Lake Pūkaki Reservoir Hydro Storage and Dam Resilience Works

Pūkaki Dam Rip-Rap Design and Construction Methodology

Meridian Energy Limited

31 October 2025

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1. Introduction

Meridian Energy Limited (Meridian) have engaged GHD Limited (GHD), to assist with obtaining consents to authorise the operation of Lake Pūkaki below the current normal minimum level of 518.0 m above mean sea level (m RL), for a three-year period, and for civil works at Pūkaki Dam to improve the structures resilience to wave action during lower lake operational levels.

1.1 Project Background

1.1.1 Waitaki Power Scheme

The Waitaki Power Scheme (WPS) is a nationally and regionally significant component of New Zealand's electricity supply infrastructure. It is New Zealand's largest and most flexible hydroelectricity power scheme and therefore has a critical role to play in the electricity system and economy. It consists of eight power stations (two owned by Genesis Energy and six owned by Meridian Energy), commissioned between 1936 and 1985, together having an installed capacity of 1,761 MW, being ~29% of New Zealand's installed hydro capacity.

Within the WPS, Meridian Energy has 1,571 MW (89.2%) connected capacity and Genesis Energy 190 MW (10.8%).

Lake Pūkaki is a modified natural lake and is managed as part of the WPS. It is New Zealand's largest hydro storage lake containing an average of 1,767 GWh of stored water in normal operating conditions. Its maximum normal storage equates to 47.5% of New Zealand's historical average hydro energy storage.

Meridian is currently authorised to dam the Pūkaki River to control and operate Lake Pūkaki between the levels of 518.0 m RL above mean sea level (m RL) (normal consented minimum lake level) and 532.5 m RL (maximum consented storage level).

1.1.2 Meridan's Application

Meridian is seeking approvals under the Fast Track Approvals Act (FTAA) to enable access to water stored in Lake Pūkaki below 518.0 m RL, without the currently applicable security of supply triggers, thereby enabling the better planning and utilisation of the available stored generating capacity. Further information on the background to the proposal and the benefits of allowing access to additional water is provided in the Substantive Application document that supports the FTAA application.

Meridian is proposing to access the additional storage for a time-bound period of three years, until the end of 2028. For the purpose of this report 'Eased Access', refers to the ability to use water from Lake Pūkaki between 513.0 m RL and 518.0 m RL without a SSA or OCC being initiated by the SO. The ability to access stored water below 518.0 m RL will be incorporated into Meridian's electricity generation models and water stored in Lake Pukaki (both above and below 518.0 m RL) will continue to be managed to supply the market. The three-year period is to allow for additional generation capacity that is currently being built, to come online. For further clarification, the existing lake operation framework and proposed activity is detailed below in Table 1.

Existing Framework	Proposed Activity
Operation of Lake above 518.0 m RL (CRC905321.7).	Operation of Lake above 518.0 m RL (CRC905321.7). UNCHANGED.
Operation of Lake between 515.0 m RL and 518.0 m RL as a discretionary activity at times of a Security of Supply Alert initiated by the System Operator (CRC185833).	Operation of Lake between 513.0 m RL and 518.0 m RL for a period of 3 years without a Security of Supply Alert or Official Conservation Campaign being initiated by the System Operator.
Operation of Lake between 513.0 m RL and 518.0 m RL as permitted activity during an Official Conservation Campaign initiated by the System Operator (Permitted Activity).	

Table 1 Proposed Activity – Eased Access

In addition to the temporary ability to lower the lake level, Meridian seeks consent for the installation of rip-rap on the face of the Pūkaki dam and its left and right abutments to provide protection from wave erosion, when operating the lake a lower water levels. Rip-rap will be placed to a minimum level of 510.5 m RL, with earthworks/site preparation activities extending to a minimum level of 509.6 m RL. If achieved in a single construction effort, rock armouring will take a total of 12-18 weeks to complete. However, due to hydrology dictating the low lake level opportunities that are necessary for the work, it is expected that the construction will be done in multiple stages over several years and that works may be required to be completed beyond 2028.

Meridian has stockpiled rock for this purpose on its land adjacent to the Pūkaki dam since 2014, but the rock armouring has not been undertaken due to the existing supply triggers never being initiated by the SO, with the result that the lake level has not been low enough over that period to allow the works to be completed.

1.2 Report Author and Contributions

The qualifications and experience of the report authors are set out in Appendix A. The author confirms that they have read the Code of Conduct for Expert Witnesses contained in the Environment Court Practice Note (2023) and agree to comply with it. In that regard, the lead author confirms that this engineering report is written within their expertise, except where stated that the author is relying on the assessment of another person. The author confirms that they have not omitted to consider material facts known to them that might alter or detract from the opinions expressed.

1.3 Limitations

This report has been prepared by GHD Limited on the instructions of Meridian Energy, in accordance with the agreed scope of work. It is intended to support Meridian's application under the Fast-track Approvals Act 2024 and may be relied upon by the Expert Panel and relevant administering agencies for the purposes of assessing the application.

While GHD Limited has exercised due care in preparing this report, it does not accept liability for any use of the report beyond its intended purpose. Where information has been supplied by the Client or obtained from external sources, it has been assumed to be accurate unless otherwise stated

2. Purpose and scope of work

This report has been prepared to support the SA by providing the following scope of work. This report also provides information to support other technical assessments that have been completed to support the SA submission.

Figure 1 shows the location of the structures under consideration in this report and Section 6 provides further details on the proposed works.

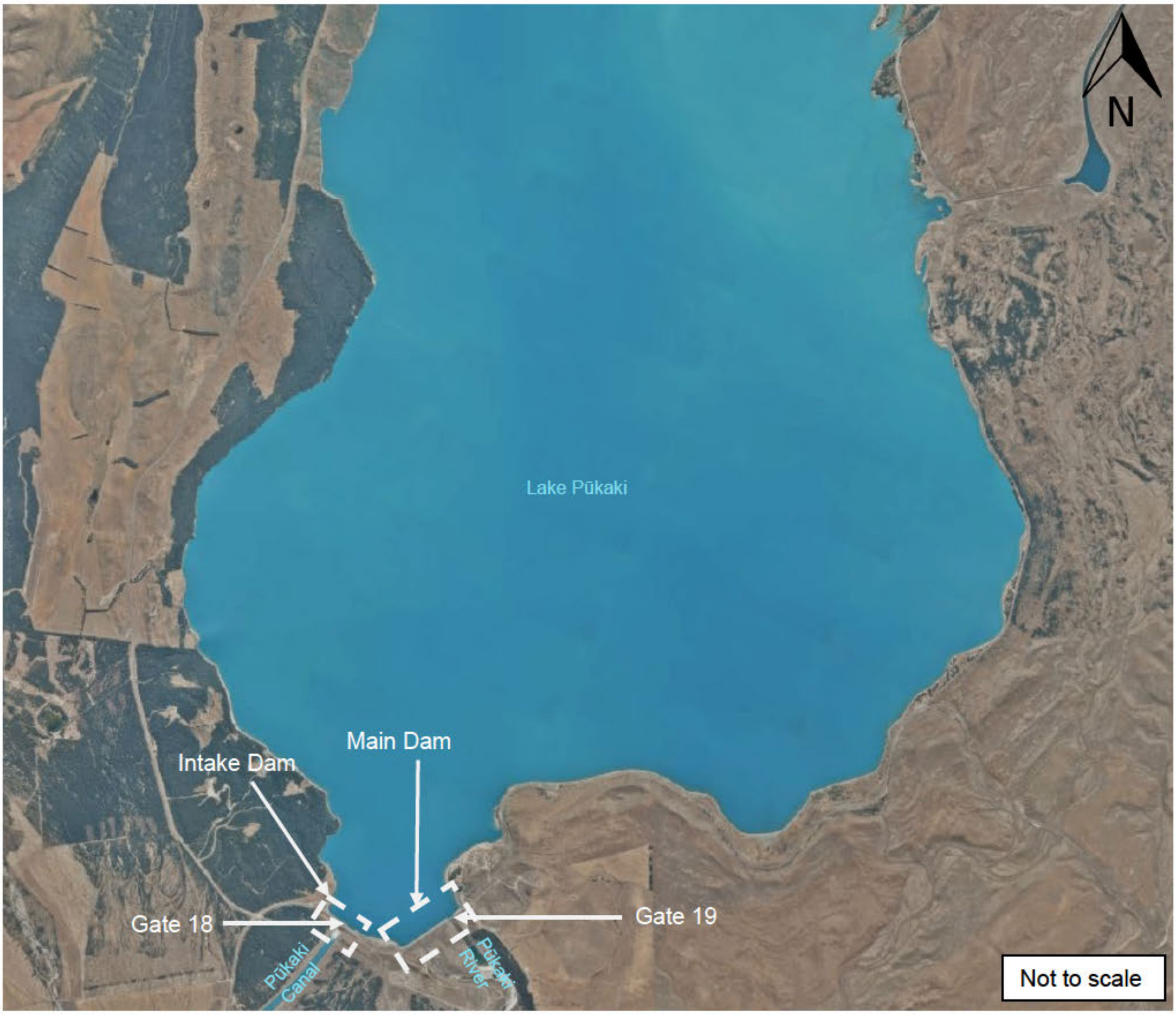


Figure 1 Site overview with indicative locations of the key structures (Aerial photo source: LINZ, 2022)

2.1 Main Dam

– The primary focus of this report is:
  - The preliminary design of additional rip-rap protection for the Main Dam for lake levels between 518.0 m RL and 513.0 m RL.
  - Development of a preliminary construction methodology for the placement of the rip-rap.
  - Review effects on dam safety of the dam protection works, i.e. the construction of additional rip-rap protection, and operating the lake at a lower level (513.0 m RL).
  - Complete a high level assessment of the natural hazards associated with the proposed works and lake level changes
– The extent of the dam protection works is confined to the main dam and the left and right abutment areas where low permeability material was placed on the lakebed (blankets).
– The report includes figures and sketches showing the location, scale and construction methodology of the proposed works.

2.2 Intake Dam

– While it is considered unlikely by Meridian and GHD that additional rip-rap work will be required at the Intake Dam based on the as-built drawings, the site will be inspected during any low lake event to confirm this. In the event that additional rip-rap is required, this report provides a description of how the site will be accessed.
– Review effects on dam safety of the dam protection works, i.e. the operating the lake at a lower level (513.0 m RL).

2.3 Assumptions

– Temporary lowering of the minimum operating reservoir level from 518.0 m RL to 513.0 m RL is likely to have a negligible impact on the slope stability at the upstream shoulder of the Main Dam, especially when the drawdown rate is slow. Given its low risk, other than the dam safety assessment review included in Section 12 of this report, further assessment of upstream shoulder slope stability is deemed inconsequential and is not considered further.
– The extent of new rip-rap placement is constrained by the reservoir (lake) level. Rip-rap can only be placed when the lake is lowered. The maximum submerged working depth for the construction equipment is around 600mm vertically (i.e. depth of water the equipment can sit in – it is expected that the excavator arm will reach deeper into the water). Two indicative excavator sizes to be used for construction are a 45-tonne excavator with a maximum reach length of 7 m, and a 30-tonne long reach excavator with a maximum reach length of 15 m. Information on likely construction equipment has been provided by Rooney Group.
– The actual duration and level of any low lake level event below 518.0 m RL is uncertain. It is likely that the construction of the rip-rap enhancement/protection works will be carried out during multiple events over several years.
– Pūkaki dam is a large dam as defined in the Building Act 2004 and is also classified as a High PIC (Potential Impact Classification) dam. The proposed rip-rap construction will modify the dam and therefore a Building Consent will be required for the works.

2.4 Reliance

In the preparation of this report GHD has relied on several sources of existing data and inputs from other parties. This includes:

– A review of the Pūkaki Dam Wave and Armouring Assessment report completed by Damwatch, dated November 2013.
– Rooney Group has provided advice on the construction methodology for the project including:
  - Construction sequencing
  - Likely machinery to be used

- Likely duration of activities
- How the likely intermittent nature of lake lowering will be addressed through multiple mobilisations.

– Meridian engineers have provided as-built information for the Main Dam and Intake Dam.

  Pukaki Reservoir 2024 Annual Dam Safety Review and Pukaki Reservoir 2024 Comprehensive Dam Safety Review provided by Meridian engineers.

3. Glossary

Table 2 gives the definition or description of abbreviations and key terms used throughout this report.

Table 2 Glossary of terms and abbreviations

Abbreviation	Term / expansion	Definition / description
	Appurtenant structure	A structure at the dam site, other than the dam itself, which is designed and is required for the safe containment and control of the reservoir contents and reservoir discharges under all loading conditions. Pipelines and penstocks downstream of intake structures should be considered appurtenant structures if there are no gates or valves designed to isolate them from the reservoir contents#.
CDSR	Comprehensive dam safety review	A comprehensive, periodic, independent review of the design, construction, operation, and performance of a dam, and all systems and procedures that affect dam and reservoir safety, against current dam safety guidelines, standards, and industry practice#.
FTAA	Fast Track Approvals Acy	Alternative process for gaining resource consents
IDSR	Intermediate dam safety review	A dam performance review that identifies dam safety issues and categorises them into physical infrastructure issues, potential or confirmed dam safety deficiencies, and non-conformances. It is based on inspection and review of surveillance, operation, maintenance, and test records*. An example of an IDSR is an Annual Dam Safety Report (ADSR).
MOW	Ministry of Works	
mRL	Reduced Level	Height in m above a common vertical datum – typically New Zealand Vertical datum 2016 (NZVD2016) but may vary at any location.
NZDSG	New Zealand Dam Safety Guidelines	Guidance document published by NZSOLD for dam safety in a New Zealand context*.
NZSOLD	New Zealand Society on Large Dams	An Engineering New Zealand technical society and publisher of the 2024 New Zealand Dam Safety Guidelines (NZDSG)*.
	Outlet works	A combination of intake structure, conduit, flow control and energy dissipation device to allow the release of water from a reservoir#.
OCC	Official Conservation Campaign	Declared by the SO. Allows lake to be operated down to 513.0 mRL
PFM	Potential failure mode	A specific chain of events or set of circumstances that could result in the uncontrolled release of all or part of the contents of a reservoir#.
SO	System Operator	Transpower
SSA	Security of Supply Alert	Declared by the SO. Allows lake to be operated down to 515.0 mRL

Note: # These definitions were copied directly from the NZDSG (NZSOLD, 2024).
* These descriptions were adapted from the NZDSG (NZSOLD, 2024).

4. Site description

4.1 Site location overview

The Pūkaki Reservoir is located in the Mackenzie Basin, Canterbury, and forms a central component of the upper Waitaki Hydro Scheme. It lies downstream of Lake Tekapo and upstream of the Ohau Canal system, acting as a major storage and regulation point for hydroelectric generation. Some of the key surrounding infrastructure includes:

- Tekapo Canal: A canal that transfers water from Lake Tekapo to Pūkaki Reservoir via Tekapo B Power Station.
- Pūkaki Main Dam: An earth embankment dam at the southern end of the lake, regulating outflows.
- Gate 19: Spillway located on the Main Dam left abutment
- Intake Dam and Gate 18: An earth embankment dam located at the southern end of the lake. The Canal inlet structure is located within the Intake Dam and controls water diversion into the Pūkaki – Ohau Canal, feeding Ohau A, B, and C power stations.

A site plan showing the locations of key infrastructure is provided in Figure 1.

4.2 Typical operation of Pūkaki Reservoir within the Waitaki Scheme

The Pūkaki Reservoir functions as a strategic storage lake, storing inflows from upstream sources and regulating outflows for downstream generation. Its operation typically involves:

- Inflow: Water enters Pūkaki via the Tekapo Canal, following generation at Tekapo B power station. The lake is also fed by a number of stream and rivers – the most prominent being the Tasman River.
- Storage: Pūkaki stores significant volumes of water, with levels managed seasonally to optimise generation and meet consented environmental flow requirements.
- Outflow: Water is released through the Pūkaki Canal Intake into the Pūkaki–Ohau Canal, supplying the Ohau A, B, and C stations. Additional releases may occur via the Pūkaki Spill Gates into the Pūkaki River, for gate testing and flood management purposes.

The operation of the Pūkaki Reservoir is managed by Meridian. Operational decisions are guided by hydrological forecasts, electricity demand, and consent conditions, with infrastructure such as gates, spillways, and telemetry systems supporting precise control.

4.3 Development timeline

The development of the Pūkaki Reservoir and associated infrastructure occurred as part of the broader Waitaki Hydro Scheme expansion. Key milestones include:

Table 3 Key development timeline

Year	Development	Description
1952	Original Pūkaki Dam	Initial earth dam constructed to impound Pūkaki Reservoir. This initial dam was later submerged by the Pūkaki Main Dam
1970s	Tekapo Canal & Tekapo B	Canal and power stations built to divert water from Lake Tekapo to Pūkaki
1977	Pūkaki Main Dam and Intake Dam	Two earth dams across the southern end of the lake. These dams raised the level of the Pūkaki Reservoir by 37 m and submerged the old Pūkaki Dam in the process.

For detailed descriptions of the Main Dam and Intake Dam, refer to Sections 5.1 and 5.2 of this report.

4.4 Reservoir levels

The current resource consent operating range of the Pūkaki reservoir levels is between 518.0 m RL and 532.5 m RL. The characteristics of the Pūkaki reservoir are summarised in Table 4.

Table 4 Key Pūkaki reservoir levels (Dam Safety Intelligence Limited, 2024)

Description	Reservoir level (m RL)	Date
Historic maximum level	533.51	December 1995
Maximum normal operating level	532.50	N/A
Minimum normal operating level	518.20	N/A
Minimum consent operating level	518.00	N/A
Historic minimum level	519.19	June 1992
Extreme minimum level during periods of low national hydro storage	515.00	N/A
Extreme minimum level during an Electricity Supply Emergency	513.00	N/A

5. Key infrastructure summary

The following subsections highlights the key dam features, levels, and values which were obtained from the following documents provided by Meridian:

– Dam Safety Intelligence Limited. (2024). Pukaki Reservoir 2024 Annual Dam Safety Review.
– Pickford, T., Grilli, J., & Pott, J. (2024). Pukaki Reservoir Comprehensive Dam Safety Review.

5.1 Main Dam

Table 5 summarise the overview of Main Dam.

