOP pit lakes (at 480 mRL) is estimated to be reached after 95 years, at which time the pit lakes combine and eventually fully submerge the FRBF.
- The combined pit lake reaches a long-term water elevation between 486 and 494 mRL, based on current climatic inputs, with the modelled lake level range accounting for short-term fluctuations due to storm events, seasonal fluctuations due to cyclic wet and dry periods, long-term fluctuations due to extended wet or dry periods and uncertainties in long term climate change behaviour. This long-term water level is below the lowest pit rim elevation in the northwest of the TSF, which has a fill level of 514 mRL and natural in situ shist level of 497 mRL. The in situ schist level in the south of the pit is 487 mRL, below the Frasers South Waste Rock Stack (FSWRS). Seepage in this area is currently captured in the Murphys Sump and returned to the pit.

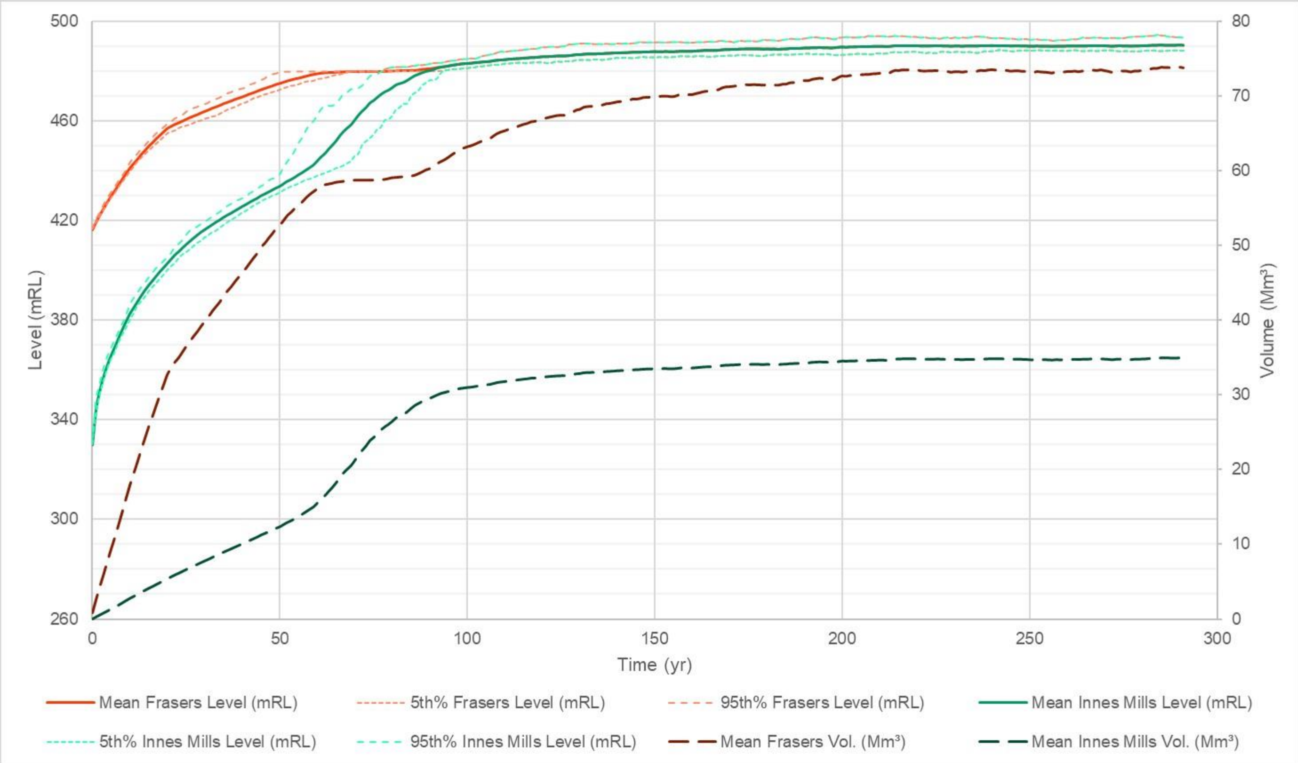

Figure 2.7 FTSF and IMOP pit water filling model over time

3 Basis of Design

The basis of design for FTSF Stage 2 is provided in Table 3.1.

Table 3.1 Stage 2 basis of design

Design parameter	Design criteria	Reference
General		
Survey datum	MGPG (Macraes Gold Project Grid)	OGNZL
Site survey	30 December 2021 – site_surface_20211230_MGPG.dxf	OGNZL
Potential Impact Classification	Operation – Low, Closure – Low; Section 6.	WSP
Production and scheduling		
Waste rock	Section 2.1. 81.5 Mt waste rock disposal in total.	OGNZL
Slurried tailings	Section 2.2. 35.5 Mt slurried tailings disposal in total.	OGNZL
FRBF embankment design		
Embankment type	Waste rock backfill	OGNZL
Embankment zoning	A 50 m wide section of controlled backfilling on the upstream face for seepage control. This will be end tipped and track rolled in 5 m lifts to limit segregation, achieve a higher density and a lower permeability. Material and construction specifications will be outlined during detailed design.	WSP
Crest elevation	480 mRL	OGNZL
Crest width	100 m	OGNZL
Embankment battering Downstream Upstream	 Approximately 1V:3H overall Below 420 mRL: 1V:1.33H inter-bench, 1V:2.2H overall Above 420 mRL: 1V:3H overall	OGNZL
Embankment benching Downstream Upstream	 None Below 420 mRL: 13.5 m wide Above 420 mRL: None	OGNZL
Geotechnical design		
Material strength parameters	Table 7.1	WSP
Static stability design	<u>Load case</u> — <u>Minimum requirement</u> Long-term drained — FoS > 1.5 Short-term undrained — FoS > 1.5 Residual undrained (post-seismic) — FoS > 1.2	NZSOLD 2015

<table>
<tr><th>Design parameter</th><th>Design criteria</th><th>Reference</th></tr>
<tr><td rowspan="2">Seismic deformation design</td><td><u>Operations</u>:
<u>PIC</u> | <u>Load case</u> | <u>Design event</u> | <u>Minimum requirement</u>
Low | OBE | 1:150 AEP | Minor deformations acceptable provided the dam remains functional and the resulting damage is easily repairable.
Low | SEE | 1:500 AEP to 1:1,000 AEP | Deformations are acceptable provided they do not lead to an uncontrolled release of the impounded contents.</td><td>NZSOLD 2015</td></tr>
<tr><td><u>Closure</u>:
<u>PIC</u> | <u>Load case</u> | <u>Design event</u> | <u>Minimum requirement</u>
Low | SEE | 1:10,000 AEP | Deformations are acceptable provided they do not lead to an uncontrolled release of the impounded contents.</td><td>NZSOLD 2015, ICMM 2020</td></tr>
<tr><td colspan="3">Hydraulic design</td></tr>
<tr><td>Inflow design flood (IDF)</td><td>1:100 AEP to 1:1,000 AEP based on a Low PIC</td><td>NZSOLD 2015</td></tr>
<tr><td>Design freeboard
(Greater of)</td><td><u>Load case</u> | <u>Minimum requirement</u>
Maximum reservoir level normal | Wind set up and wave runup for the highest 10% of waves caused by a sustained wind speed with an AEP greater than 1 in 100.
Maximum reservoir level inflow design flood | IDF plus 1.0 m</td><td>NZSOLD 2015</td></tr>
<tr><td>Spillway</td><td>None required, as overtopping is not a credible failure mode during operations as there is significant freeboard to the FRBF crest.</td><td>WSP</td></tr>
<tr><td colspan="3">FTSF tailings management</td></tr>
<tr><td>Deposition strategy</td><td>At least three full-bore spigots depositing from the FRBF embankment, beaching sub-aerially towards the decant pond in the south-east corner.</td><td>WSP</td></tr>
<tr><td>Slurry pipeline benching</td><td>~15 m wide benches with 20 m inter-bench height and inter-bench slope of 1V:1.33H</td><td>OGNZL</td></tr>
<tr><td>Tailings sub-aerial beach slope</td><td>1%</td><td>WSP</td></tr>
<tr><td>Average settled dry density</td><td>1.25 t/m^3</td><td>WSP</td></tr>
<tr><td>Tailings storage level</td><td>Estimated maximum level of 416.5 mRL</td><td>OGNZL</td></tr>
<tr><td colspan="3">FTSF water management</td></tr>
<tr><td>Decant pond</td><td>An average 2 m deep decant pond in the south-east corner</td><td>WSP</td></tr>
</table>

3.1 Regulatory requirements

New Zealand dam design is governed by the Resource Management Act (1991) and Building Act (2004). The New Zealand Dam Safety Guidelines (NZSOLD 2015) are generally accepted as a means of demonstrating compliance with the acts for dam design and forms an alternate solution under the Building Act.

The process for dam development and approval is presented in Figure 3.1. This report has been developed to provide the necessary assessments for resource consent. Information presented for resource consent "must demonstrate that hazards are manageable and appropriate" and need not be undertaken to a detailed design level of assessment.

In addition to the national regulatory requirements, OGNZL is committed to complying with the Global Industry Standard on Tailings Management (GISTM) published by the International Council on Mining and Metals, UN Environment Programme and the Principles for Responsible Investment (ICMM et al. 2020).

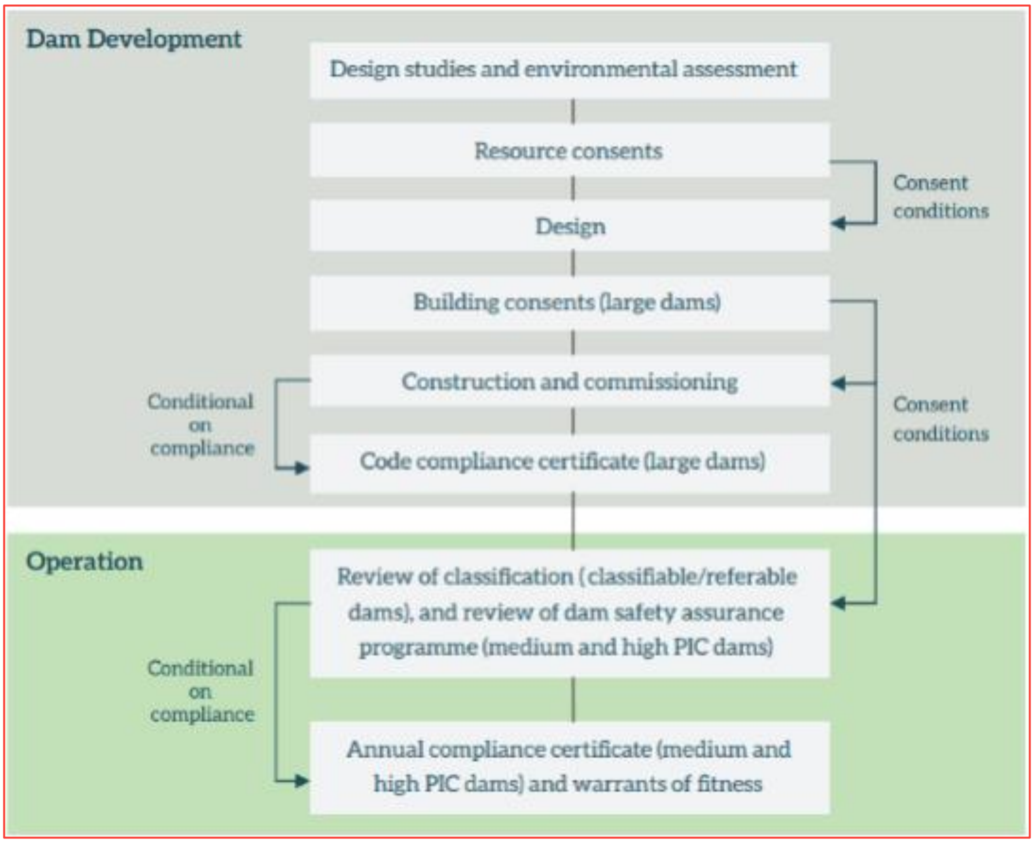

Figure 3.1 Legislative requirements for dam development and operation (NZSOLD 2015)

4 Site Conditions

4.1 Climate

A detailed description of the local climate at Macraes is given in Macraes Gold Project Expansion - Water Management (Woodward-Clyde 1996a), Macraes Gold Project Expansion – Groundwater Impact Assessment (Woodward-Clyde 1996b) and more recently in Macraes Phase III Project Water Management Section 2 – Climate (Golder 2010). These reports include relevant historical records relating to rainfall, evaporation, runoff and temperatures.

The mean annual rainfall recorded since 1959 at the Glendale Station Site, located at the northwest upstream end of the TTTSF, is 628 mm with a max and min annual rainfall of 914 mm (1978) and 395 mm (1998) respectively. A probable maximum precipitation (PMP) of 700 mm was originally estimated for the Macraes Mine site for a 48-hour storm (Woodward-Clyde (NZ) Ltd in 1996). A 72-hour PMP of 761 mm was estimated by EGL more recently (EGL 2022a).

4.2 Topography

Site topography has been summarised from assessments undertaken by GHD (2022) as part of the Macraes Phase 4 consenting project. Topography of the wider Macraes site is driven by the geologic evolution of the region. Long term weathering and erosion of the underlying rock resulted in a distinctive low relief peneplain which is bounded by North Branch Waikouaiti River to the west, Deepdell Creek to the north, and Murphys Creek to the south. Deepdell Creek has been deeply incised into this erosional surface resulting in steep valley slopes and minimal alluvial deposition. In contrast, the North Branch Waikouaiti River is characterised by shallow relief, broad valleys and alluvial deposition.

The original topography has been altered by thirty years of mining and waste deposition. Mining has been generally aligned with the orientation of the major shear zone. This has altered portions of original catchments in the main Macraes mine site, but the primary streams and rivers surrounding the mining site remain and are ephemeral in nature.

The Macraes mine site is located within the Shag River/Waihemo and Waikouaiti River catchments, as shown in Figure 4.1. The Shag River flows in a south-easterly direction and enters the ocean close to Matakaea. The Waikouaiti River North Branch flows in a southerly direction from the mine site and enters the ocean near Karitane. The catchments consist primarily of agriculture and forestry.

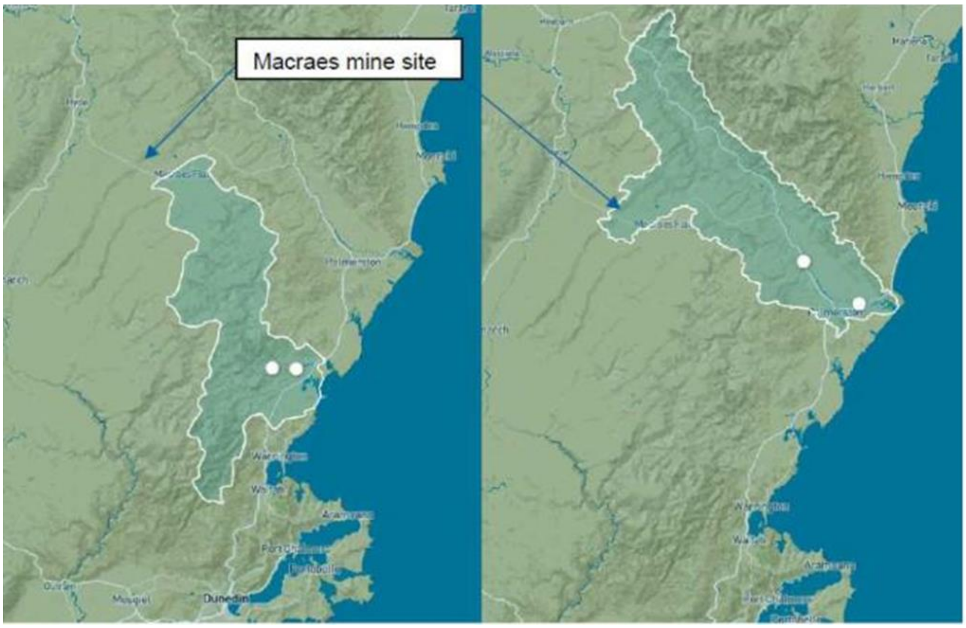

Figure 4.1 Waikouaiti Northern Branch and Shag River / Waihemo catchments (GHD 2022)

4.3 Geology

Site geology has been summarised from assessments undertaken by PSM (2022, 2024) as part of the Macraes Phase 4 consenting project.

4.3.1 Regional geology

The Macraes Flat area is within the extensively deformed and moderately metamorphosed Otago-Haast Schist Belt. The schist comprises a sequence of gradational psammitic and pelitic lithologies derived by metamorphism of Mesozoic aged sandstone and mudstone. The rocks are strongly foliated and depending on the origins are either light grey, quartz rich and laminated (psammite) or dark grey to green, micaceous, and finely laminated (< 5 mm thick) (pelite).

Mineralisation occurs within the north-south trending Hyde-Macraes Shear Zone (HMSZ) which has a strike length of at least 35 km. The HMSZ thickness varies from 5 to 140 m and is defined between the upper relatively continuous low angle Hanging Wall Shear (HWS) and lower sub-parallel Footwall Fault (FF). Its tectonic displacement has been inferred to be hundreds of metres. The strain associated with tectonic displacement was probably concentrated within the intra-shear pelite due to its finer grained composition compared to the coarse-grained psammite above and below the Shear Zone. The structural geology of the area is dominated by two main orthogonal fault sets, striking to the north and east.

The Shear Zone dips gently to the east from Stoneburn in the south to Coronation in the north but displays a broad bend at Nunns, turning to dip to the northeast (Figure 4.2).

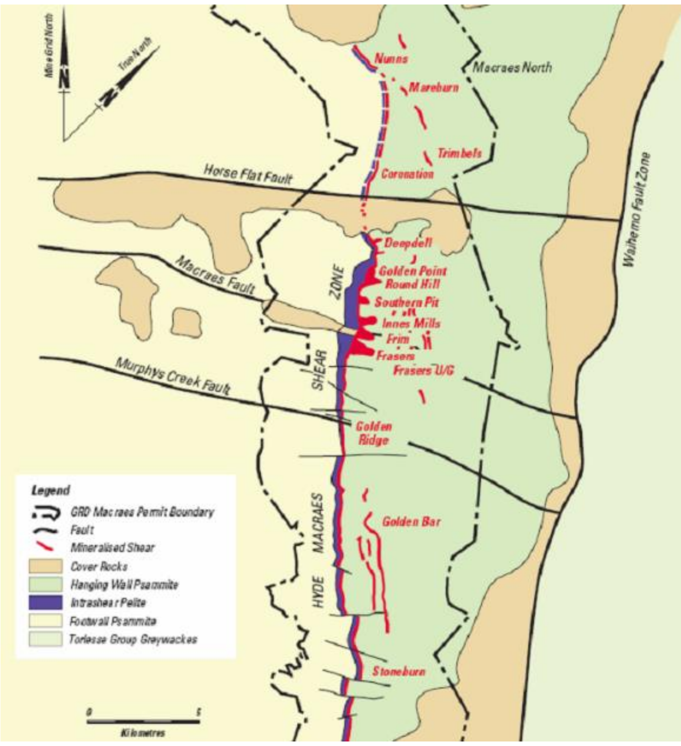

Figure 4.2 Plan of Macraes Mine showing various pits, deposits and the HMSZ (PSM 2022)

4.3.2 Local geology

The HMSZ at Round Hill is approximately 100 m thick and dips about 15° to 20° to the east. Repeated deformation has resulted in numerous faults, ramp thrusts, recumbent folds and a penetrative shallow east dipping cleavage. This cleavage is parallel to the HMSZ and largely overprints bedding and earlier deformation fabrics. However, within the intra-shear pelite, this has been transposed by a south dipping penetrative crenulation cleavage. High angle (60°) stockwork veining is common within the HMSZ.

4.3.3 Geological fault structures

There are three main large-scale faults around FROP; the Footwall Fault, Macraes Fault Zone and Murphys Gully Fault.

4.3.3.1 Footwall Fault

The Footwall Fault (FF) is a north-south trending regional scale fault typically dipping between 10° and 20° that delineates the base of the mineralised zone at Macraes. Geological studies completed in the late 1990s highlight the Deepdell Creek landforms as an ancient landslide with the FF as its basal plane. This provided precedent for slope movement along the FF predating mining activity. The condition of the sliding surface results in a very low friction angle, creating a highly sensitive structure that responds to small changes in pore pressure and loading.

4.3.3.2 Macraes Fault Zone

The Macraes Fault Zone (MFZ) is defined by a wide deformation zone of very poor quality, low strength rock mass dipping 50° to 60° towards 020° to 030°. The zone traverses obliquely through the northern extents of the existing FROP and IMOP pit shells and is expected to intersect the base of the FRBF.

The faulted and sheared rock mass of the MFZ will be located beneath the downstream toe of the proposed FRBF but is not expected to have an adverse impact on embankment stability. The MFZ however has a higher permeability than that surrounding rock mass which may influence seepage through this highwall.

4.3.3.3 Murphys Gully Fault

The Murphys Gully Fault (MGF) is a normal fault dipping 60° to 70° towards 004° to 010° and is a zone approximately 100 m wide of crushed rock, clay gouge and rock blocks. This structure occurs in the south wall of FROP and delineates the southern boundary of the pits' ore zone. The rock mass to the north of the MGF has been dragged up resulting in a steepening of foliation from 25° to 50° to subvertical over a length of approximately 200 m. Faulting occurs along this steepened foliation on the west wall typically resulting in planar slides. The location and presence of the MGF is not expected to have a discernible impact on development of the FTSF.

4.3.4 Prior pit wall performance

Large-scale slope instabilities have occurred during FROP mining. The following summarised events are of significance to either FRBF foundation conditions or potential stability implications within the existing slopes during TSF filling.

4.3.4.1 East Wall

2012

A section of the east wall failed in late 2012 during mining of Frasers Stage 5. The failure ultimately extended approximately 170 m laterally and 115 m vertically, from 405 mRL down to 290 mRL. The failure was a structurally controlled planar mechanism, with sliding along a continuous shear or fault structure oriented sub-parallel to the east wall with a dip of approximately 44° toward the west. The rear failure plane appears to have come close to, or daylighted, at the failure toe.

Cross-cutting second order joints were observed at the flanks of the failure. These structures act as side-release planes truncating on the continuous rear failure plane. A series of conjugate structures were observed to be associated with the main shear/fault structure. Removal of displaced material at the base failure plane was completed leaving an overhang.

2022

A package of stopes within FRUG, known as the "3P's", are located beneath the east wall of FROP. In December 2022, a localised production blast within these stopes initiated slope movement along a package of geological structures, extending laterally from the 2012 failure and truncated by the Hanging Wall Shear at its base. To limit further strain in the rock mass, all further development within the 3P's was halted following the observed movement.

4.3.4.2 West Wall

Pre-April 2014

Prior to April 2014, the Frasers west wall experienced three large, rapid movement events in response to mining and rainfall.

1. The first occurred on 10 June 2012 when the wall moved approximately 10 m as a result of mining re-commencing in the area around 12000 mN – 12300 mN on the 285 mRL bench, below the previously mined Frasers 4C pit. Negligible rain fell in this period.
2. The second occurred on the 15 August 2012. Two 80 mm rain events occurred two weeks apart in July and August 2012. After the first 80 mm of rain, the movement rate of the west wall increased from 4 mm/day to 40 mm/day and remained roughly constant for two weeks until the second 80 mm of rain caused the wall to move 10 m on 15 August.
3. The third occurred on 5 January 2013 largely in response to 50 mm rain event two days prior, but also to mining activity at the bottom of the Frasers 5 pit in the preceding weeks. The wall moved approximately 65 m.

Between 5 January 2013 and the 19 April 2014, the upper sections of the west wall recorded displacements of approximately 2.5 m. In that same time, the lower sections of the west wall displaced approximately 0.1 m. This was in keeping with the expectation that slope movement responses to mining could be separated between mining the upper and lower sections of the west wall.

April 2014

A 20 Mm^3 failure occurred within the west wall on 19 April 2014 following a heavy rainfall event and is considered to be a reactivation of the January 2013 failure. The failure extent is summarised below:

- The northern margin is well-defined at approximately 12500 mN. It is created by a series of discrete joints and cracks induced by previous movement including the 5 January 2013 failure
- The southern margin of the failure is indistinct, blending into the open pit excavation. It approximately coincides with 11800 mN
- The failure stopped against the east wall and pushed up tens of metres of toe heave
- The FF is the basal plane of the failure and has been exposed in part of the failure headscarp
- Areas of the failure mass moved up to 200 m into the pit.

4.3.4.3 FRUG interactions

The Frasers underground mine (FRUG) includes a series of drives and stopes located beneath the FROP highwall. Development of underground workings causes a redistribution of stresses within the rock mass and yielding can occur where the induced stress exceeds the rock mass strength. This is expressed in the FROP as large-scale fracturing with increased dilation along geological structures. Dilated geological structure is visible throughout the pit wall with localised zones of caving in the pit floor where existing "Panel 1" workings have been mined out.

The FRUG Panel 1 workings with the least rock cover are located beneath the proposed FRBF, which may result in further subsidence due to surcharge loading from backfilling activities. This would be expected to choke rapidly underground and ongoing subsidence is expected to be negligible.

During construction of the FRBF the highwall rock mass will be progressively supported with additional buttressing from the placed fill. The rock mass is expected to maintain elevated secondary permeabilities as water migrates along dilated geological structures.

4.4 Seismicity

4.4.1 Regional seismicity

Site seismicity has been summarised from prior analyses and interpretations undertaken by EGL (2022a). The site is in an area of low historic seismicity and there are some nearby faults that are considered active with low slip rates, but they have the capability of generating large, rare earthquakes. These include the nearby Taieri Ridge and Billys Ridge Faults and the more distant Hyde and Waihemo faults. These faults all have annual mean slip rates of less than 0.5 mm/year and are considered capable of generating earthquakes with magnitudes in the range of about Mw 6.4 to 7.3. The Alpine Fault is the largest and most active fault in New Zealand which is located about 200 km northwest of the site. It has an annual mean slip rate of 25 mm/year and is considered capable of earthquakes of up to about Mw 8.3.

4.4.2 Seismic hazard analysis

4.4.2.1 Site-specific PSHA

Bradley Seismic Ltd (Bradley 2021) undertook an update of the site-specific probabilistic seismic hazard analysis (PSHA) for the Macraes mine site in 2021. This seismic hazard study replaced a previous PSHA by the Geological and Nuclear Sciences (GNS) undertaken in 2005. Probabilistic estimates of seismic hazard in terms of acceleration response spectra (5% damping) were provided for return periods of 1:150, 1:500, 1:1,000, 1:2,500 and 1:10,000 years.

Shear wave velocity measurements were undertaken by Southern Geophysical Ltd. A Vs_{30} = 1,500 m/s is generally representative of Macraes site conditions, except where over the Macraes Fault Zone where a Vs_{30} = 1,100 m/s is more representative. This is appropriate for the FRBF and has also been adopted for seismic hazard studies at the adjacent TTTSF. The results of the 2021 seismic hazard study are lower than those in the 2005 study. The reasons for this include:

- Explicit specification of the shear-wave of the site (as compared to binary ‘rock’ classification in the 2005 study, which on average reflects significantly less stiff site conditions)
- Use of 2014-era ground-motion prediction models compared to 1997-era models in the 2005 study which are recognised to lead to over-prediction of ground motions from smaller magnitude earthquakes
- The 2021 study does not use ‘magnitude weight’ or ‘spectra smoothing’, which was applied in the 2005 study in order to overcome known issues with the adopted ground motion model.

4.4.2.2 National seismic hazard model (NSHM)

The New Zealand National Seismic Hazard Model (NSHM) was updated by the Institute of Geological and Nuclear Sciences (2022). Results have been published with response spectra at Vs_{30} = 1,500 m/s and Vs_{30} = 1,000 m/s and therefore, Vs_{30} = 1,000 m/sis appropriate over the Macraes Fault Zone. Results indicate response spectra are generally larger than Bradley (2021).

4.4.2.3 Comparison between the site-specific and national seismic models

Median (RotD50) horizontal accelerations are typically appropriate for analysing slope deformations of embankments. A comparison of the RotD50 spectra is presented in Figure 4.3 for the NSHM (2022) and site specific PSHA (2021) based on a Vs_{30} of 1,000 m/s and 1,100 m/s respectively. Results indicate response spectra form the 2022 NSHM are generally larger than the 2021 PSHA. Both seismic models have been considered for assessing seismic deformations of FRBF as outlined in Section 10.2.

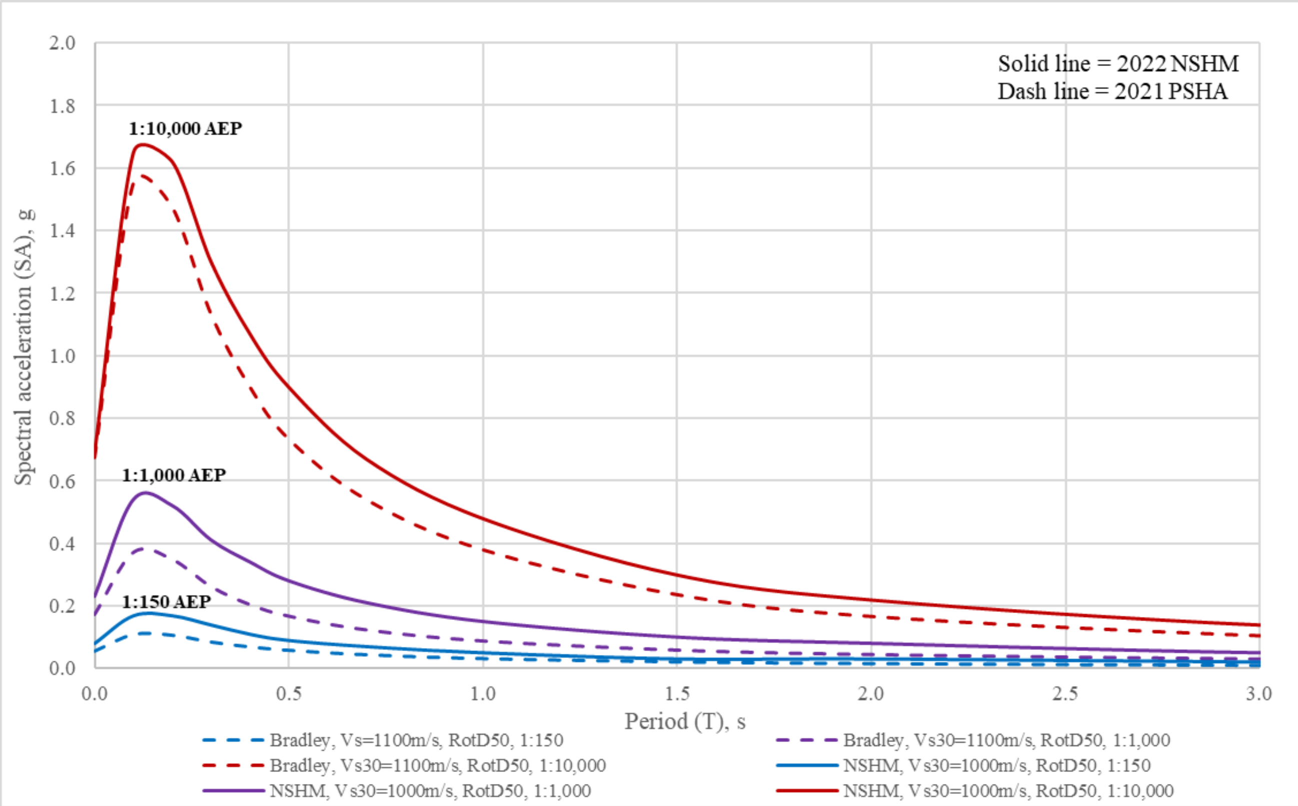

Figure 4.3 Macraes RotD50 spectral acceleration comparison between PSHA and NSHM

5 Potential Failure Modes

A failure modes and effects analysis (FMEA) has been conducted for the operational and closure phases of FTSF Stage 2 to identify potential failure modes (PFMs), evaluate the risk of each and develop suitable risk controls. A total of 24 PFMs were considered, as outlined in the FMEA and Risk Assessment summary report contained in Appendix A.

PFMs were specifically assessed with respect to dam safety implications and do not consider the day-to-day risks during construction or operations which shall be defined and categorised in task specific risk assessments, such as a high wall failure or supernatant water loss into the FRUG, and OGNZL Principal Hazard Management Plans.

5.1 Credible failure modes

Credible failure modes refer to technically feasible failure mechanisms given the materials present in the structure and foundations, the properties of these materials, the configuration of the structure, drainage conditions and surface water controls and are not associated with a probability of an event occurring (ICMM et. al. 2020)

Credible failure modes identified for Stage 2 are summarised in Table 5.1, but it is emphasised that these do not indicate loss of containment or catastrophic failure. Most technically feasible failure modes cause minor damage to the TSF containment structure. Section 5.1.1 and 5.1.2 outline credible failure modes that may result in either catastrophic failure of potential loss of containment.

Table 5.1 FTSF Stage 2 credible failure modes

Project phase	Credible failure modes identified	Risk profile for credible failure modes identified			
		Low	Medium	High	Extreme
Operation	11	10	1	-	-
Closure	12	11	1	-	-

5.1.1 Credible failure modes with potential catastrophic failure

Catastrophic failure is defined as a failure mode that diminishes structural integrity to the extent that the facility cannot continue to operate to store tailings or allows a significant release of contents. No catastrophic failure modes were identified.

- Operation: Freeboard between the advancing backfill and rising tailings beach is more than 75 m during construction (based on scheduling in Section 11) and 63.5 m at the end of deposition (based on a final tailings level of 416.5 mRL). The FMEA did not identify any failure modes where catastrophic release of contents is credible; given the significant internal freeboard, embankment geometry, material properties, and limited tailings depth above the in situ pit floor.
- Closure: Long-term water balance modelling indicates an ultimate pit lake level of 494 mRL which is approximately 10 m below the lowest pit perimeter level (in the northwest). A failure with catastrophic release of contents outside of the combined pit is therefore not credible.

5.1.2 Credible failure modes with potential containment loss

Containment loss refers to an uncontrolled release of either tailings (can be slurried or dry tailings) or contaminated water (through seepage or overflows) outside of the TSF boundary. Credible failure modes with potential containment loss are limited to either tailings dust exposure or seepage issues during long-term closure and are summarised in Table 5.2. The risk level for each of these is appropriately low and satisfactory. Loss of supernatant water into the FRUG is considered to be an operational risk with no potential for external containment loss.

- Operation: There are no credible failure modes that would lead to a potential containment loss of slurried tailings or contaminated water to the surrounding environment, predominantly due to the significant freeboard forecast. Loss of airborne tailings dust has been identified as the only potential containment loss. Loss of supernatant water into the FRUG is considered to be an operational risk, with insignificant environmental consequences.
- Closure: There are no credible failure modes with potential containment loss of slurried tailings or water overflow, based on freeboard to the minimum pit perimeter level. Loss of airborne tailings dust and seepage through to groundwater or FSWRS (based on pit lake elevations) have been identified as potential containment losses.

Table 5.2 Associated risk controls for failure modes with potential containment loss and

PFM No.	Failure mode description	Highest risk level	Project phase	Preventative & mitigation controls
18	Seepage from FTSF leading to surface water release into environment.	8 (M)	Closure	— Consider enhanced passive treatment to improve quality of seepage water to reduce consequence. — Frasers South WRS design to consider design & installation of preventative controls
19	Seepage into the pit floor and through the highwalls into groundwater.	5 (L)	Closure	— Water modelling assessment to infer magnitude of seepage flows, quality and timing of migration for control evaluation.
25	Dry tailings beach and high wind resulting in loss of dry tailings into the environment.	5 (L)	Operation & Closure	During operations: — Beach management to keep the surface wet — Operation in accordance with the OMS Manual — Consider wetting tailings slurry in later years of operation to create a flatter beach During closure: — Pit lake closure strategy — Redirect seepage flows and sources of water from other Macraes operations to increase cover extent — Review closure design options in detailed design, such as a partial wet cover with rockfill capping on the perimeter.