Table 5 Overview of Main Dam

Details	Description	Detail basis / reference
Name	Main Dam, including the wing dam on the true left side of the (Gate 19) service spillway structure. Note: this dam is also referred to as the Pūkaki High Dam.	(Dam Safety Intelligence Limited, 2024)
Appurtenant structure(s)	Service spillway structure (Gate 19) and the construction diversion culvert	(Dam Safety Intelligence Limited, 2024)
Dam type	Zoned, earth embankment dam	(Dam Safety Intelligence Limited, 2024), (Pickford, Grilli, & Pott, 2024)
Dam crest level	Nominal level of 537.75 m RL	(Dam Safety Intelligence Limited, 2024), (Pickford, Grilli, & Pott, 2024)
Dam crest length	Crest length of about 610 m for the Main Dam and about 130 m for the wing dam.	(Dam Safety Intelligence Limited, 2024)
Dam height	76 m high main dam embankment,18 m high wing dam	(Pickford, Grilli, & Pott, 2024)

Typical cross sections of the main dam and right abutment are presented in Figure 2 and Figure 3, derived from the as-built drawings L6124/1 and L6124/23 (Ministry of Works and Development, 1980). Elevations shown in the original drawing have been converted to Lyttleton datum, expressed in metres.

The characteristic of the selected embankment zones is summarised in Table 6.

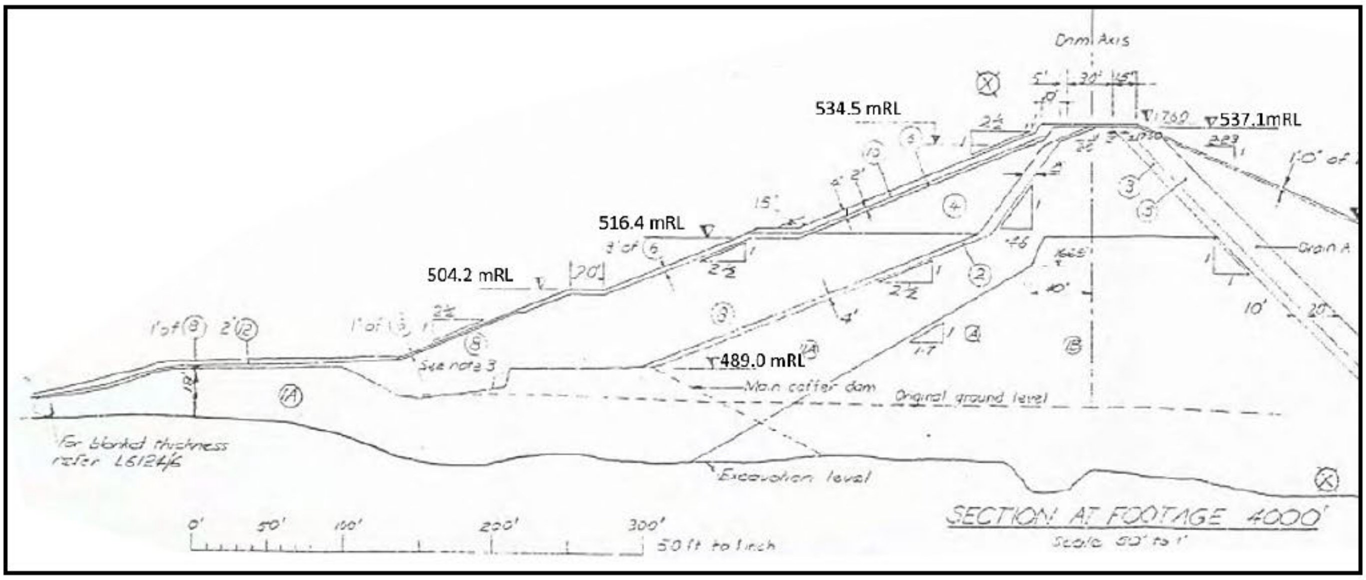


Figure 2 Main Dam typical cross section

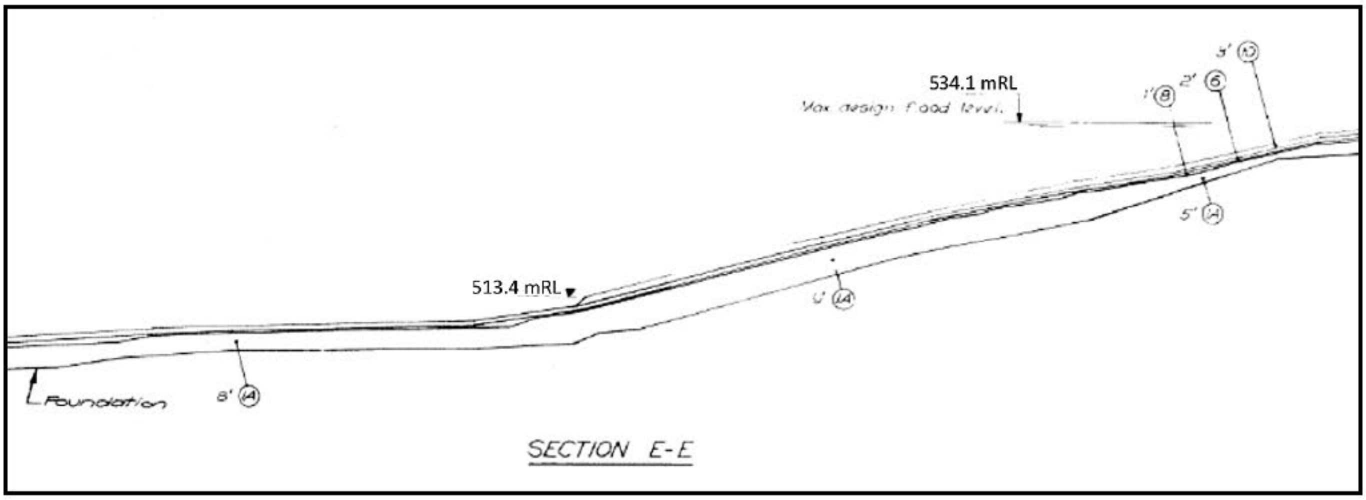


Figure 3 *Right abutment typical cross section*

Table 6 *Selected embankment zone description*

Zone	Description	Gradation
Zone 1A	Core	D_{50} = 0.055 to 8.5 mm; Maximum size = 152 mm
Zone 4	Shoulder	D_{50} = 10 to 65 mm; Maximum size = 480 mm
Zone 6	Rip-rap bedding	D_{50} = 28 to 150 mm; Maximum size = 750 mm
Zone 8	Shoulder	D_{50} = 10 to 65 mm; Maximum size = 480 mm
Zone 10	Rip-rap	D_{50} = 450 to 900 mm; Maximum size = 1200 mm

5.2 Intake Dam

Table 7 summarises the overview of Intake Dam.

Table 7 *Overview of Intake Dam*

Details	Description	Detail basis / reference
Name	Intake Dam	(Dam Safety Intelligence Limited, 2024)
Appurtenant structure(s)	Canal inlet structure (Gate 18)	(Dam Safety Intelligence Limited, 2024)
Dam type	Zoned, earth embankment dam	(Dam Safety Intelligence Limited, 2024), (Pickford, Grilli, & Pott, 2024)
Dam crest level	Nominal level of 537.75 m RL	(Dam Safety Intelligence Limited, 2024), (Pickford, Grilli, & Pott, 2024)
Dam crest length	Crest length of about 640 m	(Dam Safety Intelligence Limited, 2024)
Dam height	35 m	(Pickford, Grilli, & Pott, 2024)

Typical cross section of the Intake Dam is presented in Figure 4, derived from the as-built drawing L6124/27 (Ministry of Works and Development, 1980). Elevations shown in the original drawing have been converted to Lyttleton datum, expressed in metres.

The zoning and materials used to construct the Intake Dam are the same as for the Main Dam, which the characteristic of the selected embankment zones is summarised in Table 6.

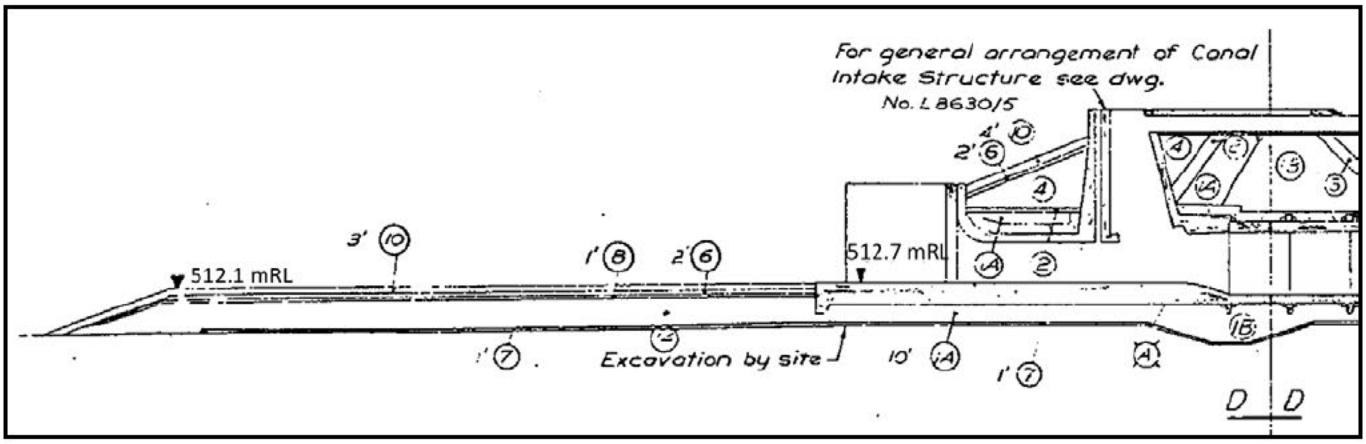


Figure 4 *Intake Dam typical cross section*

6. Proposed work

Meridian Energy is seeking consent to temporarily access the contingent storage capacity of Lake Pūkaki by lowering the minimum reservoir level from the current 518.0 m RL to 513.0 m RL. This operational adjustment is proposed for a defined period of three years, concluding at the end of 2028. The intent is to enhance operational flexibility in lake level management, supporting broader strategic and energy generation goals during this time-bound window.

Lowering the lake level to 513.0 m RL will expose sections of the upstream areas of infrastructure that are currently submerged at a depth where they are not exposed to wave action and do not require rip-rap protection. The implications vary across dam components:

– Main Dam
  - Upstream Dam Face
    - The existing Zone 10 rip-rap terminates at about 517.3 m RL (refer to Figure 2). The only area that may have existing Zone 10 armouring at lower levels than 517.3 mRL is in the immediate vicinity of the diversion culvert entrance (see Figure 5) – although this is based on photographs taken during construction rather as-built drawings.
    - Below this elevation, the upstream face is protected only by Zone 6 bedding material, which consists of smaller-sized rock and offers reduced resistance to wave action.
    - These areas with exposed Zone 6 bedding material are more susceptible to erosion, particularly during high wind events that generate significant wave energy.
  - Abutments
    - Sections of the upstream abutments and areas of natural ground below the dam are covered by a impermeability blanket (Zone 1A) placed to assist in minimising seepage through the natural ground. The extent of the blanket is shown in Figure 5. The blanket requires protection from wave erosion.
    - The cross section along the left abutment is not available on the as-built drawing set.
    - For the right abutment, based on as-built drawings, Zone 10 rip-rap is indicated to terminate at approximately 512.5 m RL (refer to Figure 3). However, previous dive inspections have only confirmed Zone 10 rip-rap is present down to 517.0 m RL and no as-built information is available for the left abutment. Aerial photographs taken during construction suggest that Zone 10 rip-rap was not placed below approximately 517.0 m RL. Therefore, for the purpose of this report it has been assumed additional rip-rap will need to be placed from 517.0 m RL for both abutments to protect the impermeability blanket and any existing Zone 6 material. Additional dive surveys will be completed to confirm if this is required.
  - Proposed Works
    - To ensure the structural integrity of the dam during the proposed operational period, Meridian proposes targeted dam protection works. These works will involve the placement of additional rip-rap along the newly exposed upstream face of the Main Dam and areas of the abutments protected by the impermeability blanket, extending wave protection coverage to allow a revised minimum operating level of 513.0 m RL.

– Intake Dam
  - As-built drawings indicate that the upstream face and impermeable blanket are already protected by the Zone 10 rip-rap (refer to Figure 4)
  - It is considered unlikely that additional rip-rap placement is required for this structure to support lowering of the reservoir level down to 513.0 m RL

- However, this study has proposed that the site is inspected at low water levels and has considered how the site will be accessed if additional rip-rap works were considered necessary.

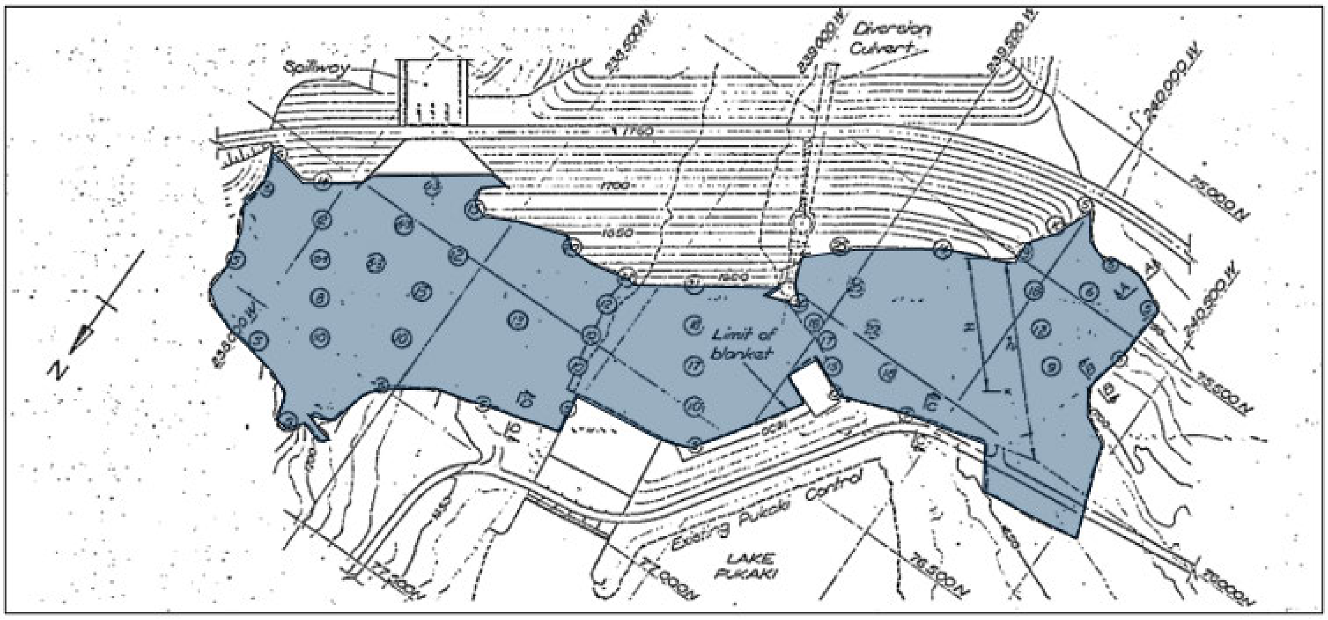


Figure 5 ***Main Dam upstream impermeable blanket extent (numbers in circles indicate thickness in feet)***

7. Main Dam and abutments

7.1 Previous report by Damwatch on rip-rap

In 2013, Damwatch Engineering Limited (Damwatch) was commissioned by Meridian to conduct a wave and armouring assessment in support of lowering the minimum operating level of Lake Pūkaki to 513.0 m RL. A review of the Pūkaki Dam Wave and Armouring Assessment report (Damwatch, November 2013) was undertaken by GHD and the key findings in relation to the Main Dam and abutments are summarised below. Findings in relation to the Intake Dam are discussed in Section 8.1:

– **Rip-rap upgrade requirements:**

  Upgrading of rip-rap is necessary where Zone 6 bedding material is exposed to wave action during the 1 in 100 annual exceedance probability (AEP) events. Critical areas identified for protection against wave erosion include:

  - Main Dam
  - Main Dam abutments
  - Intake Dam (discussed in Section 8.1)

– **Wave modelling and rip-rap design:**

  Meridian commissioned the National Institute of Water & Atmospheric Research (NIWA) to perform numerical wave modelling to assess rip-rap requirements (National Institute of Water & Atmospheric Research Limited, 2013). Wave heights were modelled for reservoir levels of 513.0 m RL and 532.5 m RL. Damwatch noted that wave height estimates are required for lake levels ranging from 517.0 m RL down to 513.0 m RL. Adjustments were made to NIWA's reported values accordingly.

  The significant wave height for the 1 in 100 AEP event was updated to 2.0 m for the rip-rap design. This value represents the average of the highest one-third of waves occurring during a storm period.

– **Extent of existing rip-rap:**

  The extent of existing Zone 10 and 6 materials is uncertain due to discrepancies between as-built records and dive inspection data. It is recommended that the actual extents of the rip-rap be confirmed via dive inspection when the lake levels fall below 520.0 m RL.

– **Recommended rip-rap grading:**

  Rip-rap grading was determined using the Van der Meer (1988) equation. The recommended rock sizes for a 2.0 m significant wave height are summarised in Table 8.

Table 8 Recommended rock grading for 1 in 100 AEP 2.0 m wave parameters – Damwatch (2013)

Embankment slope	D_{min} (m)	D_{50} (m)	D_{max} (m)
1 in 2.5	0.32	0.63	0.95
1 in 5.0	0.23	0.45	0.68
1 in 7.5	0.18	0.36	0.54
I in 10.0	0.16	0.32	0.48

– **Rip-rap depth recommendation:**

  A minimum rip-rap depth of 2.5 m below the lake level of 513.0 m RL is recommended across all critical locations. This corresponds to a lower protection limit of 510.5 m RL.

– **Extent of additional rip-rap:**

  Additional rip-rap should be placed between the lower extent of existing rip-rap and the newly exposed areas (i.e. 510.5 m RL). A lateral buffer zone of 50 m shall be allowed beyond the assumed extent of the upstream impermeable blanket.

– **Rip-rap quantities:**

  Indicative quantities of rip-rap required for protection down to 510.5 m RL is presented in Table 9.

Table 9 Indicative rip-rap quantities for protection down to 510.5 m RL

Parameter	Main Dam left abutment	Main Dam	Main Dam right abutment	Total
Median rock size, D_{50} (m)	0.36	0.63	0.45	-
Plan area (m^2)	6,100	9,000	14,300	29,400
Rock volume (m^3)	4,400	11,300	12,900	28,600
Rock mass (tonne)	11,700	30,000	34,100	75,800

7.2 Independent check of rip-rap design check

7.2.1 Introduction

GHD has completed an independent assessment of the rip-rap design for the Main Dam, applying the latest industry best practice. The primary purpose of this assessment is to validate the suitability of the design recommendations presented in the Damwatch Engineering Limited (2013) report.

The independent assessment incorporates several updates to the design methodology compared to 2013 Damwatch study:

- **Wind speed estimation:**

  Wind speeds have been re-evaluated using the latest Australia/New Zealand wind design standard (AS/NZS), updated in 2021. This ensures alignment with current regional climatic data and design criteria.
- **Rip-rap design methodology:**

  The rip-rap design has been developed using the approach outlined in Geotechnical Engineering of Dams by Fell, MacGregor, Stapledon, Bell, and Foster (2015). This publication is widely recognised as a leading reference in dam engineering and reflects current best practice in geotechnical design, particularly for embankment dam.

7.2.2 Design wave height

Based on Fell, MacGregor, Stapledon, Bell, and Foster (2015), the analytical process for estimating design wave height involves evaluating the potential wave conditions generated by wind over the reservoir surface. The process is dependent on several key factors:

- Storm duration and return period: Used to define design events (e.g., 1 in 100 AEP).
- Fetch length: The uninterrupted distance over water that wind travels, influencing wave development.
- Wind speed and direction: Typically based on historical meteorological data or regional wind design standards. GHD's independent check utilised the AS/NZS wind design standard.
- Reservoir geometry: Including water depth and surface area, which affect wave propagation and energy.

7.2.2.1 Fetch

Fetch was determined in accordance with the procedure provided by Fell, MacGregor, Stapledon, Bell, & Foster (2015). This procedure involves constructing nine radials from the point of interest on the dam at three-degree intervals, as shown in Figure 6. The lengths of these radials were measured and arithmetically averaged to calculate the effective fetch.

It is important to note that fetch directions deviating from the perpendicular to the dam alignment (i.e., 0°) result in reduced wave heights. Table 10 shows the wave height reduction factor R_H corresponding to various fetch angles.

To evaluate rip-rap requirements associated with lowering the minimum operating reservoir level from 518.0 m RL to 513.0 m RL, a critical design reservoir level of 518.0 m RL was adopted. However, due to the lack of a bathymetric contour at exactly 518.0 m RL, fetch length estimation was based on the closest available contour - 518.16 m RL, as shown in Figure 7 (Works Consultancy Services, 1996). This is a conservative approach, as a higher reservoir level typically results in a longer fetch length, thereby representing a worst-case scenario for wave generation.

For the main dam, the estimated fetch length is approximately 29.5 km at a fetch angle of roughly 40°, which corresponding to a wave height reduction factor of 0.90.

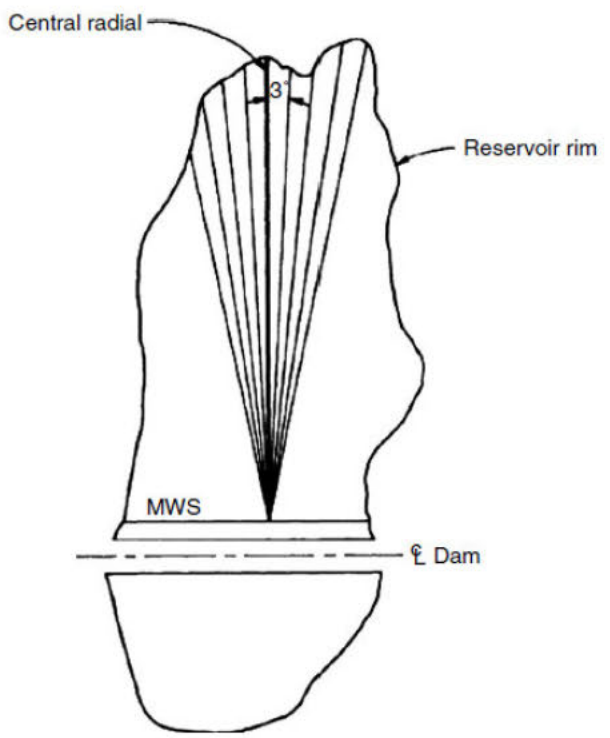
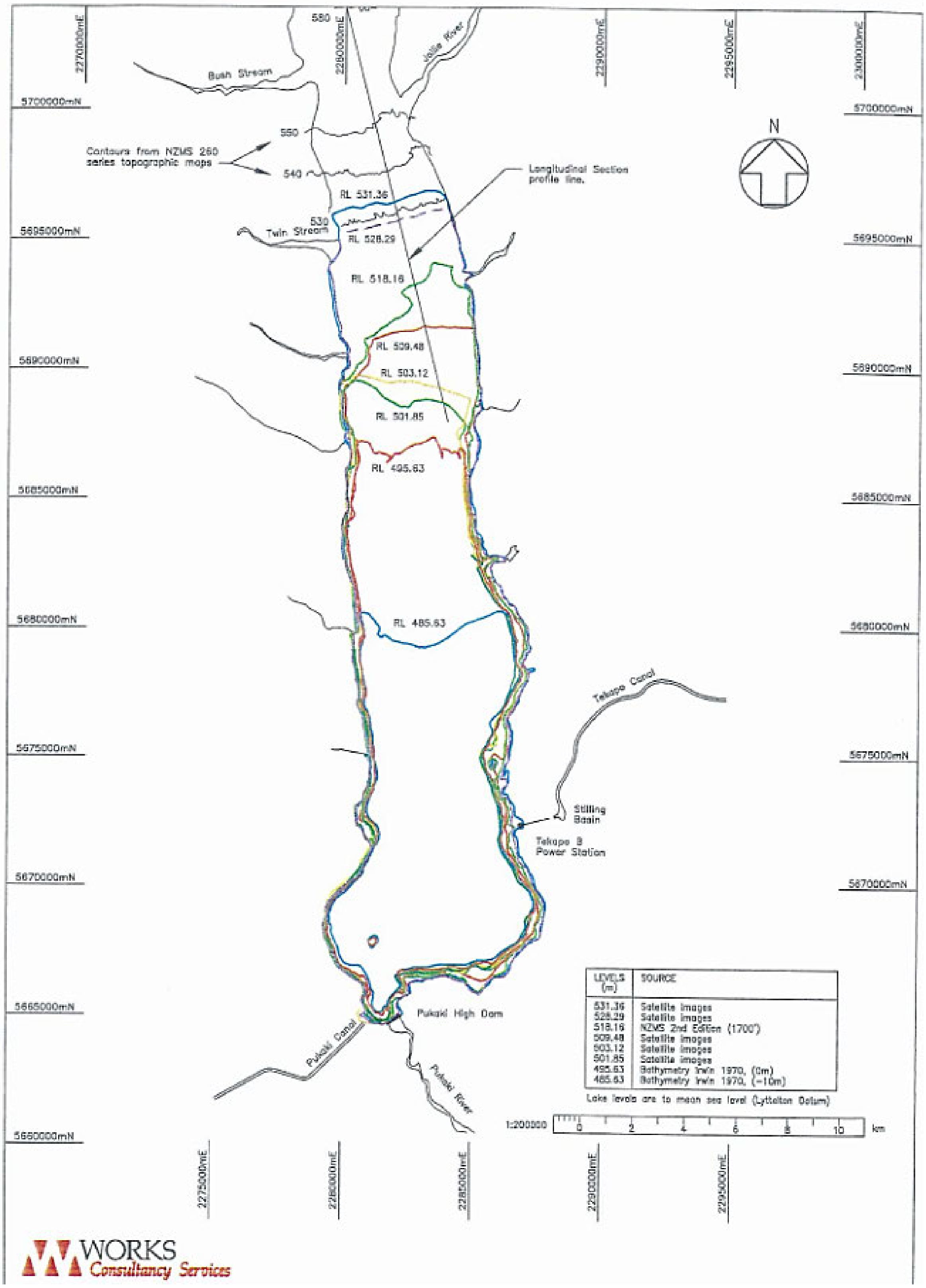


Figure 13.2 Method for calculating effective fetch (USBR, 2012).

Figure 6 ***Method for calculating effective fetch (USBR, 2012)***

Table 10 ***Wave height reduction factor***

Fetch Angle β (°)	Wave Height Reduction Factor R_H
0	1.0
20	0.96
40	0.90
60	0.84
80	0.75



LEVELS (m)	SOURCE
531.36	Satellite images
528.29	Satellite images
518.16	NZMS 2nd Edition (1700')
509.48	Satellite images
503.12	Satellite images
501.85	Satellite images
495.63	Bathymetry Irwin 1970, (0m)
485.63	Bathymetry Irwin 1970, (-10m)

Figure 7 Lake Pūkaki areas digitised from satellite images, topographic, and bathymetric (Works Consultancy Services, 1996)

7.2.2.2 Design wind speed

The wind and wave design criteria adopted for this assessment are based on the guidelines provided by the New Zealand Society on Large Dams (2024). In accordance with these guidelines, the design wave height is defined as the average of the highest 10% of waves generated by sustained wind. This wave height is influenced by the effective fetch length and is calculated for an AEP of 1 in 100, at the maximum normal reservoir level.

For the purpose of this assessment, a reservoir level of 518.0 m RL was adopted for the wind design calculations, rather than the maximum normal operating level of 532.5 m RL. This adjustment aligns with the scope of the assessment, which focuses on evaluating rip-rap enhancements required to accommodate the proposed lowering of the minimum operating reservoir level.

Design wind speed was calculated using the methodologies outlined in Australia and New Zealand Standards (2021) and U.S. Army Corps of Engineers (2003). The wind speed derived from Australia and New Zealand Standards (2021) corresponds to a 0.2 second gust duration. The equation used to estimate this gust wind speed is provided below:

$$V_{\mathrm{sit},\beta} = V_{\mathrm{R}} M_{\mathrm{c}} M_{\mathrm{d}} \left(M_{\mathrm{z,cat}} M_{\mathrm{s}} M_{\mathrm{t}} \right)$$

Table 11 summarises the design inputs/assumptions used in the wind and wave analysis. The resulting gust wind speed for an AEP of 1 in 100 is provided in Table 12.

Table 11 Wind speed calculation inputs / assumptions

Description	Input	Reference
Structure	Main Dam	Project specific
Region	NZ2	AS/NZS 1170.2:2021 Figure 3.1(A)
Average recurrence interval, R	100 years	(Fell, MacGregor, Stapledon, Bell, & Foster, 2015)
Regional gust wind Speed, V_R	42 m/s	AS/NZS 1170.2:2021 Table 3.1 (A)
Climate change multiplier, M_c	1	AS/NZS 1170.2:2021 Table 3.3
Cardinal direction	West, northwest, north, northeast	Main Dam is running in a southwest to northeast direction; upstream to the northwest and downstream to the southeast; wind is assumed to be coming from west, northwest, north, and northeast directions.
Wind direction multiplier, M_d	(1.0) west, (1.0) northwest, (0.95) north, (0.9) northeast	AS/NZS 1170.2:2021 Table 3.2 (B). Given the site is located at the boundary of Zones A2 and A3, the highest M_d of both is adopted in the assessment.
Terrain category	TC1 – Very exposed open terrain (e.g. lakes)	AS/NZS 1170.2:2021 Section 4.2.1
Height	≤ 3 m	Project Specific. Height shall be ~0 m
Terrain/height multiplier, $M_{z,cat}$	0.97	AS/NZS 1170.2:2021 Table 4.1
Shielding multiplier, M_s	1.0	AS/NZS 1170.2:2021 Section 4.3.1 and Table 4.2
Hill-shape multiplier, M_h	1.0	AS/NZS 1170.2:2021 Section 4.4.2 and Table 4.3
Lee multiplier, M_{lee}	1.0	AS/NZS 1170.2:2021 Section 4.4.3
Site elevation above mean sea level	518.0 m RL	Project specific. 518.0 m RL is the critical design value.
Topographic multiplier, M_t	1.08	AS/NZS 1170.2:2021 Section 4.4.1

Table 12 Wind speed summary

Structure	Lake level (m RL)	0.2s duration gust wind speed	
		m/s	km/hr
Main Dam	518.0	39.5	142.3

7.2.2.3 Wave height

The wave height calculation method adopted in this assessment follows the approach documented by Fell, MacGregor, Stapledon, Bell, & Foster (2015). This method is applicable under the condition that the reservoir is relatively deep compared to the wind-generated wavelength (i.e., water depth > 0.5L). The deep-wave wavelength, L, is calculated using the following equation:

$$L = 1.56T^2$$

where:

T = wave period = $0.335F^{0.33}V_W^{0.33}(1.1 + 0.01V_W)^{0.167}$

Based on bathymetric data presented in Figure 7, the average reservoir depth at a lake level of 518.0 m RL is estimated to exceed 18.7 m, which satisfies the depth criterion (i.e., depth > 0.5L).

The design wave height was calculated using the following equation:

$$Hs = 0.00366(F)^{0.5}V_W(1.1 + 0.01V_W)^{0.5}$$

where:

F = fetch length (km)

V_w = sustained wind speed (km/hr)

A wave height reduction factor of 0.9 was adopted to account for the fetch direction not being perpendicular to the dam axis.

Additionally, to estimate the wave height corresponding to the highest 10% of waves, a wave height amplification factor of 1.27 was applied, as recommended by Fell, MacGregor, Stapledon, Bell, & Foster (2015).

The resulting wave heights are summarised in Table 13.

Table 13 Wave height summary – independent check

Structure	Reservoir level (m RL)	Significant wave height, Hs (m)	Top 10% significant wave height Hs (m)
Main Dam	518.0	2.27	2.59

7.2.3 Sizing of the graded rock in the rip-rap

The weight of graded rock used in the rip-rap design was calculated using Equation 13.9 in Fell, MacGregor, Stapledon, Bell, & Foster (2015).

$$W_{50} = \frac{\gamma_r H^3}{K_{RR}(S_r - 1)^3 \cot\theta}$$

The equivalent sieve size of the rip-rap material was derived using the following equation:

$D_{50} = 1.15(W/\gamma_r)^{0.33}$.

A summary of the design inputs/assumptions for rip-rap design at the Main Dam to support the lowering of the reservoir level is shown in Table 14. The results are provided in Table 15.

Table 14 Rip-rap calculation inputs and assumptions

Description	Input	Reference
Unit weight of rip-rap (γ_r)	26 kN/m^3	Project specific
Design wave height	2.59 m	Highest 10% wave height provided in Table 13
Stability coefficient (K_{RR})	2.5	(Fell, MacGregor, Stapledon, Bell, & Foster, 2015) – for angular quarried rock and non-breaking waves
Specific gravity of rip-rap rock relative to the water in the dam (S_r)	2.65	Project specific - γ_r / γ_w
Angle of upstream slope of the dam measured from the horizontal (θ)	21.8°	Project specific – 1V:2.5H upstream shoulder slope angle

Table 15 Rip-rap summary

Description	Value
Weight of the 50% size in the rip-rap (W_{50})	16.1 kN
D_{50}	1.0 m
D_{100}	1.5 m
$D_{15, target}$	0.5 m
Fine limit	No more 10% than passing 75 mm
Minimum unit weight of rip-rap	2.65 t/m^3

A comparison with the 2013 Damwatch design recommendations is documented in Section 7.3.

7.2.4 Material compatibility assessment for rip-rap bedding

A qualitative material compatibility assessment was carried out in accordance with the procedure outlined by Fell, MacGregor, Stapledon, Bell, & Foster (2015) to evaluate the suitability of Zone 6 bedding material as a non-critical filter between Zone 8 and the proposed rip-rap (Zone 10) at the Main Dam.

Grading curves of both Zone 8 and Zone 6 materials are shown in Figure 8.

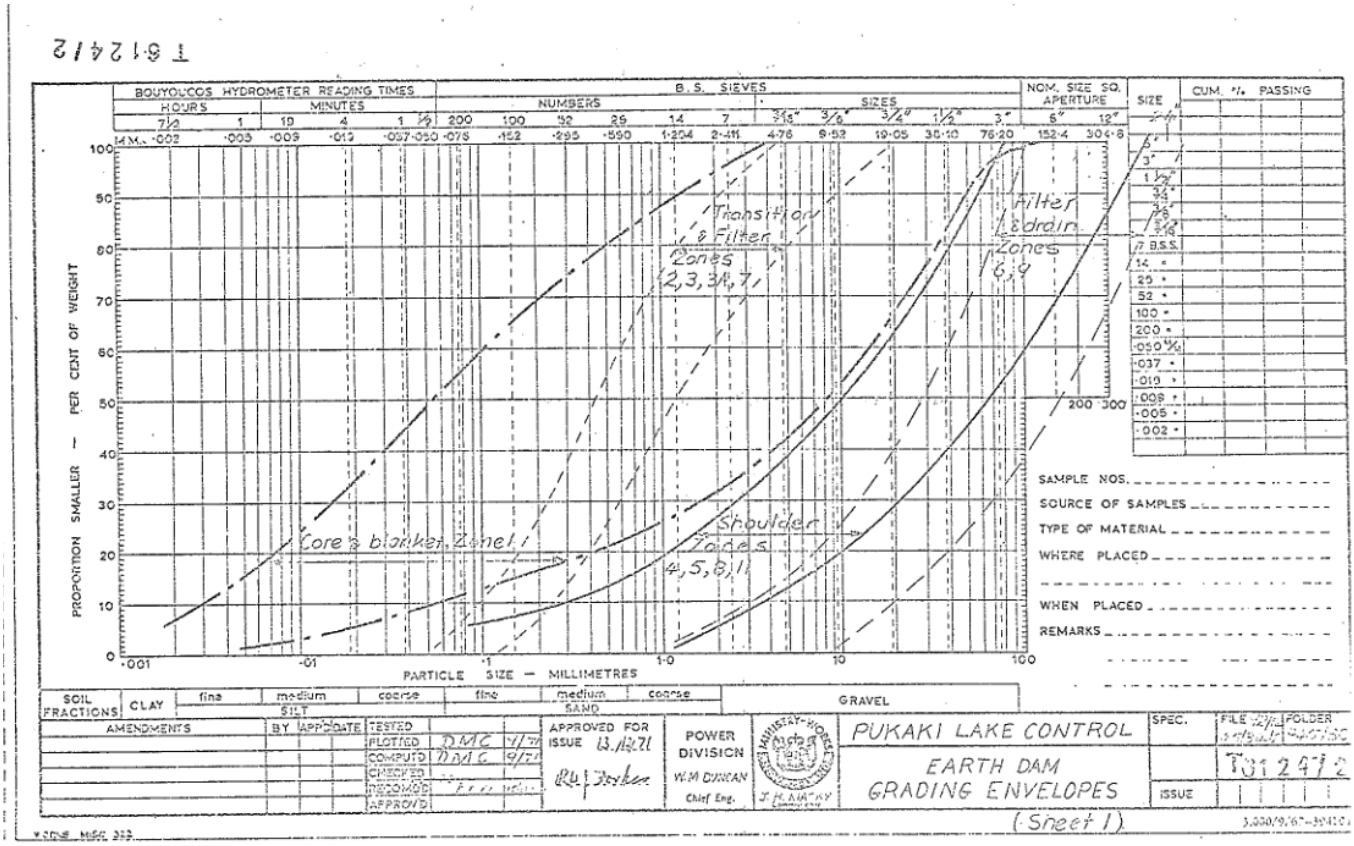


Figure 8 Grading curve (Ministry of Works and Development, 1980)

The design requirements for filter materials placed beneath rip-rap are as follows:

– Coarseness criterion: The filter must be sufficiently coarse to prevent washout through the rip-rap voids.
– Fineness criterion: The filter must be fine enough to prevent internal erosion of the underlying soil.