6 Potential Impact Classification

An assessment of the Potential Impact Classification (PIC) has been carried out for the Stage 2 design in accordance with the procedure set out in the NZDSG (NZSOLD 2015).

6.1 Dam break assessment

An initial dam break flood hazard assessment has been undertaken, considering only a qualitative study of input data. This has been undertaken in lieu of two or three-dimensional modelling of the FTSF break flood, as the pathway for any release of contents is well defined and fully contained within the FROP and IMOP pits.

The potential for a seiche wave, caused by a pit wall failure, to overtop the pit perimeter was considered in the FMEA, but discounted for both during operations and closure, as:

- **During operations**: Water volume and depth is limited and there is significant freeboard to the FBRF crest
- **During closure**: There will be a minimum of 10 m freeboard between the pit rim and maximum modelled pit lake, which equates to 22 Mm^3 of contingency storage to accommodate potential pit wall failure generated seiche waves.

6.1.1 Dam break potential during operations

Mining within IMOP downstream of FRBF is planned to conclude in 2028 when the tailings level within FTSF is estimated to reach a maximum of 400 mRL. The head difference between the upstream tailings surface and downstream pit floor is projected to be 20 m across a backfill width of 700 m. Catastrophic failure, leading to a loss of tailings, through such a width of backfill is considered not credible. This arrangement is illustrated in Figure 6.1.

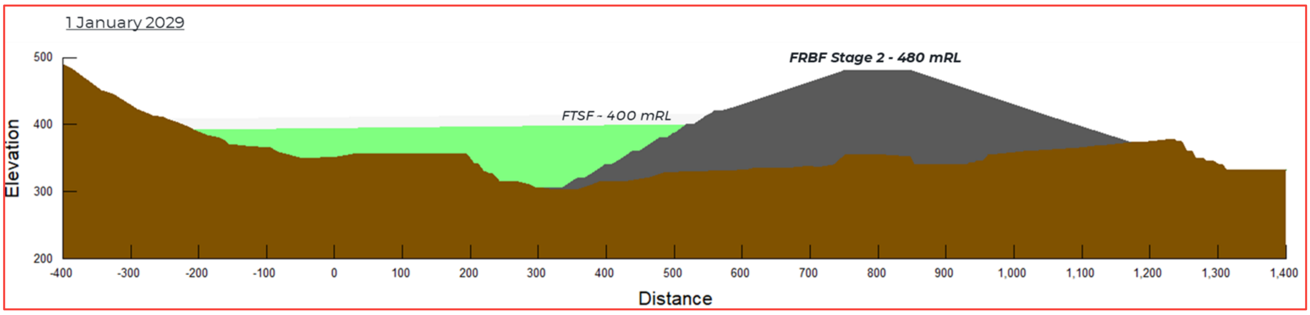

Figure 6.1 FRBF and FTSF filling level at the end of IMOP mining downstream

The FMEA did not identify any credible failure modes that result in the loss of containment downstream during operations; given the significant freeboard, embankment geometry, backfill material properties and limited tailings depth above the pit floor.

6.1.2 Dam break potential during closure

Mining in IMOP downstream of FRBF ceases prior to TSF closure. Mine involvement is therefore limited to post-closure monitoring or sampling that is brief, low in frequency and covered by operational risk assessments.

Pit lakes will develop either side of the FRBF embankment and fully submerge the structure some 95 years post closure. Any embankment failure and loss of containment during lake filling would be fully contained within the connected FROP and IMOP pits.

6.2 Consequence assessment

A Consequence assessment has been undertaken for both the operational and closure phase of FRBF Stage 2.

6.2.1 Damage level

Table 6.1 summarises the damage level for each assessment category (NZSOLD 2015) during operation and closure. There are no risks to public assets (housing, infrastructure and the community), the natural environment or major mine infrastructure under both the operations and closure phases, as any potential failure is fully contained within the pits or ensuing pit lakes. There is therefore no damage condition to assess.

Table 6.1 Stage 2 FRBF assessed damage level

Project phase	Damage level of each defined category					Assessed overall damage level
	Housing	Critical or major infrastructure		Natural Environment	Community recovery time	
		Damage	Time to restore			
Operation	None	None	None	None	None	**None**
Closure	None	None	None	None	None	**None**

6.2.2 Population at Risk

Population at risk (PAR) is defined as "the number of people likely to be affected by an inundation greater than 0.5 m depth if a dam failure occurred" (NZSOLD 2015).

- During operation - PAR of zero as there is no potential for tailings to flow from FTSF into IMOP
- After closure - PAR remains zero as the pit lake levels rise, as:
  - All mining has ceased
  - Any operational involvement will be limited to post-closure sampling that is brief, low frequency and covered by operational risk assessment
  - No public access allowed
  - Pit lake levels (maximum 494 mRL) remain well below the lowest pit rim elevation of 514 mRL.

6.2.3 Potential Loss of Life

Potential loss of life (PLL) is dependent on many factors, a number of which are related to human behaviour and interaction under adverse conditions such as dam break inundation (NZSOLD 2015). There is no potential loss of life as the PAR is assessed as 0.

6.3 Classification

The PIC of FRBF Stage 2 is assessed as **LOW** (NZSOLD 2015, Table 3.1), in view of the negligible damage, zero PAR and zero PLL, as presented in Table 6.2.

Table 6.2 PIC for FRBF Stage 2

Project phase	Damage Level	PAR	PLL	PIC
Operation	None	0	0	**Low**
Closure	None	0	0	**Low**

The Consequence Category assessment is based on key design assumptions which may change throughout the life of FTSF, such as the final maximum tailings elevation. An intermediate dam safety review should be undertaken annually to ensure that deviations from the design are captured and the resultant risks assessed, with a comprehensive dam safety review and potential impact classification reassessment done every five years.

7 Material Characteristics

Material strength parameters adopted for limit equilibrium stability analyses are based on prior assessments undertaken for designs of TTTSF raises. The latest assessment is summarised in the TTTSF RL570 Technical Report (EGL 2022a). Material strength parameters adopted for the analysis of FRBF are presented below.

7.1 In situ rock

Strength parameters are taken as the lower bound strengths typically used for pit design at Macraes (EGL 2022a). This is defined as deeper, less weathered rock greater than 5 m below original ground levels. No strength losses are expected under seismic conditions. The pit floor is expected to be competent, hard rock and not susceptible to liquefaction.

Effective cohesion (c')	150 kPa
Effective friction angle (ϕ')	45°
Unit weight (γ)	23.5 kN/m^3.

7.2 Waste rock

Macraes waste rock consists of a mixture of coarse-to-fine graded psammitic and pelitic schist, with a high proportion of fines. An example of this rock is shown in Figure 7.1, excavated from a test pit in the Frasers West WRS.

Figure 7.1 Typical Macraes waste rock (Frasers West WRS test pit)

FRBF will be constructed with schist waste rock generally dumped over a 15-to-20 m high tip-head, leading to segregation of the rock, with the coarser rock towards the bottom and the finer rock towards the top of the tip-head. It is estimated that the top one-third of each tip-head would be dominated by a fine-grained matrix and the bottom two-thirds by a more uniform, coarse mixed matrix. This segregation is observed in previous waste rock stacks, as shown in Figure 7.2.

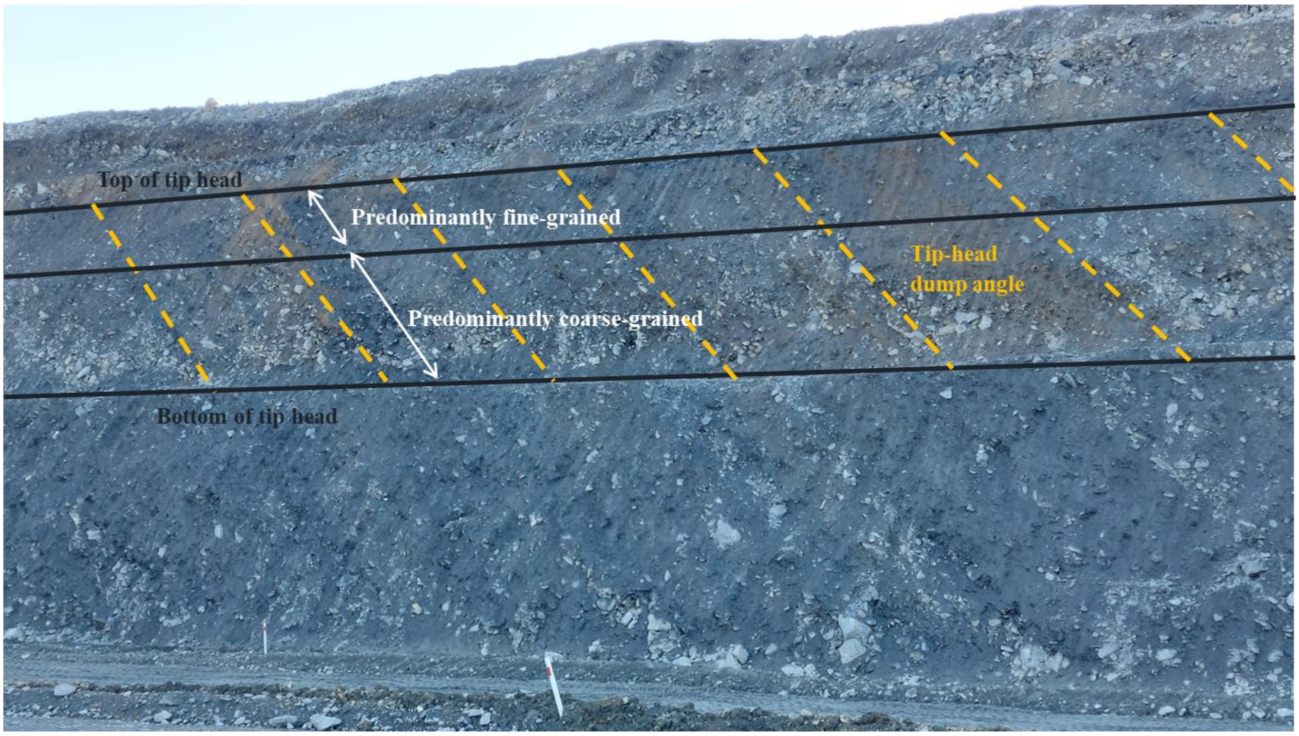

Figure 7.2 Waste rock segregation from tip head dumping (from historic backfill at the IM6 cut face)

7.2.1 Shear strength

7.2.1.1 Peak shear strength

A shear strength function has been adopted for peak strengths consistent with waste rock in WRS (EGL 2019) and TTTSF (EGL 2022a) design. A reduced density has been adopted to account for uncompacted tip-head layering.

Shear strength (τ) $1.29\sigma_v'^{0.91}$

Unit weight (γ) 20 kN/m^3.

7.2.1.2 Softened shear strength

The behaviour of waste rock during earthquake shaking is dependent on the particle size distribution, placed density and severity of seismic events. Waste rock material forming the backfill is assumed to be placed loose-to-medium dense.

Small seismic events such as the OBE (1:150 AEP, 0.08g) are not expected to incur strong earthquake shaking and residual softening is not expected. There is potential for some excess pore-pressures to be generated and thus a softened shear strength of 90% of the undrained peak strengths has been considered for the waste rock matrix.

Larger seismic events that induce significant shaking such as the Maximum Credible Earthquake (MCE) may cause loose, saturated, fine-grained components of silts and sands to undergo more significant residual softening. Conservatively, this has been assumed under operational SEE conditions (1:1,000 AEP, 0.23g) and larger.

7.2.2 Static liquefaction

Static liquefaction of the backfill has been ruled out for the following key reasons:

- Liquefiable materials would need to be notably contractive with rapid strength loss under shear to produce brittle behaviour. A material typically has to be in a fine and in a loose to very loose condition and there has to be sufficient static shear stress to drive the development of a progressive failure. The backfill is comprised of end tipped and uncompacted loose to medium dense waste rock, which is unlikely to be subject to flow liquefaction.

- Higher permeability of the rock fill will help mitigate the development of excess pore pressure in the zones with a finer material matrix (fine segregated waste rock). This mechanism mitigates the development of a progressive failure under static loading conditions.

7.3 Tailings

Slurried tailings will be deposited into FTSF through spigots on the slurry pipeline laid along the benches on the upstream side of FRBF, which will be relocated up to the next bench ahead of the rising tailings beach. The tailings beach will slope towards the decant pond in the south-east corner of FTSF.

Geotechnical strength parameters have generally been adopted from test data and analyses undertaken for tailings in the TTTSF (EGL 2022a). The tailings strength parameters adopted are outlined in the following sections.

7.3.1 Shear strength

7.3.1.1 Peak drained shear strength

Effective cohesion (c’)	0 kPa
Effective friction angle (ϕ’)	32°
Unit weight (γ)	18.5 kN/m^3.

7.3.1.2 Peak undrained shear strength

Effective cohesion (c’)	0 kPa
Shear strength ratio (s_u/σ_v’)	0.26

7.3.1.3 Softened shear strengths

A liquefaction assessment for TTTSF tailings concluded the tailings are expected to liquefy under a minimum 1:150 AEP event. Laboratory testing of the critical state approach indicates a residual undrained shear strength ratio (s_u/σ_v’) of 0.12 (EGL 2022a). This has been adopted for all slurried tailings assessed under seismic load conditions, as it would be reasonable to assume saturation throughout full tailings depths.

7.4 Material strength summary

Material strength parameters adopted for the analysis of FRBF are summarised in Table 7.1.

Table 7.1 Summary of material strength parameters

Material	Description	Static stability: Drained strengths	Static stability: Undrained strengths	Static stability: Softened strengths	Seismic deformation: OBE 1:150 AEP	Seismic deformation: SEE 1:1,000 AEP to 1:10,000 AEP	Reference
In-situ rock	Deeper, less weathered in situ rock	γ = 23.5 kN/m^3 c′ = 150 kPa ϕ' = 45°			γ = 23.5 kN/m^3 c′ = 150 kPa ϕ' = 45°		EGL 2022a
Waste rock	Anticipated to consist of a mixture of completely to slightly weathered psammitic and pelitic schist	γ = 20 kN/m^3 $\tau = 1.29\sigma_v'^{0.91}$		Unsaturated: γ = 20 kN/m^3 $\tau = 1.032\ \sigma_v'^{0.91}$ *(80% peak)* Saturated: γ = 20 kN/m^3 Coarse grained: $\tau = 1.032\ \sigma_v'^{0.91}$ *(80% peak)* Fine grained: c′ = 0 kPa $s_u/\ \sigma_v'$ = 0.2	γ = 20 kN/m^3 $\tau = 1.161 s_v'^{0.91}$ *(90% peak)*	Unsaturated: γ = 20 kN/m^3 $\tau = 1.032\ \sigma_v'^{0.91}$ *(80% peak)* Saturated: γ = 20 kN/m^3 Coarse grained: $\tau = 1.032\ \sigma_v'^{0.91}$ *(80% peak)* Fine grained: c′ = 0 kPa $s_u/\ \sigma_v'$ = 0.2	EGL 2022a
Slurried tailings	Tailings pumped into FTSF	γ = 18.5 kN/m^3 c′ = 0 kPa ϕ' = 32°	γ = 18.5 kN/m^3 c′ = 0 kPa s_u/σ_v' = 0.26	γ = 18.5 kN/m^3 c′ = 0 kPa s_u/σ_v' = 0.12 *(liquefied)*	γ = 18.5 kN/m^3 c′ = 0 kPa s_u/σ_v' = 0.12 *(liquefied)*		EGL 2022a

8 Backfill Seepage Analysis

A seepage analysis was conducted for Stage 2 operations to assess the potential for water to seep from tailings into FRBF. Results are applied as phreatic conditions within pseudo-static stability models reported in Section 9 and 10.

8.1 Approach

A 2D groundwater model was developed using SEEP/W, which is a numerical modelling package utilising finite element methods to solve governing equations for groundwater flow through saturated and unsaturated porous media. The 2D model is based on the cross-section shown in Figure 2.3 and Figure 2.4, which depict the critical path for seepage to occur through FRBF to IMOP.

Two scenarios were assessed to simulate the expected range of conditions, as described below:

- **Scenario 1:** Water source is from both supernatant released by the settling tailings and rainfall recharge. This simulation is most representative of real on-site conditions. In this scenario, it is anticipated that the decant pond water level will be managed by pumping to minimise its depth.
- **Scenario 2:** Water source is from supernatant water and the permanent decant pond, introduced via a water total head boundary (i.e., a constant head boundary). This represents a conservative case in which supernatant and rainfall runoff water accumulates on the tailings beach forming a persistent pond.

Results from Scenario 2 have been adopted for modelling purposes as they represent a more conservative phreatic level. The modelled scenarios undertaken in this assessment are also based on the following assumptions:

- The ambient groundwater system is assumed to be entirely hydraulically disconnected from FTSF and does not influence the flow processed in the FTSF. This has been undertaken to specifically assess seepage effects through the backfill from deposited tailings and rainfall.
- All hydro-stratigraphic units (HSU) are isotropic: horizontal (Kh) and vertical (Ky) hydraulic conductivity is equal.
- No consolidation has occurred in the tailings and therefore the permeability is homogenous throughout the profile.
- The progression of seepage after the end of operations has not been modelled as both pits either side of FRBF will start to fill with water and create pit lakes. Seepage through the backfill is of no concern at this point.

8.2 Boundary conditions

Table 8.1 outlines the boundary conditions used for the assessment.

Table 8.1 Boundary conditions

Name	Scenario	Boundary Type	Value	Comments
Groundwater	1 & 2	Constant head	220 mRL	Groundwater level significantly below the pit base to not influence flow through FTSF
Seepage face	1 & 2	Water rate	0 m^3/s	Removes potential seepage water from the northern seepage face of the model
Rainfall recharge	1	Water flux	1 $mm^3/day/mm^2$	A nominal rainfall value used to model a constant recharge inflow.
Decant pond	Scenario 2	Constant head	At tailings discharge level	Conservatively assumes the decant pond extends to the backfill (i.e., all subaqueous deposition) due to the small surface area and high rate of rise.

8.3 Hydraulic parameters

Hydraulic parameters adopted for all material types are presented in Table 8.2 and outlined as follows:

- Hydraulic conductivity estimates for tailings are based off geotechnical and laboratory testing undertaken for TTTSF, which indicate a best estimate of $4x10^{-7}$ m/s for hydraulic conductivity. It is anticipated that the hydraulic conductivity for FTSF tailings may be higher by up to an order of magnitude due to the lack of consolidation from very high rates of rise for tailings deposition. The best estimate used for this analysis is therefore half an order of magnitude higher ($9x10^{-7}$ m/s).
- It is understood that natural ground comprises very low permeability schist, hence a very low hydraulic conductivity of $1x10^{-10}$ m/s was assigned.
- Hydraulic conductivity for waste rock has been estimated from the available information (EGL 2022a).
- A 50 m wide zone of *controlled* waste rock backfill is proposed on the entire upstream face to reduce permeability through backfill. This zone is proposed to be compacted in comparably thinner lifts and trafficked with loaded dump trucks to achieve a higher density and reduced permeability. A half-magnitude reduction in permeability has been assigned.

Table 8.2 Hydraulic parameters

Material type	Hydraulic conductivity (m/s)		Volumetric water content (-)
	Base case	Range	
Tailings	$9x10^{-7}$	$4x10^{-7} – 4x10^{-6}$	0.4
Waste rock – general	$1x10^{-5}$	$1x10^{-6} – 1x10^{-5}$	0.3
Waste rock – controlled	$5x10^{-6}$	-	0.3
Natural ground (schist)	$1x10^{-10}$	-	0.05

8.4 Results

Seepage is not expected through the downstream toe of FRBF by the end of FTSF Stage 2, due to the short operational life of six years. The projected phreatic surface at end of operations is shown in Figure 8.1. For stability modelling purposes, a phreatic profile that does extend through the backfill has been conservatively adopted to ensure implications to stability are considered. This phreatic surface adopted for end of FTSF Stage 2 modelling is presented in Figure 8.2.

The FMEA did consider PFMs associated with seepage through the backfill, but these were either ranked as low level risks or discounted as non-credible failure modes (such as piping of backfill). If seepage does eventuate at the downstream toe during the operational phase, it can be captured in localised pit sumps and re-pumped into the TSF containment area.

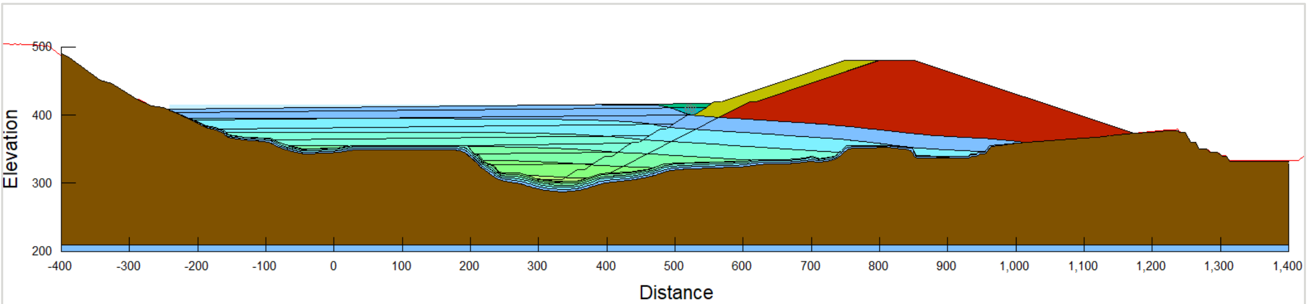

Figure 8.1 Seepage pathway modelled through FRBF at the end of FTSF Stage 2

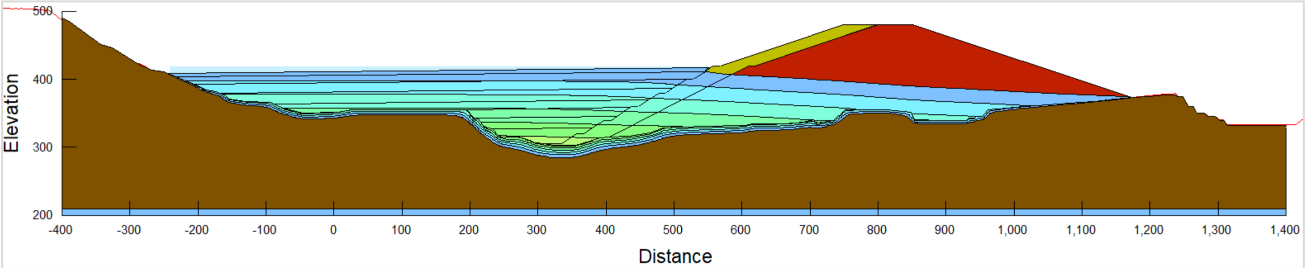

Figure 8.2 Phreatic surface through FRBF adopted for stability modelling at the end of FTSF Stage 2

9 Backfill Stability Assessment

Stability assessments have been undertaken for FRBF Stage 2 to establish factors of safety (FoS). The Morgenstern-Price method within the SLOPE/W 2-D limit equilibrium (LE) software was adopted for assessing circular, block and optimised slip profiles.

The Stage 2 backfill embankment has a stepped upstream slope profile, a crest elevation of 480 mRL, and constant-graded downstream slope as indicated in Figure 9.1.

9.1 Design requirements

Design requirements for static and seismic stability are governed by the NZDSG (NZSOLD 2015). Limit equilibrium stability load cases and minimum required Factors of Safety (FoS) are presented in Table 9.1.

Table 9.1 Static stability design requirements

Load case	Strength conditions	Failure direction	Acceptance criteria
Long-term drained	Drained strengths	U/S and D/S	FoS >1.5
Short-term undrained	Undrained strengths	U/S and D/S	FoS >1.5
Post seismic	Softened, residual or liquefied undrained strengths	U/S and D/S	FoS >1.2

Rapid drawdown has been discounted due to FMEA outcomes which indicates there are no plausible scenarios where this condition can develop – there will be a limited volume decant pond located remotely from the FRBF. End of construction conditions are not specifically assessed as backfilling and tailings disposal occur simultaneously; however, static stability assessments consider projected tailings and backfill levels throughout construction and operation to ensure worst-case conditions are assessed.

9.2 Stability scenarios

Stability assessments have been undertaken for both operational (Figure 9.1) and closure (Figure 9.2) conditions to understand the effect of seepage throughout the full facility lifecycle. Operational conditions are based on the seepage assessment shown in Figure 8.2.

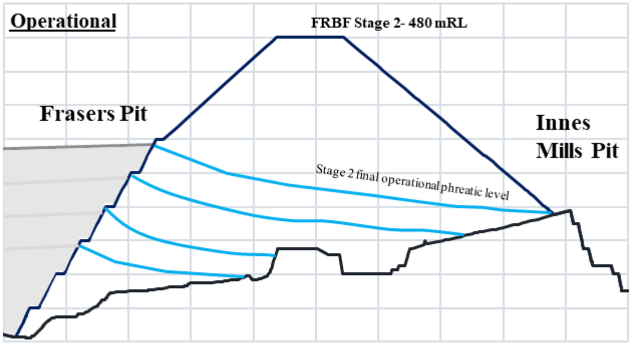

Figure 9.1 Stage 2 operational phreatic conditions

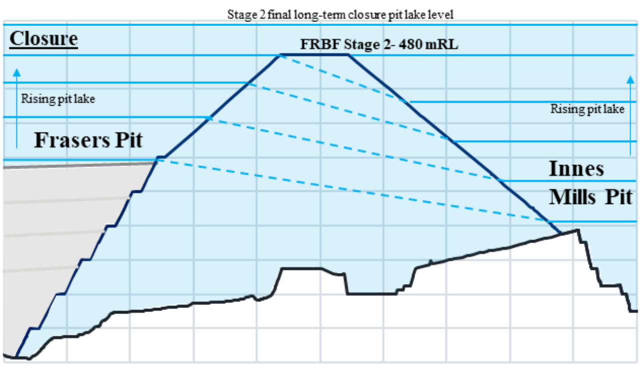

Figure 9.2 Stage 2 closure phreatic conditions

9.3 Results

LE slope stability analysis results are summarised in Table 9.2, with referenced Slope/W stability outputs in Appendix B.

Table 9.2 Stage 2 FRBF slope stability results

<table>
<tr><th>Project phase</th><th>Load Case</th><th>Direction</th><th>Critical tailings elevation</th><th>Critical phreatic conditions</th><th>Minimum FoS achieved</th><th>Figure (Appendix B)</th></tr>
<tr><td rowspan="6">Operation</td><td>Long-term drained</td><td rowspan="3">D/S</td><td rowspan="3">416.5 mRL
(end of FTSF Stage 2 operations)</td><td rowspan="3">Based on SEEP/W analysis for final operational tailings level</td><td>2.3</td><td>Figure B.1</td></tr>
<tr><td>Short-term undrained</td><td>2.3</td><td>Figure B.2</td></tr>
<tr><td>Post seismic</td><td>1.2</td><td>Figure B.3</td></tr>
<tr><td>Long-term drained</td><td rowspan="3">U/S</td><td rowspan="3">386 mRL
(end of FRBF Stage 2 construction)</td><td rowspan="3">Based on SEEP/W analysis for corresponding operational tailings level</td><td>2.2</td><td>Figure B.4</td></tr>
<tr><td>Short-term undrained</td><td>2.2</td><td>Figure B.5</td></tr>
<tr><td>Post seismic</td><td>1.2</td><td>Figure B.6</td></tr>
<tr><td rowspan="6">Closure</td><td>Long-term drained</td><td rowspan="3">D/S</td><td rowspan="6">416.5 mRL
(end of FTSF Stage 2 operations)</td><td rowspan="6">Varied – worst-case combination of upstream and downstream water levels based on long-term pit lake filling data</td><td>2.0</td><td>Figure B.7</td></tr>
<tr><td>Short-term undrained</td><td>2.0</td><td>Figure B.8</td></tr>
<tr><td>Post seismic</td><td>0.9</td><td>Figure B.9</td></tr>
<tr><td>Long-term drained</td><td rowspan="3">U/S</td><td>2.4</td><td>Figure B.10</td></tr>
<tr><td>Short-term undrained</td><td>2.4</td><td>Figure B.11</td></tr>
<tr><td>Post seismic</td><td>1.5</td><td>Figure B.12</td></tr>
</table>

9.4 Summary of effects

9.4.1 During operations

Factors of safety for each load case exceed minimum requirements in the NZDSG (NZSOLD 2015) and are summarised in Table 9.2.

9.4.2 Closure

Results following closure indicate that slip failures may occur on the downstream slope of the FRBF under seismic conditions (FoS 0.9) if the following conditions occur:

- The waste rock segregates into loose coarse and fine layers that extend across the width of the backfill
- The fines layers are saturated
- Seismic conditions are significant enough to cause residual softening of the saturated fine layers.

However, any such surficial slip failures on the IMOP side of FRBF will not compromise the tailings retention capacity of FRBF, considering that the crest of FRBF is >70 m wide and FRBF is close to 500 m wide at the tailings beach level.

10 Backfill Seismic Assessment

10.1 Design requirements

Seismic deformation design requirements are governed by the NZDSG (NZSOLD 2015) and are presented in Table 10.1. Most embankments will, under large seismic loads, yield during part of the loading cycle, resulting in some permanent deformations. However, that does not mean the dam has “failed” provided the deformations are tolerable and the settlement does not lead to overtopping due to a loss of freeboard.

Table 10.1 Seismic deformation design requirements

Facility phase	Load case	Seismic conditions	PGA	Strength conditions	Acceptance criteria
Operations	Operating Basis Earthquake (OBE)	1:150 AEP	0.08g	Softened, residual or liquefied undrained strengths as appropriate	Minor deformations acceptable provided the dam remains functional and the resulting damage is easily repairable
	Safety Evaluation Earthquake (SEE) NOTE 1	1:1,000 AEP	0.23g	Softened, residual or liquefied undrained strengths as appropriate	Deformations are acceptable provided they do not lead to an uncontrolled release of the impounded contents
Closure	Safety Evaluation Earthquake (SEE)	1:10,000 AEP	0.69g	Softened, residual or liquefied undrained strengths as appropriate	Deformations are acceptable provided they do not lead to an uncontrolled release of the impounded contents

Notes:

[1] The upper bound loading of 1:1,000 AEP has been adopted for SEE seismic design due to the downstream mining operations. NZDSG requires a loading between 1:500 and 1:1,000 AEP.

10.2 Deformation

10.2.1 Scenarios considered

OBE and SEE loadings have been adopted for assessing seismic deformation in both operational and closure scenarios.

10.2.2 Assessment approach

The assessment approach is based on the procedure for estimating shear-induced seismic slope displacements (Bray and Macedo 2019) and is outlined as follows:

1. LE pseudo-static analyses have been undertaken at $^{1}/_{3}$H, $^{2}/_{3}$H and full height H failure in the FRBF. Ground motion amplification factors have been applied for each based on observed relationships between the base and crest transverse acceleration measured from a database of prior earthquakes (Harder 1989).
   - Amplification factors adopted are provided in Table 10.2
   - Horizontal seismic coefficients representing the spectral acceleration response of each earthquake have been applied in the limit equilibrium analyses
   - Amplified spectral acceleration loads are provided in Table 10.3

2 Hazard response spectra from the site specific PSHA (2021) and NSHM (2022) were considered, with the larger of the two (the 2022 NSHM) used for determining upper-bound deformation estimates for each loading case. Spectral acceleration for both seismic models are reported in Table 10.3.

3 Some yielding may occur and result in some permanent seismic deformation, where the limit equilibrium post seismic FoS is less than 1.0. These deformations are likely to be superficial and have no effect on the tailings containment performance of FRBF. Permanent deformations have been estimated using the Bray and Macedo (2019) approach, which is a Newmark (1965) type sliding block approach. Estimated deformations are provided in centimetres as a range between the lower estimate of 84% probability of exceedance and upper estimate of 16% probability of exceedance. These estimates are provided in Table 10.4.

Table 10.2 Seismic amplification factors between crest and base

Load condition	Event probability	PGA (g)	Crest amplification factor (Harder 1989)	Amplification factors		
				1/3H	2/3H	H
OBE operations	1:150 AEP	0.08	4.0	3.0	2.0	1.0
SEE operations	1:1,000 AEP	0.23	2.7	2.1	1.6	1.0
SEE closure NOTE 1	1:10,000 AEP	0.69	1.4	1.3	1.1	1.0

Notes:

[1] 1:10,000 AEP return period adopted for post-closure seismic criteria based on GISTM (2020) guidance.

Table 10.3 Amplified response spectra used for deformation estimates

Load condition	Failure location	Amplification factor	Height (m)	$V_{S FRBF}$	1.3T(s)	Sa(1.3T(s))		Amplified Sa(1.5T(s)) NOTE 1
						Bradley (2021)	NSHM (2022)	
OBE operations (1:150 AEP)	1/3H	3.0	37	1100	0.11	0.12	**0.17**	0.51
	2/3H	2.0	73	1100	0.23	0.11	**0.16**	0.32
	H	1.0	110	1100	0.34	0.09	**0.13**	0.13
SEE operations (1:1,000 AEP)	1/3H	2.1	37	1100	0.11	0.42	**0.54**	1.13
	2/3H	1.6	73	1100	0.23	0.36	**0.49**	0.79
	H	1.0	110	1100	0.34	0.27	**0.38**	0.38
SEE closure (1:10,000 AEP)	1/3H	1.3	37	1100	0.11	1.58	**1.65**	2.14
	2/3H	1.1	73	1100	0.23	1.38	**1.54**	1.69
	H	1.0	110	1100	0.34	1.18	**1.21**	1.21

Notes:

[1] Adopts larger spectral acceleration from either the site-specific Bradley (2021) or national NSHM (2022).

10.2.3 Results

Estimated deformation under OBE and SEE seismic events is presented in Table 10.4 and the seismic stability outputs are provided in Appendix C.

Table 10.4 Seismic deformation estimates

Facility phase	Load condition	Failure location	FoS	k_y (g)	Moment Magnitude (M_w)	Seismic displacement NOTE 1		Figure (Appendix C)
						Probability of negligible displacement	Estimated displacement range (m)	
Operations	OBE (1:150 AEP)	1/3H	< 1.0	0.45	6.8	96	< 0.01	Figure C.1
		2/3H	> 1.0	-	-	100	0	Figure C.2
		H	> 1.0	-	-	100	0	Figure C.3
	SEE (1:1,000 AEP)	1/3H	< 1.0	0.42	6.9	27	< 0.05	Figure C.4
		2/3H	< 1.0	0.25	6.9	8	< 0.08	Figure C.5
		H	< 1.0	0.22	6.9	48	< 0.02	Figure C.6
	Aftershock (1:1,000 AEP)	1/3H	< 1.0	0.42	5.9	27	< 0.02	-
		2/3H	< 1.0	0.25	5.9	8	< 0.05	-
		H	< 1.0	0.22	5.9	48	< 0.01	-
Closure NOTE 2	SEE (1:10,000 AEP)	1/3H	< 1.0	0.10	7.1	0	0.47 – 2.05	Figure C.7
		2/3H	< 1.0	0.10	7.1	0	0.44 – 1.89	Figure C.8
		H	> 1.0	0.09	7.1	0	0.36 – 1.55	Figure C.9
	Aftershock (1:10,000 AEP)	1/3H	< 1.0	0.10	6.1	0	0.26 – 1.12	-
		2/3H	< 1.0	0.10	6.1	0	0.24 – 1.03	-
		H	< 1.0	0.09	6.1	0	0.20 – 0.95	-

Notes:

[1] Estimated displacement based on Bray and Macedo (2019).

[2] Closure analyses adopt fully submerged phreatic conditions based on expected inundation of FRBF within 110 years.

10.3 Settlement

Settlements of up to 500 mm may occur in some areas of the FRBF crest post closure, as a result of a significant seismic event, as shown in Table 10.4. But these very small settlements will not compromise the tailings containment performance of the FRBF, as there is around 63.5 m of freeboard between the final tailings beach and crest of FRBF

10.4 Summary of effects

10.4.1 During operations

Seismic deformations and settlement are not expected to affect the FRBF performance during operations. A summary of the analyses undertaken for OBE and SEE is outlined in Table 10.5.