For impervious soil classified as Group 3 (i.e., sands and sandy gravels with a small content of fines), the no-erosion filter design must satisfy the following particle size relationship:

$D_{15F} \leq 4D_{85B}$

where:

D_{15F} = 15% finer size of the filter material

D_{85B} = 85% finer size of the base soil (including gravels)

Based on the grading characteristics of Zone 6 and Zone 8 materials, the use of Zone 6 as a filter beneath the rip-rap meets the above criteria, confirming its suitability for the intended application.

7.3 Comparison between GHD's independent assessment and Damwatch 2013 report

7.3.1 Introduction

This section provides a detailed comparison between GHD's independent assessment and the Damwatch 2013 report, focusing on two critical design parameters: wave height estimation and rip-rap sizing for the main dam. The comparison highlights methodological differences and updates in design standards.

7.3.2 Wave height estimation

Both GHD's and Damwatch's assessments yield broadly consistent results in terms of wave height estimation, despite differences in lake level assumptions and modelling approaches. GHD's independent check, based on the 2021 AUS/NZ 1170 Standard, confirms the continued applicability of the NIWA modelling used in the Damwatch report, acknowledging the limitations in historical wind data and bathymetry.

The estimated significant wave heights differ by approximately 13.5%, which is considered acceptable given the inherent uncertainties in site-specific modelling. The minor differences are attributed to updated standards.

Table 16 summarises the key results from both GHD's and Damwatch's assessments.

Table 16 Comparison of wave height estimation

Aspect	Damwatch (2013)	GHD's independent assessment
Critical lake level (m RL)	517.0	518.0
Significant wave height (m)	2.00 (interpolated)	2.27
Top 10% significant wave height (m)	2.55 (inferred)	2.59
Methodology	NIWA modelling with limited reference data	2021 AUS/NZ 1170 Standard

7.3.3 Rip-rap sizing

The rip-rap sizing recommendations provided in the Damwatch (2013) report are considered outdated and no longer applicable for current design purposes. Damwatch employed the Van der Meer (1988) and Hudson (1974) methods, which yielded smaller median rock sizes (D50) and relied on input parameters from older versions of the U.S. Army Corps of Engineers Shore Protection Manual (USACE SPM) (1977).

In contrast, GHD's independent assessment adopted the methodology outlined in Fell, MacGregor, Stapledon, Bell, & Foster (2015), which reflects modern industry practice and incorporates updated guidance from USACE SPM 1984. This approach resulted in a recommended D_{50} of 1.0 m, consistent with both recalculated values and historical performance observations.

Table 17 Comparison of rip-rap sizing for Main Dam

Method	Slope assumed	D_{50} (m)
Van der Meer (1988)	1:2.5	0.63
Hudson (1974)	1:2.5	0.59
Fell, MacGregor, Stapledon, Bell, & Foster (2015)	1:2.5	1.0

The recommended D_{50} of 1.0 m is justified through a combination of updated design standards and empirical performance data. GHD's recalculation, based on the revised wave height inputs and stability coefficients outlined in the USACE SPM (1984), yields a D_{50} of 1.0 m, supporting the need for larger rip-rap sizing. Field observations and photographic evidence further validate this recommendation, showing that existing rip-rap at the normal reservoir level typically ranges from 0.9 to 1.0 m in diameter. The 2024 Dam Safety Review describes this rip-rap as "uniform, large, and stable," with no signs of erosion, indicating satisfactory long-term performance.

7.4 Recommendations

Based on the outcomes of GHD's independent assessment, a review of historical performance and a comparative analysis with the Damwatch (2013) report, the following recommendations are proposed to guide the rip-rap enhancement works for the Main Dam and associated abutments. These recommendations aim to improve erosion resistance and align with current engineering best practices. As discussed in Section 2.3, a building consent will be required for these works and the rip-rap design will be further refined as part of the building consent application process.

– **Uniform rip-rap sizing:**

  For the purposes of the Fast Track consenting process, GHD has conservatively assumed a uniform median rock size (D_{50}) of 1.0 m across the entire rip-rap zone, including the Main Dam and abutments. However, as part of the building consent process this can be re-evaluated as it is likely a smaller rip-rap size can be utilised for parts of the abutments. A summary of the proposed rip-rap details is provided in Table 15.

– **Rip-rap layer thickness:**

  The rip-rap layer should be placed with a minimum thickness of 1.0 × D_{max}, equating to 1.5 m.

– **Bedding layer and thickness:**

  A well-graded bedding layer should be installed beneath the rip-rap to prevent soil migration and promote drainage. The bedding material must satisfy the grading limits of the existing Zone 6 material. The recommended bedding thickness is 0.9 m for the Main Dam and 0.6 m for the abutments. Where existing Zone 6 material does not satisfy the thickness requirement, additional Zone 6 equivalent materials shall be placed.

– **Vertical extent of rip-rap coverage:**

  Rip-rap protection should extend from the existing Zone 10 elevation down to a minimum of 510.5 m RL. Where the thickness of existing Zone 6 material is insufficient to meet the bedding thickness requirements, additional bedding should be placed to achieve the specified thickness (0.9 m for the Main Dam and 0.6 m for the abutments).

– **Horizontal extent of rip-rap coverage:**

  Rip-rap protection should be applied continuously along the full length of the Main Dam and abutments. For the abutments, the rip-rap shall extend at least 50 m beyond the upstream impermeable blanket, ensuring adequate coverage of critical zones exposed to wave action.

– **Dive inspection:**

  As noted in the Damwatch (2013) report and Section 5 of this report, the extent of the existing Zone 10 and 6 materials is uncertain due to discrepancies between as-built records and dive inspection data. To resolve these uncertainties, it is recommended that a dive inspection be undertaken to confirm the actual extent of rip-rap coverage down to at least 509.6 m RL.

A plan showing the indicative extent of rip-rap enhancement coverage (i.e., work zones), cross sections and other details are presented in Section 9.

8. Intake Dam

8.1 Previous report by Damwatch on rip-rap

GHD has undertaken a review of the Pūkaki Dam Wave and Armouring Assessment report prepared by Damwatch (2013), with general findings summarised in Section 7.1. This subsection focuses specifically on observations and recommendations related to the Intake Dam.

– **Extent of existing Zone 10 material - as-built drawings:**

  The as-built documentation indicates that Zone 10 rip-rap material lines the intake channel and extends across the upstream face of the embankment and the upstream impermeable blanket. However, the lower boundary of the Zone 10 placement is not clearly defined, introducing some uncertainty regarding the full vertical extent of protection.

– **Extent of existing Zone 10 material - dive inspection:**

  Dive inspection data suggests that portions of the upstream face of the Intake Dam may lack complete coverage by Zone 10 material above elevation 516.4 m RL.

– **Rip-rap enhancement work:**

  Based on available information, rip-rap upgrading is not considered necessary for Intake Dam. Much of the area in front of the Intake Dam comprises natural ground and is not protected by an upstream impermeable blanket, reducing the need for additional rip-rap. The assumed extent of existing rock armour and blanket coverage has been derived from as-built drawings; however, the reliability of these records remains uncertain.

– **Further dive inspection:**

  To resolve uncertainties regarding the extent and sizing of existing rip-rap, it is recommended that further investigation be undertaken when lake levels are sufficiently low.

8.2 Recommendations

Based on the review of available documentation, the following recommendations are provided for the Intake Dam:

– **Rip-Rap enhancement works:**

  No immediate rip-rap enhancement works are anticipated at the Intake Dam based on the as-built documentation.

– **Dive inspection:**

  A targeted dive inspection is recommended to verify the extent and condition of the existing rip-rap materials (Zone 6 and 8) down to a minimum of 509.6 m RL. This will help confirm coverage and identify any areas requiring remediation.

– **Emergency works during reservoir drawdown**:

  Any wave-induced erosion observed in the vicinity of the Intake Dam during reservoir level lowering shall be addressed by Meridian through emergency works.

– **Rip-rap requirements (if needed):**

  Should rip-rap improvement works be deemed necessary following inspection, the specifications shall align with those adopted for the Main Dam and abutments to ensure consistency in performance and durability.

– **Access for remediation works:**

  Access tracks suitable for rip-rap remediation activities at the Intake Dam are detailed in Section 10 of this report.

9. Construction methodology – Main Dam and abutments

9.1 General

This section outlines the proposed construction activities for the Main Dam rip-rap placement. This methodology is based on the assumptions outlined in the following sections. As discussed in the following sections, the final construction program is largely dependent on the duration, timing and progression of low lake level events. These parameters will be assessed collaboratively by the contractor and Meridian prior to construction commencing.

9.2 Programme

If the rip-rap placement programme is completed in a single stage, the estimated duration is approximately 12 to 18 weeks. However, it is unlikely that the lake level will be maintained below 518.0 m RL for an extended period allowing all works to be completed in a one continuous phase. In addition, the lowest lake level achieved during any event is more likely to be nearer to 518.0 m RL than 513.0 m RL.

Meridian undertook modelling to understand potential changes to lake levels from the proposed activity (Meridian, 2025). The modelling draws on 91 years of hydrological and meteorological data for the lake, and the current understanding of the NZ energy system (supply and demand analysis) resulting in forecasts of stored water (energy), which can be used to understand potential changes to lake levels. The Meridian modelling indicates the following:

Modelled First Year of Operation (2026)

– If Meridian is granted access to water between 518.0 m RL and 513.0 m RL, modelling data indicates lake levels are typically held lower, but still in the normal operating range above 518.0 m RL most of the time, only falling below 518.0 m RL on occasion.
– There is approximately a 3% probability that lake levels in any given week will be below 518.0 mRL. Therefore, on average the lake level will be below 518.0 m RL for only 1.5 weeks in the first year of operation.
– 23% of the modelled hydrological sequences dip below 518.0 m RL in the first year. However, most instances are short duration and not deep. Of the 23% that fall below 518.0 m RL:
  - 9 fall between 518.0 – 517.0 m
  - 6 fall between 517.0 m – 516.5 m
  - 3 fall between 516.5 m – 516.0 m
  - 2 fall between 516.0 m – 515.0 m
  - 1 falls below 515.0 m

– In terms of duration, in the worst-case scenario, the lake level falls below 518.0 m RL in September and does not return above 518.0 m RL until December (a duration of no more than 4 months). However, the likelihood of this scenario is extremely low – approximately 1% (1 of the 91 hydrological sequences modelled).

Modelled Subsequent Years of Eased Operation (2027 and 2028)

The pattern is broadly the same in subsequent years although the probability of falling below 518.0 m RL in any given week increases very slightly to 3.5% in 2027 and 4% in 2028. Based on this information, it is likely that:

– Construction activities may be short in duration (a few weeks) and occur over multiple stages.
– It may take multiple years to complete all the required works. This may extend beyond the three-year period being considered as part of this application when decisions regarding access to the lower lake levels returns to the System Operator (SO), Transpower.
– Access is expected to be more frequent at higher lake levels within the 518.0 m RL to 513.0 m RL range, rather than at the lower end.

Based on this information, the assumed approach in this report for rip-rap placement is a multi-stage process with rip-rap being placed when lake levels allow. Section 9.6 provides a summary of the proposed rip-rap placement process based on the following programme assumptions:

– Forecasting lake levels within a period of a few weeks is generally achievable based on predicted generation flows from the lake, predicted inflows, and predicted rainfall events in a 1-to-2-week window. Based on this data, guidance can be provided to a contractor as to when lake levels are likely to reach required levels for construction to commence and how long they are likely to stay low in the short to medium term.
– Given the time required to mobilise and demobilise from the site, contractor guidance indicates that the minimum duration for any construction stage is 3 weeks.
– Inflow events, whether predicted or not, can result in a relatively rapid rise in lake level. Historical data indicates that the lake can rise up to 1 m in one day and 3 m in one week. Therefore, the construction sequence must include contingency plans for rapid site demobilisation, ensuring the site is left in a safe and environmentally appropriate condition prior to water inundating the works area.
– Historical data indicates that low lake levels at Lake Pūkaki most frequently occur during mid to late winter and early spring. These conditions are advantageous for accessing the upstream dam face for rip-rap placement. However, the same period is also associated with the strongest wind events, which significantly increases the potential for wave action impacting the exposed upstream face of the dam. Where practicable, critical shoreline and dam face activities will be scheduled outside the high-risk seasonal window.

Construction activities will be restricted to the following schedule:

– Daily: 6:00 a.m to 7:30 p.m.
– No work during the following periods:
  - Good Friday to Easter Monday (inclusive)
  - 24, 25, 26 and 31 December and 1 January
  - New Zealand Public Holidays

9.3 Existing infrastructure owned by others

The carpark that is located on Meridian's core land will be closed to the public during the works. The Mt Cook Alpine Salmon Shop and toilet facilities are also situated on land owned by Meridian and will be closed during construction works.

Re-routing of the A2O trail and Te Arahoa Track will be required to retain accessibility (see GHD 2025.

9.4 Work zones and approach to construction

As illustrated in Figure 9, the rip-rap placement works are divided into three primary work zones:

– Right abutment
– Left abutment
– Main Dam

Figure 9 *Work zones*

The proposed construction methodology, as outlined in Section 9.6, involves placing rip-rap in two sequential tranches, defined by elevation ranges:

- Tranche 1 - From 518.6 m RL to 514.5 m RL (Main Dam); from 517.0 m RL to 513.0 m RL (abutments)
- Tranche 2 - From 514.5 m RL to 510.5 m RL (Main Dam); from 513.0 m RL to 510.5 m RL (abutments)

Rip-rap placement for Tranche 2 will only commence once Tranche 1 is fully completed. Each tranche will be implemented concurrently across all three work zones. As discussed in Section 9.2, it is likely that each tranche will be constructed in multiple stages, depending on lake level conditions and site accessibility.

9.5 Site preparation

It is likely that the required preparatory activities can be completed prior to the lake reaching the required level, thereby ensuring readiness for a low lake level event. Some activities are one-time activities, while others may need to be undertaken for each construction event.

9.5.1 Site security during construction

For each construction event, site security will be maintained through the installation of temporary fencing and controlled access measures. Temporary fencing will be erected to prevent public access to the designated work area, with lockable site gates provided to secure the entry points. The proposed fencing layout is shown on Figure 10 and Figure 11.

To ensure safety and minimise public interference, access to the existing carpark will be closed for the full duration of each construction event. The installation of the fencing and access control is expected to require approximately two days to complete.

Figure 10 ***Dam and right abutment - security fencing, closed access, access ramps and temporary buildings***

Figure 11 ***Left abutment - security fencing, closed access and access ramp***

9.5.2 Construction access

Access to the right abutment and Main Dam will be established via the main carpark site entrance (see Figure 10). Dedicated access ramps will be established using an excavator to relocate existing Zone 10 materials as required, followed by the placement of granular material to infill voids within Zone 10/6 materials. This process will create a stable running surface suitable for road truck movement.

Access to the left abutment will be provided via the existing unsealed road (see Figure 11).

The constructed access ramps are expected to be partially inundated between the construction activities and as lake levels rise. The ramps will remain in place between construction events. To minimise wave induced erosion, the ramps will be monitored throughout active construction to ensure adequate coverage and thickness of Zone 6 material protecting the embankment. Prior to site demobilisation, sections of ramps vulnerable to wave action will be backfilled with existing Zone 10 materials or rip-rap materials specified in this project to enhance durability and reduce erosion risk.

Minor reinstatement works may be required for each ramp prior to each construction event to restore access affected by wave action.

The expected duration for the initial ramp construction is 10 days.

9.5.3 On-Site facilities

Temporary offices and work room facilities/ablutions will be established on site for the duration of each construction event. The proposed locations are shown on Figure 10 and Figure 11.

9.5.4 Rock supply and stockpile management

Rock material has been previously harvested and stockpiled near the site. The locations of the existing stockpiles are shown on Figure 12. At present, approximately 23,000 tonnes of rock is available, which is sufficient to complete the proposed works across all three work zones down to 514.0 m RL.

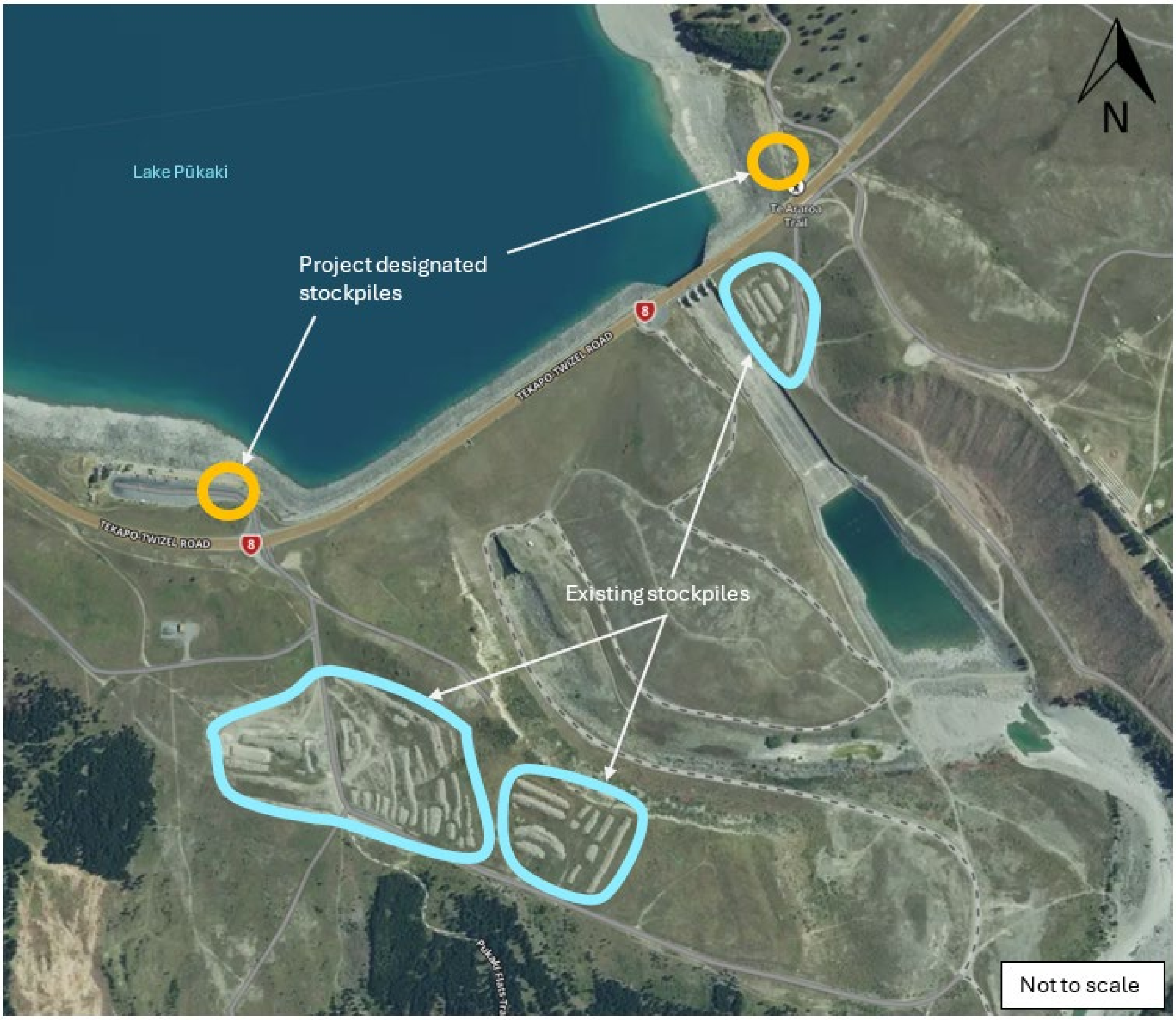


Figure 12 ***Stockpile locations***

As the existing stockpiles are depleted, additional rock will be brought to site from existing quarries within the region. An additional 50,000 tonnes of rock will be required to support lake operation to 513.0 m RL, which includes rip-rap placement to 510.5 m RL plus rip-rap bedding (as required).

Prior to the commencement of active construction, rock will be transported by road trucks to two designated stockpile areas as shown in Figure 12:

– Pūkaki Dam stockpile area at the existing carpark
– Upstream stockpile area on the left abutments

Both stockpile areas shall be managed by a 20-tonne excavator, operated by personnel responsible for directing the stockpiling of different sizes of rock within the stockpile zones. This excavator will also be used to load the rip-rap onto road trucks for delivery to active work areas for final placement.

9.5.5 Dive survey

Uncertainty exists regarding the extent of Zone 10 material on the abutments below 517.0 m RL. A pre-construction dive survey will be conducted at both the left and right abutments to assess the extent and condition of the existing rip-rap protection. The survey will target the vertical range from 517.0 m RL down to 510.5 m RL, encompassing the full depth of the rip-rap zone relevant to the proposed construction interface.

The survey shall be carried out along approved transects, with rip-rap characteristics documented at regular 4 m horizontal intervals. At each interval, divers shall record the following parameters:

– Rip-rap size distribution (e.g. D_{50}, D_{max})
– Stone angularity and interlocking condition
– Presence of voids, displacement, or degradation
– Any signs of undermining or erosion at the toe

Photographic and/or video documentation should supplement the recorded observations to provide visual confirmation of rip-rap condition and placement.

The primary objective of the dive survey is to confirm the final positioning of the construction benches at both abutments. The survey findings will be used to:

– Confirm the extent and condition of the existing rip-rap (Zone 10)
– Identify any areas requiring remedial works prior to bench construction
– Refine the construction methodology and alignment based on actual site conditions

9.6 Construction sequencing

9.6.1 Tranche 1 – Main Dam (rip-rap placement 518.6 m RL to 514.5 m RL)

The primary objective of Tranche 1 construction at the Main Dam is to establish a key toe at 514.5 m RL to facilitate the placement of rip-rap along the upstream face. A minimum 900 mm thick rip-rap bedding will be placed around the cut face of the key toe prior to placement of rip-rap to ensure integration with existing materials.

Key elevations:

– Base of rip-rap bedding = 514.5 m RL
– Base of rip-rap layer = 515.4 m RL

Construction activities will commence upon notification from Meridian, confirming that lake levels are forecast to fall to or below 517.9 m RL and remain at or below that level for a minimum duration of three weeks to provide an adequate work period.

The proposed construction sequence is as follows:

– An existing construction bench, approximately 11 m wide, exists along the Main Dam at 517.3 m RL. The bench is currently covered with approximately 1.2 m thick Zone 10 material, which must be removed to allow access. Machinery access will begin once lake levels reach 517.9 m RL or lower, as the proposed earthmoving equipment is capable of operating in up to 600 mm depth of water (Figure 13 and Figure 14).

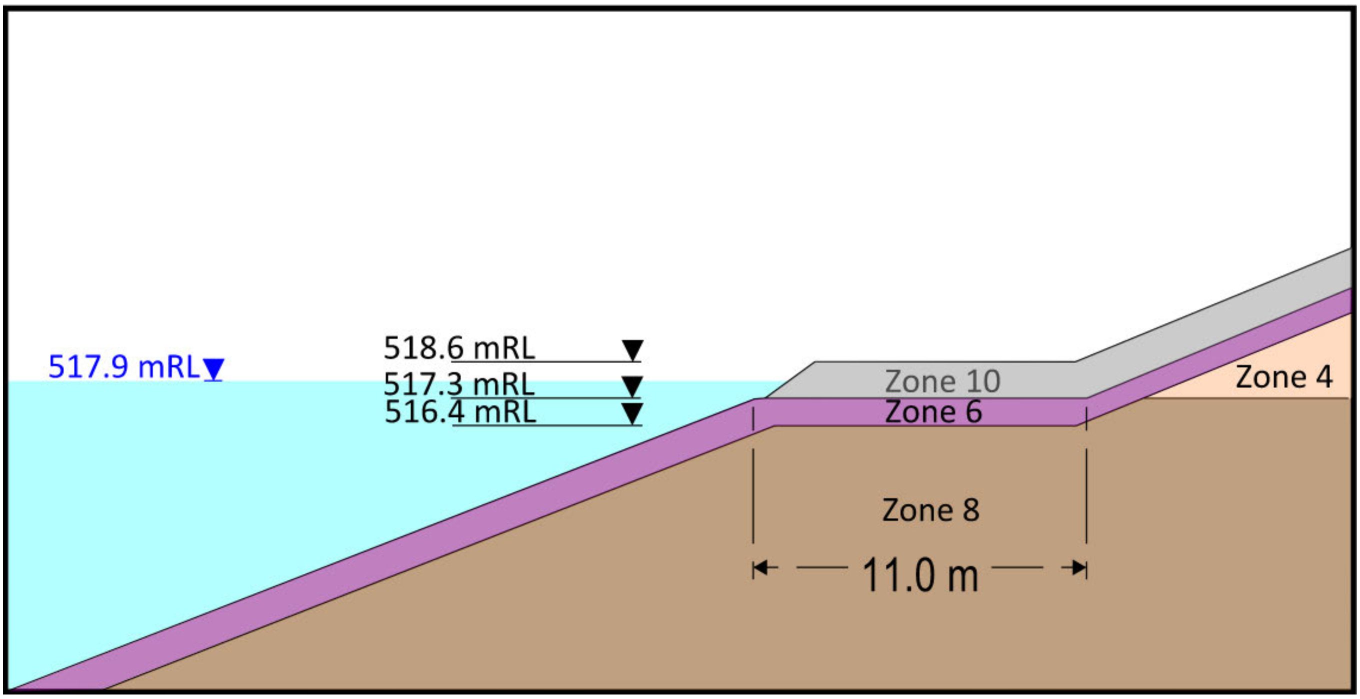


Figure 13 Schematic sketch - cross section at Main Dam upstream showing the existing construction bench (517.3 m RL)

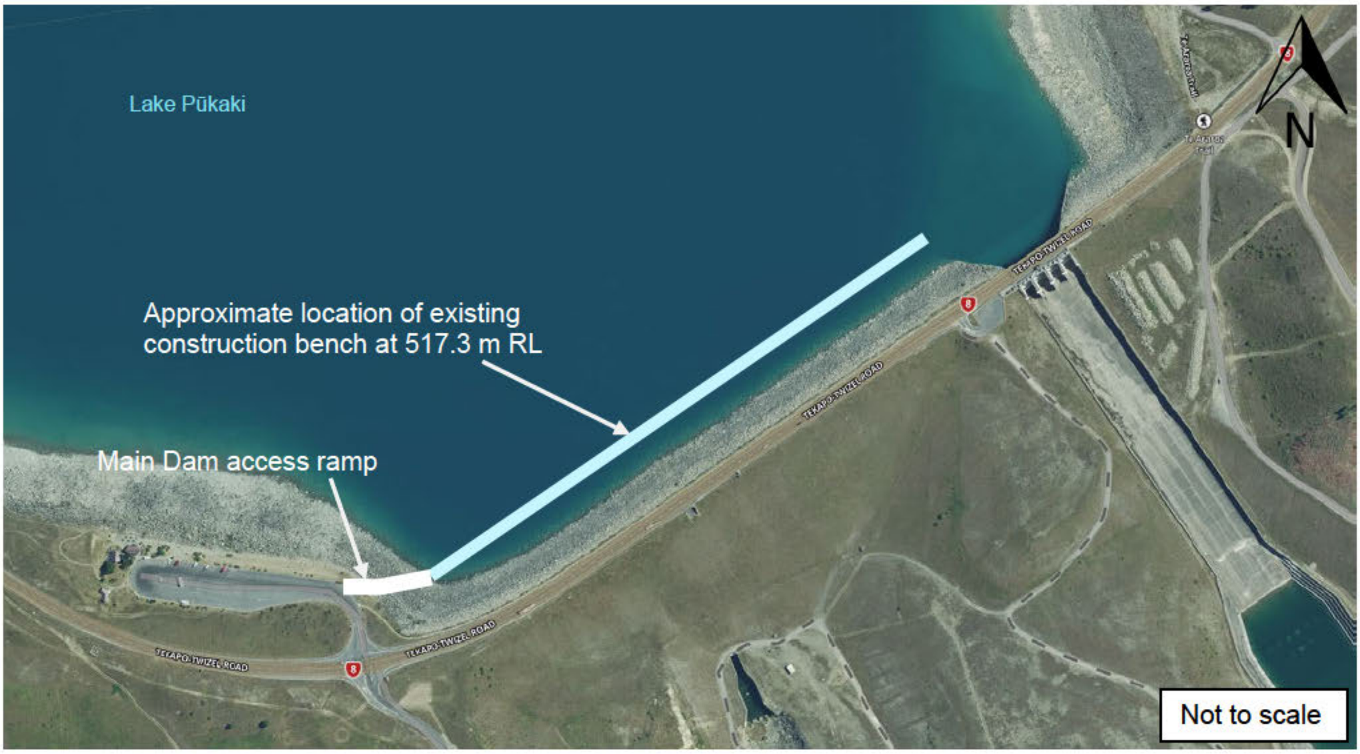


Figure 14 *Site plan (Main Dam) and indicative 517.3 m RL construction bench*

- An approximately 5 m wide strip along the outer edge of the track will be stripped of existing Zone 10 material using a 45-tonne excavator. Material meeting the specified rip-rap grading requirements will be stockpiled upslope for potential reuse (see Figure 15). This process will commence from the constructed access track, which is located near the main carpark, and continue along the full length of the Main Dam. This activity is expected to take 1 week.

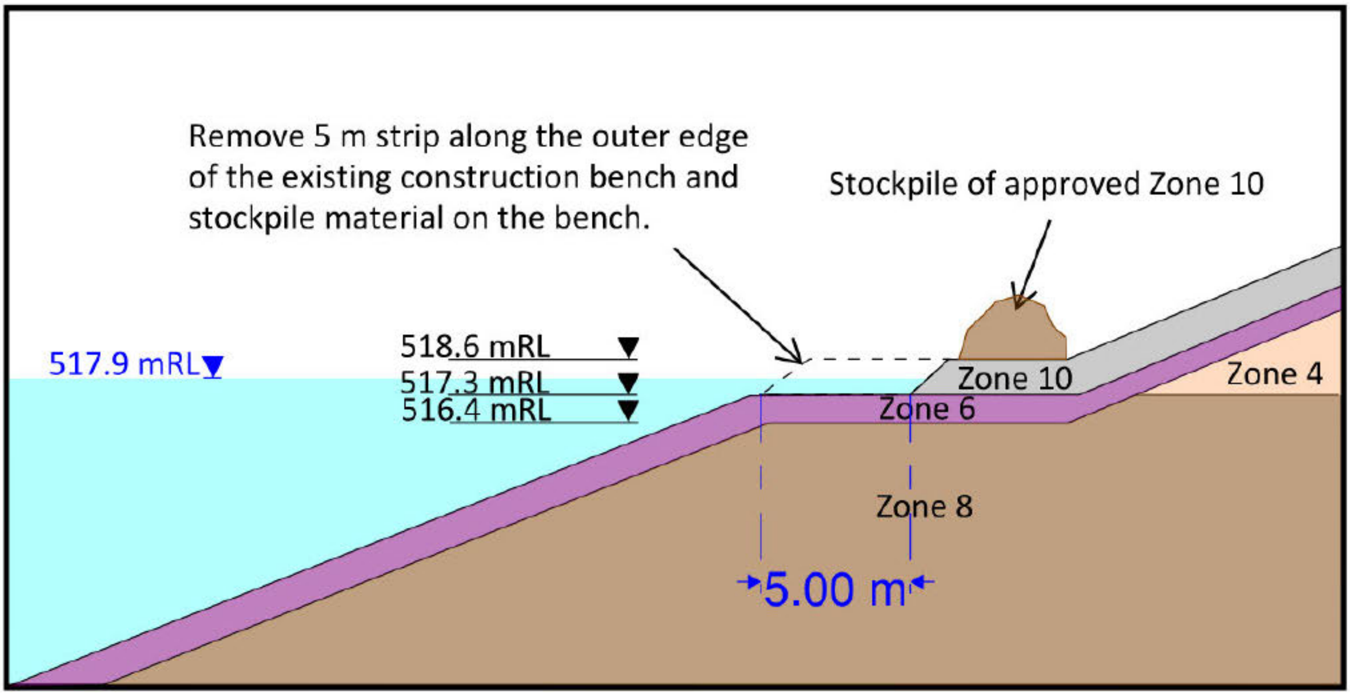


Figure 15 *Schematic sketch – Tranche 1 – Main Dam – establishment of construction bench at 517.3 mRL*

- Construction of the key toe installation and rip-rap placement will proceed in 40 m wide sections, from the true left end of the Main Dam, progressing back toward the access track to minimise exposure to wave action.

- The 45-tonne excavator will be used to remove Zones 6 and 8 materials at 514.5 m RL to form a 2.4 m wide key toe (see Figure 16). The trench will be lined with 900 mm thick rip-rap bedding, keyed into the existing Zone 6 layer above the trench. The excavator has a vertical reach of 2.8 m on the dam face (i.e. reach limit of 7 m on a 1V:2.5H slope). This work can be completed underwater, without requiring lake levels to drop below 514.5 m RL.
- Excavated Zone 6 material may be reused as rip-rap bedding, provided they meet the project's grading specifications.
- Excavated Zone 8 material is to be transported and disposed of at an approved off-site disposal facility.
- Rip-rap will then be placed from the toe trench up the upstream face to 517.3 m RL. This includes replacement of the rip-rap on the construction bench (see Figure 17).
- Each 40 m section is expected to take 1 week to complete.