Table 10.5 Evaluation of seismic performance under operational conditions

Load case	Estimated settlement	Estimated deformation	Acceptance
OBE 1:150 AEP	Negligible in comparison to freeboard	Non-permanent or negligible (<0.01 m) deformations	Acceptable; functionality of FTSF not impacted.
SEE 1:1,000 AEP	Negligible in comparison to freeboard	Non-permanent or negligible (<0.08 m) deformations	Acceptable; functionality of FTSF not impacted and no uncontrolled contents released.

10.4.2 Post closure

Results indicate deformations of up to 2 m may occur post closure under SEE loading conditions (1:10,000 AEP) when the waste rock becomes fully saturated following eventual inundation.

Such deformations may result in a surficial slip failure in the downstream slope, but any such very low probability (Table 10.4) post-closure slip failure will not affect the tailings containment capability of FRBF as:

1. The backfill would be submerged by the combined Fraser-Innes Mills pit lake
2. No release of contents outside of the pit extent could occur under such a failure scenario.

It should be noted that there are likely to be many natural slopes in the surrounding area that will also deform at this extreme level of seismicity.

11 Pit Wall Stability

This section presents a summary of the geotechnical assessment of the FTSF pit slope stability carried out by PSM (2024), with the aim of providing confidence that:

- Operational safety can be maintained throughout operation
- The pit walls will maintain sufficient stability during backfilling and under seismic loading scenarios post closure.

Static and seismic analyses undertaken for the east wall and west wall considered for the following conditions:

1. Prior to construction – mining completed, prior to FRBF backfilling and tailings deposition
2. During operation – throughout FTSF filling with a final tailings level of 416.5 mRL
3. During closure – a long-term pit lake level of 489 mRL fully-submerging FRBF and FTSF tailings

11.1 Results

11.1.1 Static stability results

Generally, the most adverse stability condition occurs prior to backfilling. The FoS gradually increases as tailings provides additional buttressing support to the pit walls.

- East wall: Modelled scenarios indicate stability within the rock mass has a FoS greater than 1.5, with the exception of the slip zone shown in Figure 11.1

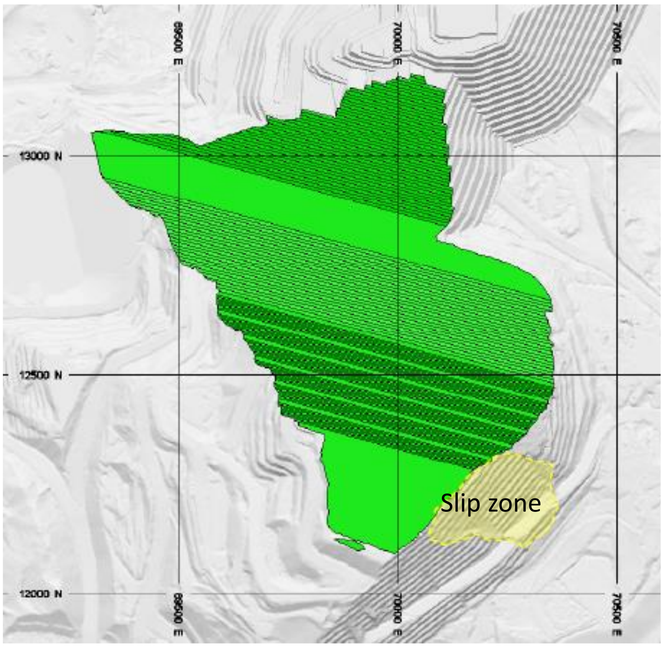

Figure 11.1 Slip zone in east high wall

- West wall: Remains in a marginally stable condition consistent with observed long-term creep triggered by large rainfall events. OGNZL have demonstrated past performance in managing complex open pit slope instabilities with regular management controls that can be applied during operational mining which include:
  - Rigorous slope monitoring procedures using both radar and GPS to capture real time slope movement
  - A documented history of geotechnical model development, stability analysis and external advice
  - Development, review and implementation of pit wall TARPs with regular risk assessments.

11.1.2 Seismic stability results

- East wall: Modelled scenarios indicate seismic stability within the rock mass has a FoS greater than 1.5 for both OBE and SEE seismic loadings, with the exception of the slip zone.
- West wall: Stability under OBE and SEE seismic loading conditions has a FoS < 1. The west wall planar sliding mechanism will be partially buttressed by FRBF in the north of the pit. Three-dimensional effects from the backfill are likely to provide additional confinement and buttressing against sliding along the Footwall Fault (FF). The analyses are likely to be a lower bound estimate of west wall stability.

11.2 Summary of effects

11.2.1 During operations

Potential pit wall slope failure mechanisms during operation are shown on Figure 11.2

- East wall: While not predicted to occur during FTSF filling, established highwall failure mechanisms are predominantly associated with structurally controlled kinematic block slides. These typically progress slowly with increased rockfall around the boundary fringes prior to initiating large-scale displacements. Should a similar failure initiate, there is potential to generate small-scale seiche waves, but the impact is likely to be insignificant and have no external consequence to the proposed FTSF geometry. OGNZL may decide on the basis of monitoring or modelling, to buttress the slip zone to mitigate risks during the operation of FTSF.
- West wall: Placement of backfill and tailings is expected to improve the stability in comparison to current conditions, however, remobilisation of the failed psammite rock mass is expected to be a relatively slow, ductile deformation due to increasing pore pressures.
  - Based on modelled thicknesses of failed psammite, an estimated volume of 3.5 Mm3 remains on slope. This mass could potentially creep downslope until sufficient tailings are in place to provide buttressing support. This level is expected to be at approximately 380 mRL.
  - Any instability would be expected to displace tailings and temporarily increase the rate of rise. The greatest potential impact on FTSF levels would occur from a subaerial slide when tailings levels are below 380 mRL and the ratio of slide material to tailings volume is greatest.

11.2.2 Post closure

Highwall movement is anticipated under SEE seismic loading, with potential for global scarp failure to extend up to approximately 70 m behind the design pit crest. It should be noted that there are likely to be many natural slopes in the surrounding area that will also deform at this level of shaking.

The anticipated consequences for FTSF are negligible as the volume of final landform material that is susceptible to subaerial sliding and could initiate a seiche wave is minimal. Submerged material is buttressed by tailings and is therefore not expected to experience large displacements.

Irrespectively, PSM recommend defining a strip of land/zone of influence around the crest of the combined pits to isolate the hazards associated with ground movement and falling from height. Based on a FoS of 1.5, an exclusion zone at approximately 150 m from the pit crest is recommended. Further geotechnical assessment is recommended to better define the exclusion zone.

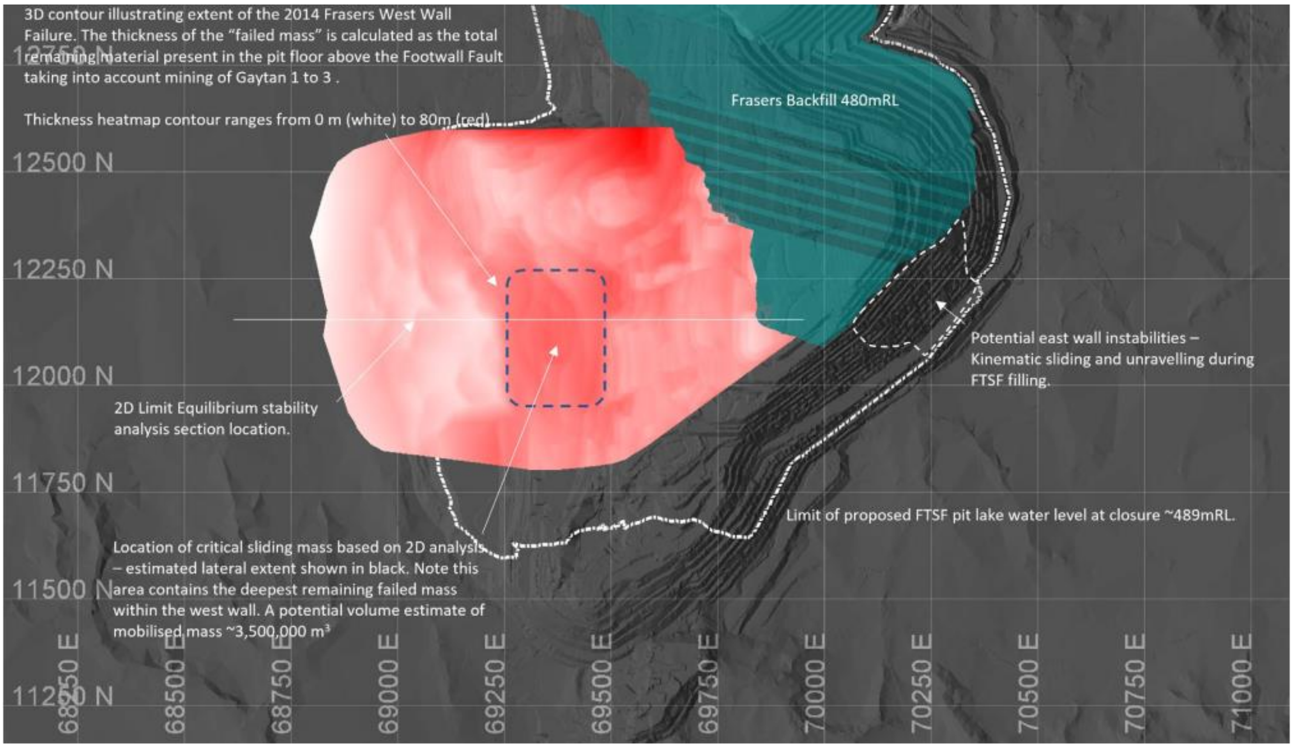

Figure 11.2 PFMs with increased susceptibility during FTSF operation (PSM 2024)

11.3 Discussion

The following comments have been drawn from an assessment of the PSM analyses:

1. OGNZL have previously demonstrated that the risks associated with highwall movement can be managed through successful implementation of a programme that includes radar monitoring and TARPs
2. OGNZL will consider buttressing the failure zone in the east highwall, on the basis of analysis and monitoring, which has a marginal factor of safety, to prevent slide failures during the operation of FTSF
3. The FTSF will have sufficient freeboard and excess storage capacity to accommodate remobilised pit wall failure masses and/or seiche waves generated by a pit wall failure
4. Potential pit slope failures of the west wall are predicted to be gradual, reducing the risk of generating seiche waves.

12 Tailings Management

12.1 Tailings operating plan

The tailings operating plan is described below.

12.1.1 *Slurry pipeline*

The tailings slurry discharge pipeline will be laid along the upstream face of the FRBF benches to allow the slurry to be discharged into the FTSF (Figure 12.1).

- The tailings pipeline will have three spigots, spaced along the length of the bench, to allow the location of the decant pond to be controlled in the south-east corner of FROP, adjacent to the FSWRS
- The tailings will beach sub-aerially from the spigots toward the decant pond in the south-east corner of FTSF
- The slurry discharge pipeline will be lifted onto the next higher bench as the tailings beach rises, before it becomes inundated by the tailings (Figure 12.2).

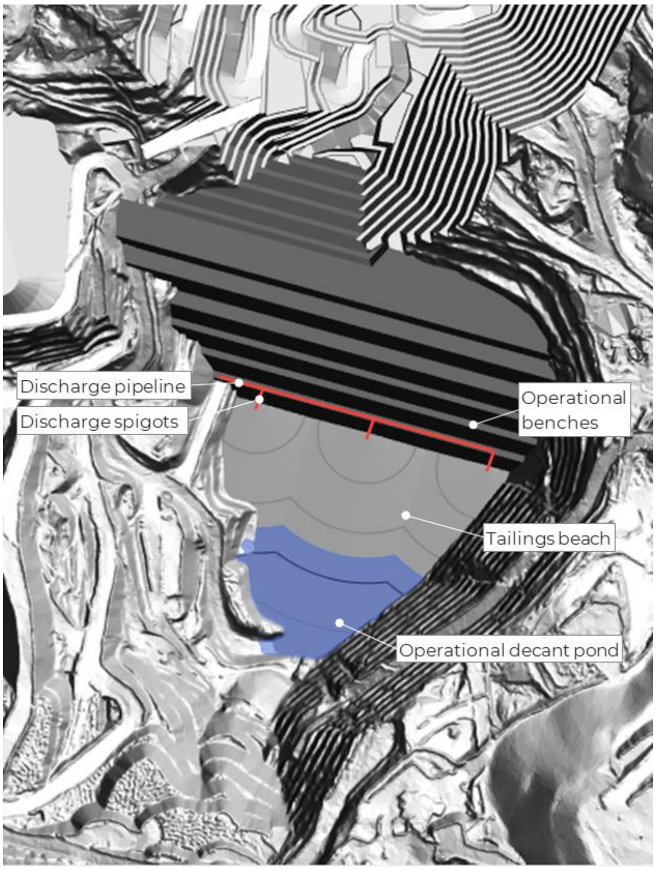

Figure 12.1 Plan of Stage 2 tailings operations (beginning)

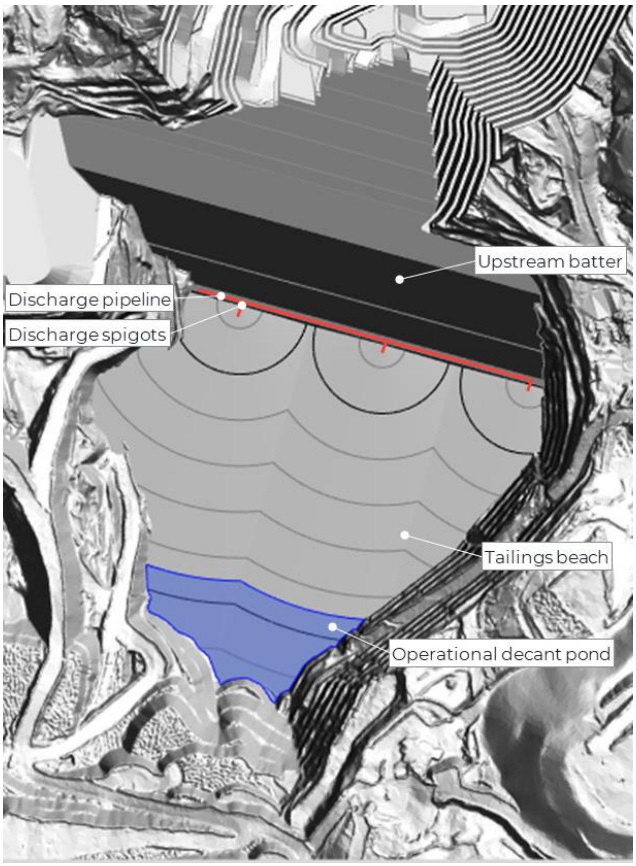

Figure 12.2 Plan of Stage 2 tailings operations (end of operations)

12.1.2 Return water pumping

Floating return water pumps located in the decant pond will be connected to a return water pipeline routed along either the east or west side of the pit, as indicated in Figure 12.3.

- The decant water will be pumped back to the process plant for reuse through three staging ponds located at progressively higher elevations
- A ramp will be developed down the face of the FSWRS to the return water pumps to be accessed for maintenance
- The pumps will be sized so that the extent of the decant pond can be maintained as small as practical to maximise the exposed tailings beach.

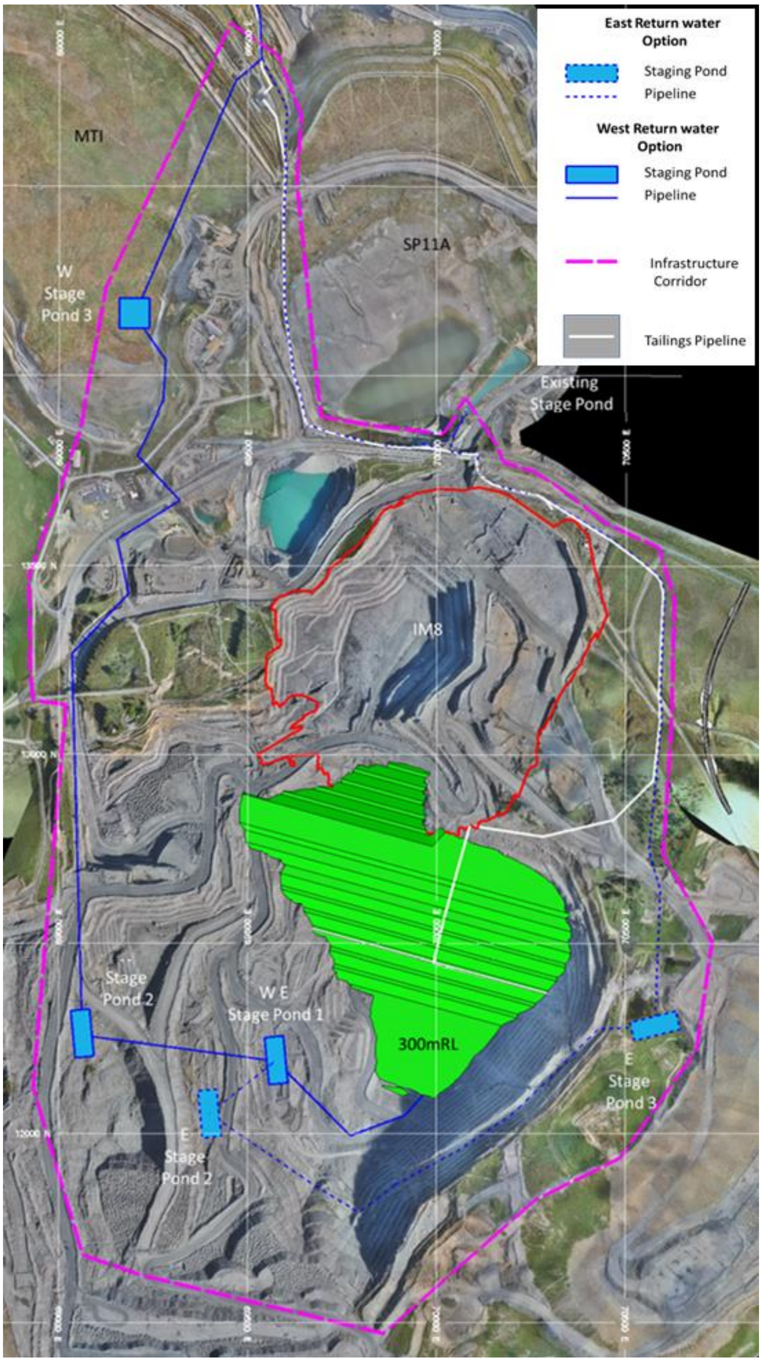

Figure 12.3 FTSF return water pumping system, showing staging ponds

12.2 Tailings deposition modelling

Tailings deposition modelling has been undertaken using Muk3D, a 3-dimensional tailings deposition software program, to establish the maximum tailings storage capacity and filling forecast for the life of the FTSF. The following parameters were used in the model:

- Tailings beach slope: An estimated slope of 1%, based on TTTSF tailings beach surveys
- Settled dry density: An average settled dry density of 1.25 t/m^3, based on historically tailings densities measured at in SP10 TSF, achieved for a similar tailings slurry at high rates of rise
- Tailings production forecast: As per Table 2.2.

12.2.1 FTSF total storage capacity

The estimated tailings storage capacity within FTSF is as follows (Figure 12.4):

- FTSF Stage 1: 6 Mt tailings at an estimated final tailings elevation of approximately 343 mRL
- FTSF Stage 2: 35.5 Mt tailings at an estimated final tailings elevation of approximately 416.5 mRL.

The maximum storage capacity of FTSF is approximately 94 Mt at 478 mRL, allowing 2 m freeboard to the crest of the Stage 2 FRBF, providing an additional 58.5 Mt of tailings storage capacity above the proposed FTSF tailings beach.

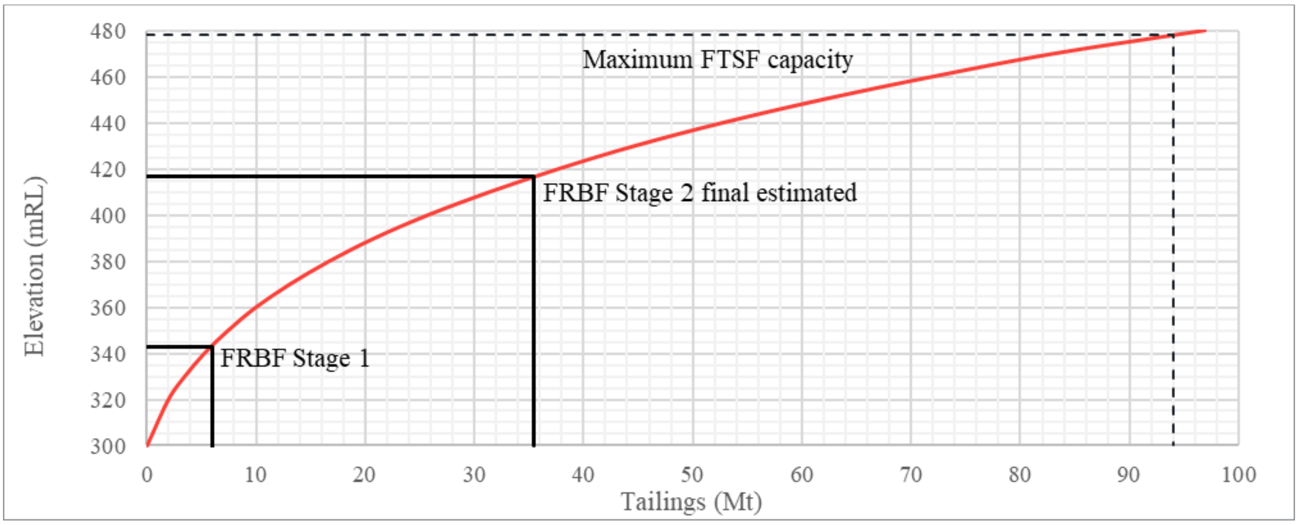

Figure 12.4 FTSF tailings stage-storage filling curve to FRBF crest

12.2.2 Tailings rate of rise

The tailings rate of rise (RoR) is shown in Figure 12.5. The RoR will be extremely high for FTSF Stage 1, due to a very confined footprint in the base of Frasers pit. This RoR reduces to 30 m per year at the start of FTSF Stage 2 and gradually reduces to less than 15 m per year over the following two years. The projected RoR for the final year of deposition is 5 m per year. High rates of rise result in reduced opportunity for tailings to desiccate or consolidate to any degree during the short operational life, but this is not expected to be a concern as:

1. Significant excess freeboard remains at the end of operations, meaning, consolidation is of negligible importance for maximising storage capacity
2. The closure strategy is for a water cover, so that no mechanical equipment will need to access the very low bearing capacity tailings to place capping materials.

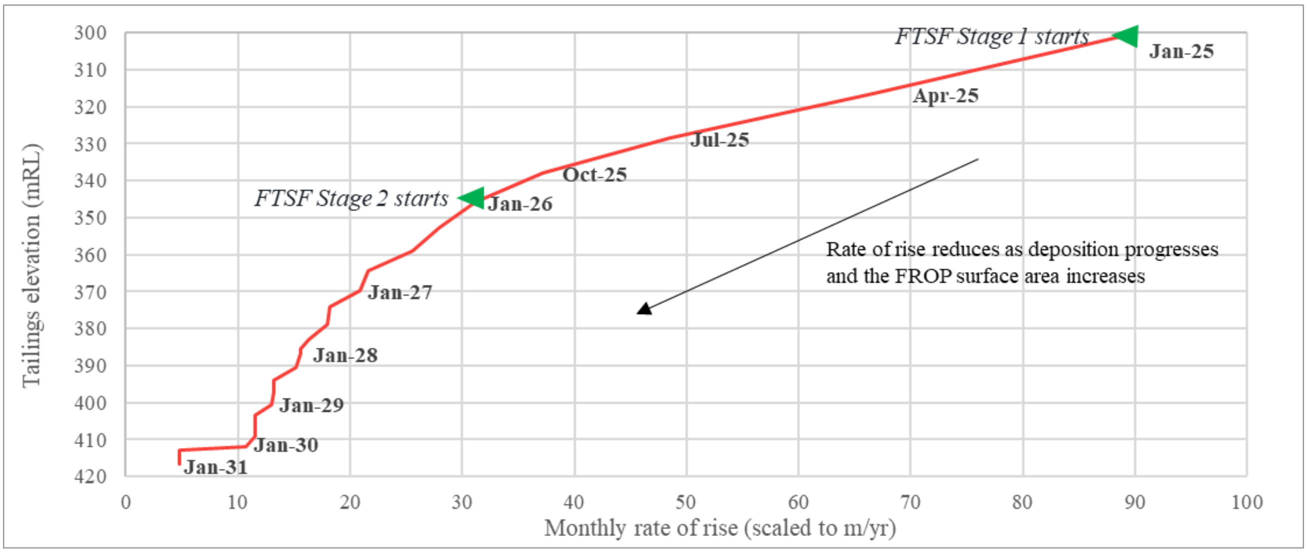

Figure 12.5 FTSF tailings rate of rise throughout operations

12.2.3 Tailings and backfill scheduling

Construction of FRBF is projected to remain well ahead of the rising tailings beach, based on the waste rock and tailings production forecasts, providing sufficient freeboard during the construction of the FRBF to prevent overtopping into IMOP. The projected levels throughout FRBF construction and FTSF operation are shown in Figure 12.6. The FRBF crest level is maintained at 450 mRL for some time after Stage 2 backfilling commences, due to the downstream toe and batter slope which are required to be raised to final profiles first.

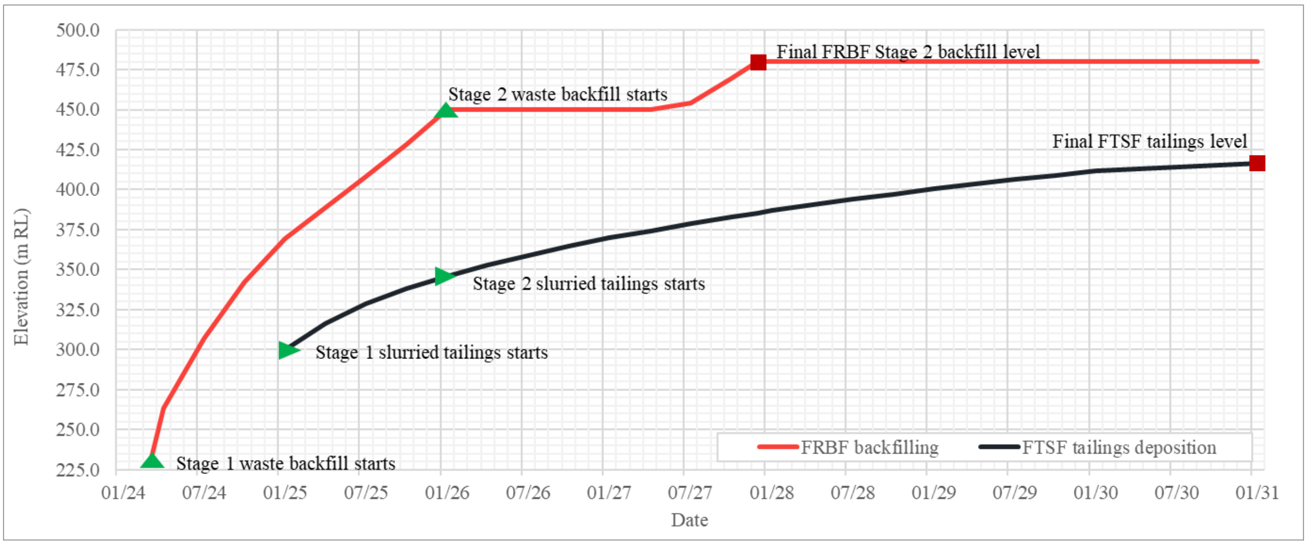

Figure 12.6 Projected FRBF tailings level and backfill crest during construction and operation

Freeboard between the tailings level and FRBF crest have been calculated at key intervals to demonstrate that overtopping of FRBF is not a credible failure mode. These key intervals and available freeboards are:

- Start of Stage 2 construction (January 2026): 107 m freeboard
- End of Stage 2 construction (November 2027): 115 m freeboard
- Critical lowest freeboard during Stage 2 construction (May 2027): 75 m freeboard
- End of Stage 2 tailings operations (December 2030): 63.5 m freeboard.

13 Dam Safety Management

The NZDSG provides guidance on dam safety objectives and principles applicable to the design, construction, operation, assessment and rehabilitation of dams in New Zealand. Requirements of a dam safety management system are typically incorporated into an Operations, Maintenance and Surveillance Manual (OMS) and Emergency Action Plan (EAP).

Dams should have emergency action plans in place if there is a population at risk or if the implementation of emergency actions could reduce the potential consequences of failure (NZSOLD 2015). A separate EAP is not required for Low PIC facilities; but appropriate emergency preparedness information is outlined in an OMS Manual as part of good dam safety management.

13.1 OMS Manual

An OMS Manual will be developed during detailed design to include general information on the facility and dam safety requirements on the following subjects:

- Quality assurance and management of change procedures
- Regulatory compliance requirements
- Roles, responsibilities and training competencies
- Operational procedures for surface water, seepage and tailings deposition management
- Maintenance activities, including reporting requirements and frequencies for typical maintenance activities
- Surveillance and monitoring regime, including inspection requirements (type and frequency of inspection) and monitoring instrumentation requirements (type and frequency of data review)
- An overview of identified dam safety risks and key controls
- An overview of emergency protocols, preparedness actions, access and communication plans and the identification of emergency triggers, which are outlined in Trigger Action Response Plans (TARPs)

Dam safety management systems detail procedures and activities for the management of dam safety and, importantly, provide an auditable record of dam performance and the Owner’s commitment to dam safety.

14 FTSF Closure

A conceptual closure plan for the Macraes mine; waste rock stacks, backfills, open pits and TSFs, is presented in Figure 14.1 and is consistent for both the FRBF Stage 1 and Stage 2 designs.

The TSF return water pumping system will be removed and the FTSF water pond will be allowed to develop across the tailings beach to provide a full water cover. The water cover will in time become a permanent pit lake maintained by rainfall, groundwater seepage and runoff from the surrounding catchments, including possibly from the rehabilitated TTTSF to the east. Assessments by GHD in Section 2.3 indicate the long-term pit lake water level fluctuates between 486 and 494 mRL.

The FROP pit lake is forecast to reach the top of FRBF after approximately 65 years, where it will be allowed to flow into IMOP across the FRBF crest until both lakes reach 480 mRL and fully submerges FRBF. An engineered overflow channel is not considered to be necessary for the following reasons:

1 The depth of flow when the FRBF eventually overtops will be shallow, being seasonal catchment rainfall dependent, and would occur over a minimum crest length of >300 m and crest width of ±100 m, reducing the risk of downstream erosion due to a large concentrate flow

2 No release of contents outside of the pit extent could occur under any failure scenario, as the crest elevation of FRBF is more than 30 m below the lowest pit rim elevation.

It is worth noting that seepage through the backfill may equalise the water levels in the pit lakes much sooner than the modelling shows, eliminating the potential for overtopping.

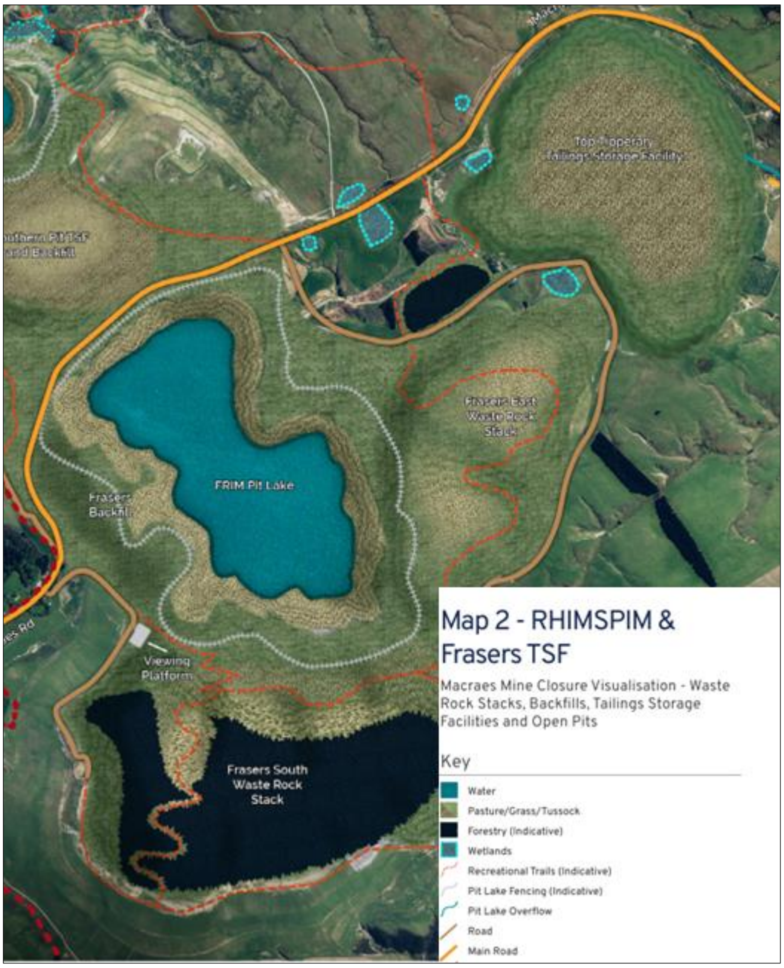

Figure 14.1 Golden Point Pit, Southern Pit TSF, Innes Mills Pit and FTSF at closure

15 Risks and mitigation

Key potential risks identified for FTSF Stage 2 are outlined in Table 15.1, along with proposed mitigation controls which are a combination of design, operation, monitoring and surveillance measures.

Table 15.1 FTSF Stage 2 main risks

Risk No.	Category	Risk	Mitigation
1	Design	Inadequate overall design	— Designer appropriately qualified with relevant experience — Peer reviewed design, although not strictly required for a Low PIC structure. — Producer Statement PS1 (Design) for the detailed design, which will be subject to review during Building Consent

2	Design	Deviations from design assumptions and/or criteria	— Outline key design assumptions in the OMS Manual and requirements that, if triggered, may warrant a review of design criteria and the potential impact classification. This includes:
			  — The maximum forecast tailings level
			  — Backfill geometry and minimum width at tailings level
			  — Downstream mining and deviations from the schedule
			  — Changes to regulatory or corporate governance criteria
			  — Outcomes from intermediate and comprehensive dam safety review
			— Undertake an intermediate dam safety review annually and a comprehensive dam safety review every 5 years
			— Formally review the PIC every 5 years

2	Construction	Construction not in accordance with design	— Detailed design to include a technical specification detailing Hold Point and Witness Point requirements for construction. — Designer inspections during the construction process. — Producer Statement PS4 (Construction Review) by an appropriately qualified design professional who undertakes construction monitoring of the building works. — A construction report, including as-built drawings, used to compare with issued for construction (IFC) drawings
3	Operation	Backfill becomes unstable and collapses into the TSF and/or Innes Mills pit. (Identified in the FMEA)	— Stability assessment undertaken during design to confirm design geometry and batter grades. — Operated and constructed to design. — Mitigation through the dam safety management system, which includes establishing and implementing an OMS Manual.