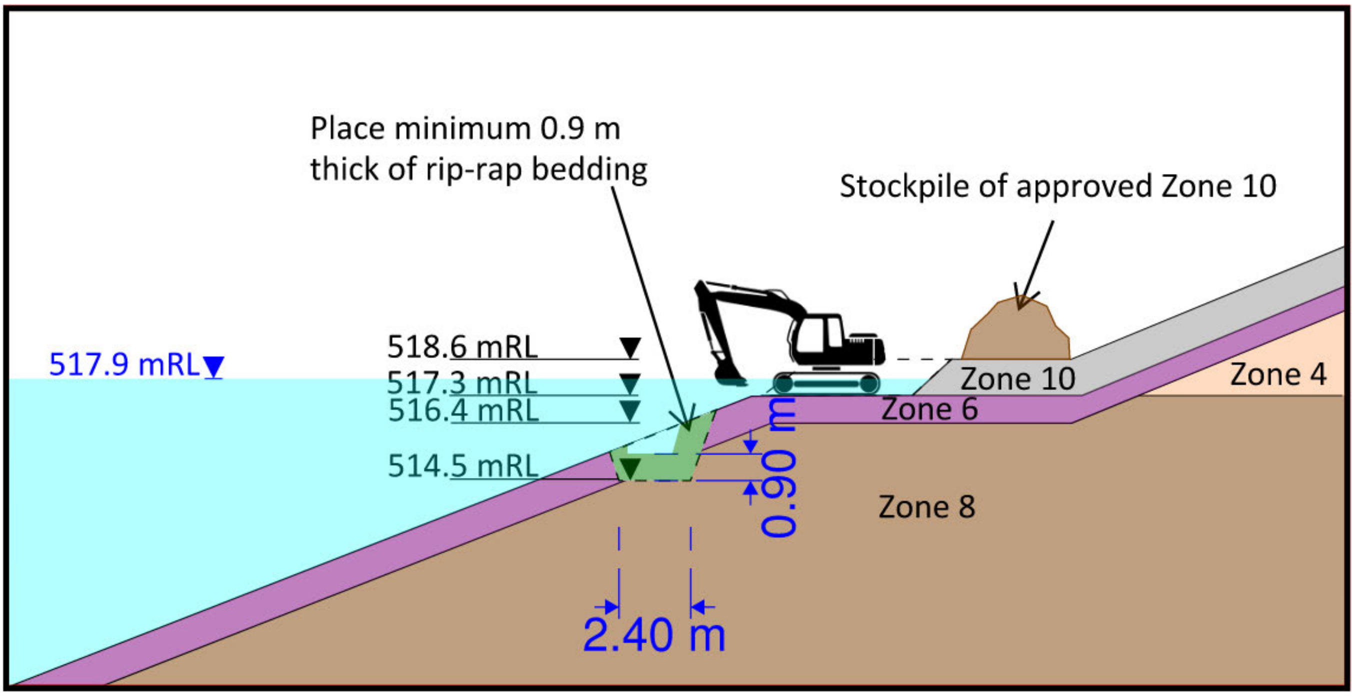


Figure 16 Schematic sketch – Tranche 1 – Main Dam – construction of key toe at 514.5 m RL and installation of rip-rap bedding

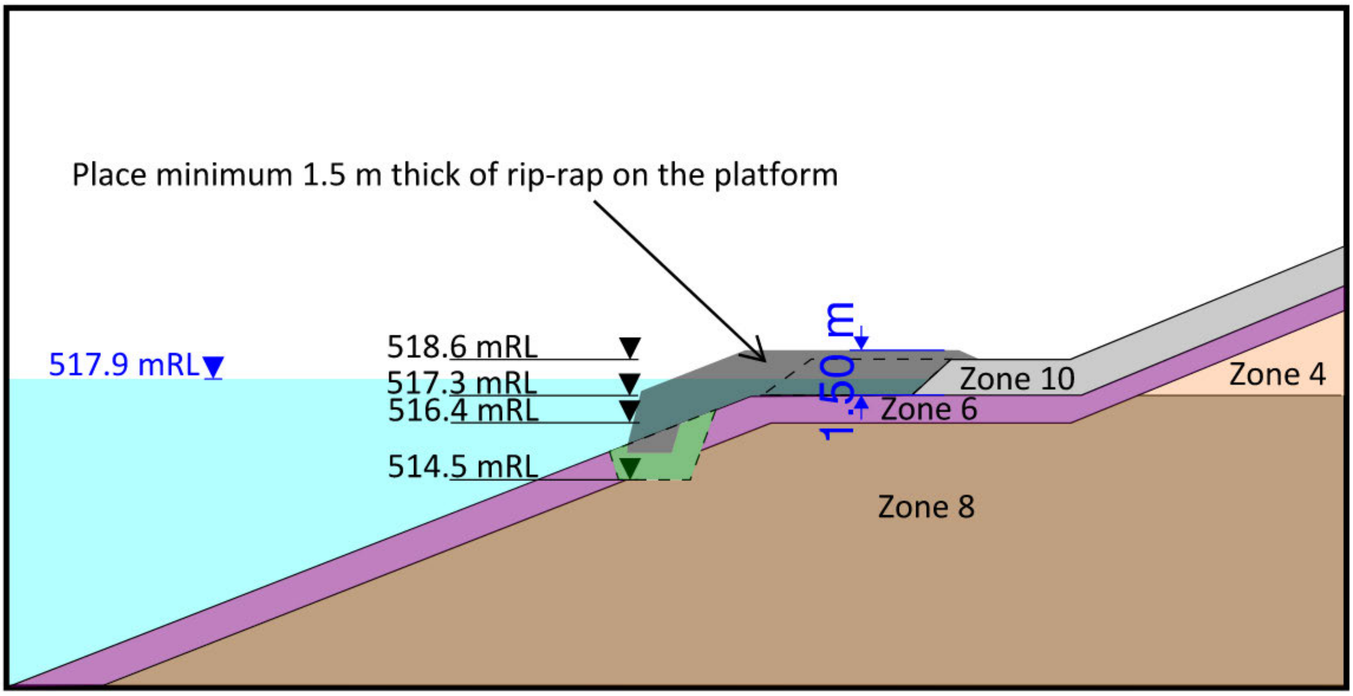


Figure 17 *Schematic sketch – Tranche 1 – Main Dam – installation of rip-rap along upstream face and on the construction bench*

– If significant inflow rainfall events are imminent and lake level is predicted to rise, and where work from the 517.3 m RL has not been completed, it will be necessary to close the site by backfilling the excavated key toe with rip-rap bedding and rip-rap; and reinstating rip-rap rock on the 517.3 m RL bench. This will be done using either:
  - rock stored on the bench to be placed back into its original position; or
  - where rock stored on the bench has been used for placement down to 515.4 m RL it will be replaced with stockpiled rock. This process is expected to take 5 days.
  - Other demobilization activities are outlined in Section 9.7.

9.6.2 Tranche 1 – left and right abutment (rip-rap placement 517.0 m RL to 513.0 m RL)

The primary objective of Tranche 1 construction at the left and right abutments is to establish a key toe at 513.0 m RL to facilitate the placement of rip-rap along the abutment slope. A minimum 600 mm thick rip-rap bedding will be placed around the cut face of the key toe prior to placement of rip-rap to ensure integration with existing materials.

Key elevations:

– Base of rip-rap bedding = 513.0 m RL
– Base of rip-rap layer = 513.6 m RL

It is assumed that Tranche 1 construction for the left and right abutments will be undertaken concurrently with the Main Dam Tranche 1 construction.

The proposed construction sequence is as follows:

– Machinery will be able to commence access to the abutments when lake levels reach 517.9 m RL as the proposed earth moving equipment is capable of operating in up to 600 mm depth of water.
– There is no existing construction bench along the abutments (see Figure 18). A new construction bench will be formed at 517.3 m RL using a 45-tonne excavator, following a cut-and-fill methodology, with excavation restricted to Zone 10 material only (see Figure 19). Cutting into existing Zones 6 and/or 8 will not be

permitted. Excavated Zone 10 material may be reused to extend the construction bench by placing it along the shoulder.

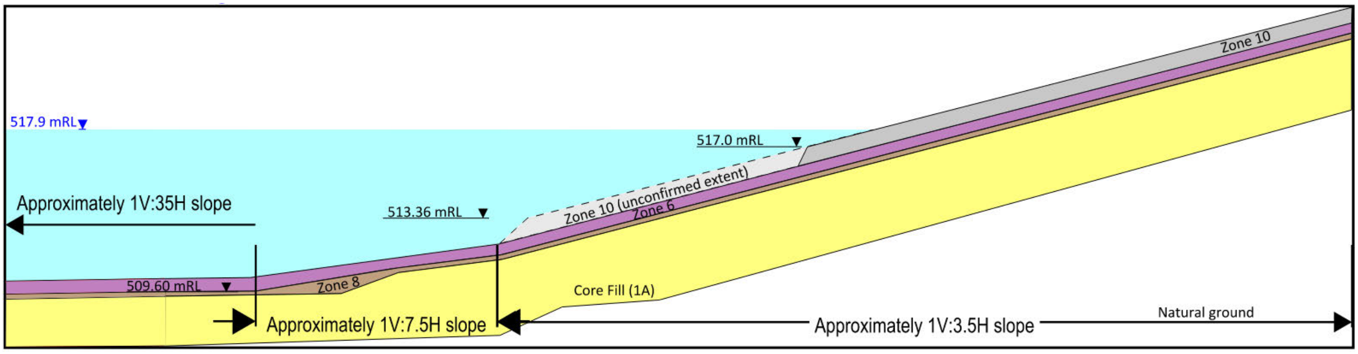


Figure 18 Schematic sketch – existing cross section at abutments

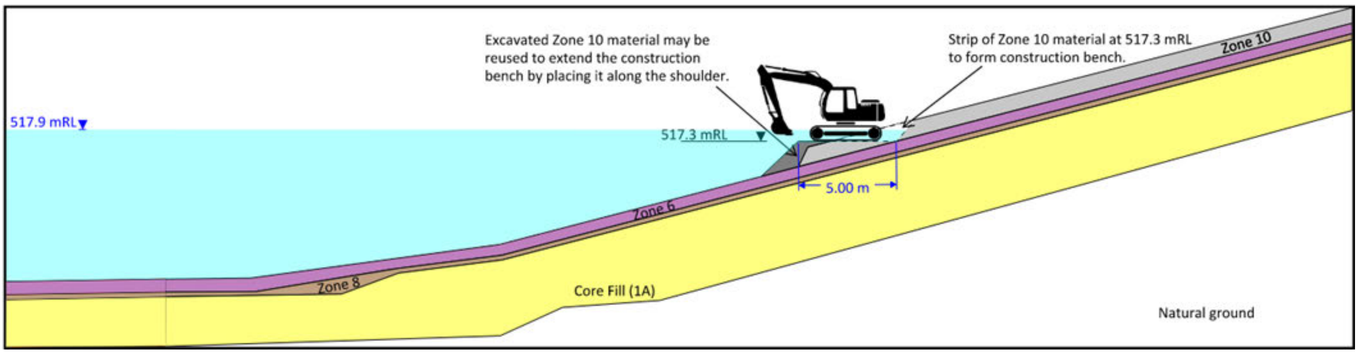


Figure 19 Schematic sketch – Tranche 1 – abutments – establishment of construction bench at 517.3 m RL – Not to Scale

– The construction bench will be established along the full length of each abutment (see Figure 20) with excavated rip-rap placed at 15 m intervals to start the formation of the groynes. Imported granular material will be placed on the excavated bench as a running course for construction. This process is expected to take 1 week.

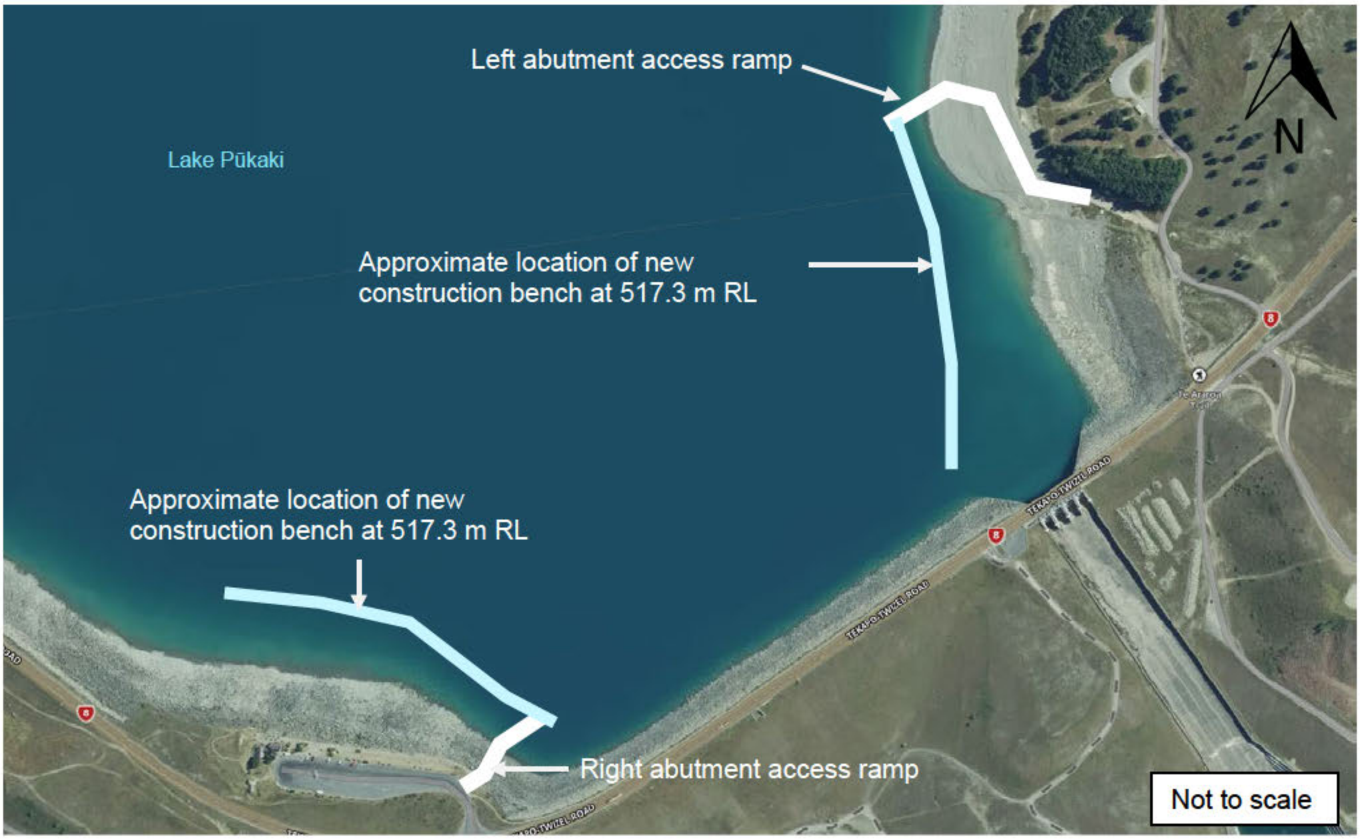


Figure 20 Site plan (abutments) and indicative 517.3 m RL construction bench

– Once the construction bench is formed, the 45-tonne excavator will extend the first groyne perpendicular to the abutment face using additional imported rock. Work will commence at the groyne furthest away from the access ramp and progress backwards. The slope of the abutments is considerably flatter than the Main Dam and the groyne is required to allow the excavator to reach the base of the toe trench. The groynes will have a minimum width of 5 m (see Figure 21).

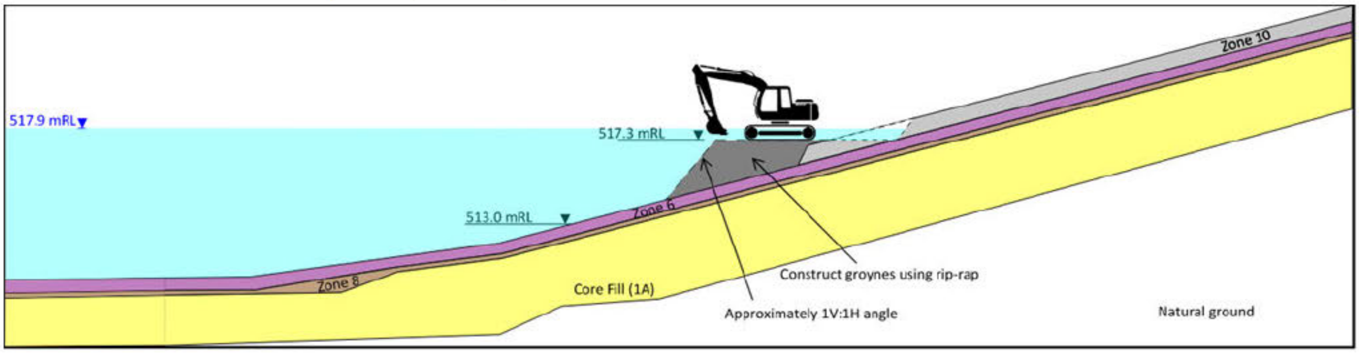


Figure 21 Schematic sketch – Tranche 1 – abutments – construction of groynes perpendicular to the abutment face – Not to Scale

– Once the first full groyne has been established, a minimum 2.1 m wide toe trench will be excavated to 513.0 m RL and a 600 mm layer of rip-rap bedding placed in the trench to marry into the existing Zone 6 layer (see Figure 22).

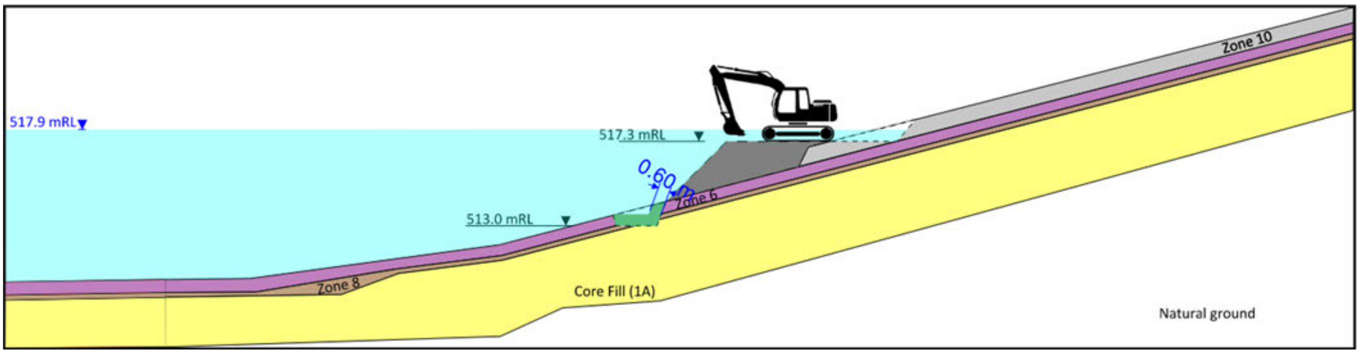


Figure 22 ***Schematic sketch – Tranche 1 – abutments - construction of key toe at 513.0 m RL and installation of rip-rap bedding – Not to Scale***

- The excavator will then deconstruct the groyne as it moves back towards the construction bench, placing a minimum 1.5 m thick rip-rap in the toe trench and up the face of the abutment to 517.3 m RL. This will include replacing the removed rip-rap on the construction bench at 517.3 m RL and marrying in with the upslope materials (see Figure 23).

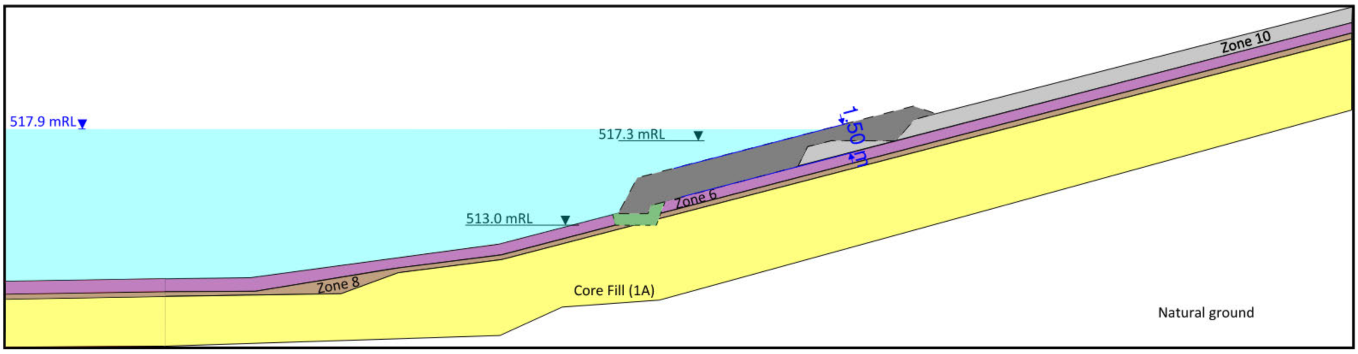


Figure 23 ***Schematic sketch – Tranche 1 – abutments – installation of rip-rap along upstream face and backfilling of construction bench – Not to Scale***

- Work will progress backwards towards the abutment access track. Each groyne will be used to access an approximately 15 m section of the abutment. The construction sequence for each groyne and associated 15 m section of abutment is expected to take 4 days.
- In the event of imminent significant rainfall inflow and rising lake level, and where Tranche 1 works remain incomplete, the following protective measures shall be implemented prior to site demobilisation:
  - Backfill the excavated key toe with a minimum 0.6 m thick rip-rap bedding and a minimum of 1.5 m thick rip-rap
  - Reinstate a minimum of 1.5 m thick rip-rap along the face of the abutment to 517.3 m RL.
  - Place a minimum of 1.5 m thick of rip-rap on the construction bench at 517.3 m RL.
  - The groynes will remain in place until the next low lake level event allows access to the site.
  - Other demobilization activities are outlined in Section 9.7.

9.6.3 Tranche 2 – rip-rap placement

Following the completion of Tranche 1 work, construction activities for Tranche 2 may commence. Access to Tranche 2 will require lake levels to reach a minimum of 513.0 m RL.

9.6.3.1 Main Dam (rip-rap placement 513.0 m RL to 510.5 m RL)

The primary objective of Tranche 2 construction at the Main Dam is to establish a key toe at 509.6 m RL to facilitate the placement of rip-rap along the targeted upstream face to a minimum depth of 510.5 m RL. A minimum 900 mm thick rip-rap bedding shall be placed around the cut face of the key toe prior to placement of rip-rap to ensure integration with existing materials.

Key elevations:

- Base of rip-rap bedding = 509.6 m RL
- Base of rip-rap layer = 510.5 m RL

Currently, no existing work bench provides access for Tranche 2 works. A new bench must be constructed. The proposed sequence of work is as follows:

- Extend the existing ramp to 512.4 m RL (see Figure 24).

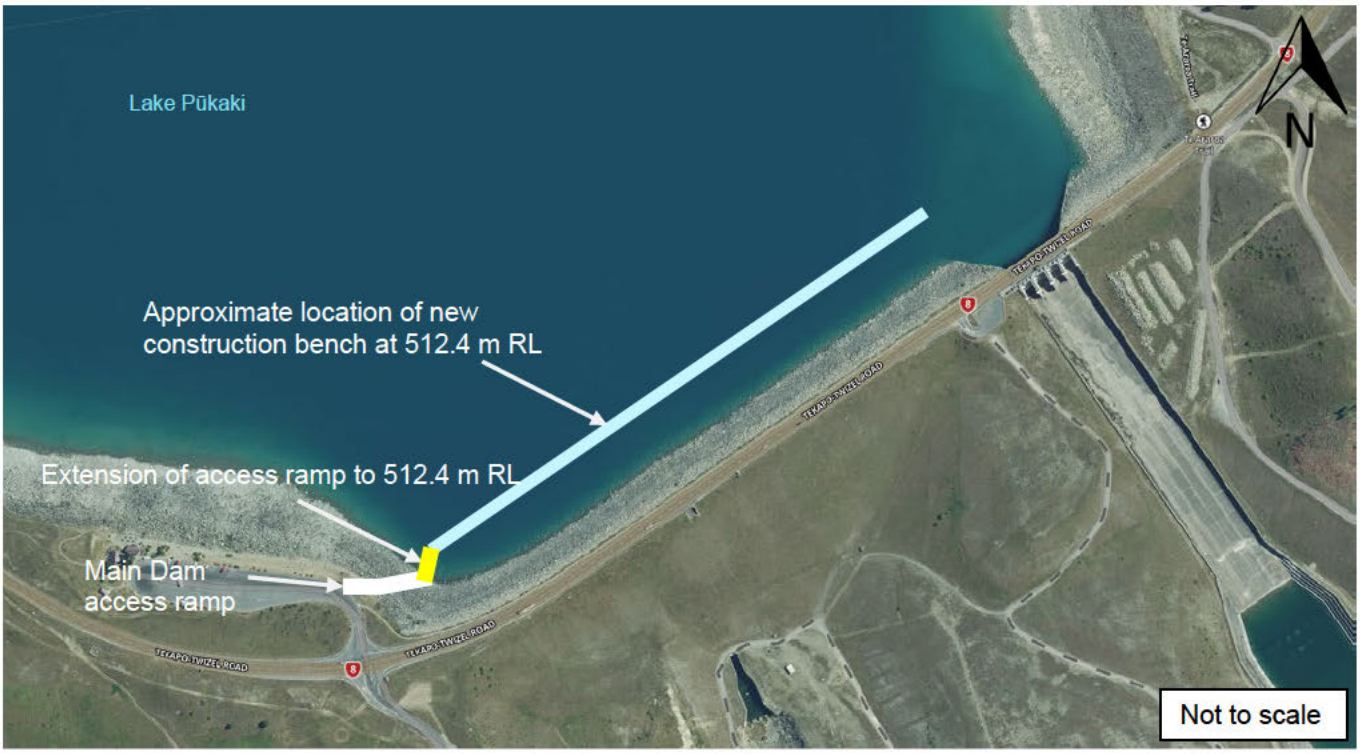


Figure 24 Site plan (Main Dam) and indicative 512.4 m RL construction bench

- Create a 7.3 m wide construction bench at 512.4 m RL through excavation into Zones 6 and 8.
  - Excavated Zone 6 material may be reused as rip-rap bedding, provided they meet the project's grading specifications.
  - Excavated Zone 8 material is to be transported and disposed of at an approved off-site disposal facility.
  - A 900 mm thick rip-rap bedding shall be placed on the bench and along cut face to marry into the existing Zone 6 layer above the bench (see Figure 25). Bedding placement shall occur immediately after exposure of Zone 8.

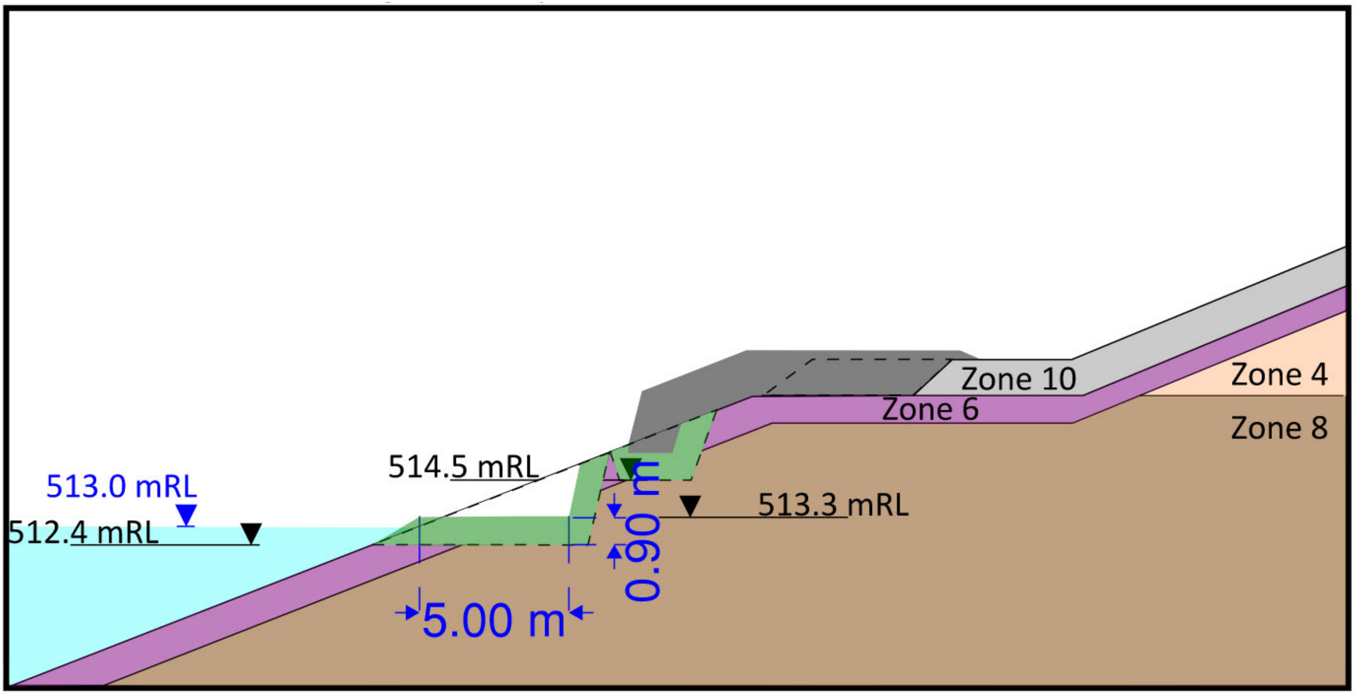


Figure 25 ***Schematic sketch – Tranche 2 – Main Dam – establishment of construction bench at 512.4 m RL and placement of rip-rap bedding on construction bench and up the cut face – Not to Scale***

– A long-reach excavator (with reach limit of 15 m) will be used to remove existing Zones 6 and 8 materials at 509.6 m RL to create a 2.4 m wide key toe for rock placement (See Figure 26).
  - Excavated Zone 6 material may be reused as rip-rap bedding, provided they meet the project's grading specifications.
  - Excavated Zone 8 material is to be transported and disposed of at an approved off-site disposal facility.
  - The trench will be lined with 900 mm of rip-rap bedding, integrated with the Zone 6 layer above.

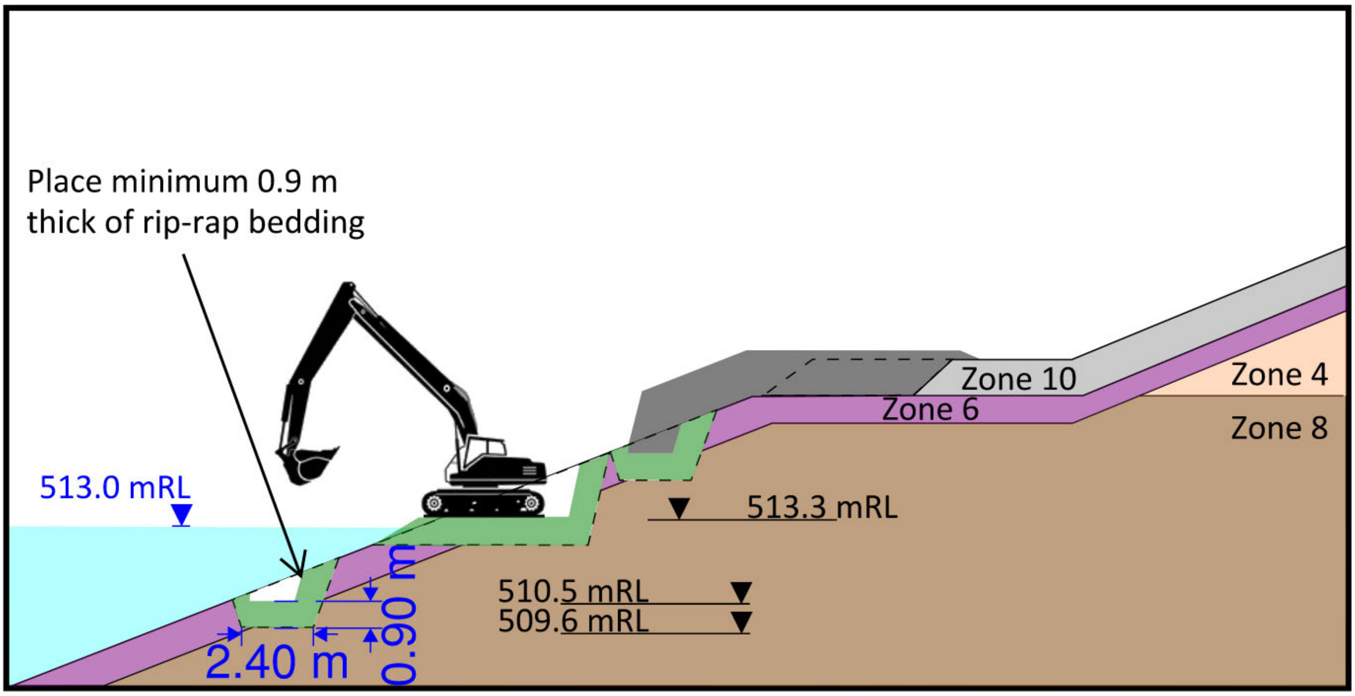


Figure 26 ***Schematic sketch – Tranche 2 – Main Dam – construction of key toe and installation of rip-rap bedding – Not to Scale***

– Rip-rap will then be placed in the toe trench and up the face of the dam to 514.5 m RL and across the 5 m bench to tie into the upslope Zone 10 material (see Figure 27). This can be done using a 45-tonne excavator.

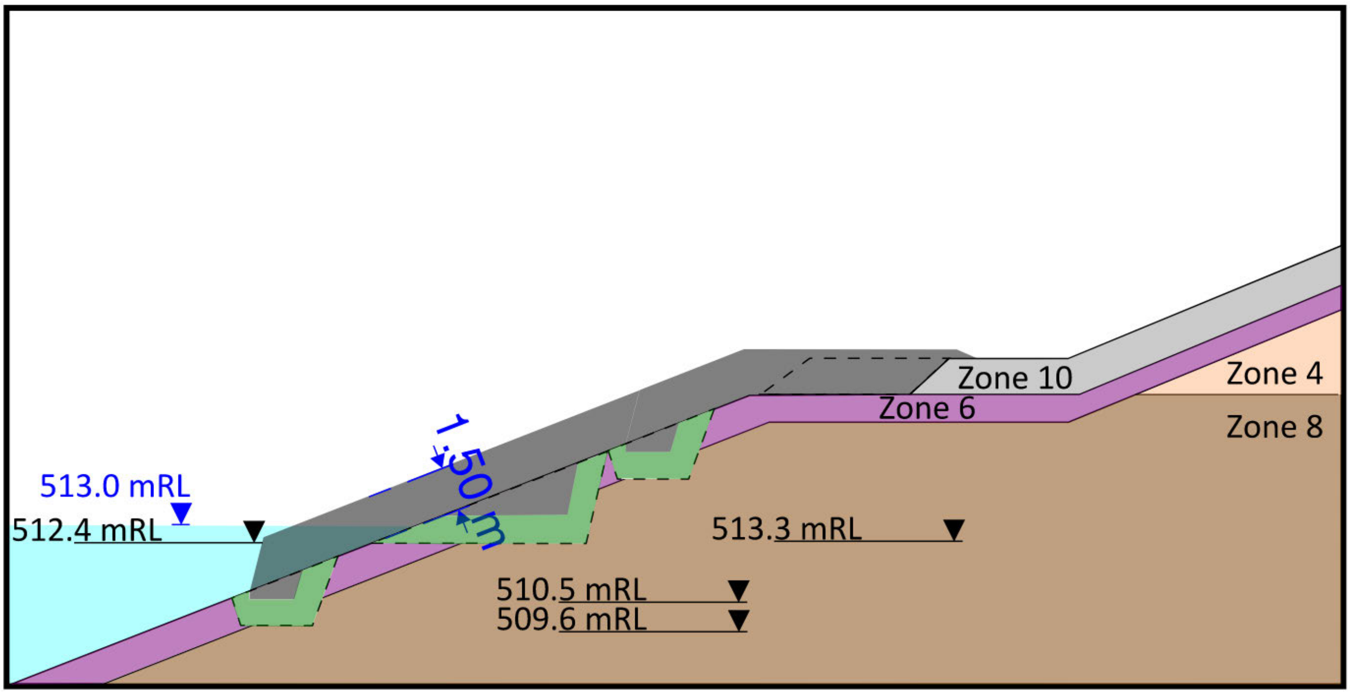


Figure 27 Schematic sketch – Tranche 2 – Main Dam – Placement of rip-rap and backfilling of construction bench – Not to Scale

– In the event of imminent significant rainfall inflow and rising lake levels, and where Tranche 2 works remain incomplete, the following protective measures shall be implemented prior to site demobilisation:
  - Backfill the excavated key toe with a minimum of 0.9 m thick rip-rap bedding and a minimum of 1.5 m thick rip-rap
  - Reinstate a minimum of 1.5 m thick rip-rap along the face of the abutment to 513.3 m RL.
  - Place a minimum of 1.5 m thick of rip-rap on the construction bench at 513.3 m RL.
  - Upslope of the construction bench where Zone 6 or rip-rap bedding is exposed, a minimum of 1.5 m thick rip-rap shall be placed in front to prevent wave attack.

  Upon recommencement of works, previously placed rip-rap may be reused in the continued construction of Tranche 2.

Other demobilization activities are outlined in Section 9.7

9.6.3.2 Abutments (rip-rap placement 513.0 m RL to 510.5 m RL)

The primary objective of Tranche 2 construction at the left and right abutments is to install a minimum of 1.5 m thick of rip-rap at 510.5 m RL. In areas where the existing slope geometry may compromise the stability of the rip-rap, such as steeper gradients, a key toe detail shall be incorporated. This detail shall mirror the design used in Tranche 1 abutments. In flatter terrain where the risk of rip-rap movement is minimal, a key toe is not required.

Key elevations:

– Base of rip-rap layer = 510.5 m RL

Currently, no existing work bench provides access for Tranche 2 works. A new bench must be constructed. The proposed sequence of work is as follows:

– Extend the existing ramp to 513.4 m RL (see Figure 28).