Risk No.	Category	Risk	Mitigation
5	Operation & Closure	Pit wall instability	During operation: — TSF designed with sufficient freeboard and excess capacity to accommodate the remobilised failure mass and/or seiche wave generated by a pit wall failure. — On the basis of monitoring or modelling, OGNZL may consider internally buttressing the eastern highwall (from the pit floor upwards) to manage safety risks during operations that are attributed to slip zone failures. — Continual monitoring throughout backfilling and operation of the TSF by implementing a programme that includes radar monitoring and TARPs. OGNZL have demonstrated during pit mining that the risks associated with highwall movement can be actively managed with an appropriate monitoring regime. During closure: — 150 m exclusion zone around the pit crest — Continuation of the pit wall monitoring programme
6	Operation & Closure	Failure to contain wind-blown tailings. (Identified in the FMEA)	During operations: — Beach management to keep the surface wet — Operation in accordance with the OMS Manual During closure: — Divert surface runoff water preferentially into the FTSF to increase the water cover over the tailings — Construct a rockfill capping on the tailings beach adjacent to the FRBF
7	Closure	Seepage from TSF leading to surface water release into environment. (Identified in the FMEA)	— Consider range of mitigation options (enhanced passive treatment, capture and discharge during high flows, pump systems back to the FTSF in perpetuity) to reduce risk. — Frasers South WRS design to consider preventative controls or filtering design

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Appendix A

Failure Modes and Effects Analysis

OCEANA GOLD NZ LIMITED

FRASERS TSF FAILURE MODES AND EFFECTS ANALYSIS (FMEA)

MACRAES GOLD MINE

February 2024

Question today
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FRASERS TSF FAILURE MODES AND EFFECTS ANALYSIS (FMEA) MACRAES GOLD MINE

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Rev	Date	Details
A	7 February 2024	Draft issue for client comment

	Name	Date	Signature
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Reviewed by:	Craig Johnson	7 February 2024	
Approved by:	Mike Gowan	7 February 2024	

WSP acknowledges that every project we work on takes place on First Peoples lands.
We recognise Aboriginal and Torres Strait Islander Peoples as the first scientists and engineers and pay our respects to Elders past and present.

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Terms & abbreviations

Audit	The process used to confirm implementation of and compliance with controls specified to manage risk. An audit is critical when high risks are controlled by procedures.
Catastrophic failure	A failure mode that diminishes structural integrity to the extent that the facility cannot continue to operate to store tailings and allows significant release of contents.
Containment loss	An uncontrolled release of either tailings or contaminated water outside of the boundary.
Consequence	The outcome of an event affecting objectives. Consequences may be expressed qualitatively or quantitatively, and may be a loss, injury, disadvantage, or gain. There may be a range of possible outcomes associated with an event.
Credible failure mode	Technically feasible failure mechanisms given the materials present in the structure and foundations, the properties of these materials, the configuration of the structure, drainage conditions and surface water controls. Not associated with a probability of an event occurring.
Failure Mode	The process by which an element or component can fail and cause loss of system function.
Failure Mechanism	The physical, chemical, or other processes, including human actions and inactions, which can lead to a failure. The cause.
Likelihood	Chance of something happening (it may be expressed as a probability or frequency).
Monitoring	Continual checking, supervising, critically observing, or determining the status to identify change from the performance level required or expected.
"Rainy Day" Failure	Failure resulting from a major storm/rain event, e.g., overtopping.
Residual Risk	Risk remaining after risk treatment.
Risk	The effect, measured in terms of consequence and likelihood.
Risk Analysis	Process to comprehend the nature of risks and the level of risk.
Risk Control	Measure that is modifying risk.
Risk Evaluation	The process of comparing the results of risk analysis with risk criteria to determine whether the risk and/or its magnitude is acceptable or tolerable.
Risk Identification	The process of finding, recognising, and describing risks.
Risk Management	Coordinated activities to direct and control an organisation regarding risk.
Risk Treatment	Process to modify risk.
SFAIRP	So far as is reasonably practicable.
"Sunny Day" Failure	Failure under typical operating conditions, e.g., seismic event.

1 Introduction

1.1 Background

OceanaGold (New Zealand) Limited (OGNZL), a subsidiary of OceanaGold Corporation, owns and operates the Macraes gold mine located approximately 60 km north of Dunedin, South Island, New Zealand.

A new tailings storage facility (TSF), to be named Frasers TSF (FTSF), is planned to be located within the mined-out Frasers pit (FROP), with tailings contained by a waste rock embankment between the Frasers and the Innes Mills pits, to be called the Frasers Backfill (FRBF).

OGNZL has engaged WSP to undertake a Failure Mode and Effect Analysis (FMEA) for the proposed FTSF design. The purpose of the FMEA is to provide a robust evaluation of failure modes that could contribute to a failure of the TSF, with specific focus on the potential for catastrophic failures that would result in a loss of tailings and/or mine contaminated water.

The FMEA was conducted originally for earlier FTSF conceptual designs in August 2022 in Dunedin by Dr Bill Danaher, of Risk Management Intercontinental Pty Ltd on behalf of WSP, and was attended by the appropriate Macraes and WSP personnel.

This report has been prepared for OGNZL to document the outcomes of the FMEA for the current FTSF design.

2 Scope

The overall scope of the FMEA was to:

- Identify and document potential failure modes of the TSF
- Assess the failure modes and ensure that suitable risk controls are either in place, or have been recommended, in relation to management of the failure modes.

Potential failure modes were specifically assessed with respect to dam safety implications and do not consider the day-to-day risks during construction or operations which shall be addressed by the site Health and Safety Management System and task specific risk assessments.

2.1 Objectives

Detailed objectives of the FMEA were to:

- Identify potential TSF failure modes
- Determine whether those failure modes are credible or non-credible
- Determine whether any credible failure modes are catastrophic
- Understand and document potential effects (consequences) should failure occur with those credible failure modes
- Document the risk controls currently in place, or proposed within the project scope, for the prevention and management of each credible failure mode and its consequences
- Provide a risk ranking in relation to each credible failure mode and to make recommendations as appropriate for additional risk treatments.

3 Risk management process

Risk management is an integral part of good management practice. It is an iterative process consisting of steps, which, when taken in sequence, enable continual improvement in decision-making. Risk management is not a matter of becoming risk averse and unnecessarily avoiding risks. Risk management enables an organisation to understand its risks and decide how to manage those risks.

Good risk management processes reduce the element of "surprise" in an organisation's business activities and ensures that resources are allocated to management of risks. The risk management process is presented in the Figure 3.1 flowchart, which shows the key steps for this method.

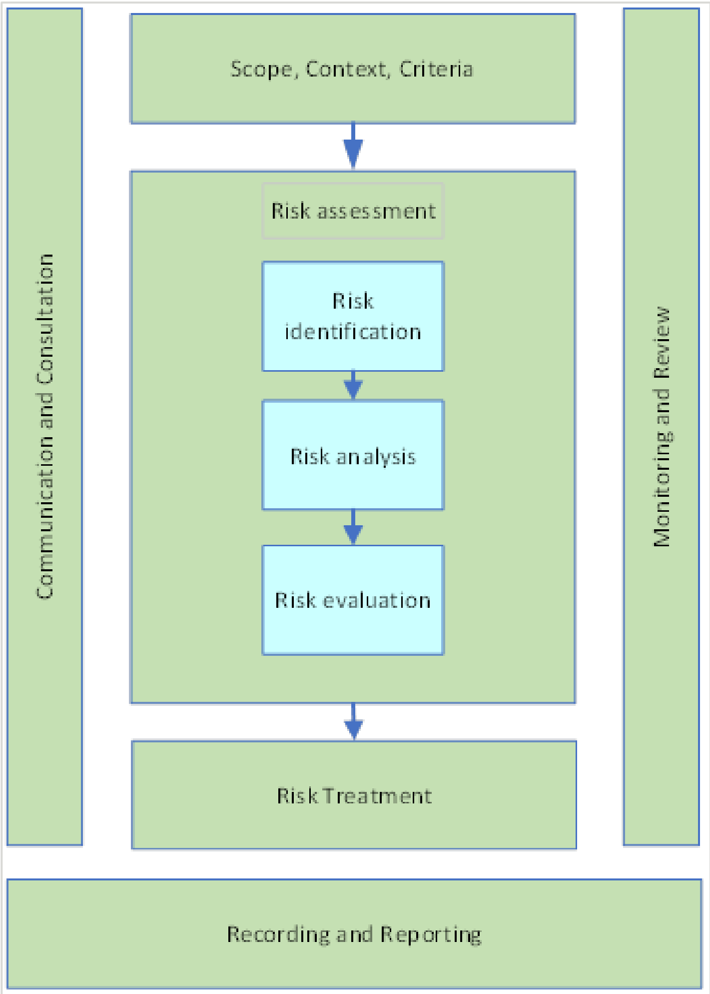

Figure 3.1 Risk management process (ISO 31000-2018)

Each step, as applied to the FMEA for the FTSF, is discussed on the following pages.

<u>It is noted that although terms are often used interchangeably, there is a significant difference between the process of risk assessment and that of risk management.</u>

Risk assessment is fundamentally a "desktop" exercise, which assists an organisation to understand its risks and develop strategies for managing those risks. The full process of risk management also involves subsequent implementation of added risk controls, and ongoing monitoring and review of risk controls to enable an organisation to confirm that risk treatment strategies have been implemented and remain effective.

It is also noted, that in the case of safety-related risks, there is typically a requirement to manage risks "so far as is reasonably practicable" (SFAIRP).

4 FMEA assessment history

The FMEA process commenced with a site visit by Mike Gowan and Craig Johnson (WSP) on 27th May 2022 to meet with the mine project and geotechnical teams. This visit included an inspection of the Frasers Pit and Top Tipperary TSF (TTTSF) and culminated in discussions on the proposed design.

4.1 Initial workshop

A site workshop followed on 8th and 9th August 2022 to identify potential failure modes (PFMs), establish credible failure modes, and quantify the risk, controls and residual risk of each. This session was facilitated by Bill Danaher, with Mike Gowan and Craig Johnson of WSP providing technical support. Workshop participants are listed in Table 4.1.

Table 4.1 FMEA workshop participants

Name	**Title**	**Organisation**
Bill Danaher	Facilitator	RMI
Mike Gowan	Tailings Technical Director	WSP
Craig Johnson	Tailings Engineer	WSP
Dean Ferguson	MP4 Project Manager	Resource Reserve Ltd
Marty Hughes	Senior Projects Engineer	OGNZL
Brian Adams	Principal Geotechnical Engineer	OGNZL
Gavin Lee	Environment and Community Manager	OGNZL
Philip Jones	acting Technical Services Manager	OGNZL
Duncan Ross	Consenting & Community Lead	OGNZL
Tim Mulliner	Technical Director - Environment	GHD
Rohan Lucas	Environmental Engineering and Geomorphology and Director	Alluvium Pty Ltd
Yuanzhi Chan	Senior Geotechnical Engineer	EGL
Trevor Matuschka	Director	EGL

4.2 Subsequent updates

Credible failure modes and risks were reviewed in November 2023 to reflect changes to TSF design and the mine plan which introduce a staged approach to operation. Personnel involved in the review process are in Table 4.2.

Table 4.2 Review participants

Name	**Title**	**Organisation**
Bill Danaher	Facilitator	RMI
Mike Gowan	Tailings Technical Director	WSP
Craig Johnson	Tailings Engineer	WSP
Dean Ferguson	MP4 Project Manager	Resource Reserve Ltd
Marty Hughes	Senior Projects Engineer	OGNZL
Eric Torvelainen	Senior Geotechnical Engineer	EGL
Ethan Glover	Consenting consultant	Mitchell Daysh
Pip Walker	Environmental Lawyer	Environment Law NZ

5 Failure modes overview

Various documents have presented summaries of the ‘causes’ of TSF failure, including ICOLD’s Bulletin 121 (ICOLD, 2001). The data summarised in Bulletin 121 – Tailings Dams, Risk of Dangerous Occurrences, Lessons learnt from practical experiences – is presented in Figure 5.1. The data indicates that the bulk of failures are attributed to slope instability (including foundation and earthquake in this category), overtopping or piping erosion/seepage. The causes identified from investigation into recent failures have supported this dataset.

The mechanisms that can result in catastrophic failure of a TSF are well known. A broad overview of each of the failure modes is presented in the following sections, along with typical causes. We note that it is common for failure to occur due to multiple causes being combined, and there are techniques to consider all credible combinations, discussed in Chapman and Williams (2019). However, for the purposes of the FMEA, the causes have been considered separately initially, with a view to more detailed studies being undertaken if required.

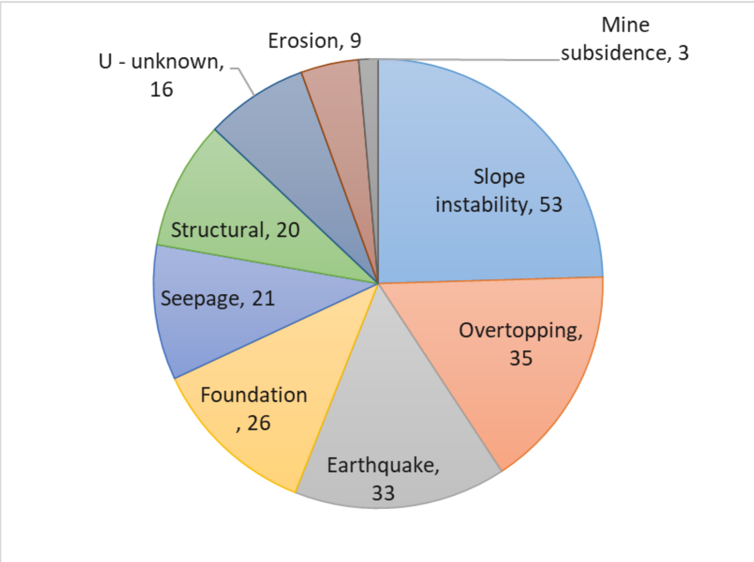

Figure 5.1 Summary of failure modes – ICOLD (2001)

5.1 Slope instability

Instability of an embankment slope is typically caused by one of the following mechanisms:

1 Excessive pore water pressure in the embankment. An increase in pore pressure results in a decrease of the effective strength of the embankment, which could lead to slope failure, slumping/sloughing, deformation and ultimately loss of the facility through overall failure. Rising pore water (phreatic) pressure is a key contributor to static liquefaction, highlighting the need for the design engineer to fully characterise and understand the potential for undrained failure of contractive materials. Excess pore water pressures could be caused by:

— A decant pond larger than designed, whether from supernatant water or successive rainfall events

— Failure of drainage in the embankment or external to the TSF

— Lack of drainage due to poor understanding of ground conditions

— Presence of a liner without due consideration of over-liner drainage

— Rapid loading of the tailings, either through high rates of rise or movement due to blasting or seismicity

2 Removal of resistive forces along either upstream or downstream slopes. The resistive forces could be stabilisation measures, previously implemented to maintain acceptable stability levels, such as buttresses. When these structures are inadvertently removed or reduced, it could result in slope failure. Removal of material could be caused by:

- Unauthorised excavation
- Authorised excavation without consideration of the impact on slope stability

3 Excessive erosion of the embankment slopes. This could cause localised failure, or where excessive erosion causes steep and deep erosion gullies that cut into the embankment crest, these events could result in instability and slope failure. Excessive erosion could be caused by:

- Wind or surface water/rainfall
- Uncontrolled traversing of fauna (cattle, goats, etc.) across the slopes
- Failure of operational pipelines along the embankment crest or along the slope
- Lack of vegetation/slope revetment
- Dispersive materials
- Lack of adequate surface water control measures

4 Foundation failure. Failure of the foundation could occur through a number of ways, including through excessive loading which exceeds the strength of the foundation material, through seepage and piping (discussed separately below), through seismic loading or through weak zones within the foundation. The foundation conditions are normally assessed during the design of the structure, prior to commencement of construction, as poor or inadequate foundation conditions are normally challenging to rectify if they are detected post construction. Foundation failure could result in excessive deformation and settlement of the crest of the dam, thereby impacting its storage capacity, but it could also result in upstream or downstream slope failures with subsequent loss of containment. Foundation failure could be caused by:

- Poor investigation and failure to identify weaker layers
- Lack of adequate laboratory testing to characterise the material
- Lack of recognition of transition to normally consolidated conditions
- Piping of materials
- Loading beyond the capability of the foundation, due to pore water pressures or placement of materials

5 Differential settlement. As noted above, foundation failure could result in excessive deformation and settlement of the crest of the dam, resulting in slope failure with subsequent loss of containment. However, differential settlement could also occur within the embankment itself, or at the abutments, resulting in cracking and ultimately failure of the embankment. It is noted that while cracking in itself may not result in failure, a large rainfall event could exacerbate the issue. Differential settlement could be caused by:

- Poor characterisation or unexpected performance of foundation
- Variability in material compaction, particularly around infrastructure
- Under-compaction relative to the load of the embankment and consolidation of the embankment materials
- Presence of organic materials
- Construction with materials that may change character and volume (e.g. dissolve)
- Excessive shaking (seismicity)

5.2 Overtopping

Overtopping occurs when the storage capacity is insufficient to contain a rainfall event, freeboard is compromised, and the embankment crest overtops. With water retaining structures (dams), this could occur if the outlet structures (decant outlets or spillways) are blocked, obstructed or damaged, the embankment crest elevation is reduced (seismic loading causing deformation), or during extreme rainfall events that exceed the design capacity.

Overtopping of a TSF can occur when it is operated without sufficient freeboard, when the decant pond is excessive or located against the embankment and not at the decant structure, when spillways are blocked or obstructed (if they exist) or decant facilities are out of service (pump failure), damaged or obstructed, due to embankment deformation from foundation failure or seismic events or when excessive rainfall events exceed the design capacity. Overtopping could be caused by:

- Overfilling the TSF and reducing the available freeboard, or poor deposition management resulting in freeboard being compromised
- Allowing the pond to grow beyond the maximum allowable size, through inattention or water recovery equipment failure, combined with a rainfall event of sufficient size
- A rainfall event occurring beyond the capacity of the TSF to manage it (i.e. greater than the design flood event)
- An influx of material into the TSF that reduces available water storage capacity or results in a seiche wave forming
- Unauthorised discharge of water into TSF
- Incorrect calculation of runoff from external catchments.

5.3 Piping erosion

Piping failure occurs when seepage through the embankment profile starts to dislodge and remove solid particles and discharge the solids in suspension downstream of the embankment. This phenomenon is generally indicated by seepage water being murky/muddy, which is an indication that solids are in suspension within the seepage water. Once solids start to be removed from the embankment, typically starting at the downstream side and propagating upstream into the embankment, an eroded ‘pipe’ starts to form. With ongoing removal of solids, and no remedial action, the pipe could propagate through the embankment and create a conduit from where water or tailings inside the facility could discharge. Ongoing seepage and removal of solids through the ‘pipe’ could result in progressive increase in the ‘pipe’ dimensions to a point where the overlying material cannot be supported and collapse of the embankment takes place.

There needs to be a sufficient hydraulic gradient and the material needs to be susceptible to internal erosion for piping erosion to occur, which could be caused by:

- An operating pond larger than designed, whether by deposition or successive rainfall events
- Failure of drainage measures in the TSF, in the embankment or external to the TSF
- Lack of drainage due to poor understanding of ground conditions.

If the hydraulic gradient is present, internal erosion could then be caused by:

- Poor design – Incorrect selection of embankment materials or filter materials (grain size, material character)
- Lack of filter system in place
- Preferential pathways created by organic matter or fauna
- Interface erosion along infrastructure (e.g., pipelines installed in embankment)
- Variability in material compaction or non-homogeneous fill, particularly around infrastructure.

5.4 Other failure modes

Structural component failure and sabotage are also credible failure modes. Where storage facilities contain structural components, e.g., concrete wing walls at spillways, concrete spillway sills, concrete decant structures, failure of those components could result in any of the failure mechanisms listed above. For the purposes of this assessment, the focus has been directed to the more common failure modes outlined previously, however, structural failure has been considered where relevant. Sabotage has not been considered, as we assume that this is covered in the OGNZL site-wide risk framework, along with access control.

6 FMEA & risk assessment process

6.1 Overview

The following method was adopted for the FMEA and risk assessment:

1. The context and battery limits of the FMEA were established based on discussions between WSP and OGNZL
2. Risk is defined as the "effect of uncertainty on objectives", and so it is not possible to identify and assess risks without first establishing context and objectives:
    a. WSP presented a context setting presentation in relation to the Fraser TSF at the commencement of the initial FMEA workshop session
    b. The presentation established background information in terms of TSF design and operation, and the FMEA process
    c. The FMEA and associated report were subsequently updated to reflect changes in the TSF design and tailings deposition practices
3. A Microsoft Excel spreadsheet template was used as the basis to develop and record the FMEA
4. Failure mode identification was undertaken prior to the workshop session by review of previous FMEA studies, and input from WSP personnel, with additional failure modes identified added during the workshop session using brainstorming activities
5. The process involved in the workshop session included:
    - Confirmation of the potential failure mode
    - Determination of whether the failure mode was credible or non-credible
    - Determination of whether the failure mode could lead to catastrophic failure
    - Determination of whether the failure mode was a "sunny day" or a "rainy day" failure
    - Determination of possible location of failure
    - Documentation of current control measures or those controls proposed within the project scope
    - Risk ranking based upon the current controls
    - Documentation of recommended additional risk treatments
    - Consensus was reached regarding the information and ratings that are included in the FMEA register
6. Risks were ranked using the Oceana Risk Ranking Matrix
7. A FMEA Risk Register was prepared and provided to workshop attendees for review
8. A draft report presenting the FMEA process and outcomes was then prepared.

As the technical advice generated from both internal and external sources within the workshop and review sessions was assumed appropriate and accurate, it was not subject to detailed validation.

6.2 FMEA register

A Microsoft Excel spreadsheet was used to document the FMEA and risk register. This register is the key outcome and deliverable of a risk assessment and should be maintained as a live document with regular reviews and updates throughout the facility lifecycle.

The register considers the following key fields:

- The TSF component affected (in situ pit floor, pit wall, backfill, water management, pipelines or tailings beach)
- A description of the potential failure mode (what can happen), possible causes (how and why) and maximum effect
- Whether the PFM is credible or non-credible
- Whether there is potential containment loss
- Whether there is potential catastrophic failure
- Applicable climate condition (sunny and/or rainy-day failure)
- Location of failure (backfill, east highwall, southern waste rock stack, west wall)
- Current and/or proposed control measures – prevention and mitigation
- The consequence, likelihood and overall risk
- Recommended additional risk treatments.

6.3 Risk analysis and evaluation

The purpose of evaluating risk is to assign consequences and the likelihood of those consequences for a given risk. Consequence and likelihood are combined to give a measure of risk. This analysis is undertaken by considering the existing or proposed risk controls or treatments.

Failure modes were evaluated on the basis of the containment performance of the TSF, with the Oceana Gold Risk Ranking Matrix was used for initial classification, and prioritizing risks.

It was noted during the workshop that a specialised risk ranking matrix may be required for ranking catastrophic failure modes where the likelihood may be very low. This has been discounted at this stage of design, with recommendations to consider alternate risk assignment methods during detailed design of the facility.

It should also be noted that three types of risk analysis (qualitative, semi-quantitative and quantitative) are possible. A semi-quantitative analysis was used and is reported.

6.4 Risk treatment

Risk treatment strategies are typically within the following categories:

- Risk avoidance - requires that a given activity is not undertaken as a means of managing its associated risk. Risk avoidance has limited applicability.
- Risk transfer - transferring risk to another party either by contractual transfer or direct physical transfer of the risk.
- Reduction of consequence or likelihood – typically through the hierarchy of controls:
  - Elimination of a risk
  - Substitution of a lesser risk
  - Reduction of risk by engineering controls
  - Reduction of risk by procedural controls
  - Use of protective equipment (for safety risks)
- Risk retention – those risk that cannot be eliminated or avoided and must be kept to some extent. Risk management enables risk retention to be undertaken with knowledge.

7 Description of the FTSF

The following stages of FTSF were used for the FMEA and considered in the risk assessment:

- FTSF Stage 1: TSF operation; Frasers Backfill constructed to 450 mRL and tailings slurry disposal to 345 mRL
- FTSF Stage 2: TSF operation; Frasers Backfill constructed to 480 mRL and tailings slurry disposal to 416 mRL
- FTSF Closure: Long-term pit lake submerging Frasers Backfill during filling to a maximum lake level of 494 mRL.

Each stage was independently assessed to evaluate stage-specific risks. These risks are documented in separate worksheets in the FMEA register.

7.1 FTSF Stage 1 & Stage 2

Details of the FTSF design are presented in the feasibility design report for each stage (WSP 2023a, 2023b). Key design features are summarised in Table 7.1 and presented in Figure 7.1 Figure 7.2, Figure 7.3 and Figure 7.4.

Table 7.1 Key features for the Stage 1 and Stage 2 design

Feature	**Description**	**FTSF Stage 1**	**FTSF Stage 2**
Frasers Backfill	Embankment type	Waste rock backfill	Waste rock backfill
	Embankment crest level	450 mRL	480 mRL
	Embankment crest width	75 m	100 m
	Embankment benching	10 m wide downstream 14 m wide upstream below 420 mRL 30 m wide upstream above 420 mRL	No downstream benching 14 m wide upstream below 420 mRL No upstream benching above 420 mRL
	Embankment battering (overall)	1V:1.9H downstream overall 1V:2.2H upstream overall	1V:3H downstream 1V:2.2H upstream to 420 mRL 1V:3H upstream above 420 mRL
	Embankment battering (inter-bench)	Natural angle of repose (1V:1.33H) on both upstream and downstream inter-benches	No downstream benches Natural angle of repose (1V:1.33H) on benches to 420 mRL No upstream benches above 420 mRL
Frasers TSF	Deposition strategy	Tailings deposition from one of a minimum three full-bore spigots located on upstream side of embankment	Tailings deposition from one of a minimum three full-bore spigots located on upstream side of embankment

Feature	Description	FTSF Stage 1	FTSF Stage 2
	Tailings pipelines	Located on the upstream crest of 14 m wide benches, relocated periodically onto next bench as tailings beach rises	Located on the upstream crest of 14 m wide benches, relocated periodically onto next bench as tailings beach rises
	Tailings storage level	345 mRL	416 mRL
	Decant pond	Located in south-east corner, with expected operating depth of 2 m	Located in south-east corner, with expected operating depth of 2 m

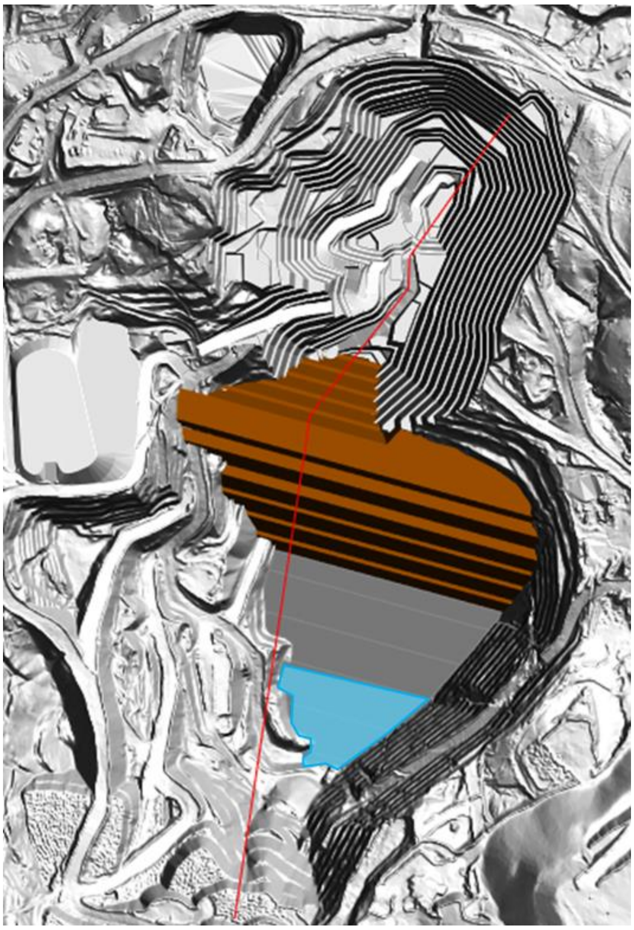

Figure 7.1 FTSF Stage 1 operational plan

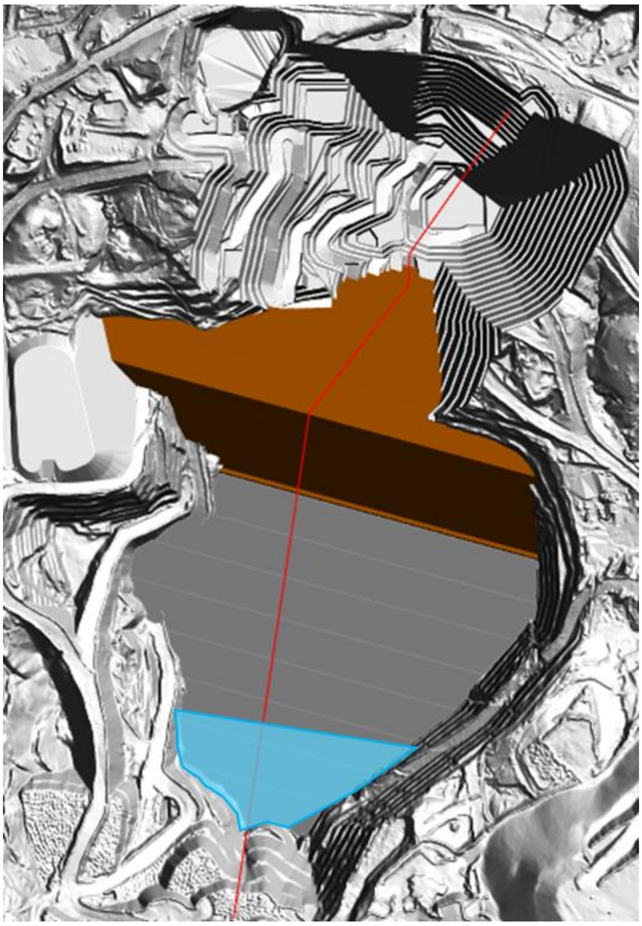

Figure 7.2 FTSF Stage 2 operational plan

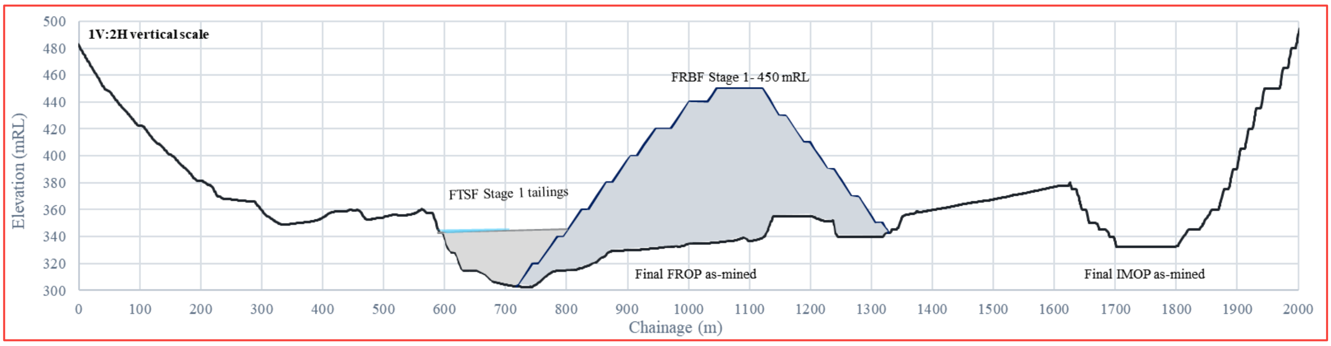

Figure 7.3 FTSF Stage 1 operational cross-section

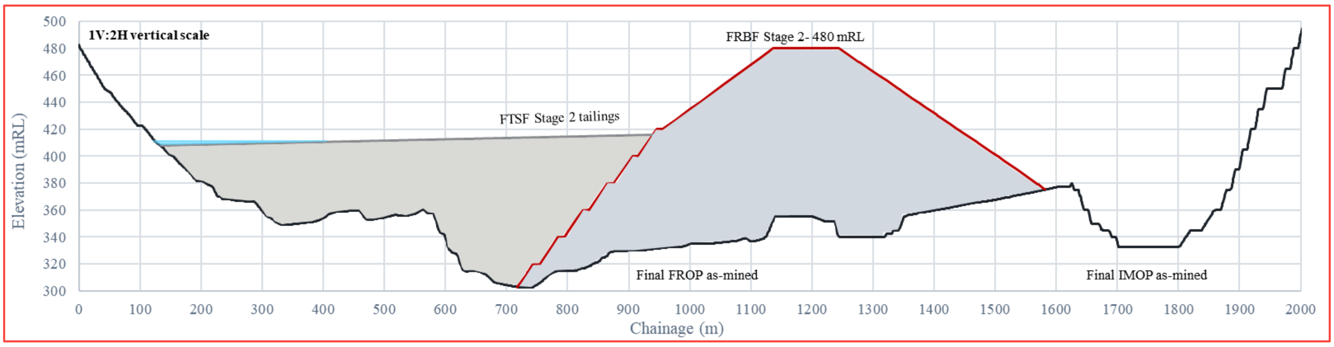

Figure 7.4 FTSF Stage 2 operational cross-section

7.2 FTSF Closure

The closure strategy is consistent for both stages of the TSF, irrespective of whether it pauses at the end of Stage 1 or progresses through to the end of Stage 2. This conceptual plan includes the following pertinent details:

- Deveopment of a pit lake providing a water cover over the tailings in the FTSF and a pit lake accumulating within the Innes Mills pit (IMOP). Both are maintained by rainfall, groundwater seepage and runoff from surrounding catchments.Water levels are predicted to rise gradually over time due to a positive water balance.
  - Stage 1 arrangement: GHD (2023) has predicted that the FTSF water cover will reach the 450 mRL backfill crest after approximately 50 years before then overflowing into the rising IMOP, with levels equalising at 450 mRL after 60 years. The backfill will become fully-inundated after that point. This modelling estimates that the long-term stabilised water level will fluctuate between 486.5 and 489.7 mRL.
  - Stage 2 arrangement: GHD (2024) has predicted that the FTSF water cover will reach the 480 mRL backfill crest after approximately 65 years before then overflowing into the rising IMOP, with levels equalising at 480 mRL after 95 years. The backfill will become fully-inundated after that point. This modelling estimates that the long-term stabilised water level will fluctuate between 486 and 494 mRL.
- The lowest point on the pit rim of the combined FTSFand IMOP is at 505 mRL, a minmum of 11 m above the final pit lake level and equivalent to 22 Mm^3 additional storage capacity. This confirms that the long-term pit lake will be fully-containment within the pits.

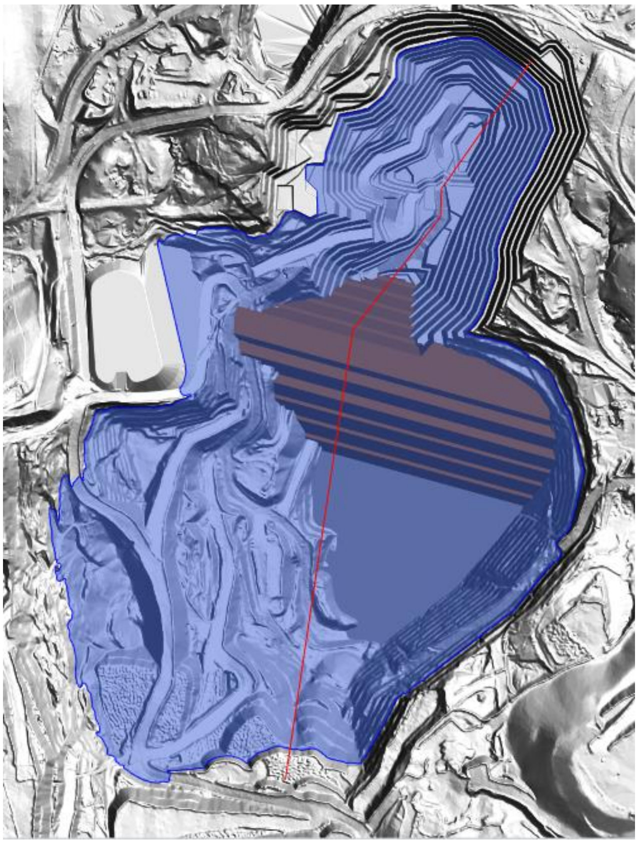

Figure 7.5 FTSF Stage 1 closure pit lake

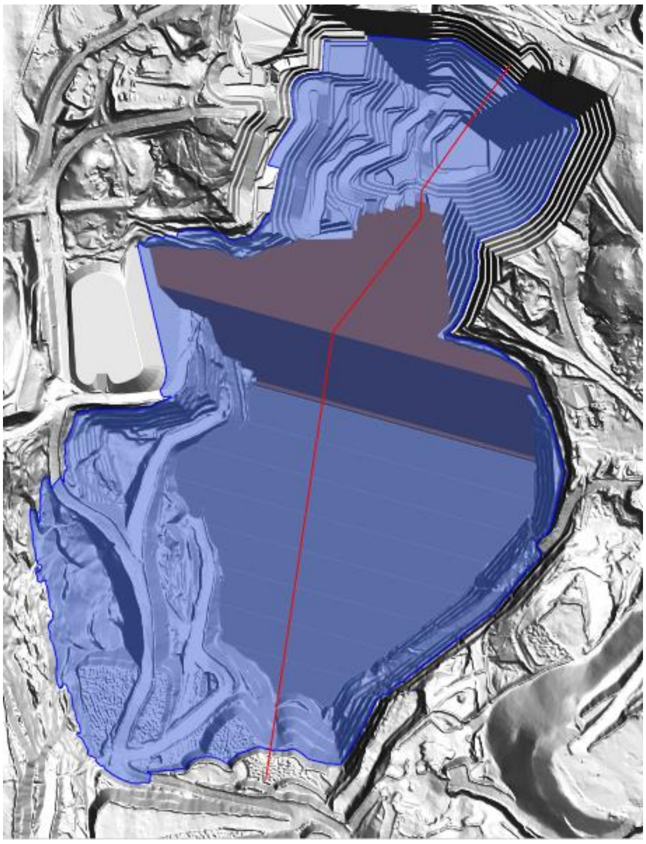

Figure 7.6 FTSF Stage 2 closure pit lake

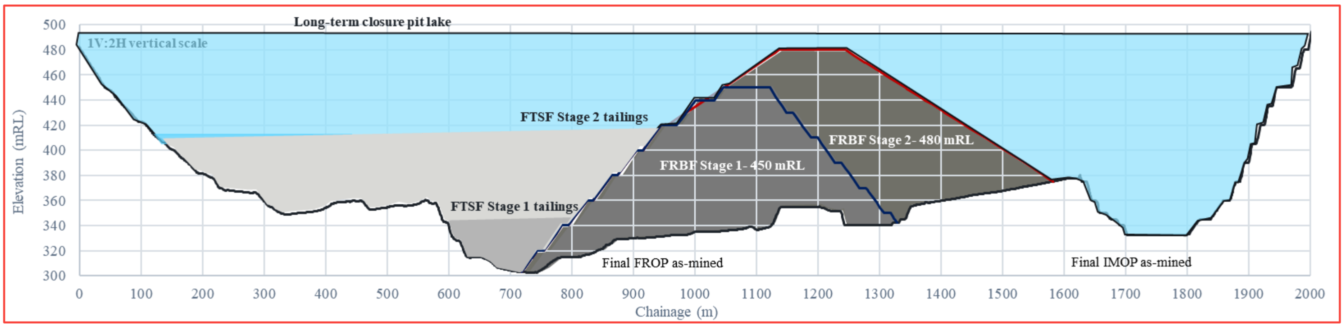

Figure 7.7 FTSF closure (stage 1 or Stage 2) pit lake cross-section

8 FMEA & risk assessment outcomes

The FMEA and risk assessment was undertaken for each lifecycle phase identified; FTSF Stage 1, FTSF Stage 2 and Closure. The following sections provide details on credible failure modes and risk levels for each lifecycle phase. Full details are available within the overall FMEA register in Appendix A.

8.1 FTSF Stage 1

Twenty-four (24) PFMs were identified for FTSF Stage 1, however, only 11 were deemed as credible failure modes.

8.1.1 Credible failure modes with catastrophic potential

No credible failure modes were classified as catastrophic.

8.1.2 Summary of credible failure modes

Table 8.1 provides a risk level summary for each credible failure mode.

Table 8.1 Summary of credible failure modes for FTSF Stage 1

Risk No.	Possible failure mode	Risk Level	Recommended Risk Treatment
4	Wave erosion results in collapse of pit wall.	1 (L)	None recommended
6	Pit wall becomes unstable and collapses into TSF.	2 (L)	None recommended
7	Seismic induced instability of pit wall.	1 (L)	None recommended
10	Backfill becomes unstable and collapses into TSF and/or Innes Mills.	9 (M)	None recommended
11	Seismic induced instability of backfill.	6 (L)	None recommended
14	Liquefaction/softening of backfill.	1 (L)	None recommended
15	Wave erosion results in local instability of backfill.	2 (L)	None recommended
21	Piping of rockfill/tailings into FRUG voids.	1 (L)	None recommended
22	Tailings deposition pipeline leak/burst.	4 (L)	None recommended
23	Return water (decant in south) pipeline leak/burst.	4 (L)	None recommended
24	Failure to contain wind-blown tailings.	3 (L)	None recommended

8.2 FTSF Stage 2

Twenty-four (24) PFMs were identified for FTSF Stage 2, however, only 11 were deemed as credible failure modes.

8.2.1 Credible failure modes with catastrophic potential

No credible failure modes were classified as catastrophic.

8.2.2 Summary of credible failure modes

Table 8.2 provides a risk level summary for each credible failure mode.

Table 8.2 Summary of credible failure modes for FTSF Stage 2

Risk No.	Possible failure mode	Risk Level	Recommended Risk Treatment
4	Wave erosion results in collapse of pit wall.	2 (L)	None recommended
6	Pit wall becomes unstable and collapses into TSF.	2 (L)	None recommended
7	Seismic induced instability of pit wall.	1 (L)	None recommended
10	Backfill becomes unstable and collapses into TSF and/or Innes Mills.	9 (M)	None recommended
11	Seismic induced instability of backfill.	6 (L)	None recommended
14	Liquefaction/softening of backfill.	1 (L)	None recommended
15	Wave erosion results in local instability of backfill.	1 (L)	None recommended
21	Piping of rockfill/tailings into FRUG voids.	1 (L)	None recommended
22	Tailings deposition pipeline leak/burst.	4 (L)	None recommended
23	Return water (decant in south) pipeline leak/burst.	4 (L)	None recommended
24	Failure to contain wind-blown tailings.	5 (L)	None recommended

8.3 FTSF Closure

Twenty-one (21) PFMs were identified for FTSF Stage 1, however, only 12 were deemed as credible failure modes.

8.3.1 Credible failure modes with catastrophic potential

No credible failure modes were classified as catastrophic.

8.3.2 Summary of credible failure modes

Table 8.3 provides a risk level summary for each credible failure mode.

Table 8.3 Summary of credible failure modes for FTSF Closure

Risk No.	Possible failure mode	Risk Level	Recommended Risk Treatment
4	Wave erosion results in local instability of pit wall.	4 (L)	None recommended
6	Pit wall becomes unstable and collapses into TSF.	2 (L)	None recommended
7	Seismic induced instability of pit wall.	1 (L)	None recommended
10	Backfill becomes unstable and collapses into TSF and/or Innes Mills.	4 (L)	None recommended
11	Seismic induced instability of backfill.	4 (L)	None recommended
12	Internal erosion (piping) through backfill.	2 (L)	None recommended
13	Seepage through waste rock backfill.	1 (L)	None recommended
14	Liquefaction/softening of backfill.	1 (L)	None recommended
15	Wave erosion results in local instability of backfill.	4 (L)	None recommended

Risk No.	Possible failure mode	Risk Level	Recommended Risk Treatment
17	Seepage from TSF leading to surface water release into environment.	8 (M)	Review design in relation to capture and return of seepage flows - option of treatment plant.
18	Seepage through the pit floor and walls into groundwater.	5 (L)	None recommended
21	Failure to contain wind-blown tailings.	5 (L)	Review closure options (such as partial wet cover with upper rockfill capping) if water modelling suggests partial coverage for a period of time.

9 Discussion

Consultation and communication are essential parts of the risk management process. The selection of a multidisciplinary FMEA workshop team ensured that appropriate consultation occurred. The facilitator notes that adequate input was obtained from all attendees and consensus was generally reached about risk levels.

Communication of risk is an ongoing process. However, the development of the FMEA Risk Register provides the basis for communication of these aspects of risk to appropriate personnel. The Risk Register is available in Appendix A and represents an understanding by the workshop group of risks associated with the FTSF, although it cannot be guaranteed that the level of risk will not change over time and that new risks will not appear. Therefore, the document is intended to be maintained as a live document and updated over the facility lifecycle through an ongoing strategy of monitoring and reviewing risks.

10 Conclusion

The FMEA process has shown that there are no critical failure modes for any of the three stages of development and closure of the current FTSF design. There are only two, shown in Table 8.3, that may require action either immediately after tailings operations cease (number 21) or when the pit lakes reach a critical level (number 17).

We thus conclude that the FTSF will present no risk to the environment or the community.

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WSP 2023, Frasers Backfill Stage 1 Design for Consent Application, PS204746-REP-006, Revision 0, December 2023

WSP 2024, Frasers Backfill Stage 2 Design for Consent Application, PS204746-REP-007, Revision A, February 2024

Appendix A

FMEA Register

Stage 1 Tailings

Risk No.	Component	Possible failure mode - What can happen / go wrong?	Possible causes (How? Why?)	Effect description	Is the failure mode credible?	Potential containment loss? (tailings slurry, dust, contaminated water)	Is the failure catastrophic?	Probable maximum consequence	Sunny Day Failure?	Rainy Day Failure?	Location of failure: FRBF / North highwall	East highwall	Southern WRD	West slope	Notes/comments	Current Control Measures - Prevention	Current Control Measures - Mitigation	Consequence (with controls)	Likelihood of consequence (with controls)	Risk Level	Recommended Risk Treatments
1	Pit Floor (In situ rock)	Internal erosion (piping) of foundations.	Incompatibility of foundation and tailings. Inconsistency of material particle size distribution. Inadequate foundation preparation. High phreatic surface in tailings leads to weakening of foundation soils.	Piping erosion through foundation due to seepage leading to environmental release.	No										Deemed non-credible based on nature of pit floor foundation - not erodible, solid rock. Seepage into the FRUG is addressed as a separate failure mode.						
2	Pit Floor (In situ rock)	Seismic event resulting in loss of strength in foundation.	Blasting near pit. Earthquake.	Movement in foundation leading to collapse of backfill. Release of tailings and/or water through cracks in foundation into underground.	No										Deemed non-credible based on nature of pit floor foundation - not susceptible to seismic strength loss.						
3	Pit Floor (In situ rock)	Liquefaction of foundation.	Earthquake. Blasting near pit. Loading above foundation. Rapid change in loading. Limited site investigation/lack of geotechnical information.	Movement in foundation leading to collapse of backfill. Release of tailings and/or water through cracks in foundation into underground.	No										Deemed non-credible based on nature of pit floor foundation - not susceptible to liquefaction.						
4	Pit Wall	Wave erosion results in collapse of pit wall.	Wave action by decant pond water. Weather and physical location causes difficulty in access, preventing monitoring and repair. Inadequate erosion protection of face.	Collapse of pit wall into TSF resulting in wave action against embankment or decant area.	Yes	No	No	1	Yes	Yes	No	No	Yes	Yes	Can result in local, small-scale damage (erosion/scour) to embankment or decant area but no loss of containment or catastrophic failure due to freeboard.	Decant pond management.	Pit wall monitoring regime (radar). TARP for monitoring movement rates. Optional protection of decant pump area. Rockfill embankment design to mitigate erosion. Large freeboard: 60m at start of Stage 1 and increasing to 105 m at end of Stage 1.	1	E	1 (L)	None recommended.
5	Pit Wall	Rapid drawdown in pit results in loss of strength of walls and subsequent failure.	Rapid pumping-out of water. Cracking in pit floor resulting in rapid drainage to FRUG.	Collapse of pit wall into TSF.	No										Non-credible: -No capability to empty pit rapidly -Losses into underground through fractures would not be rapid enough to cause rapid drawdown. -Pond is shallow and limited water will be present. -Any pumping of water out will be slow.						
6	Pit Wall	Pit wall becomes unstable and collapses into TSF.	Inadequate wall stability FoS at the end of mining. Poor design or construction of FRS WRD. Saturation of FRS WRD material creating a slump. Presence of fault (West wall). High phreatic surface in pit wall during operation from large decant pond.	Collapse/sliding of pit wall into pit/tailings resulting in seiche wave action against embankment or decant area.	Yes	No	No	1	Yes	Yes	No	Yes	Yes	Yes	Can result in local damage (erosion/scour) to embankment or decant area but no loss of containment or catastrophic failure due to freeboard.	Buttressing effect of backfill and tailings. Decant pond management. Design to redirect surface water flows away from pit. Design of pit wall.	Pit wall monitoring regime (radar). TARP for monitoring movement rates. Optional protection of decant pump area. Rockfill embankment design to mitigate erosion. Large freeboard: 60m at start of Stage 1 and increasing to 105 m at end of Stage 1.	1	D	2 (L)	None recommended.
7	Pit Wall	Seismic induced instability of pit wall.	Blasting near pit. Earthquake.	Sliding failure leading to collapse of pit wall resulting in seiche wave action against embankment or decant area.	Yes	No	No	1	Yes	No	No	Yes	Yes	Yes	Pit wall failure from earthquake can result in local damage (erosion/scour) to embankment or decant area no loss of containment or catastrophic failure due to freeboard. Failure initiated from blasting deemed not credible - precedence from existing blasting undertaken.	Blasting separation distances. Buttressing effect of backfill and tailings. Design of pit wall. Decant pond management.	Pit wall monitoring regime (radar). TARP for monitoring movement rates. Optional protection of decant pump area. Rockfill embankment design to mitigate erosion. Large freeboard: 60m at start of Stage 1 and increasing to 105 m at end of Stage 1.	1	E	1 (L)	None recommended.
8	Pit Wall	Internal erosion (piping) through pit wall.	High phreatic surface in pit. Fractures in the walls. Increase in pond size in TSF greater than designed. Cracking and differential settlement.	Piping erosion through pit wall from seepage.	No										Not credible: -Any fractures are limited in extent -Long flow paths from pit walls to IMOP -Low phreatic surface with top of tailings at 345 mRL resulting in very flat gradient through to IMOP floor.						
9	Frasers backfill (FRBF)	Rapid drawdown in TSF results in loss of strength of waste rock backfill.	Rapid pumping-out of pit water. Cracking in pit floor resulting in rapid drainage to FRUG.	Collapse of waste rock backfill.	No										Not credible: -No capability to empty pit rapidly. -Deposited tailings act as a low permeable layer on pit floor.						
10	Frasers backfill (FRBF)	Backfill becomes unstable and collapses into TSF and/or Innes Mills.	Incorrect design. Inadequate monitoring. Poor design and construction of backfill. Saturation of backfill creating a slump. High phreatic surface in backfill wall.	Upstream slope failure into TSF. Downstream slope failure into IMOP. Reputational damage to OceanaGold.	Yes	No	No	3	Yes	Yes	Yes	No	No	No	Considers dam safety risks only and not the risk to operational personnel. Small-scale failure possible but no loss of containment or catastrophic failure due to freeboard.	Stability assessment to be undertaken to confirm a safe interim design profile for disposal. Avoid over-steep stack profile. Tailings deposition providing buttress. Embankment design geometry	Inspection and monitoring regime. Large freeboard: 60m at start of Stage 1 and increasing to 105 m at end of Stage 1.	3	D	9 (M)	None recommended.
11	Frasers backfill (FRBF)	Seismic induced instability of backfill.	Blasting near backfill. Earthquake.	Sliding failure leading to collapse of backfill into TSF or into IMOP. Reputational damage to OceanaGold.	Yes	No	No	3	Yes	No	Yes	No	No	No	Considers dam safety risks only and not the risk to operational personnel. Small-scale failure possible but no loss of containment or catastrophic failure due to freeboard.	Stability assessment for design seismic event. Blasting separation distances. Embankment design geometry	Inspection and monitoring regime. Large freeboard: 60m at start of Stage 1 and increasing to 105 m at end of Stage 1.	3	E	6 (L)	None recommended.
12	Frasers backfill (FRBF)	Internal erosion (piping) through waste rock backfill.	High phreatic level in FTSF. Cracking and differential settlement. Flow pathway through high permeability layers in the backfill into Innes Mill.	Seepage through backfill into IMOP leading to piping erosion of backfill and potential failure.	No										Failure mode is not credible - the level of tailings (345 mRL) will always be below the minimum insitu floor (355 mRL) so there is no continuous path for piping across backfill.						
13	Frasers backfill (FRBF)	Seepage through waste rock backfill.	High phreatic level in FTSF. Cracking and differential settlement. Flow pathway through high permeability layers in the backfill into Innes Mill.	Seepage through backfill into IMOP leading to potential containment loss.	No										Failure mode is not credible - the level of tailings (345 mRL) will always be below the minimum insitu floor (355 mRL) so there is no continuous path for seepage across backfill.						
14	Frasers backfill (FRBF)	Liquefaction/softening of backfill.	Fine and saturated waste rock resulting in liquefaction. Saturation of localized fine materials.	Loss of strength and subsequent failure of backfill.	Yes	No	No	1	Yes	Yes	Yes	No	No	No	Localised liquefaction contained to small pockets, resulting in settlement or cracking or small movements. No loss of containment or catastrophic failure due to freeboard.	Slope stability assessment in design. Liquefaction assessment. Management of out of specification material during dumping. Construction methodology in non-continuous layers.	Monitoring regime. Large freeboard: 60m at start of Stage 1 and increasing to 105 m at end of Stage 1.	1	E	1 (L)	None recommended.
15	Frasers backfill (FRBF)	Wave erosion results in local instability of backfill.	Wave action from decant pond Weather, physical location cause difficulty in access, preventing monitoring and repair. Inadequate erosion protection of face.	Erosion of the upstream backfill face leading to local failure.	Yes	No	No	1	Yes	Yes	Yes	No	No	No	Can result in local damage (erosion/scour) to embankment but no loss of containment or catastrophic failure due to freeboard.	Decant pond management. Embankment design geometry.	Rockfill embankment design to mitigate erosion. Large freeboard: 60m at start of Stage 1 and increasing to 105 m at end of Stage 1.	1	D	2 (L)	None recommended.
16	Frasers backfill (FRBF)	Overtopping of the backfill by tailings deposition (as it is being raised).	Uncontrolled tailings deposition	Overtopping of backfill and release of tailings containment.	No										Failure mode considered to be non-credible. Large freeboard: 60m at start of Stage 1 and increasing to 105 m at end of Stage 1.						

Risk No.	Component	Possible failure mode - What can happen / go wrong?	Possible causes (How? Why?)	Effect description	Is the failure mode credible?	Potential containment loss? (tailings slurry, dust, contaminated water)	Is the failure catastrophic?	Probable maximum consequence	Sunny Day Failure?	Rainy Day Failure?	Location of failure				Notes/comments	Current Control Measures - Prevention	Current Control Measures - Mitigation	Consequence (with controls)	Likelihood of consequence (with controls)	Risk Level	Recommended Risk Treatments
											FRBF / North highwall	East highwall	Southern WRD	West slope							
17	Water management	Rain induced overtopping of the containment area.	Extreme weather event. No backfill spillway to prevent overtopping. Inadequate freeboard specified/maintained. Increased upstream external catchment and/or changes to drainage.	Overtopping of backfill or pit perimeter and release of contaminated water into mining area downstream (IMOP) or external release (pit perimeter).	No										Not credible: -Large freeboard to top of backfill: 60m at start of Stage 1 and increasing to 105 m at end of Stage 1. -Significantly higher freeboard to top of pit perimeter.						
18	Water management	Seepage from TSF leading to environmental surface water release.	Extended duration of high water level in TSF. Variation in fill material characteristics. Localised seepage paths. Inadequate seepage management. Inadequate foundation preparation.	Localised offsite release of contaminated water.	No										Not credible: -Seepage would need to be significantly up-gradient. No "downstream" surface. -Tailings at 345 mRL during operation, ground level outside the pit significantly higher.						
19	Water management	Seepage through the pit floor and walls into groundwater.	Preferential seepage paths. Unidentified geological structure. High phreatic surface in pit.	Seepage through pit walls and floor leading to groundwater contamination.	No										Not credible: -Tailings act as low permeability aquitard for the floor. -Tailings level (345 mRL) much lower than surrounding groundwater level (460 mRL), thus acting as a 'sink'. -Groundwater modelling shows limited contaminant plume after 200+ years.						
20	Water management	Seepage into the underground workings (FRUG) into groundwater.	Seepage through backfill and fractured rock into the FRUG: -Vertical seepage into FRUG stopes. -FRUG caving intercepts with highwall -Bulkhead failure or lack of sealing portals	Seepage into FRUG leading to contamination of groundwater.	No										FRUG currently filling with water. Expected to continue to fill after deposition commences. Groundwater modelling assessment indicates contaminant plume within FRUG has limited reach after 200+ years.						
21	Water management	Piping of rockfill/tailings into FRUG voids.	Piping through to FRUG. Pathway from backfill into FRUG through stopes or portal.	Erosion leading to sinkhole development in backfill.	Yes	No	No	1	Yes	Yes	Yes	Yes	No	No	Can result in localised sinkholes but no loss of containment or catastrophic failure due to freeboard.	Operational mechanism to close voids prior to backfilling.		1	E	1 (L)	None recommended.
22	Pipelines	Tailings deposition pipeline leak/burst.	Poor pipeline selection. Poor operating and maintenance practices. Inadequate monitoring. Poor pipeline location.	Backfill saturation, erosion and slip failure causing wave.	Yes	No	No	1	Yes	No	Yes	No	No	No	Can result in localised scour or batter erosion but no loss of containment or catastrophic failure due to freeboard.	Pipeline selection. Pipeline locations. Daily operational inspections of pipeline. Pressure sensors to indicate pipeline leak. Monitoring of pipeline operations. Management of construction activities around the pipelines, to ensure no damages.	Ability to cease pumping while repairs are made.	1	C	4 (L)	None recommended.
23	Pipelines	Return water (decant in south) pipeline leak/burst.	Poor pipeline selection. Poor operating and maintenance practices. Inadequate monitoring. Poor pipeline location.	Backfill saturation, erosion and slip failure.	Yes	No	No	1	Yes	No	No	No	Yes	No	Can result in localised scour or batter erosion but no loss of containment or catastrophic failure due to freeboard.	Pipeline selection. Pipeline locations. Daily operational inspections of pipeline. Pressure sensors to indicate pipeline leak. Monitoring of pipeline operations. Bunding to prevent flow into the pit, contain flows elsewhere.	Ability to cease pumping while repairs are made.	1	C	4 (L)	None recommended.
24	Tailings beach	Failure to contain wind blown tailings.	Dry tailings beach and high wind.	Loss of dry tailings into environment.	Yes	Yes	No	2	Yes	No	N/A	N/A	N/A	N/A	Very deep in pit provides some inherent limitation of the failure mode.	Beach management to keep tailings surface wet.	Active monitored; robust operational management.	2	E	3 (L)	None recommended.

Stage 2 Tailings

Risk No.	Component	Possible failure mode - What can happen / go wrong?	Possible causes (How? Why?)	Effect description	Is the failure mode credible?	Potential containment loss? (tailings slurry, dust, contaminated water)	Is the failure catastrophic?	Probable maximum consequence	Sunny Day Failure?	Rainy Day Failure?	Location of failure				Notes/comments	Current Control Measures - Prevention	Current Control Measures - Mitigation	Consequence (with controls)	Likelihood of consequence (with controls)	Risk Level	Recommended Risk Treatments
											Frasers Backfill - north highwall	East highwall	Southern WRD	West slope							
1	Pit Floor (In situ rock)	Internal erosion (piping) of foundations.	Incompatibility of foundation and tailings. Inconsistency of material particle size distribution. Inadequate foundation preparation. High phreatic surface in tailings leads to weakening of foundation soils.	Piping erosion through foundation due to seepage leading to environmental release.	No										Deemed non-credible based on nature of pit floor foundation - not erodible, solid rock. Seepage into the FRUG is addressed as a separate failure mode.						
2	Pit Floor (In situ rock)	Seismic event resulting in loss of strength in foundation.	Blasting near pit. Earthquake.	Movement in foundation leading to collapse of backfill. Release of tailings and/or water through cracks in foundation into underground.	No										Deemed non-credible based on nature of pit floor foundation - not susceptible to seismic strength loss.						
3	Pit Floor (In situ rock)	Liquefaction of foundation.	Earthquake. Blasting near pit. Loading above foundation. Rapid change in loading. Limited site investigation/lack of geotechnical information.	Movement in foundation leading to collapse of backfill. Release of tailings and/or water through cracks in foundation into underground.	No										Deemed non-credible based on nature of pit floor foundation - not susceptible to liquefaction.						
4	Pit Wall	Wave erosion results in collapse of pit wall.	Wave action by decant pond water. Weather and physical location causes difficulty in access, preventing monitoring and repair. Inadequate erosion protection of face.	Collapse of pit wall into TSF resulting in wave action against embankment or decant area.	Yes	No	No	1	Yes	Yes	No	No	Yes	Yes	Can result in local, small-scale damage (erosion/scour) to embankment or decant area but no loss of containment or catastrophic failure due to freeboard.	Decant pond management.	Pit wall monitoring regime (radar). TARP for monitoring movement rates. Optional protection of decant pump area. Rockfill embankment design to mitigate erosion. Large freeboard: 105m at start of Stage 2 and decreasing to 64 m at end of Stage 2.	1	D	2 (L)	None recommended.
5	Pit Wall	Rapid drawdown in pit results in loss of strength of walls and subsequent failure.	Rapid pumping-out of water. Cracking in pit floor resulting in rapid drainage to FRUG.	Collapse of pit wall into TSF.	No										Non-credible: -No capability to empty pit rapidly -Losses into underground through fractures would not be rapid enough to cause rapid drawdown. -Pond is shallow and limited water will be present. -Any pumping of water out will be slow..						
6	Pit Wall	Pit wall becomes unstable and collapses into TSF.	Inadequate wall stability FoS at the end of mining. Poor design or construction of FRS WRD. Saturation of FRS WRD material creating a slump. Presence of fault (West wall). High phreatic surface in pit wall during operation from large decant pond.	Collapse/sliding of pit wall into pit/tailings resulting in seiche wave action against embankment or decant area.	Yes	No	No	1	Yes	Yes	No	Yes	Yes	Yes	Can result in local damage (erosion/scour) to embankment or decant area but no loss of containment or catastrophic failure due to freeboard.	Buttressing effect of backfill and tailings. Decant pond management. Design to redirect surface water flows away from pit. Design of pit wall.	Pit wall monitoring regime (radar). TARP for monitoring movement rates. Optional protection of decant pump area. Rockfill embankment design to mitigate erosion. Large freeboard: 105m at start of Stage 2 and decreasing to 64 m at end of Stage 2.	1	D	2 (L)	None recommended.
7	Pit Wall	Seismic induced instability of pit wall.	Blasting near pit. Earthquake.	Sliding failure leading to collapse of pit wall resulting in seiche wave action against embankment or decant area.	Yes	No	No	1	Yes	No	No	Yes	Yes	Yes	Pit wall failure from earthquake can result in local damage (erosion/scour) to embankment or decant area no loss of containment or catastrophic failure due to freeboard. Failure initiated from blasting deemed not credible - precedence from existing blasting undertaken.	Blasting separation distances. Buttressing effect of backfill and tailings. Design of pit wall. Decant pond management.	Pit wall monitoring regime (radar). TARP for monitoring movement rates. Optional protection of decant pump area. Rockfill embankment design to mitigate erosion. Large freeboard: 105m at start of Stage 2 and decreasing to 64 m at end of Stage 2.	1	E	1 (L)	None recommended.
8	Pit Wall	Internal erosion (piping) through pit wall.	High phreatic surface in pit. Fractures in the walls. Increase in pond size in TSF greater than designed. Cracking and differential settlement.	Piping erosion through pit wall from seepage.	No										Not credible: -Any fractures are limited in extent -Long flow paths from pit walls to IMOP -Low relative phreatic surface with top of tailings at 416 mRL resulting in very flat gradient through to IMOP floor.						
9	Frasers backfill (FRBF)	Rapid drawdown in TSF results in loss of strength of waste rock backfill.	Rapid pumping-out of pit water. Cracking in pit floor resulting in rapid drainage to FRUG.	Collapse of waste rock backfill.	No										Not credible: -No capability to empty pit rapidly. -Deposited tailings act as a low permeable layer on pit floor.	Tailings deposited acting as low permeable layer on pit floor.					
10	Frasers backfill (FRBF)	Backfill becomes unstable and collapses into TSF and/or Innes Mills.	Incorrect design. Inadequate monitoring. Poor design and construction of backfill. Saturation of backfill creating a slump. High phreatic surface in backfill wall.	Upstream slope failure into TSF. Downstream slope failure into IMOP. Reputational damage to OceanaGold.	Yes	No	No	3	Yes	Yes	Yes	No	No	No	Considers dam safety risks only and not the risk to operational personnel. Small-scale failure possible but no loss of containment or catastrophic failure due to freeboard.	Stability assessment to be undertaken to confirm a safe interim design profile for disposal. Avoid over-steep stack profile. Tailings deposition providing buttress. Embankment design geometry	Inspection and monitoring regime. Downstream mining offsets. Downstream mining scheduling (IMOP mining concludes mid-Stage 2). Large freeboard: 105m at start of Stage 2 and decreasing to 64 m at end of Stage 2.	3	D	9 (M)	None recommended.
11	Frasers backfill (FRBF)	Seismic induced instability of backfill.	Blasting near backfill. Earthquake.	Sliding failure leading to collapse of backfill into TSF or into IMOP. Reputational damage to OceanaGold.	Yes	No	No	3	Yes	No	Yes	No	No	No	Considers dam safety risks only and not the risk to operational personnel. Small-scale failure possible but no loss of containment or catastrophic failure due to freeboard.	Stability assessment for design seismic event. Blasting separation distances. Embankment design geometry	Inspection and monitoring regime. Downstream mining offsets. Downstream mining scheduling (IMOP mining concludes mid-Stage 2). Large freeboard: 105m at start of Stage 2 and decreasing to 64 m at end of Stage 2.	3	E	6 (L)	None recommended.
12	Frasers backfill (FRBF)	Internal erosion (piping) through waste rock backfill.	High phreatic level in FTSF. Cracking and differential settlement. Flow pathway through high permeability layers in the backfill into Innes Mill.	Seepage through backfill into IMOP leading to piping erosion of backfill and potential failure.	No										Not credible: -Limited pressure head (416 mRL tailings) to drive a seepage face across the full width (1,000 m) during a relatively short operational period (up to 2030) while also piping across the full width with a layered, mixed waste rock material.						
13	Frasers backfill (FRBF)	Seepage through waste rock backfill.	High phreatic level in FTSF. Cracking and differential settlement. Flow pathway through high permeability layers in the backfill into Innes Mill.	Seepage through backfill into IMOP leading to potential containment loss.	No										Not credible: -Limited pressure head (416 mRL tailings) to drive a seepage face across the full width (1,000 m) during a relatively short operational period (up to 2030). -If seepage occurs, will be contained on IMOP, no containment loss.						

14	Frasers backfill (FRBF)	Liquefaction/softening of backfill.	Fine and saturated waste rock resulting in liquefaction. Saturation of localized fine materials. Final tailings level higher than locations - saturated materials.	Loss of strength and subsequent failure of backfill.	Yes	No	No	1	Yes	Yes	Yes	No	No	No	Localised liquefaction contained to small pockets, resulting in settlement or cracking or small movements. No loss of containment or catastrophic failure due to freeboard.	Slope stability assessment in design. Liquefaction assessment. Management of out of specification material during dumping. Slope stability assessment in design. Liquefaction assessment. Management of out of specification material during dumping. Construction methodology in non-continuous layers.	Monitoring regime. Large freeboard: 105m at start of Stage 2 and decreasing to 64 m at end of Stage 2.	1	E	1 (L)	None recommended.
15	Frasers backfill (FRBF)	Wave erosion results in local instability of backfill.	Wave action from decant pond Weather, physical location cause difficulty in access, preventing monitoring and repair. Inadequate erosion protection of face.	Erosion of the upstream backfill face leading to local failure.	Yes	No	No	1	Yes	Yes	Yes	No	No	No	Can result in local damage (erosion/scour) to embankment but no loss of containment or catastrophic failure due to freeboard. Less likely than Stage 1 as longer beach slope will restrict decant pond further away from embankment.	Decant pond management. Embankment design geometry.	Rockfill embankment design to mitigate erosion. Large freeboard: 105m at start of Stage 2 and decreasing to 64 m at end of Stage 2.	1	E	1 (L)	None recommended.
16	Frasers backfill (FRBF)	Overtopping of the backfill by tailings deposition (as it is being raised).	Uncontrolled tailings deposition	Overtopping of backfill and release of tailings containment.	No										Non-credible: -Large freeboard: 105m at start of Stage 2 and decreasing to 64 m at end of Stage 2.						
17	Water management	Rain induced overtopping of the containment area.	Extreme weather event. No backfill spillway to prevent overtopping. Inadequate freeboard specified/maintained. Increased upstream external catchment and/or changes to drainage.	Overtopping of backfill or pit perimeter and release of contaminated water into mining area downstream (IMOP) or external release (pit perimeter).	No										Non-credible: -Large freeboard to top of backfill: 105m at start of Stage 2 and decreasing to 64 m at end of Stage 2. -Significantly higher freeboard to top of pit perimeter.						
18	Water management	Seepage from TSF leading to environmental surface water release.	Extended duration of high water level in TSF. Variation in fill material characteristics. Localised seepage paths. Inadequate seepage management. Inadequate foundation preparation.	Localised offsite release of contaminated water.	No										Not credible: -Seepage would need to be significantly up-gradient. No "downstream" surface. -Tailings at 416 mRL during operation, ground level outside the pit significantly higher.						
19	Water management	Seepage through the pit floor and walls into groundwater.	Preferential seepage paths. Unidentified geological structure. High phreatic surface in pit.	Seepage through pit walls and floor leading to groundwater contamination.	No										Not credible: -Tailings act as low permeability aquitard for the floor. -Tailings level (416 mRL) much lower than surrounding groundwater level (460 mRL), thus acting as a 'sink'. -Groundwater modelling shows limited contaminant plume after 200+ years.						
20	Water management	Seepage into the underground workings (FRUG) into groundwater.	Seepage through backfill and fractured rock into the FRUG: -Vertical seepage into FRUG stopes. -FRUG caving intercepts with highwall -Bulkhead failure or lack of sealing portals	Seepage into FRUG leading to contamination of groundwater.	No										FRUG currently filling with water. Expected to continue to fill after deposition commences. Groundwater modelling assessment indicates contaminant plume within FRUG has limited reach after 200+ years.						
21	Water management	Piping of rockfill/tailings into FRUG voids.	Piping through to FRUG. Pathway from backfill into FRUG through stopes or portal.	Erosion leading to sinkhole development in backfill.	Yes	No	No	1	Yes	Yes	Yes	Yes	No	No	Can result in localised sinkholes but no loss of containment or catastrophic failure due to freeboard.	Operational mechanism to close voids prior to backfill.		1	E	1 (L)	None recommended.
22	Pipelines	Tailings deposition pipeline leak/burst.	Poor pipeline selection. Poor operating and maintenance practices. Inadequate monitoring. Poor pipeline location.	Backfill saturation, erosion and slip failure causing wave.	Yes	No	No	1	Yes	No	Yes	No	No	No	Can result in localised scour or batter erosion but no loss of containment or catastrophic failure due to freeboard.	Pipeline selection. Pipeline locations. Daily operational inspections of pipeline. Pressure sensors to indicate pipeline leak. Monitoring of pipeline operations. Management of construction activities around the pipelines, to ensure no damages.	Ability to cease pumping while repairs are made.	1	C	4 (L)	None recommended.
23	Pipelines	Return water (decant in south) pipeline leak/burst.	Poor pipeline selection. Poor operating and maintenance practices. Inadequate monitoring. Poor pipeline location.	Backfill saturation, erosion and slip failure.	Yes	No	No	1	Yes	No	No	No	Yes	No	Can result in localised scour or batter erosion but no loss of containment or catastrophic failure due to freeboard.	Pipeline selection. Pipeline locations. Daily operational inspections of pipeline. Pressure sensors to indicate pipeline leak. Monitoring of pipeline operations. Bunding to prevent flow into the pit, contain flows elsewhere.	Ability to cease pumping while repairs are made.	1	C	4 (L)	None recommended.
24	Tailings beach	Failure to contain wind blown tailings.	Dry tailings beach and high wind.	Loss of tailings into environment.	Yes	Yes	No	2	Yes	No	N/A	N/A	N/A	N/A	Deep in pit provides some inherent limitation of the failure mode.	Beach management to keep tailings surface wet.	Active monitored; robust operational management.	2	D	5 (L)	None recommended.

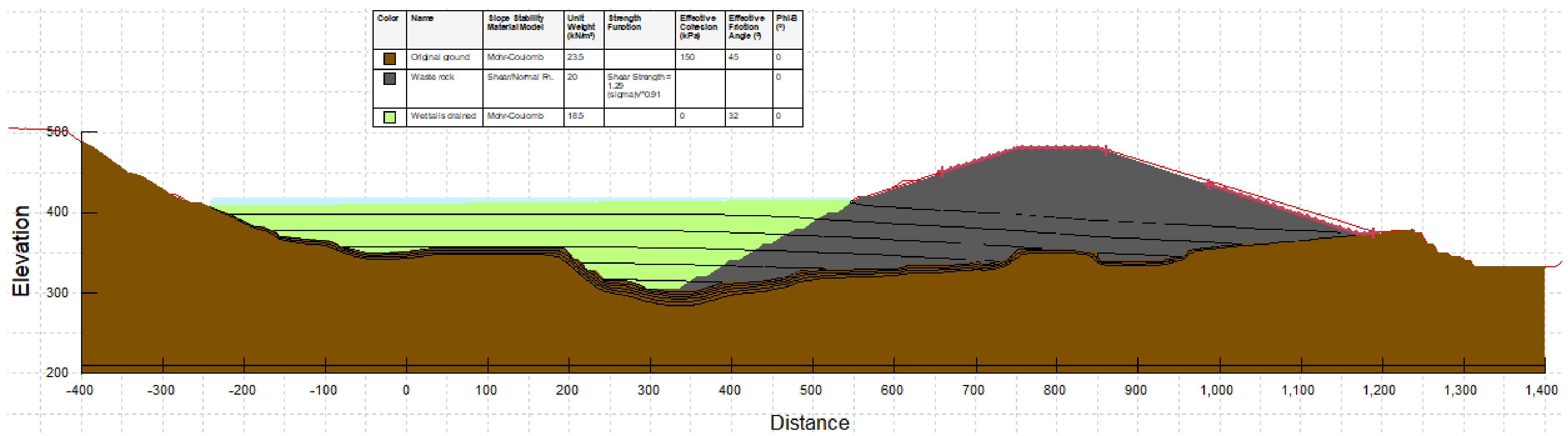
Closure

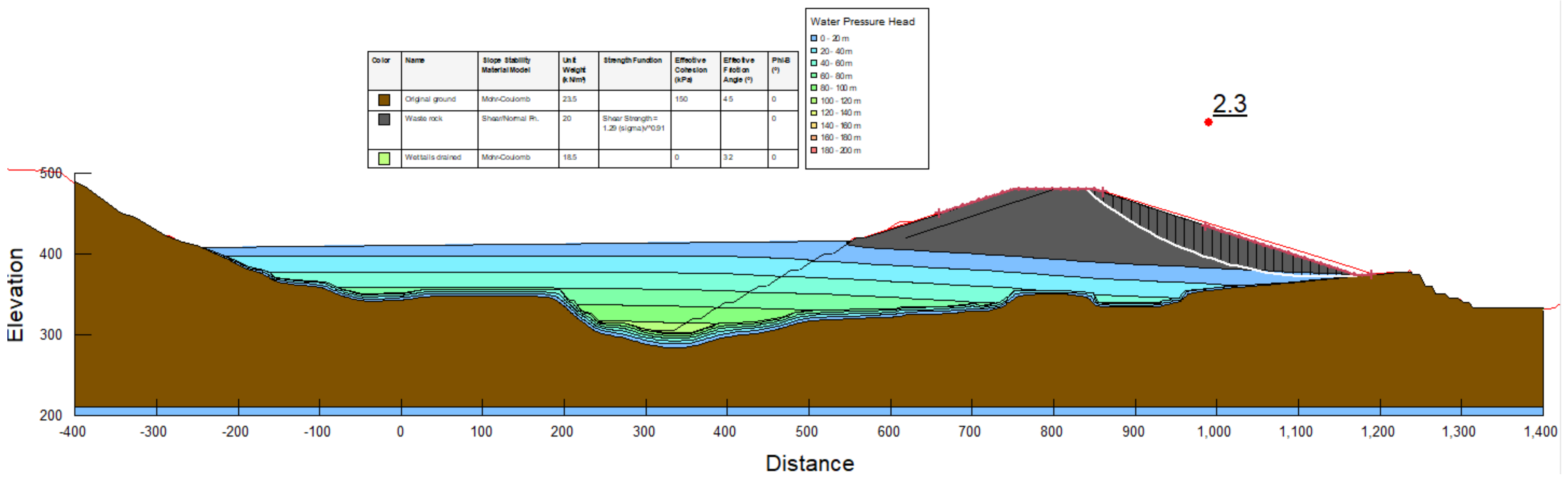
Risk No.	Component	Possible failure mode - What can happen / go wrong?	Possible causes (How? Why?)	Effect description	Is the failure mode credible?	Potential containment loss? (tailings slurry, dust, contaminated water)	Is the failure catastrophic?	Probable maximum consequence	Sunny Day Failure?	Rainy Day Failure?	Location of failure: Frasers Backfill - north highwall	Location of failure: East highwall	Location of failure: Southern WRD	Location of failure: West slope	Notes/comments	Current Control Measures - Prevention	Current Control Measures - Mitigation	Consequence (with controls)	Likelihood of consequence (with controls)	Risk Level	Recommended Risk Treatments
1	Pit Floor (In situ rock)	Internal erosion (piping) of foundations.	Incompatibility of foundation material and tailings. Inconsistency of material particle size distribution. Inadequate foundation preparation. High phreatic surface in pit from deposition leads to weakening of foundation soils.	Piping erosion through foundation due to seepage from leading to environmental release.	No										Deemed non-credible based on nature of pit floor foundation - not erodible, solid rock. Seepage into the FRUG is addressed as a separate failure mode.						
2	Pit Floor (In situ rock)	Seismic event resulting in loss of strength in foundation.	Vibration from blasting near the pit. Earthquake.	Movement in foundation leading to collapse of backfill. Release of tailings and/or water through cracks in foundation.	No										Deemed non-credible based on nature of pit floor foundation - not susceptible to seismic strength loss. Blasting not credible as no blasting activities in closure.						
3	Pit Floor (In situ rock)	Liquefaction of foundation.	Earthquake. Loading above foundation. Rapid change in loading. Shot firing - vibration. Limited site investigation/lack of geotechnical information.	Movement in foundation leading to collapse of backfill. Release of tailings and/or water through cracks in foundation into underground.	No										Deemed non-credible based on nature of pit floor foundation - not susceptible to liquefaction.						
4	Pit Wall	Wave erosion results in local instability of pit wall.	Wave action from sustained high pit lake water level. Weather, physical location and closure cause difficulty in access, preventing monitoring and repair. Closure phase with little repair maintenance. Inadequate erosion protection of face.	Collapse of pit wall into TSF resulting in wave action against backfill or southern waste rock stack.	Yes	No	No	1	Yes	Yes	No	No	Yes	Yes	Considered to be a progressive failure mode with small local failures. Longer exposure to an area of wall than during operation where water level rising with deposition. No loss of containment outside of pit or catastrophic failure due to freeboard / excess capacity at the ultimate long-term pit lake level. FRBF will be fully-submerged long-term. Prior to then wave action may result in damage to embankment batters. Wave action may result in some damage to Frasers South WRS.		Consider flattening areas more susceptible to wave erosion. 15m freeboard at max long-term pit lake level (489.7 mRL) compared to min insitu pit perimeter level (505 mRL).	1	C	4 (L)	None recommended.
5	Pit Wall	Rapid drawdown in pit results in loss of strength of walls and subsequent failure.	Cracking in pit floor resulting in rapid drainage to FRUG.	Collapse of pit wall into TSF.	No										Non-credible: -No capability to empty pit rapidly -Losses into underground through fractures would not be rapid enough to cause rapid drawdown. -No pumping of water as closure case has pit lake.						
6	Pit Wall	Pit wall becomes unstable and collapses into TSF.	Inadequate pit wall FoS at the end of mining. Poor design or construction of Frasers South WRS. Saturation of Frasers South WRS creating a slump. High phreatic surface in pit wall from high pit lake level. Presence of fault (West wall).	Collapse/sliding of pit wall into TSF resulting in seiche wave action against backfill or southern waste rock stack.	Yes	No	No	1	Yes	Yes	No	Yes	Yes	Yes	Local failures only, driven by pit wall structure. No loss of containment outside of pit or catastrophic failure due to freeboard / excess capacity at the ultimate long-term pit lake level.	Design of pit wall. Buttressing effect of backfill and tailings.	Consider flattening areas more susceptible to wave erosion. 15m freeboard at max long-term pit lake level (489.7 mRL) compared to min insitu pit perimeter level (505 mRL).	1	D	2 (L)	None recommended.
7	Pit Wall	Seismic induced instability of pit wall.	Earthquake.	Collapse/sliding of pit wall into TSF resulting in seiche wave action against backfill or southern waste rock stack.	Yes	No	No	1	Yes	No	No	Yes	Yes	Yes	Local failures only, driven by pit wall structure. No loss of containment outside of pit or catastrophic failure due to freeboard / excess capacity at the ultimate long-term pit lake level.	Design of pit wall. Buttressing effect of backfill and tailings.	Consider flattening areas more susceptible to wave erosion. 15m freeboard at max long-term pit lake level (489.7 mRL) compared to min insitu pit perimeter level (505 mRL).	1	E	1 (L)	None recommended.
8	Pit Wall	Internal erosion (piping) through pit wall.	High phreatic surface in closure pit lake. Fractures in the walls. Cracking and differential settlement in pit walls.	Seepage through the pit wall to Innes Mills. Potential piping of tailings through to Innes Mills.	No										Greater head of water than ops but not credible: -Any fractures are limited in extent -Long flow paths from pit walls to IMOP						
9	Frasers backfill (FRBF)	Rapid drawdown in TSF results in loss of strength of waste rock backfill.	Rapid pump-out of pit water. Cracking in pit floor resulting in rapid drainage to FRUG.	Local failure or collapse of backfill leading to overtopping with subsequent release of tailings and water.	No										Not credible: -No capability to empty pit rapidly. -Deposited tailings act as a low permeable layer on pit floor.						
10	Frasers backfill (FRBF)	Backfill becomes unstable and collapses into TSF and/or Innes Mills.	Incorrect/poor design. Inadequate monitoring. Poor construction of backfill. Saturation of backfill leading to slumping. High phreatic surface in backfill.	Upstream slope failure into TSF. Downstream slope failure into Innes Mills.	Yes	No	No	1	Yes	Yes	Yes	No	No	No	Local failures while pit lakes filling either side of backfill, but significant freeboard to pit perimeter so no loss of containment outside of pit. Embankment becomes fully submerged and failures below water become inconsequential.	Stability assessment and geotechnical design. Avoid over-steep stack profile. Construction to design. Tailings deposition and water providing buttress.		1	C	4 (L)	None recommended.
11	Frasers backfill (FRBF)	Seismic induced instability of backfill.	Earthquake.	Sliding failure leading to collapse of backfill into TSF or into IMOP.	Yes	No	No	1	Yes	No	Yes	No	No	No	Local failures while pit lakes filling either side of backfill, but significant freeboard to pit perimeter so no loss of containment outside of pit. Embankment becomes fully submerged and failures below water become inconsequential.	Stability assessment and geotechnical design. Tailings deposition and water providing buttress.		1	C	4 (L)	None recommended.
12	Frasers backfill (FRBF)	Internal erosion (piping) through backfill.	High phreatic level in FTSF. Cracking and differential settlement. Flow pathway through high permeability layers in the backfill into Innes Mill.	Seepage through backfill into IMOP leading to piping erosion of backfill.	Yes	No	Yes	1	Yes	Yes	Yes	No	No	No	Potential, given the increasing water head either side, however very unlikely based on low flow path and rising water level on IMOP side. No loss of containment outside of pit.	Consider aspects against piping, such as filter.		1	D	2 (L)	None recommended.
13	Frasers backfill (FRBF)	Seepage through waste rock backfill.	High phreatic level in FTSF. Cracking and differential settlement. Flow pathway through high permeability layers in backfill into Innes Mill.	Seepage through backfill resulting in loss of containment.	Yes	No	No	1	Yes	Yes	Yes	No	No	No	Some seepage expected; accounted for in water modelling, however seepage all contained on IMOP side and makes minimal difference to contaminant plume.			1	E	1 (L)	None recommended.
14	Frasers backfill (FRBF)	Liquefaction/softening of backfill.	Liquefaction of saturated fine rock particles (sands/silts). Saturation of localized fine rock. High saturation from closure pit lake levels.	Loss of strength and subsequent failure. Release of tailings and water.	Yes	No	No	1	Yes	Yes	Yes	No	No	No	Localised liquefaction contained to small pockets, resulting in settlement or cracking or small movements no loss of containment or catastrophic failure due to freeboard to pit perimeter.	Slope stability assessment in design. Liquefaction assessment. Management of out of specification material (fine rock wastes) during dumping. Construction methodology in non-continuous layers.		1	E	1 (L)	None recommended.

Risk No.	Component	Possible failure mode - What can happen / go wrong?	Possible causes (How? Why?)	Effect description	Is the failure mode credible?	Potential containment loss? (tailings slurry, dust, contaminated water)	Is the failure catastrophic?	Probable maximum consequence	Sunny Day Failure?	Rainy Day Failure?	Location of failure: Frasers Backfill - north highwall	East highwall	Southern WRD	West slope	Notes/comments	Current Control Measures - Prevention	Current Control Measures - Mitigation	Consequence (with controls)	Likelihood of consequence (with controls)	Risk Level	Recommended Risk Treatments
15	Frasers backfill (FRBF)	Wave erosion results in local instability of backfill.	Wave action from sustained high pit lake water level. Weather, physical location and closure cause difficulty in access, preventing monitoring and repair. Closure phase with little repair maintenance. Inadequate erosion protection of face.	Failure of backfill into TSF or Innes Mills.	Yes	No	No	1	Yes	Yes	Yes	No	Yes	No	Local failures while pit lakes filling either side of backfill, but significant freeboard to pit perimeter so no loss of containment outside of pit. Embankment becomes fully submerged and failures below water become inconsequential.			1	C	4 (L)	None recommended.
16	Water management	Rain induced overtopping of the containment area.	Extreme weather event. No backfill spillway to prevent overtopping. Inadequate freeboard specified/maintained. Increased upstream external catchment and/or changes to drainage.	Overtopping of pit perimeter and release of contaminated water as external release (pit perimeter).	No										Non-credible: -Ultimate long-term water level from water balance modelling (300+ years) indicated as 489.7 mRL. 15 m excess freeboard to lowest pit perimeter level.						
17	Water management	Seepage from TSF leading to surface water release into environment.	Extended duration of high water level in TSF. Localised seepage paths. Seepage through Frasers South WRS to Murphy's Creek (overtops the as-mined pit crest in south).	Localised release of contaminated water.	Yes	Yes	Yes	2	Yes	Yes	Yes	Yes	Yes	Yes	Ultimate long-term pit lake level may cause seepage outside of the pit, particularly in Frasers South WRS where insitu level is 487 mRL. Pit lake mostly filled with clean water resulting in dilution.	Enhanced passive treatment to improve quality of seepage water to reduce consequence. Frasers South WRS design to prevent or filter seepage (filter design).	Water modelling assessment to infer magnitude of seepage flows. Water quality monitoring at Murphy's Creek discharge point.	2	C	8 (M)	Review design in relation to capture and return of seepage flows - option of treatment plant.
18	Water management	Seepage through the pit floor and walls into groundwater.	Preferential seepage paths. Unidentified geological structure. High phreatic surface in pit.	Contamination of groundwater leading to loss of environmental values.	Yes	Yes	No	2	Yes	Yes	Yes	Yes	Yes	Yes	Groundwater modelling shows limited contaminant plume after 400 years. Tailings act as low permeability aquitard for the floor. Ultimate long-term pit lake level may cause seepage outside of the pit (no longer a sink), but mostly diluted with clean water.		Water modelling assessment to infer magnitude of seepage flows, quality and timing of migration.	2	D	5 (L)	Water modelling assessment to infer magnitude of seepage flows, quality and timing of migration for control evaluation.
19	Water management	Seepage into the underground workings (FRUG) into groundwater.	Seepage through backfill and fractured rock into the FRUG: -Vertical seepage into FRUG stopes. -FRUG caving intercepts with highwall -Bulkhead failure or lack of sealing portals	Seepage into FRUG leading to contamination of groundwater.	No										FRUG expected to partially fill with seepage but contamination of groundwater not credible. Factored into groundwater assessment; contaminant plume has limited reach after 200 years						
20	Water management	Piping of rockfill/tailings into FRUG voids.	Piping through to FRUG. Pathway from backfill into FRUG through stopes.	Erosion leading to sinkhole development in backfill.	No										Not credible. FRUG will be filled during operations.						
21	Tailings beach	Failure to contain wind blown tailings.	No fresh tailings to maintain wet beach. El Nino seasons reduce pond extent. Pit lake does not provide full cover. No ground cover used.	Loss of tailings into environment.	Yes	Yes	No	2	Yes	No	N/A	N/A	N/A	N/A	Long-term modelling shows the tailings will be fully submerged (420m RL) after ~18 years due to rise in pit lake. After this the FM is no longer credible.	Pit lake cover strategy Ground cover (seeding) or partial rockfill capping over tailings in upper beach areas.	Redirect seepage flows and sources of water from other Macraes operations to increase water cover extent. Consider wetter slurry in latter years to create a flatter beach slope, which will keep higher areas of beach wet in closure years.	2	D	5 (L)	Review closure options - i.e. partial wet cover with upper rockfill capping, if water modelling suggests partial coverage for a period of time.

Appendix B

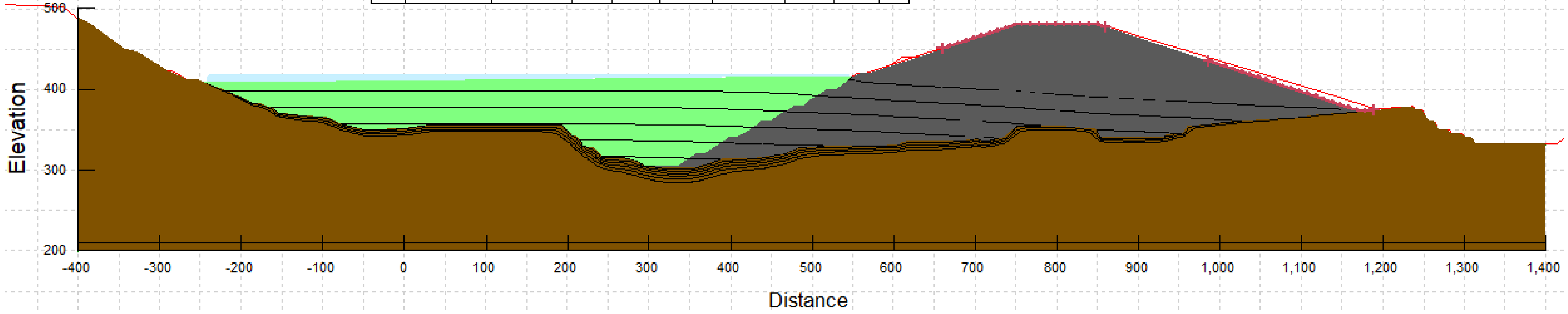
Stage 2 FRBF static stability outputs



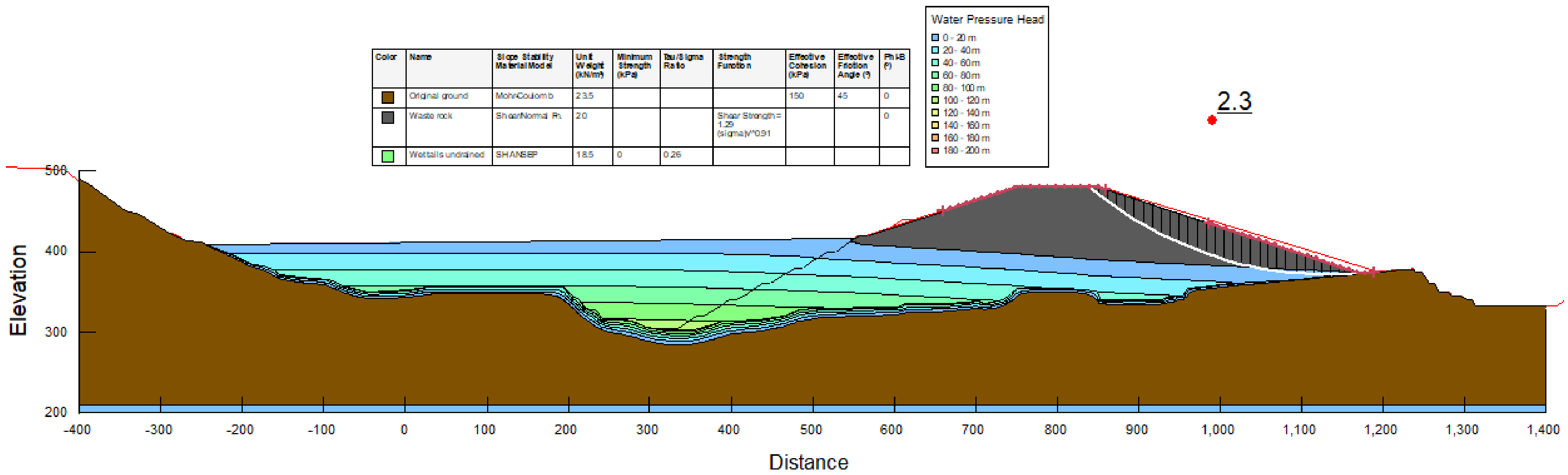


CLIENT	OCEANA GOLD	PROJECT	MACRAES FTSF - STAGE 2 DESIGN FOR RESOURCE CONSENT
DRAWN	CJ	DATE	23/01/24
TITLE	FRBF STAGE 2 OPERATIONS - STATIC STABILITY		
CHECKED	MG	DATE	
LOAD CASE	LONG TERM DRAINED	DIRECTION	DOWNSTREAM
MIN. FACTOR OF SAFETY	2.3		
SCALE	NTS	PROJECT No	PS204746
FIGURE No	B-1	REV No	A
A4			

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Minimum Strength (kPa)	Tau/Sigma Ratio	Strength Function	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
	Original ground	MohrCoulomb	23.5				150	45	0
	Waste rock	ShearNormal Fn.	20			Shear Strength = 1.29 (sigma)v^0.91			0
	Wettails undrained	SHANSEP	18.5	0	0.26				

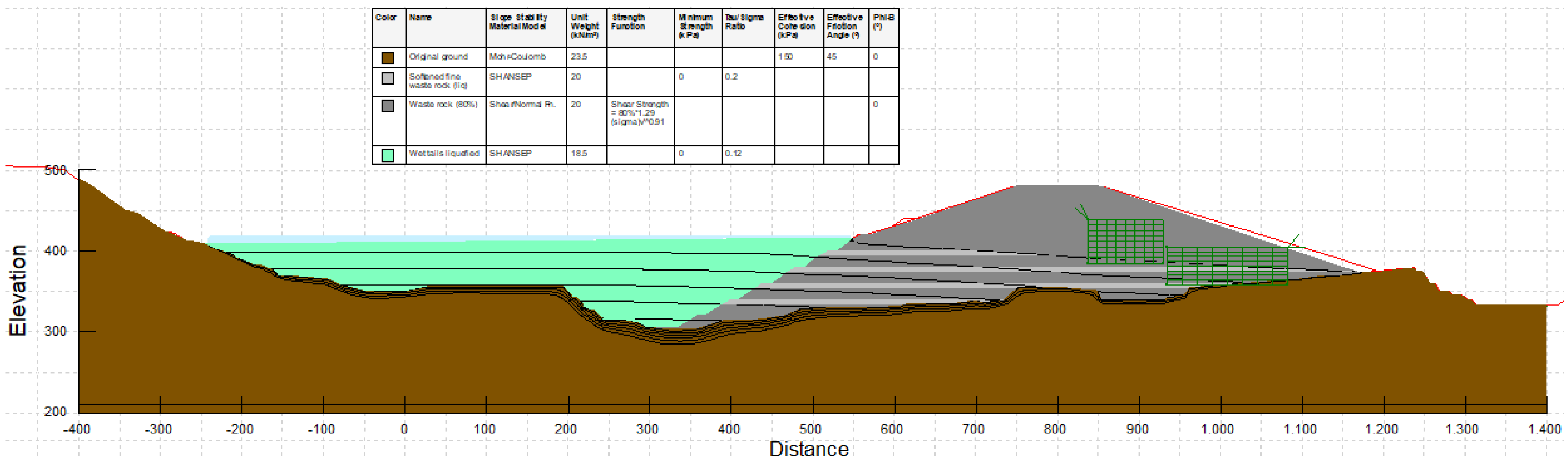


Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Minimum Strength (kPa)	Tau/Sigma Ratio	Strength Function	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
	Original ground	MohrCoulomb	23.5				150	45	0
	Waste rock	ShearNormal Fn.	20			Shear Strength = 1.29 (sigma)v^0.91			0
	Wettails undrained	SHANSEP	18.5	0	0.26				

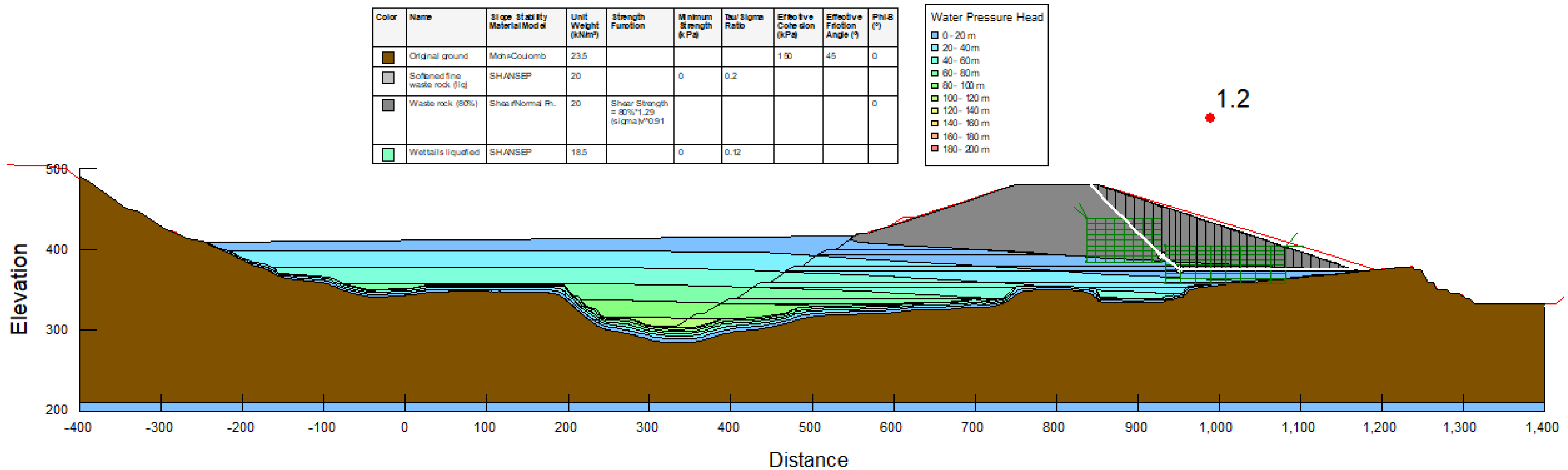


wsp

CLIENT	OCEANA GOLD	PROJECT	MACRAES FTSF - STAGE 2 DESIGN FOR RESOURCE CONSENT
DRAWN CJ	DATE 23/01/24	TITLE	FRBF STAGE 2 OPERATIONS - STATIC STABILITY
CHECKED MG	DATE	LOAD CASE SHORT TERM UNDRAINED	DIRECTION DOWNSTREAM; MIN. FACTOR OF SAFETY 2.3
SCALE NTS		PROJECT No PS204746	FIGURE No B-2; REV No A; A4

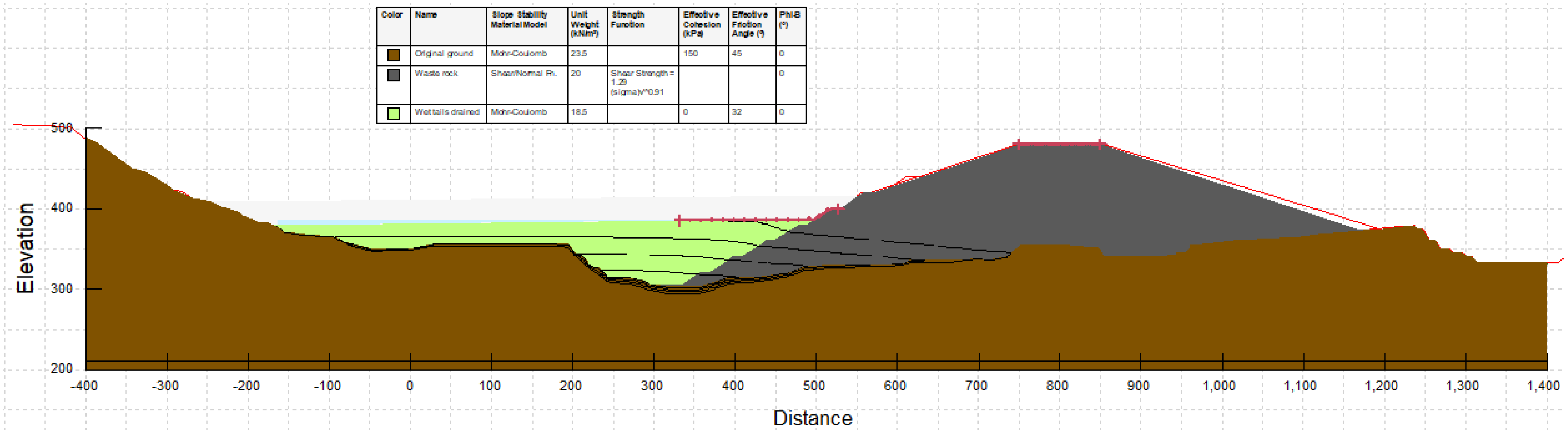


Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Strength Function	Minimum Strength (kPa)	Tau/Sigma Ratio	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
	Original ground	Mohr-Coulomb	23.5				150	45	0
	Softened fine waste rock (liq)	SHANSEP	20		0	0.2			
	Waste rock (80%)	Shear/Normal Fn.	20	Shear Strength = 80%*1.29 (sigma)^0.91					0
	Wettails liquefied	SHANSEP	18.5		0	0.12			

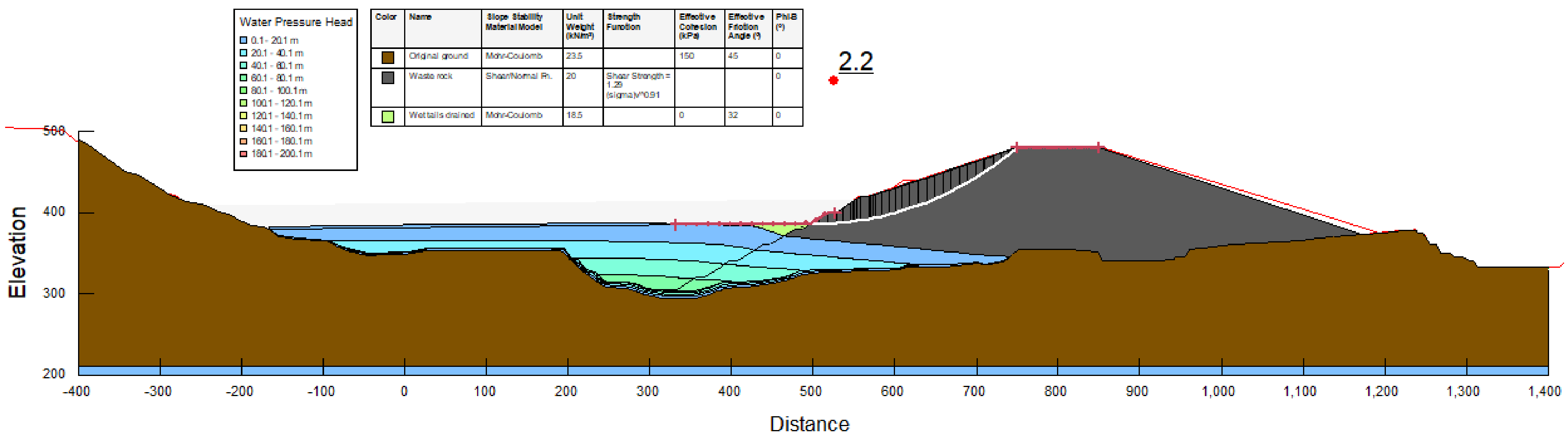


Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Strength Function	Minimum Strength (kPa)	Tau/Sigma Ratio	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
	Original ground	Mohr-Coulomb	23.5				150	45	0
	Softened fine waste rock (liq)	SHANSEP	20		0	0.2			
	Waste rock (80%)	Shear/Normal Fn.	20	Shear Strength = 80%*1.29 (sigma)^0.91					0
	Wettails liquefied	SHANSEP	18.5		0	0.12			

CLIENT	OCEANA GOLD	PROJECT	MACRAES FTSF - STAGE 2 DESIGN FOR RESOURCE CONSENT
DRAWN CJ	DATE 23/01/24	TITLE	FRBF STAGE 2 OPERATIONS - STATIC STABILITY
CHECKED MG	DATE	LOAD CASE POST SEISMIC	DIRECTION DOWNSTREAM; MIN. FACTOR OF SAFETY 1.2
SCALE	NTS	PROJECT No PS204746	FIGURE No B-3; REV No A; A4



Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Strength Function	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
	Original ground	Mohr-Coulomb	23.5		150	45	0
	Waste rock	Shear/Normal Fn.	20	Shear Strength = 1.29 (sigma)^0.91			0
	Wet tails drained	Mohr-Coulomb	18.5		0	32	0

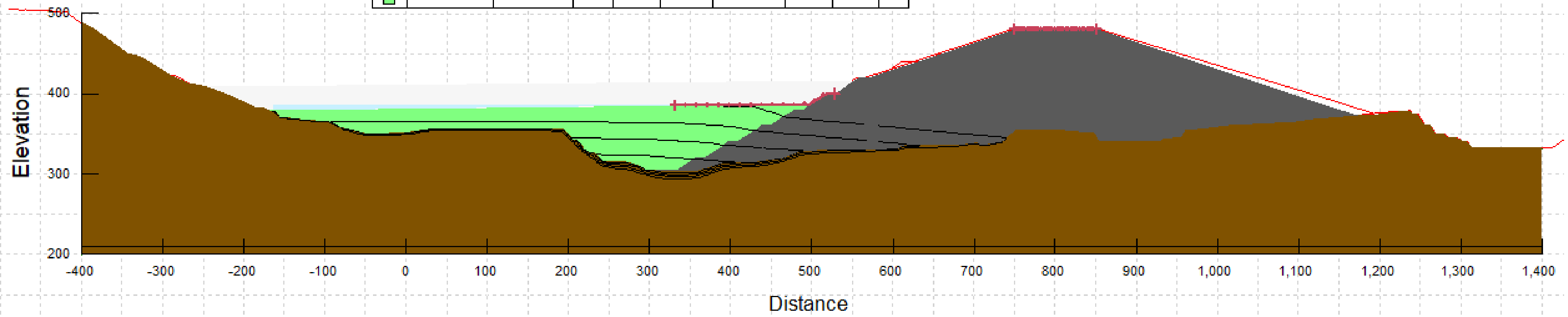


Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Strength Function	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
	Original ground	Mohr-Coulomb	23.5		150	45	0
	Waste rock	Shear/Normal Fn.	20	Shear Strength = 1.29 (sigma)^0.91			0
	Wet tails drained	Mohr-Coulomb	18.5		0	32	0

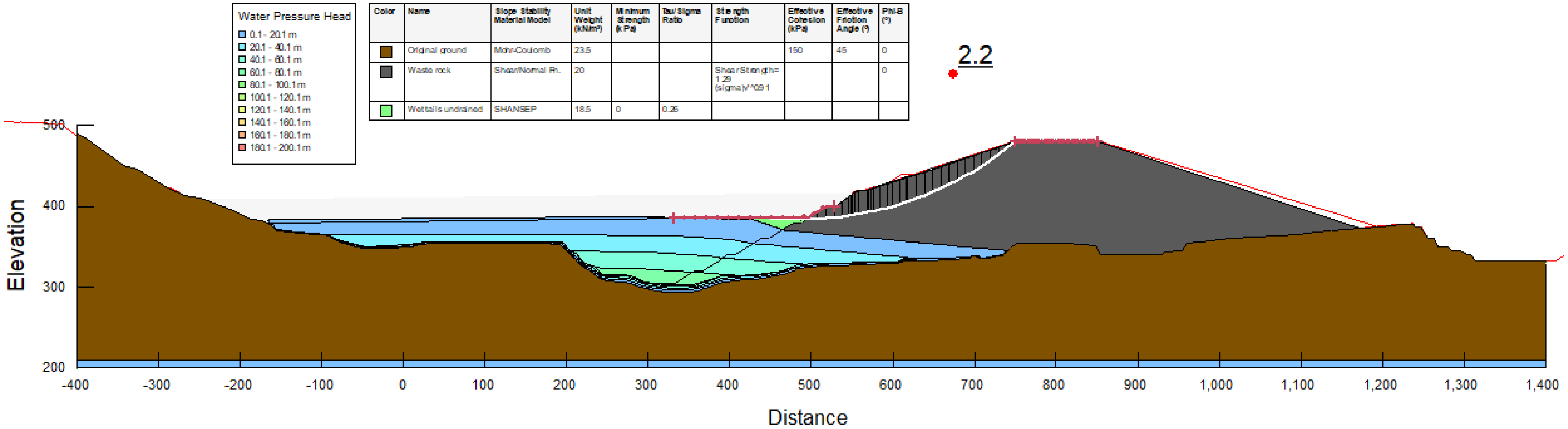
wsp

CLIENT	OCEANA GOLD	PROJECT	MACRAES FTSF - STAGE 2 DESIGN FOR RESOURCE CONSENT		
DRAWN CJ	DATE 23/01/24	TITLE	FRBF STAGE 2 OPERATIONS - STATIC STABILITY		
CHECKED MG	DATE	LOAD CASE	LONG TERM DRAINED	DIRECTION UPSTREAM	MIN. FACTOR OF SAFETY 2.2
SCALE	NTS	PROJECT No	PS204746	FIGURE No B-4	REV No A — A4

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Minimum Strength (kPa)	Tau/Sigma Ratio	Strength Function	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
	Original ground	Mohr-Coulomb	23.5				150	45	0
	Waste rock	Shear/Normal Fn.	20			ShearStrength= 1.29 (sigma)^0.91			0
	Wettails undrained	SHANSEP	18.5	0	0.26				

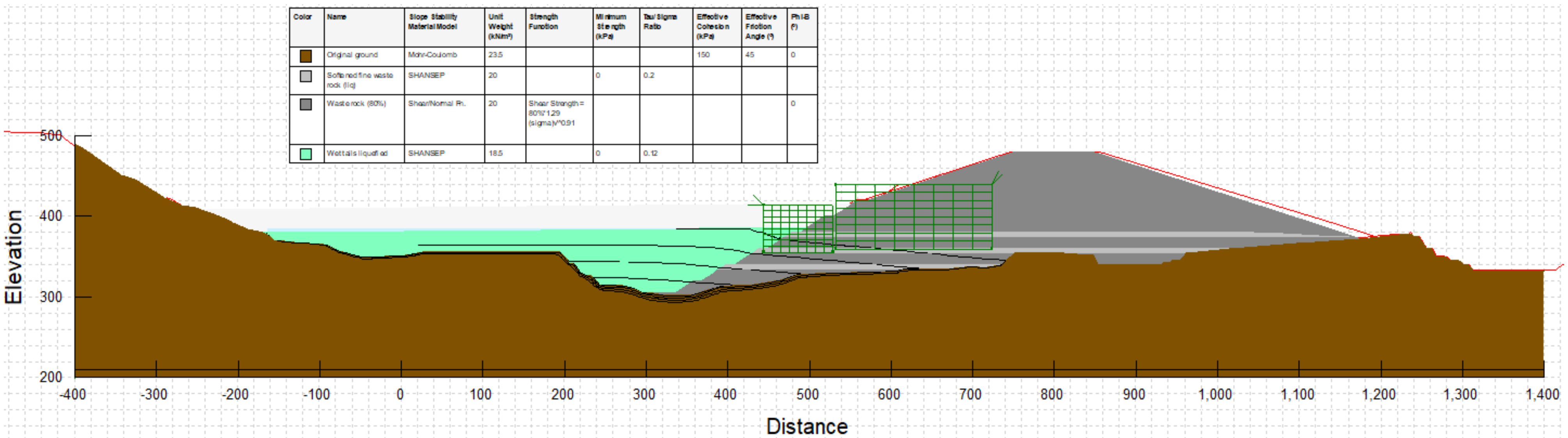


Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Minimum Strength (kPa)	Tau/Sigma Ratio	Strength Function	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
	Original ground	Mohr-Coulomb	23.5				150	45	0
	Waste rock	Shear/Normal Fn.	20			ShearStrength= 1.29 (sigma)^0.91			0
	Wettails undrained	SHANSEP	18.5	0	0.26				

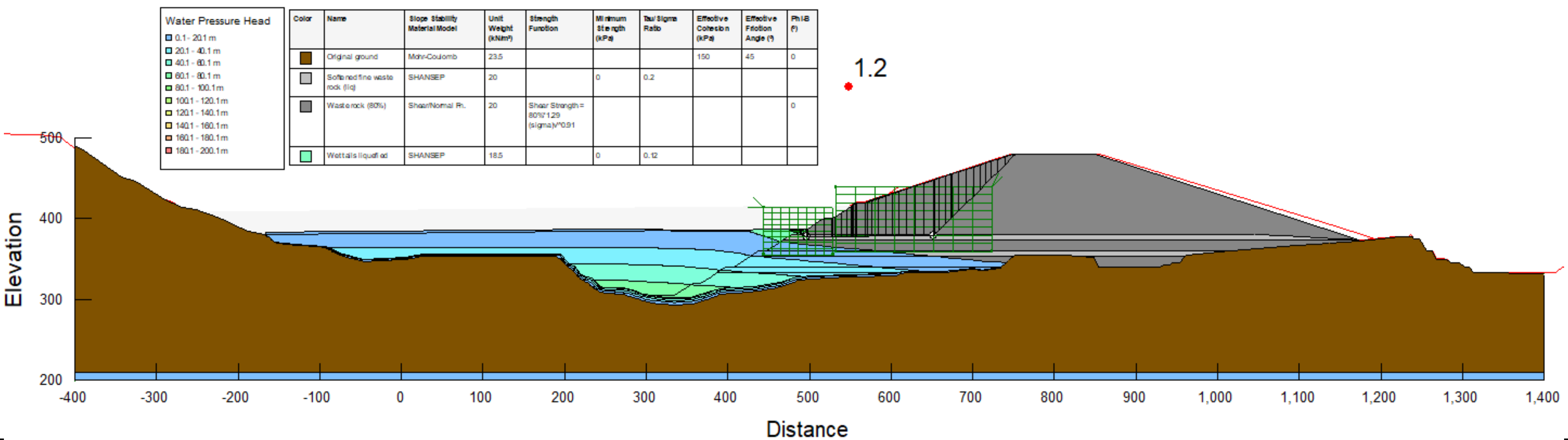


CLIENT	OCEANA GOLD	PROJECT	MACRAES FTSF - STAGE 2 DESIGN FOR RESOURCE CONSENT
DRAWN	CJ	DATE	23/01/24
TITLE	FRBF STAGE 2 OPERATIONS - STATIC STABILITY		
CHECKED	MG	DATE	
LOAD CASE	SHORT TERM UNDRAINED	DIRECTION	UPSTREAM
MIN. FACTOR OF SAFETY	2.2		
SCALE	NTS	PROJECT No	PS204746
FIGURE No	B-5	REV No	A
A4			

204746 - Oceana Gold Frasers TSF Detailed Design - Documents\5 Technical Work\Stability Modelling\Stage 2 results\FRBF Stage 2 SlopeW Static Results.pptx



Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Strength Function	Minimum Strength (kPa)	Tau/ Sigma Ratio	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
	Original ground	Mohr-Coulomb	23.5				150	45	0
	Softened fine waste rock (liq)	SHANSEP	20		0	0.2			
	Waste rock (80%)	Shear/Normal Fn.	20	Shear Strength = 80%*1.29 (sigma)^0.91					0
	Wet tails liquefied	SHANSEP	18.5		0	0.12			



Water Pressure Head

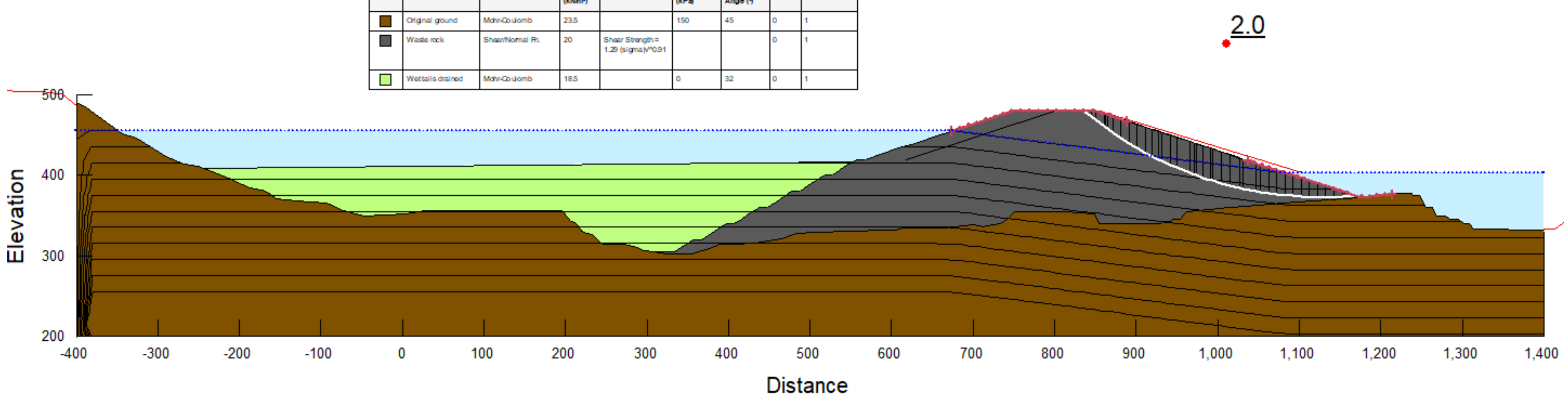
- 0.1 - 20.1 m
- 20.1 - 40.1 m
- 40.1 - 60.1 m
- 60.1 - 80.1 m
- 80.1 - 100.1 m
- 100.1 - 120.1 m
- 120.1 - 140.1 m
- 140.1 - 160.1 m
- 160.1 - 180.1 m
- 180.1 - 200.1 m

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Strength Function	Minimum Strength (kPa)	Tau/ Sigma Ratio	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
	Original ground	Mohr-Coulomb	23.5				150	45	0
	Softened fine waste rock (liq)	SHANSEP	20		0	0.2			
	Waste rock (80%)	Shear/Normal Fn.	20	Shear Strength = 80%*1.29 (sigma)^0.91					0
	Wet tails liquefied	SHANSEP	18.5		0	0.12			

wsp

CLIENT	OCEANA GOLD	PROJECT	MACRAES FTSF - STAGE 2 DESIGN FOR RESOURCE CONSENT
DRAWN	CJ	DATE	23/01/24
TITLE	FRBF STAGE 2 OPERATIONS - STATIC STABILITY		
CHECKED	MG	DATE	
LOAD CASE	POST SEISMIC	DIRECTION	UPSTREAM
MIN. FACTOR OF SAFETY	1.2		
SCALE	NTS	PROJECT No	PS204746
FIGURE No	B-6	REV No	A
A4			

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Strength Function	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)	Piezometric Surface
	Original ground	Mohr-Coulomb	23.5		150	45	0	1
	Waste rock	Shear/Normal Fn.	20	Shear Strength = 1.29 (sigma)^0.91			0	1
	Wettails drained	Mohr-Coulomb	18.5		0	32	0	1



CLIENT	OCEANA GOLD	PROJECT	MACRAES FTSF - STAGE 2 DESIGN FOR RESOURCE CONSENT
DRAWN	CJ	DATE	23/01/24
TITLE	FRBF STAGE 2 CLOSURE - STATIC STABILITY		
CHECKED	MG	DATE	
LOAD CASE	LONG TERM DRAINED	DIRECTION	DOWNSTREAM
MIN. FACTOR OF SAFETY	2.0		
SCALE	NTS	PROJECT No	PS204746
FIGURE No	B-7	REV No	A
A4			

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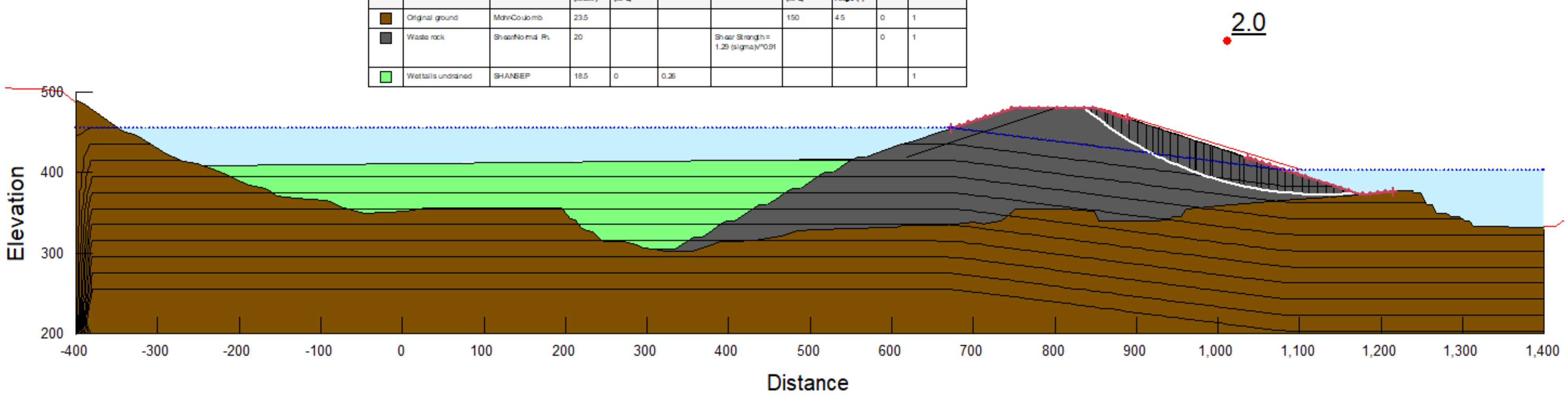
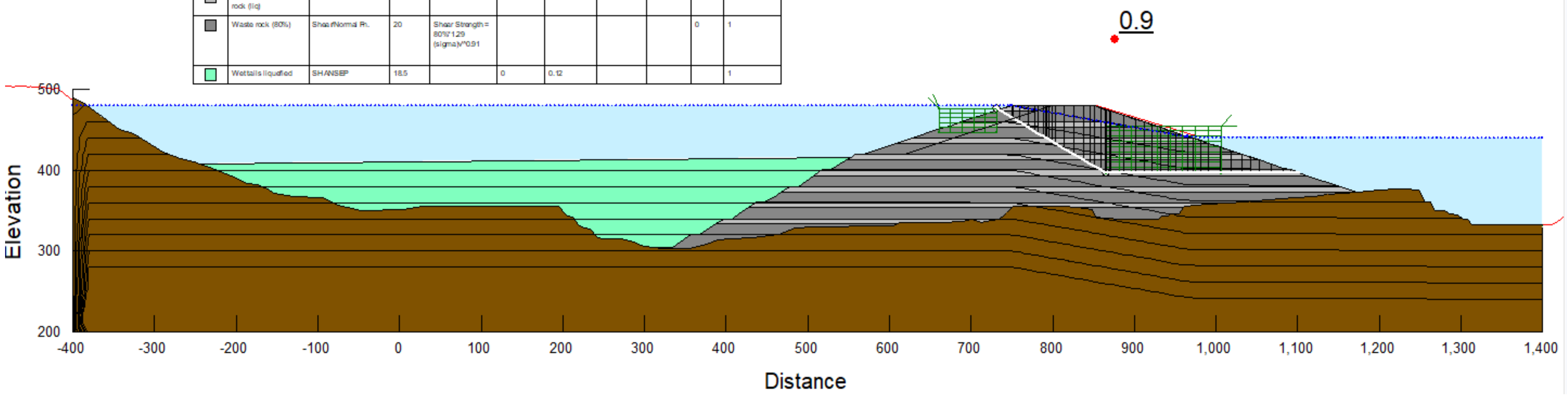
Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Minimum Strength (kPa)	Tau/Sigma Ratio	StrengthFunction	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)	Piezometric Surface
	Original ground	MohrCoulomb	23.5				150	45	0	1
	Waste rock	ShearNormal Fn.	20			Shear Strength = 1.29 (sigma)'^0.91			0	1
	Wettails undrained	SHANSEP	18.5	0	0.26					1



CLIENT	OCEANA GOLD	PROJECT	MACRAES FTSF - STAGE 2 DESIGN FOR RESOURCE CONSENT
DRAWN CJ	DATE 23/01/24	TITLE	FRBF STAGE 2 CLOSURE - STATIC STABILITY
CHECKED MG	DATE	LOAD CASE	SHORT TERM UNDRAINED; DIRECTION DOWNSTREAM; MIN. FACTOR OF SAFETY 2.0
SCALE	NTS	PROJECT No	PS204746; FIGURE No B-8; REV No A; A4

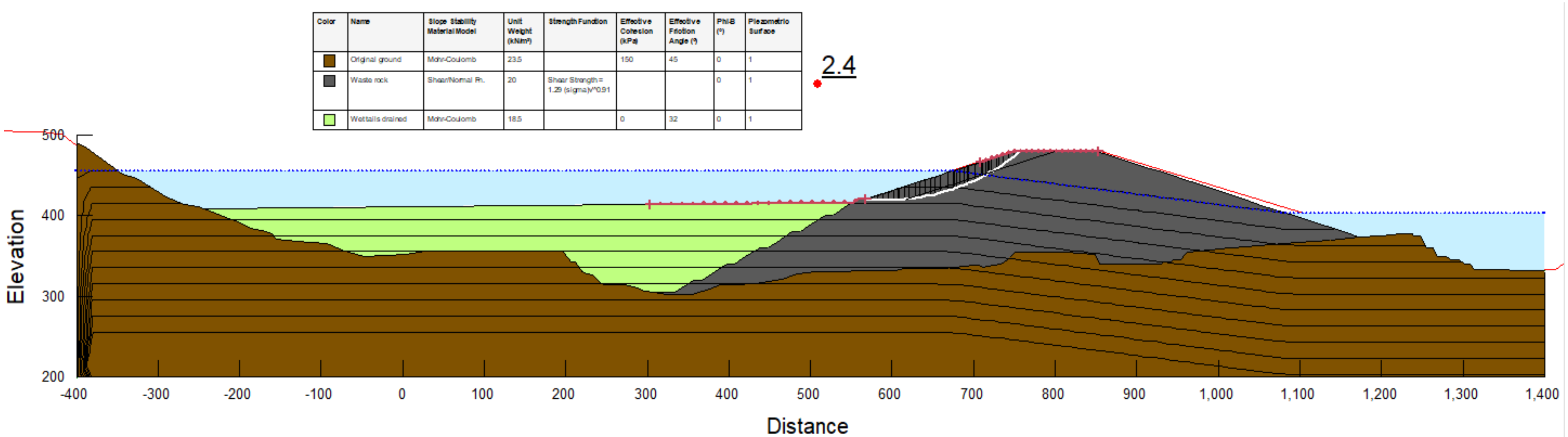
Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Strength Function	Minimum Strength (kPa)	Tau/Sigma Ratio	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)	Piezometric Surface
	Original ground	Mohr-Coulomb	23.5				150	45	0	1
	Softened fine waste rock (liq)	SHANSEP	20		0	0.2				1
	Waste rock (80%)	Shear/Normal Fn.	20	Shear Strength = 80%*1.29 (sigma)^0.91					0	1
	Wettails liquefied	SHANSEP	18.5		0	0.12				1



wsp	CLIENT OCEANA GOLD	PROJECT MACRAES FTSF - STAGE 2 DESIGN FOR RESOURCE CONSENT	
	DRAWN CJ / DATE 23/01/24	TITLE FRBF STAGE 2 CLOSURE - STATIC STABILITY	
	CHECKED MG / DATE	LOAD CASE POST SEISMIC / DIRECTION DOWNSTREAM	MIN. FACTOR OF SAFETY 0.9
	SCALE NTS	PROJECT No PS204746	FIGURE No B-9 / REV No A / A4

204746 - Oceana Gold Frasers TSF Detailed Design - Documents\5 Technical Work\Stability Modelling\Stage 2 results\FRBF Stage 2 SlopeW Static Results.pptx

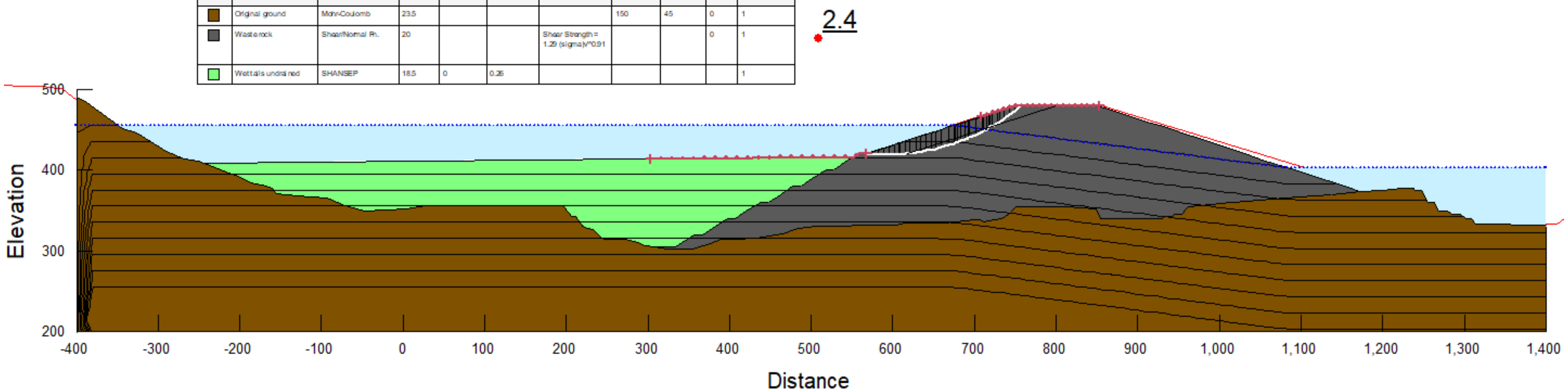
Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Strength Function	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)	Piezometric Surface
	Original ground	Mohr-Coulomb	23.5		150	45	0	1
	Waste rock	Shear/Normal Fn.	20	Shear Strength = 1.29 (sigma)^0.91			0	1
	Wet tails drained	Mohr-Coulomb	18.5		0	32	0	1



CLIENT	OCEANA GOLD		PROJECT	MACRAES FTSF - STAGE 2 DESIGN FOR RESOURCE CONSENT		
DRAWN	CJ	DATE 23/01/24	TITLE	FRBF STAGE 2 CLOSURE - STATIC STABILITY		
CHECKED	MG	DATE	LOAD CASE	LONG TERM DRAINED	DIRECTION UPSTREAM	MIN. FACTOR OF SAFETY 2.4
SCALE	NTS		PROJECT No	PS204746	FIGURE No B-10	REV No A — A4

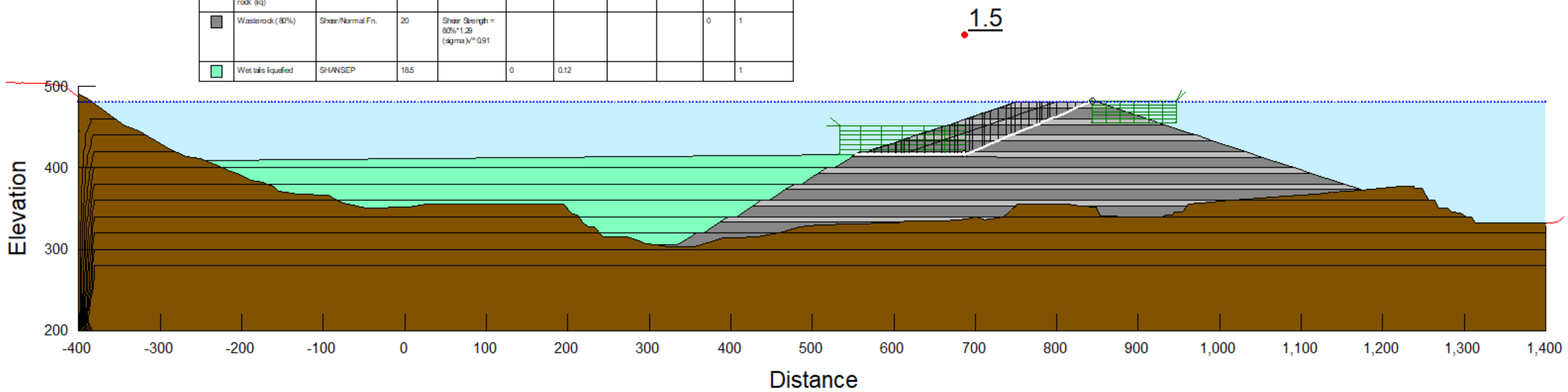
204746 - Oceana Gold Frasers TSF Detailed Design - Documents\5 Technical Work\Stability Modelling\Stage 2 results\FRBF Stage 2 SlopeW Static Results.pptx

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Minimum Strength (kPa)	Tau/Sigma Ratio	Strength Function	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)	Piezometric Surface
	Original ground	Mohr-Coulomb	23.5				150	45	0	1
	Waste rock	Shear/Normal Fn.	20			Shear Strength = 1.29 (sigma)^0.91			0	1
	Wet tails undrained	SHANSEP	18.5	0	0.26					1



CLIENT OCEANA GOLD		PROJECT MACRAES FTSF - STAGE 2 DESIGN FOR RESOURCE CONSENT	
DRAWN CJ	DATE 23/01/24	TITLE FRBF STAGE 2 CLOSURE - STATIC STABILITY	
CHECKED MG	DATE	LOAD CASE SHORT TERM UNDRAINED	DIRECTION UPSTREAM · MIN. FACTOR OF SAFETY 2.4
SCALE NTS		PROJECT No PS204746	FIGURE No B-11 · REV No A · A4

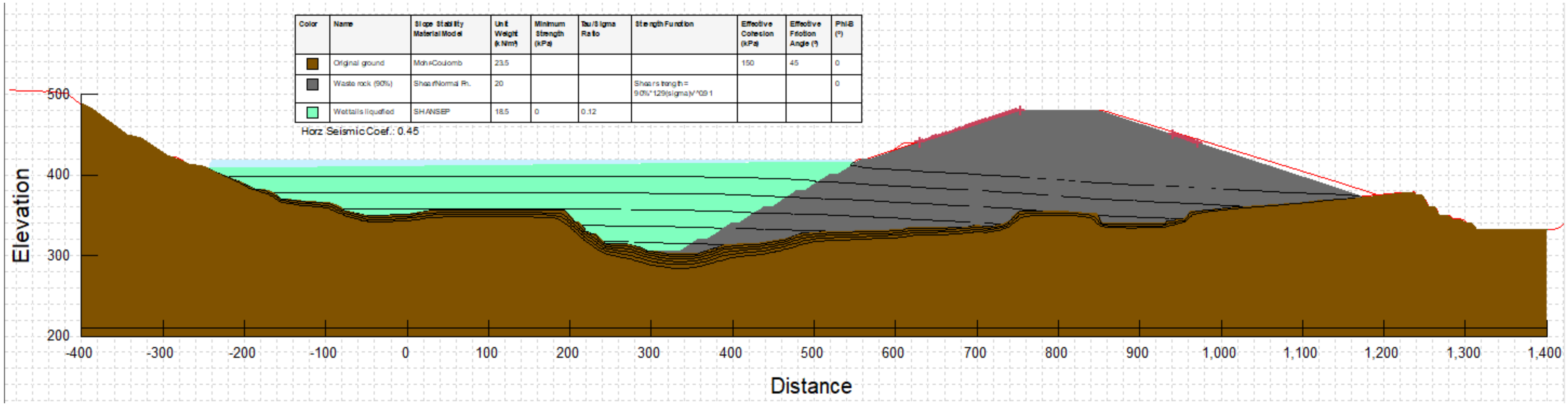
Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Strength Function	Minimum Strength (kPa)	Tau/Sigma Ratio	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)	Piezometric Surface
	Original ground	Mohr-Coulomb	23.5				150	45	0	1
	Softened fine waste rock (liq)	SHANSEP	20		0	0.2				1
	Wasterock (80%)	Shear/Normal Fn.	20	Shear Strength = 80%*1.29 (sigma)^0.91					0	1
	Wet tails liquefied	SHANSEP	18.5		0	0.12				1

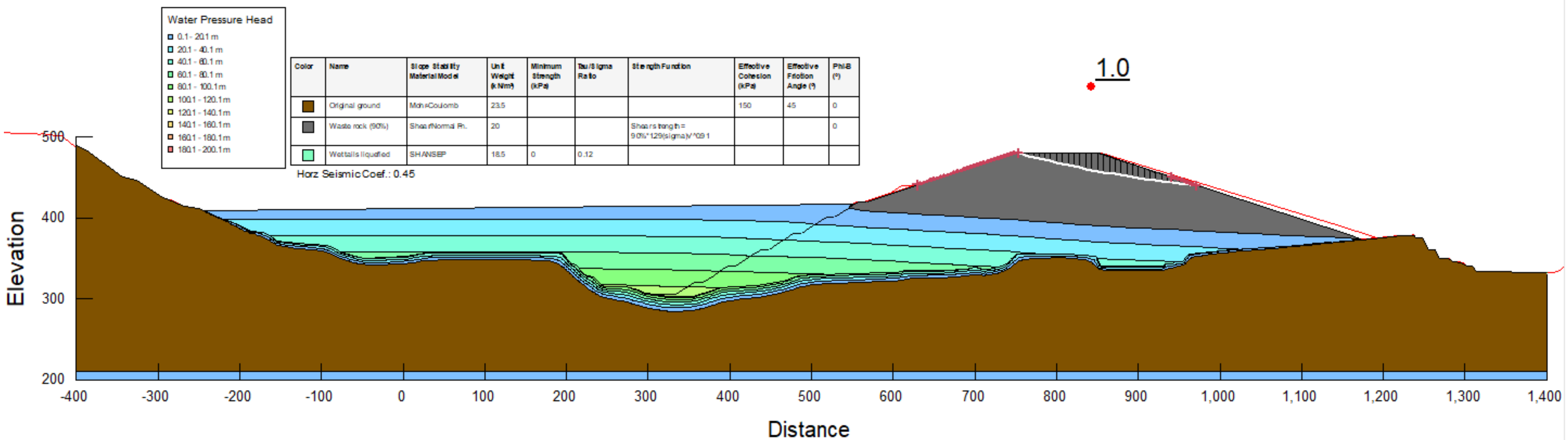


CLIENT	OCEANA GOLD		PROJECT	MACRAES FTSF - STAGE 2 DESIGN FOR RESOURCE CONSENT	
DRAWN	CJ	DATE 23/01/24	TITLE	FRBF STAGE 2 CLOSURE - STATIC STABILITY	
CHECKED	MG	DATE	LOAD CASE	POST SEISMIC	DIRECTION UPSTREAM; MIN. FACTOR OF SAFETY 1.5
SCALE	NTS		PROJECT No	PS204746	FIGURE No B-12; REV No A; A4

Appendix C

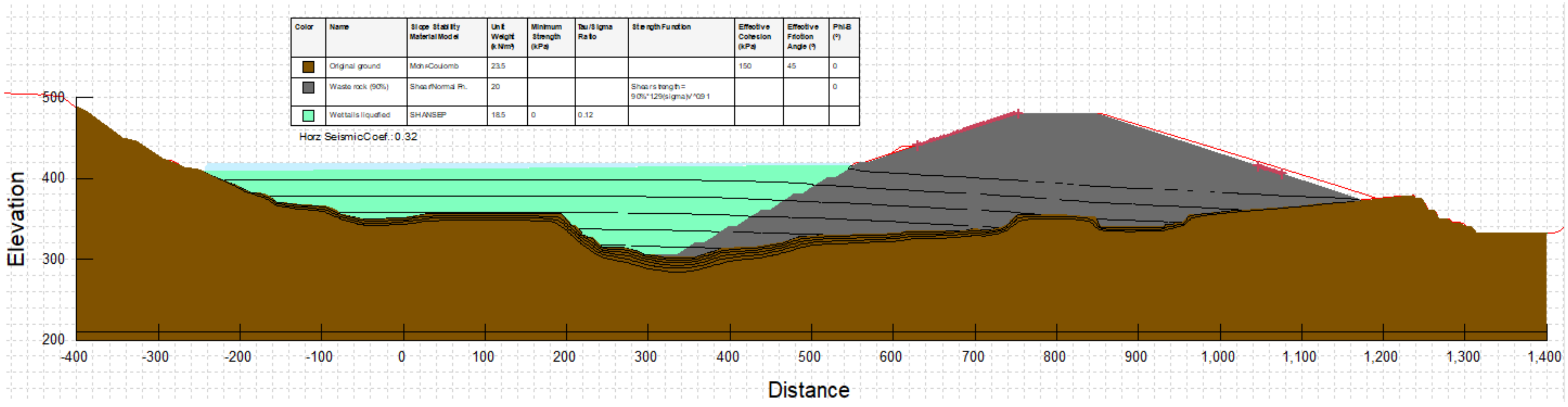
Stage 2 FRBF seismic deformation outputs

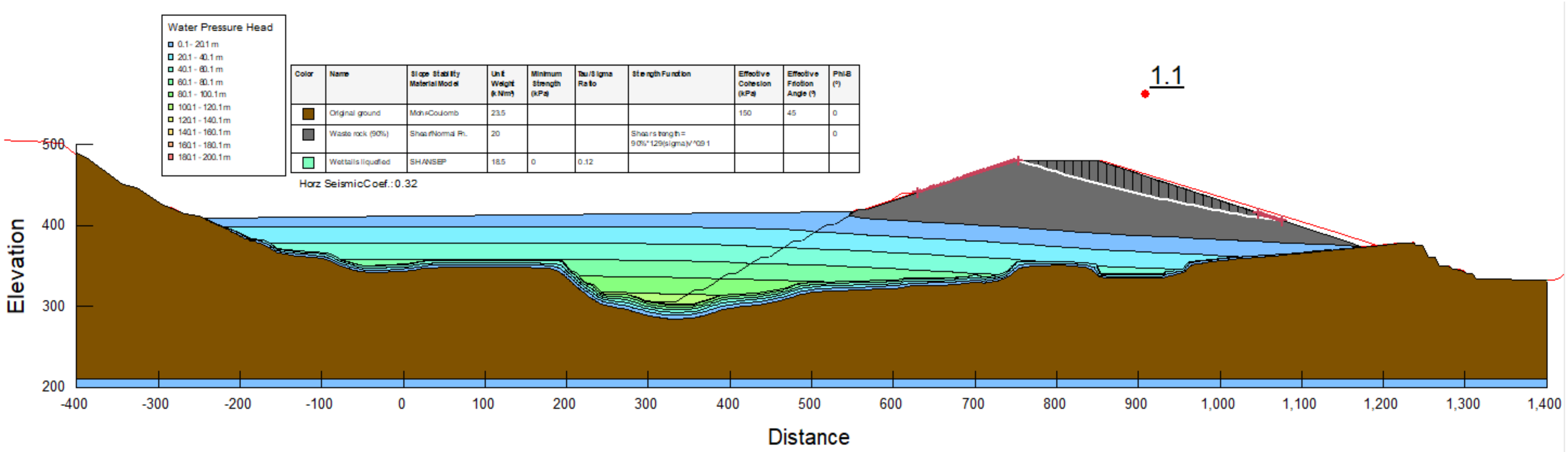




wsp	CLIENT	OCEANA GOLD		PROJECT	MACRAES FTSF - STAGE 2 DESIGN FOR RESOURCE CONSENT		
	DRAWN	CJ	DATE 23/01/24	TITLE	FRBF STAGE 2 OPERATIONS - SEISMIC STABILITY		
	CHECKED	MG	DATE	LOAD CASE	OBE (1:150 AEP)	FAILURE DEPTH 1/3H	MIN. FACTOR OF SAFETY < 1.0 / YIELD COEFFICIENT k_x 0.45
	SCALE	NTS		PROJECT No	PS204746		FIGURE No C-1 / REV No A / A4

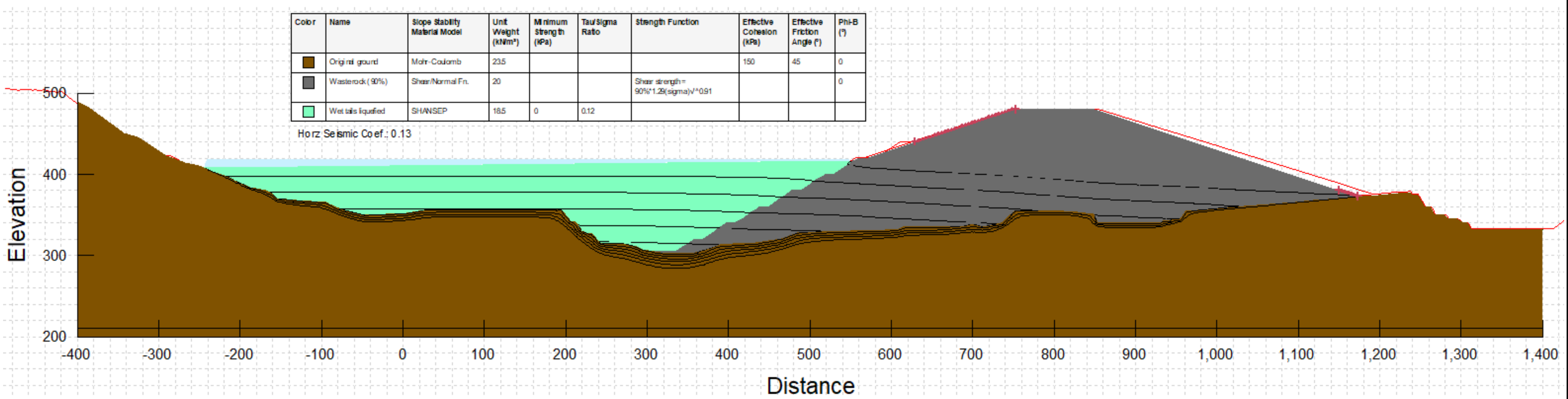
204746 - Oceana Gold Frasers TSF Detailed Design - Documents\5 Technical Work\Stability Modelling\Stage 2 results\FRBF Stage 2 SlopeW Seismic Results.pptx



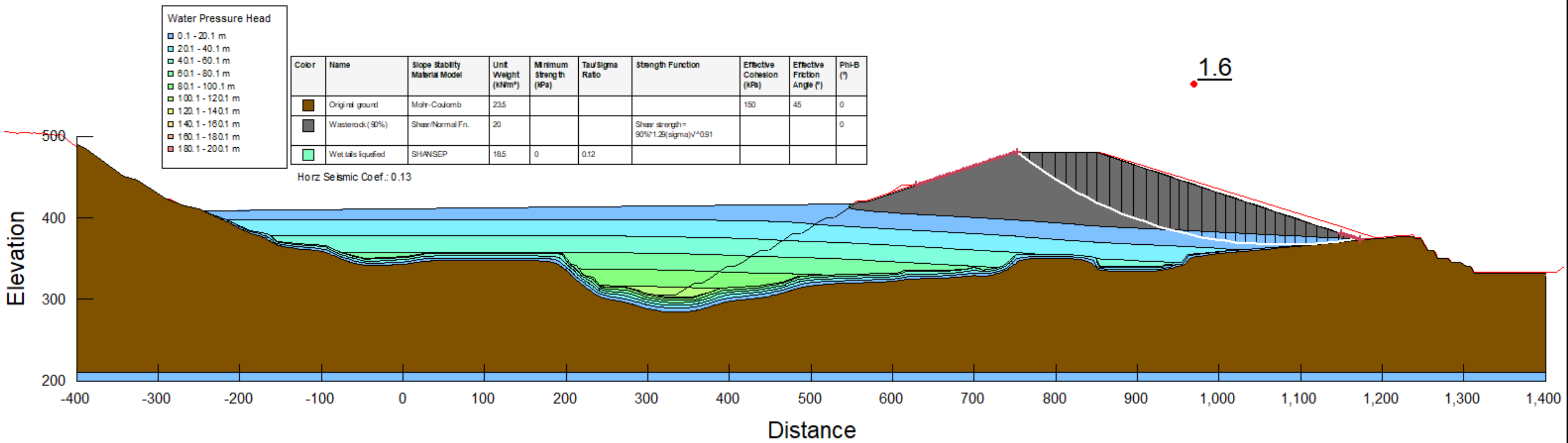


CLIENT	OCEANA GOLD	PROJECT	MACRAES FTSF - STAGE 2 DESIGN FOR RESOURCE CONSENT
DRAWN CJ	DATE 23/01/24	TITLE	FRBF STAGE 2 OPERATIONS - SEISMIC STABILITY
CHECKED MG	DATE	LOAD CASE OBE (1:150 AEP)	FAILURE DEPTH 2/3H; MIN. FACTOR OF SAFETY 1.1; YIELD COEFFICIENT k_x n/a
SCALE	NTS	PROJECT No PS204746	FIGURE No C-2; REV No A; A4

204746 - Oceana Gold Frasers TSF Detailed Design - Documents\5 Technical Work\Stability Modelling\Stage 2 results\FRBF Stage 2 SlopeW Seismic Results.pptx

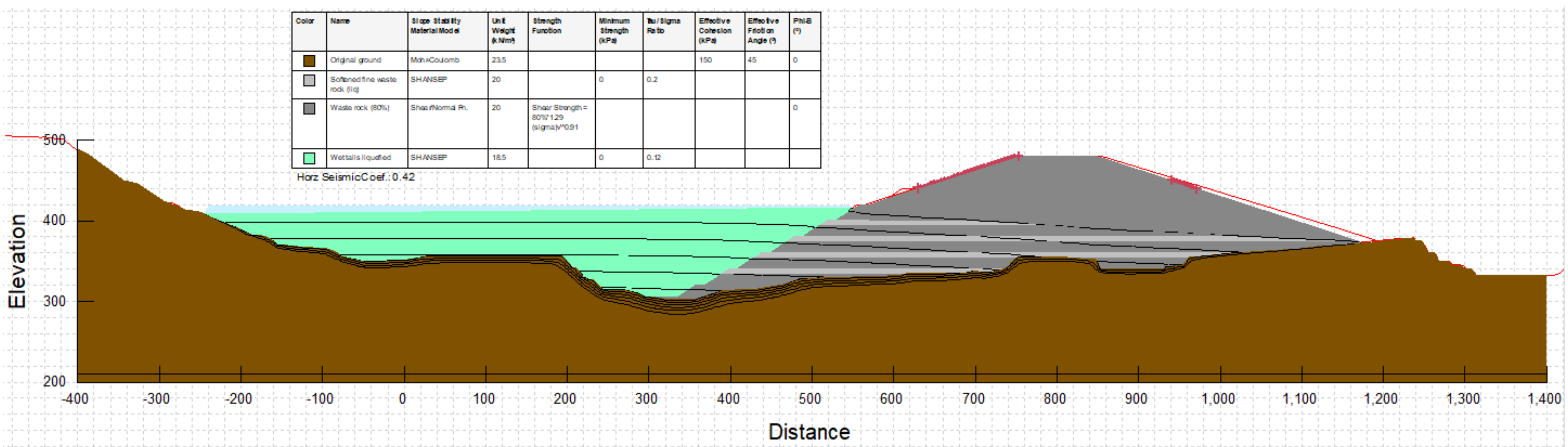


Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Minimum Strength (kPa)	Tau/Sigma Ratio	Strength Function	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
	Original ground	Mohr-Coulomb	23.5				150	45	0
	Wasterock (90%)	Shear/Normal Fn.	20			Shear strength = 90%*1.29(sigma)^0.91			0
	Wet tails liquefied	SHANSEP	18.5	0	0.12				

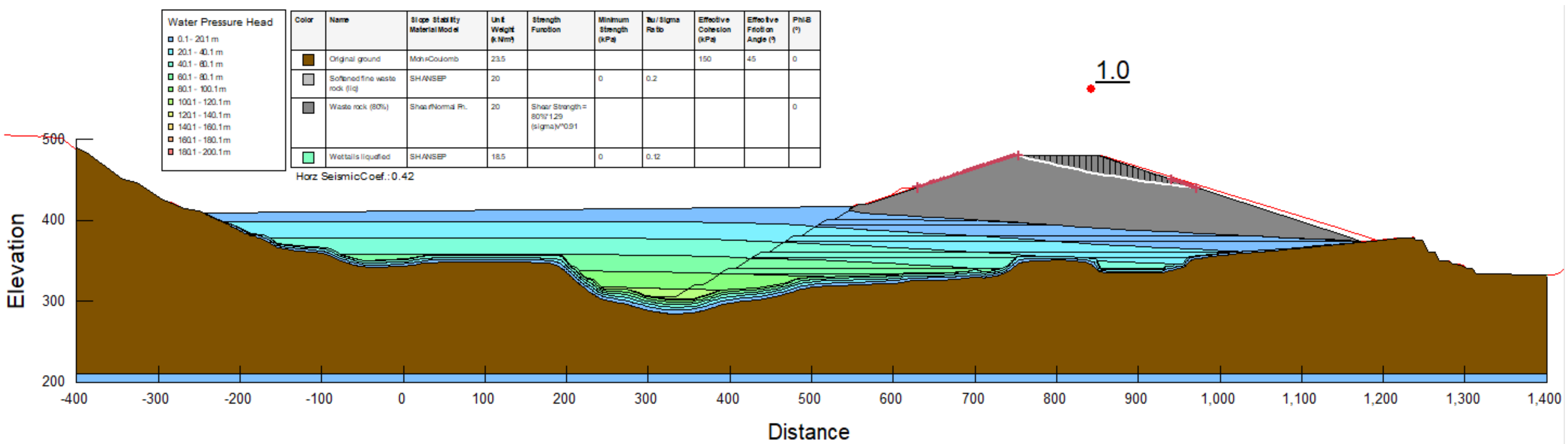


Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Minimum Strength (kPa)	Tau/Sigma Ratio	Strength Function	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
	Original ground	Mohr-Coulomb	23.5				150	45	0
	Wasterock (90%)	Shear/Normal Fn.	20			Shear strength = 90%*1.29(sigma)^0.91			0
	Wet tails liquefied	SHANSEP	18.5	0	0.12				

CLIENT	OCEANA GOLD		PROJECT	MACRAES FTSF - STAGE 2 DESIGN FOR RESOURCE CONSENT			
DRAWN	CJ	DATE 23/01/24	TITLE	FRBF STAGE 2 OPERATIONS - SEISMIC STABILITY			
CHECKED	MG	DATE	LOAD CASE	OBE (1:150 AEP)	FAILURE DEPTH H	MIN. FACTOR OF SAFETY 1.6	YIELD COEFFICIENT k_x n/a
SCALE	NTS		PROJECT No	PS204746		FIGURE No C-3	REV No A · A4



Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Strength Function	Minimum Strength (kPa)	Tau/Sigma Ratio	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
	Original ground	Mohr-Coulomb	23.5				150	45	0
	Softened fine waste rock (liq)	SHANSEP	20		0	0.2			
	Waste rock (80%)	Shear/Normal Fn.	20	Shear Strength = 80%*1.29 (sigma)^0.91					0
	Wettails liquefied	SHANSEP	18.5		0	0.12			



Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Strength Function	Minimum Strength (kPa)	Tau/Sigma Ratio	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
	Original ground	Mohr-Coulomb	23.5				150	45	0
	Softened fine waste rock (liq)	SHANSEP	20		0	0.2			
	Waste rock (80%)	Shear/Normal Fn.	20	Shear Strength = 80%*1.29 (sigma)^0.91					0
	Wettails liquefied	SHANSEP	18.5		0	0.12			

CLIENT	OCEANA GOLD	PROJECT	MACRAES FTSF - STAGE 2 DESIGN FOR RESOURCE CONSENT
DRAWN	CJ	DATE	23/01/24
TITLE	FRBF STAGE 2 OPERATIONS - SEISMIC STABILITY		
CHECKED	MG	DATE	
LOAD CASE	SEE (1:1,000 AEP)	FAILURE DEPTH	1/3H
MIN. FACTOR OF SAFETY	< 1.0	YIELD COEFFICIENT k_x	0.42
SCALE	NTS	PROJECT No	PS204746
FIGURE No	C-4	REV No	A
A4			

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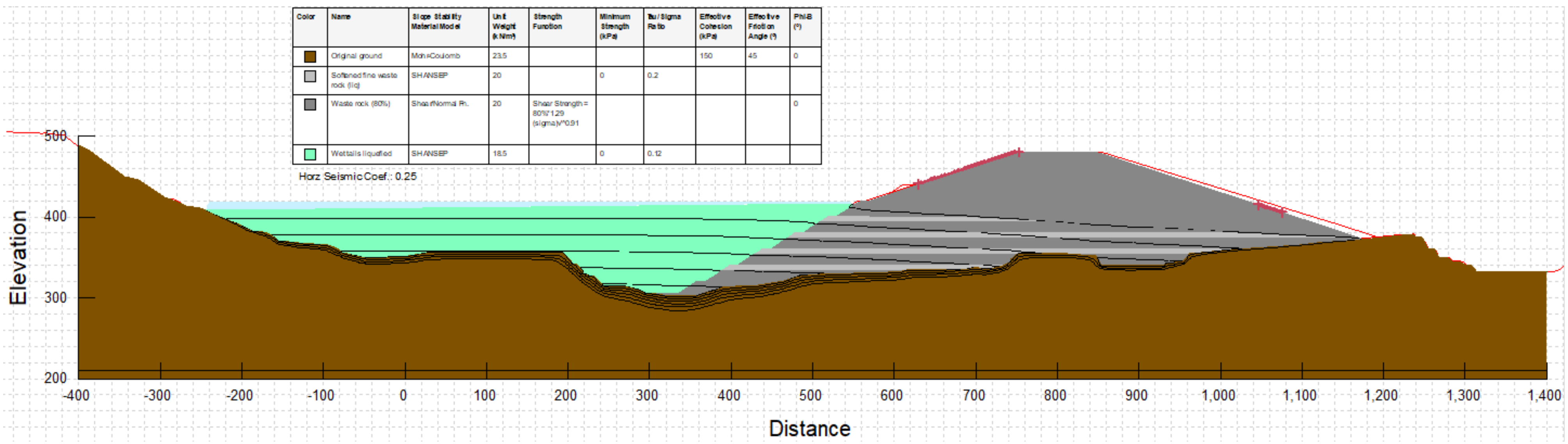
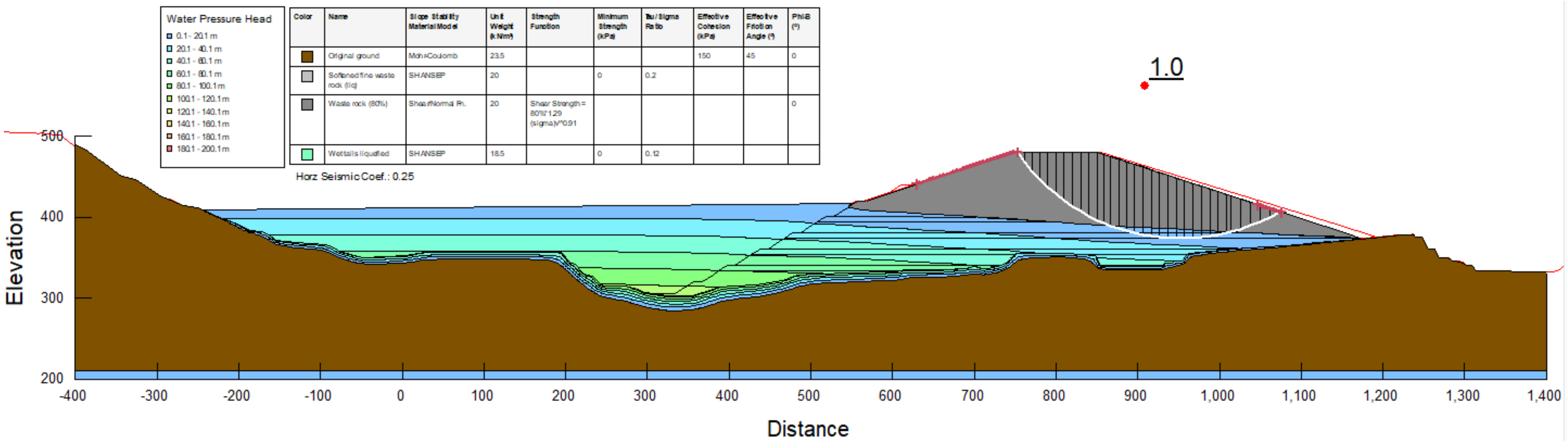


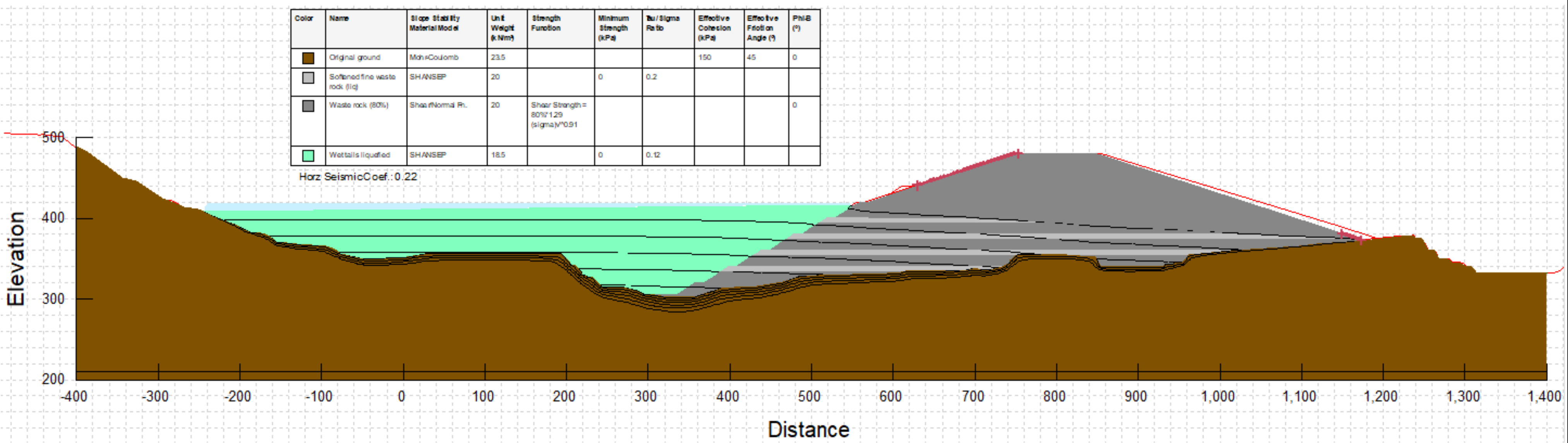
Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Strength Function	Minimum Strength (kPa)	Tau/Sigma Ratio	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
	Original ground	Mohr-Coulomb	23.5				150	45	0
	Softened fine waste rock (liq)	SHANSEP	20		0	0.2			
	Waste rock (80%)	Shear/Normal Fn.	20	Shear Strength = 80%*1.29 (sigma)\^0.91					0
	Wettails liquefied	SHANSEP	18.5		0	0.12			



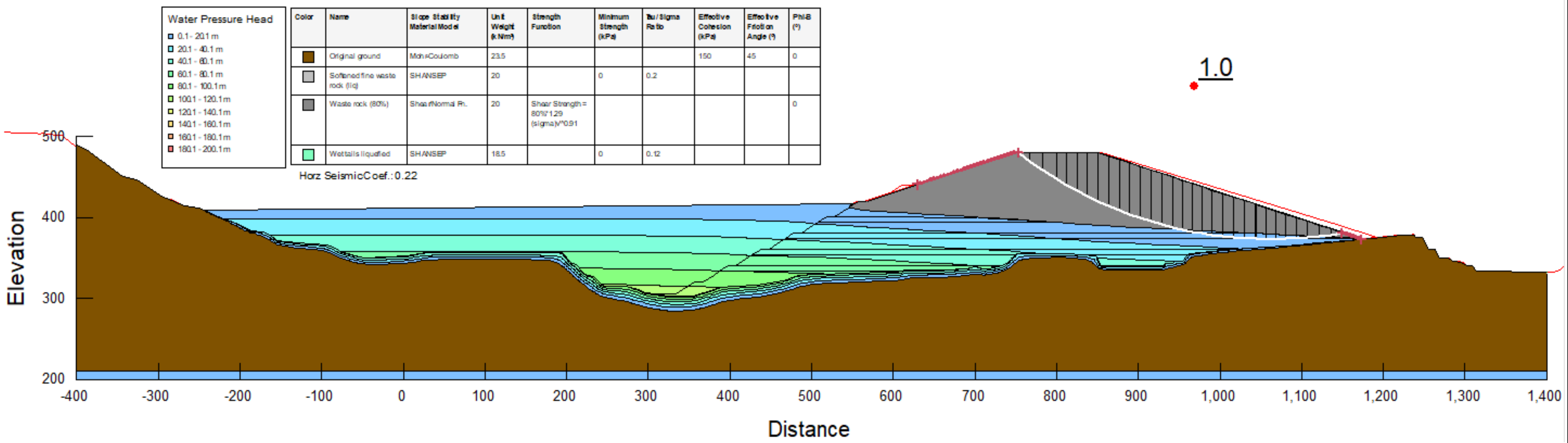
Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Strength Function	Minimum Strength (kPa)	Tau/Sigma Ratio	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
	Original ground	Mohr-Coulomb	23.5				150	45	0
	Softened fine waste rock (liq)	SHANSEP	20		0	0.2			
	Waste rock (80%)	Shear/Normal Fn.	20	Shear Strength = 80%*1.29 (sigma)\^0.91					0
	Wettails liquefied	SHANSEP	18.5		0	0.12			

wsp

CLIENT	OCEANA GOLD		PROJECT	MACRAES FTSF - STAGE 2 DESIGN FOR RESOURCE CONSENT			
DRAWN	CJ	DATE 23/01/24	TITLE	FRBF STAGE 2 OPERATIONS - SEISMIC STABILITY			
CHECKED	MG	DATE	LOAD CASE	SEE (1:1,000 AEP)	FAILURE DEPTH 2/3H	MIN. FACTOR OF SAFETY < 1.0	YIELD COEFFICIENT k_x 0.25
SCALE	NTS		PROJECT No	PS204746		FIGURE No C-5	REV No A / A4



Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Strength Function	Minimum Strength (kPa)	Tau/Sigma Ratio	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
	Original ground	Mohr-Coulomb	23.5				150	45	0
	Softened fine waste rock (liq)	SHANSEP	20		0	0.2			
	Waste rock (80%)	Shear/Normal Fn.	20	Shear Strength = 80%*1.29 (sigma)'^0.91					0
	Wettails liquefied	SHANSEP	18.5		0	0.12			



Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Strength Function	Minimum Strength (kPa)	Tau/Sigma Ratio	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)
	Original ground	Mohr-Coulomb	23.5				150	45	0
	Softened fine waste rock (liq)	SHANSEP	20		0	0.2			
	Waste rock (80%)	Shear/Normal Fn.	20	Shear Strength = 80%*1.29 (sigma)'^0.91					0
	Wettails liquefied	SHANSEP	18.5		0	0.12			

CLIENT: OCEANA GOLD		PROJECT: MACRAES FTSF - STAGE 2 DESIGN FOR RESOURCE CONSENT	
DRAWN: CJ	DATE: 23/01/24	TITLE: FRBF STAGE 2 OPERATIONS - SEISMIC STABILITY	
CHECKED: MG	DATE:	LOAD CASE: SEE (1:1,000 AEP); FAILURE DEPTH: H	MIN. FACTOR OF SAFETY: < 1.0; YIELD COEFFICIENT k_y: 0.22
SCALE: NTS		PROJECT No: PS204746	FIGURE No: C-6; REV No: A; A4

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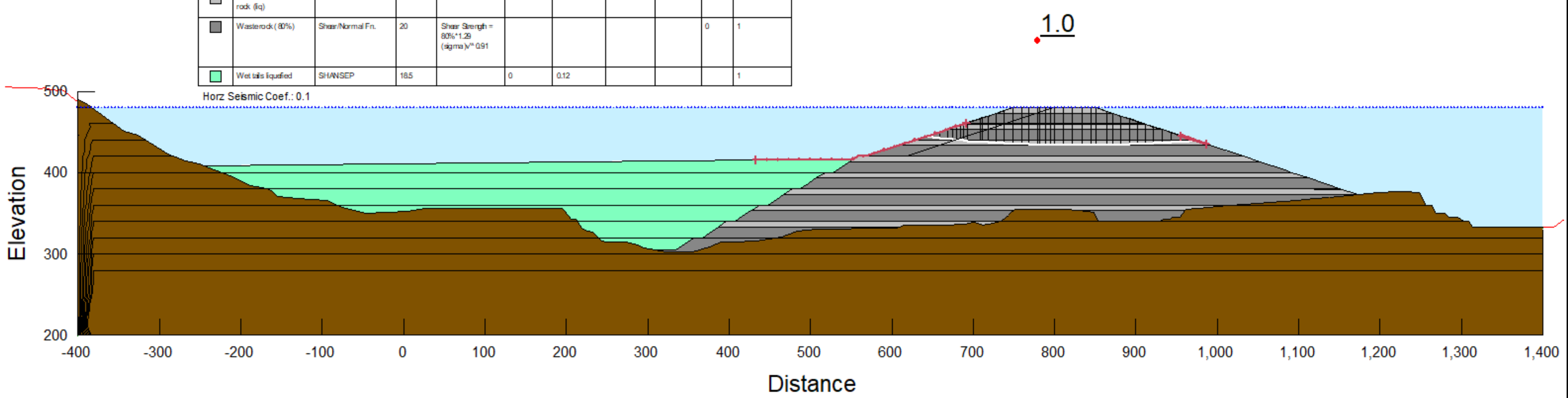
Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Strength Function	Minimum Strength (kPa)	Tau/Sigma Ratio	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)	Piezometric Surface
	Original ground	Mohr-Coulomb	23.5				150	45	0	1
	Softened fine waste rock (liq)	SHANSEP	20		0	0.2				1
	Wasterock (80%)	Shear/Normal Fn.	20	Shear Strength = 80%*1.29 (sigma)^0.91					0	1
	Wet tails liquefied	SHANSEP	18.5		0	0.12				1

Horz Seismic Coef.: 0.1

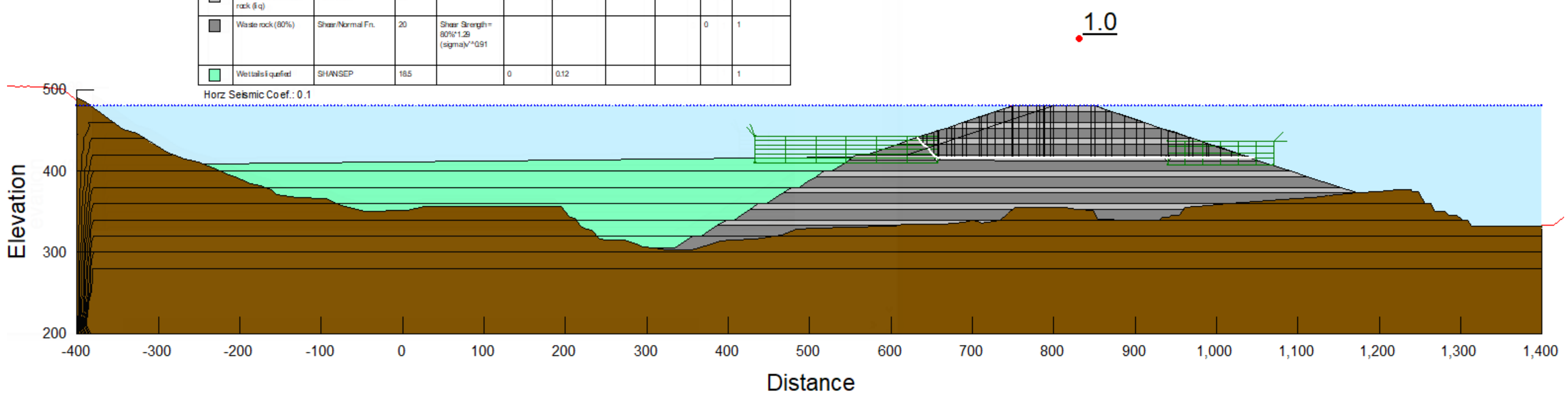


wsp	CLIENT	OCEANA GOLD			PROJECT	MACRAES FTSF - STAGE 2 DESIGN FOR RESOURCE CONSENT		
	DRAWN	CJ	DATE	23/01/24	TITLE	FRBF STAGE 2 CLOSURE - SEISMIC STABILITY		
	CHECKED	MG	DATE		LOAD CASE	SEE (1:10,000 AEP)	FAILURE DEPTH 1/3H	MIN. FACTOR OF SAFETY < 1.0	YIELD COEFFICIENT k_x 0.10
	SCALE	NTS			PROJECT No	PS204746	FIGURE No C-7	REV No A	A4

204746 - Oceana Gold Frasers TSF Detailed Design - Documents\5 Technical Work\Stability Modelling\Stage 2 results\FRBF Stage 2 SlopeW Seismic Results.pptx

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Strength Function	Minimum Strength (kPa)	Tau/Sigma Ratio	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)	Piezometric Surface
	Original ground	Mohr-Coulomb	23.5				150	45	0	1
	Softened finewaste rock (liq)	SHANSEP	20		0	0.2				1
	Waste rock (80%)	Shear/Normal Fn.	20	Shear Strength = 80%*1.29 (sigma)v'^0.91					0	1
	Wet tails liquefied	SHANSEP	18.5		0	0.12				1

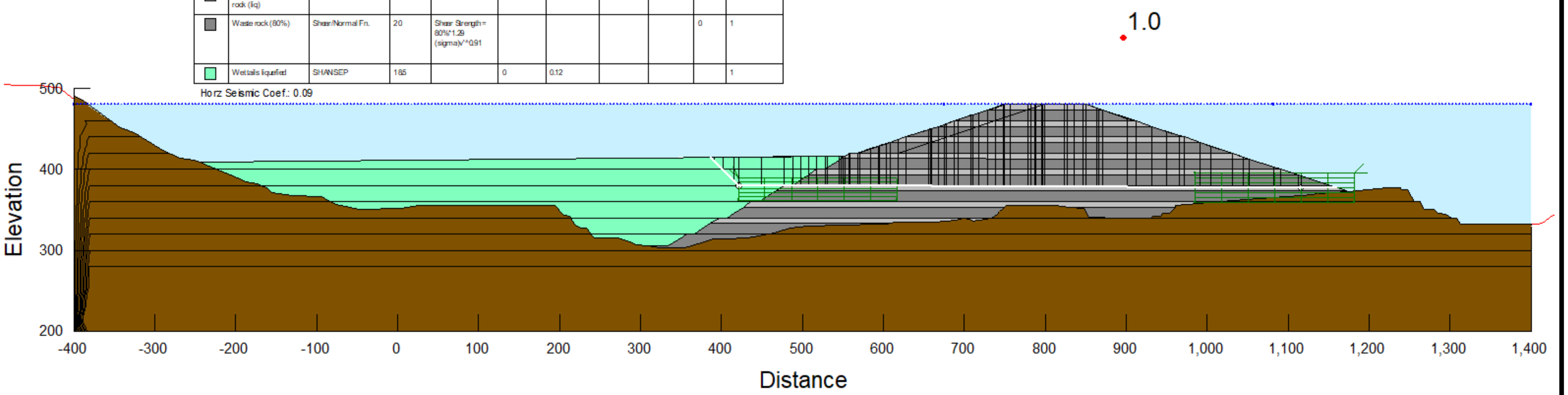
Horz Seismic Coef.: 0.1



CLIENT	OCEANA GOLD	PROJECT	MACRAES FTSF - STAGE 2 DESIGN FOR RESOURCE CONSENT
DRAWN	CJ	DATE	23/01/24
TITLE	FRBF STAGE 2 CLOSURE - SEISMIC STABILITY		
CHECKED	MG	DATE	
LOAD CASE	SEE (1:10,000 AEP)	FAILURE DEPTH	2/3H
MIN. FACTOR OF SAFETY	< 1.0	YIELD COEFFICIENT k_x	0.10
SCALE	NTS	PROJECT No	PS204746
FIGURE No	C-8	REV No	A
	A4		

Color	Name	Slope Stability Material Model	Unit Weight (kN/m³)	Strength Function	Minimum Strength (kPa)	Tau/Sigma Ratio	Effective Cohesion (kPa)	Effective Friction Angle (°)	Phi-B (°)	Piezometric Surface
	Original ground	Mohr-Coulomb	23.5				150	45	0	1
	Softened fine waste rock (liq)	SHANSEP	20		0	0.2				1
	Waste rock (80%)	Shear/Normal Fn.	20	Shear Strength = 80%*1.29 (sigma)v'^0.91					0	1
	Wettails liquefied	SHANSEP	18.5		0	0.12				1

Horz Seismic Coef.: 0.09



CLIENT	OCEANA GOLD	PROJECT	MACRAES FTSF - STAGE 2 DESIGN FOR RESOURCE CONSENT
DRAWN CJ	DATE 23/01/24	TITLE	FRBF STAGE 2 CLOSURE - SEISMIC STABILITY
CHECKED MG	DATE	LOAD CASE SEE (1:10,000 AEP)	FAILURE DEPTH H; MIN. FACTOR OF SAFETY < 1.0; YIELD COEFFICIENT k_x 0.09
SCALE NTS		PROJECT No PS204746	FIGURE No C-9; REV No A; A4