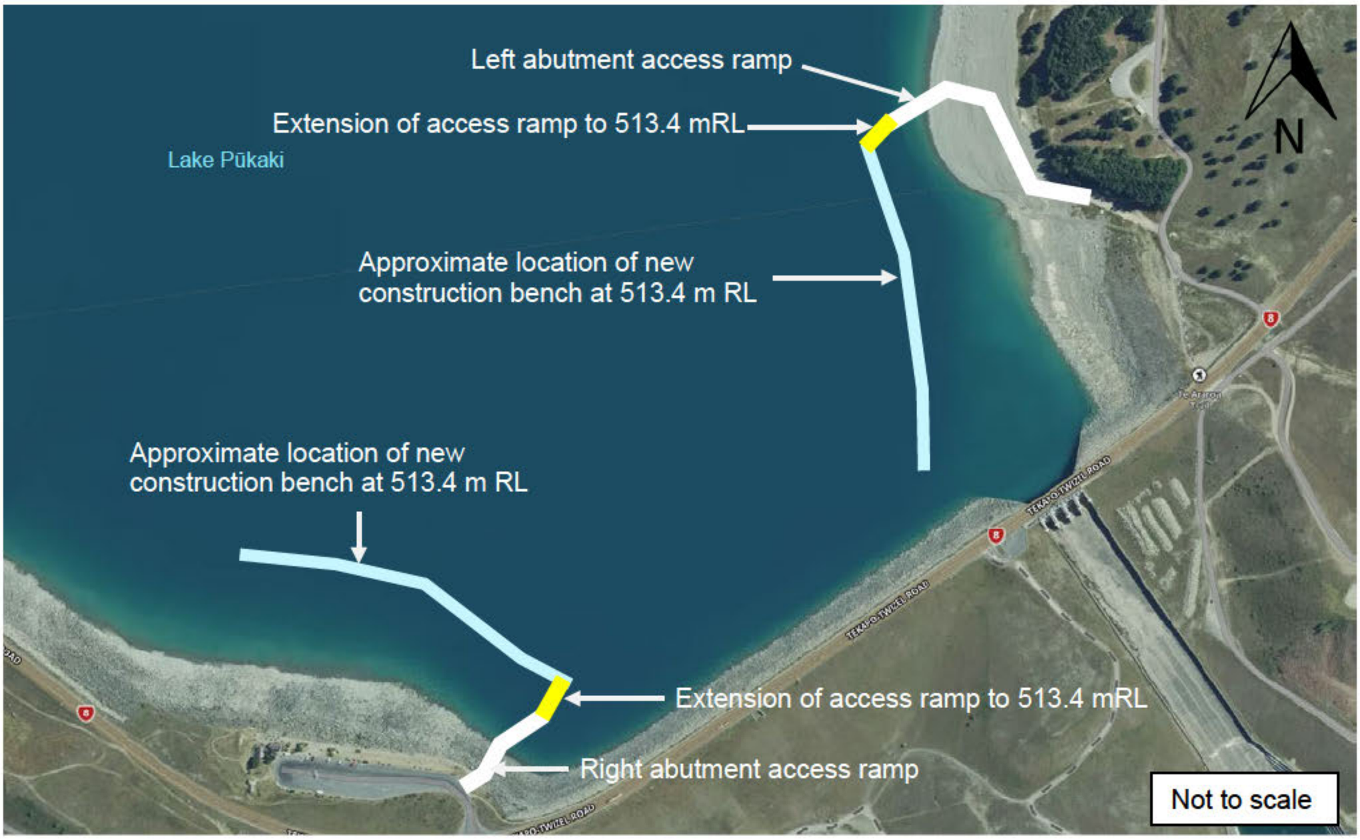


Figure 28 Site plan (abutments) and indicative 513.4 m RL construction bench

- Establish construction bench along the abutments. A new construction bench shall be formed at 513.4 m RL using a 45-tonne excavator, following a cut-and-fill methodology, with excavation restricted to Zone 10 material only (see Figure 29). Cutting into existing Zones 6 and/or 8 is not permitted. Excavated Zone 10 material may be reused to extend the construction bench by placing it along the shoulder.

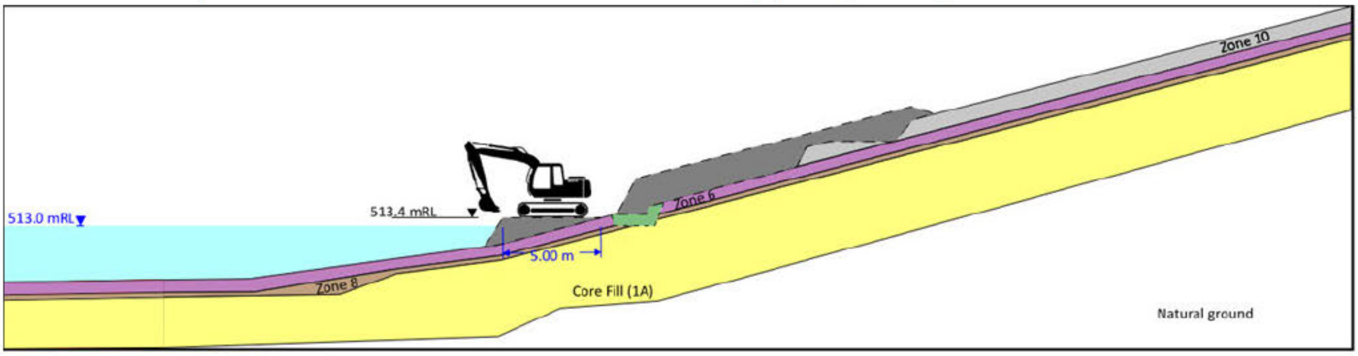


Figure 29 Schematic sketch – Tranche 2 – abutments – establishment of construction bench at 513.4 m RL – Not to Scale

- The construction bench will be established along the full length of each abutment (see Figure 28) with excavated rip-rap placed at 15 m intervals to start the formation of the groynes. Imported granular material will be placed on the excavated bench as a running course for construction. This process is expected to take 1 week.
- Once the construction bench is formed, the 45-tonne excavator will extend the first groyne perpendicular to the abutment face using additional imported rock. Work will commence at the groyne furthest away from the access ramp and progress backwards. The slope of the abutments is considerably flatter than the Main Dam and the groyne is required to allow the excavator to reach the base of the toe trench. The groynes will have a minimum width of 5 m (see Figure 30)

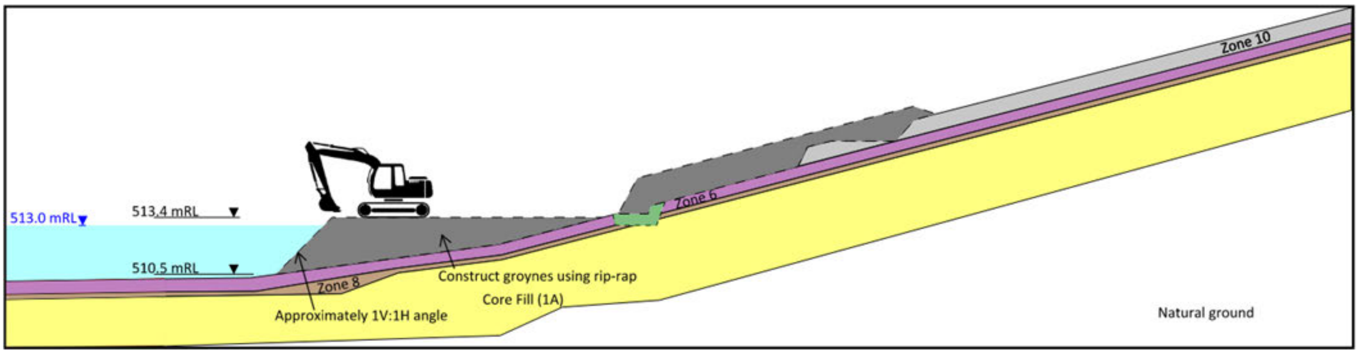


Figure 30 Schematic sketch – Tranche 2 – abutments – construction of groynes – Not to Scale

– Once the groyne has been established, if a key toe is not required, a minimum 1.5 m thick rip-rap will be placed at 510.5 m RL. The excavator will then deconstruct the groyne as it moves back towards the construction bench, placing a minimum 1.5 m thick rip-rap up the face of the abutment to 513.4 m RL. This will include replacing the removed rip-rap on the construction bench at 513.4 m RL and marrying in with the upslope materials (see Figure 31).

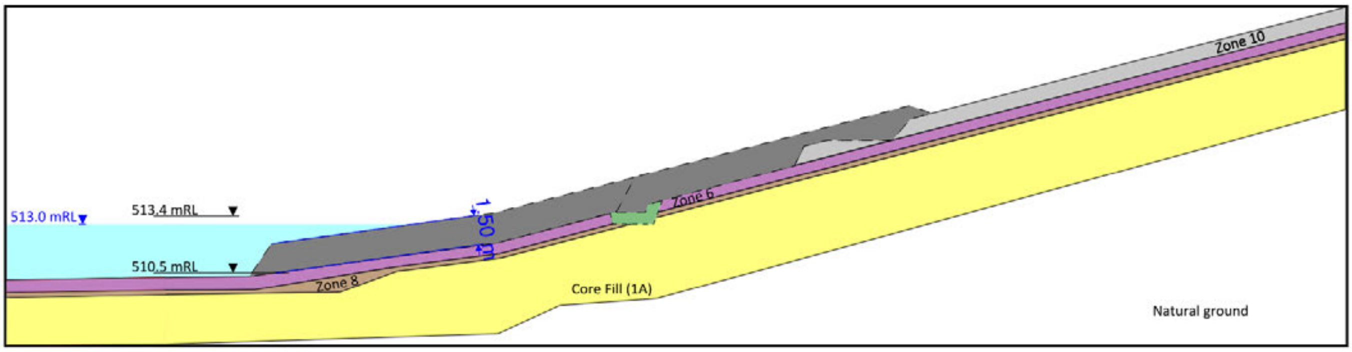


Figure 31 Schematic sketch – Tranche 2 – abutments – placement of rip-rap and backfilling of construction bench – Not to Scale

– Work will progress backwards towards the abutment access track. Each groyne will be used to access an approximately 15 m section of the abutment. The construction sequence for each groyne and associated 15 m section of abutment is expected to take 4 days.

– In the event of imminent significant rainfall inflow and rising lake level, and where Tranche 2 works remain incomplete, the following protective measures shall be implemented prior to site demobilisation:

  - Place a minimum of 1.5 m thick of rip-rap on the construction bench at 513.4 m RL.
  - The groynes will remain in place until the next low lake level event allows access to the site.

9.7 Demobilisation

In addition to the specific demobilisation activities identified in Section 9.6 the following will be undertaken:

9.7.1 Temporary Reinstatement of Site

In the event of imminent significant rainfall and associated rising lake level, and where works remain incomplete, the following measures will be implemented:

- Removal of any temporary stockpiles created during works and replacement of stockpile rock material from commercial quarries, as required.
- Re-grassing of rock stockpile areas to match surrounding existing land. This is to be progressively undertaken as works progress to minimise the duration that areas are left as bare ground.

- Temporary protection of created access ramps with zone 10 materials (rip-rap) out of the construction season to minimise erosion.

9.7.2 Final Reinstatement of the site

Once all works described in Section 9.6 are compete the following will be implemented:

– Removal of access ramps and permanent reinstatement with zone 10 materials (rip-rap).
– Complete re-grassing of stockpile areas and associated tracks
– Removal and reinstatement of all ESC features including silt fences and silt ponds once re-grassing has been completed.

Note stockpiles may be retained beyond the end of the works associated with this project to provide a source of material for other ongoing maintenance projects associated with the wider Lake Pūkaki engineering structures.

9.8 Proposed equipment

The following equipment, or equivalent alternatives, is expected to be required to complete the proposed works. This assessment assumes that construction activities will be undertaken concurrently across all three work zones: the Main Dam, Left Abutment, and Right Abutment.

Table 18 Proposed equipment list

Task	Resource	Number
Transferring rock to project designated stockpile areas	27-tonne road truck	3
Sorting and loading rock from stockpile area	20-tonne excavator	2
Enabling and construction of Tranche 1 works on Main Dam, left abutment and right abutment	45-tonne excavator Long-reach excavator	3 0
Enabling and construction of Tranche 2 works on Main Dam, left abutment and right abutment	45-tonne excavator Long-reach excavator	3 1
Carting gravel and rock to/from Main Dam and right Abutment	11-tonne road truck	3

10. Intake Dam construction methodology

The Intake Dam and its associated rip-rap will be inspected by qualified divers, subject to health and safety constraints. Given that this structure serves as the primary outlet from the lake, an outage would be required to complete a full inspection.

The primary objective of these inspections is to verify that the existing rip-rap size and extent are suitable for continued operation under reduced lake levels. Based on available as-built documentation, it is anticipated that no significant additional rip-rap placement will be required at this location. Should any remedial work be necessary, it is expected to be relatively minor in scope when compared to the interventions planned for the main dam and its abutments.

In the event works are required, to facilitate access for inspection and potential maintenance, construction of access tracks to both ends of the Intake Dam may be required. These tracks will be developed using methods consistent with those employed for the Main Dam and its abutments. The indicative access tracks are shown in Figure 32.

Figure 32 Intake Dam access tracks

11. Quality control

Rip-rap bedding material and rip-rap rock are essential components for the project. They will need to comply with the specific grading limits and be subjected to the required testing protocols to ensure suitability for use.

The contractor will be provided with design documents and a testing program for the project along with a proposed approach for material placement and any compaction requirements.

Existing Zone 6 material can be reused as the rip-rap bedding within the key toe. If additional rip-rap bedding is required, the imported fill shall satisfy the grading limit of Zone 6 material.

Rip-rap material shall meet the following gradation criteria:

– Maximum 10% by weight passing the 75 mm sieve
– D_{15} of 500 mm
– D_{50} of 1,000 mm
– Maximum particle size of 1,500 mm

In addition to gradation, the rip-rap must comply with all specified physical and durability testing requirements to confirm its performance under operational and environmental conditions.

The final design parameter will be confirmed as part of the Building Consent application process.

11.1 Environmental management

The Contractor will be responsible for preparing and finalizing a Construction Environmental Management Plan (CEMP) for the project. This will encompass sediment control, spill prevention, dust control, and protocols for machinery operating in water. As part of this an Erosion and Sedimen Control Plan (ESCP) has been prepared to support the application documentation and provides information on the key components of the plan and the issues that will be addressed (GHD 2025A).

11.2 Weather and wave conditions

Construction should be scheduled during periods of low wind and wave activity where possible, to minimise risk and improve placement accuracy.

12. Dam safety assessment

A review of the proposed lake levels changes with respect to previously completed dam safety assessments has been completed for the project and is presented in the following section. This has primarily been included to provide background information for the natural hazards assessment included in Section 13.

It is noted that dam safety issues are matters regulated under the Building (Dam Safety) Regulations 2022 rather than the RMA or Fast-Track Approvals Act. As noted in Section 2 of this report, Meridian will be applying for a building consent for the armouring works in due course.

12.1 Basis of assessment

The effects on dam safety of the following items have been assessed:

1. Operating the lake at a lower level (513.0 m RL).
2. Dam protection works, i.e. the construction of additional rip-rap protection for the Main Dam for lake levels between 518.0 m RL and 513.0 m RL.

The effects have been assessed by reviewing the two items with respect to recent dam safety assessments reported in:

1. Pickford, T., Grilli, J., & Pott, J. (2024). Pūkaki Reservoir Comprehensive Dam Safety Review. (2024 CDSR)
2. Dam Safety Intelligence Limited. (2024). Pūkaki Reservoir 2024 Annual Dam Safety Review. (2024 ADSR)

12.2 Review of Potential Failure Modes

The 2024 CDSR included review of the Potential Failure Modes (PFM) applicable for the Main Dam, diversion culvert, spillway and Intake Dam. The CDSR includes a summary of the 20 known PFMs in three tables covering the dams and appurtenant structures (Tables 7.1 to 7.3). A postulated and additional PFM is in the text of the CDSR resulting in a total of 21 PFMs. We understand the PFMs were determined by Meridian and third parties via Failure Modes and Effects Analysis workshops.

The effects on dam safety of the dam protection works and operating the lake at a lower level have been assessed by reviewing their effects on the PFMs in the 2024 CDSR. Refer to Table 19 where there is commentary on the effects on each PFM of a lower lake level (513.0 m RL) and the dam protection works.

The PFMs in the 2024 CDSR were categorised using the Federal Energy Regulatory Commission (FERC) classification system:

- Category I: Credible - highlighted PFM.

  Those PFMs where the physical possibility is evident, a fundamental flaw or weakness is identified, and conditions and events leading to the failure seem reasonable and credible.
- Category II: Credible - PFMs considered but not highlighted.

  Those PFMs that are judged to be of lesser significance and likelihood.
- Category III: Not enough information - More information or analyses are needed in order to classify.

  Those PFMs where insufficient information is available to allow a confident judgement of their significance.
- Category IV: Not Credible - Potential Failure Mode Ruled Out.

  Those PFMs that are considered to be not credible.

Table 19 Potential Failure Modes taken from 2024 CDSR with commentary on effects of a lowered lake level and the proposed dam protection works in right hand column

Asset	PFM No.	Loading	PFM Description	Effects of lowered lake level and proposed dam protection works
Main Dam and diversion culvert	Category I – credible, PFM highlighted			
	1	Post-extreme seismic	**Overtopping of the core –** initiated by inoperable gates and a rise of the reservoir level above the top of the core, resulting in seepage and erosion which overwhelms the chimney drain, unravelling of the dam toe, and a breach of the embankment.	Lowered lake levels (518.0 m RL and 513.0 m RL) will not overtop the top of core (537.14 m RL). Construction of protection works on upstream face will not damage the upstream face impermeable blanket and rip-rap placement is designed to protect the upstream face and blanket. Therefore the lowered lake level and protection works lower the risk of the PFM occurring.
	Category II – credible, PFM not highlighted			
	2	Intermediate seismic, extreme seismic, and post-extreme seismic	**Internal erosion along embankment/spillway structure interface –** initiated by a concentrated leak along the embankment/gate structure interface and a failure of the filter to arrest erosion, resulting in continued erosion and a breach of the embankment.	There is a 6m deep seepage cutoff trench located below the spillway gate structure slab indicates seepage mitigation design intent for a lowered reservoir level. The spillway slab invert level is 520.38 m RL and the seepage cutoff base level is 511.8 m RL. Lowered lake levels (518.0 m RL and 513.0 m RL) will reduce seepage pressures through the main dam and reduce the risk of a concentrated leak along the embankment/gate structure interface. Construction of protection works on upstream face will not damage the upstream face impermeable blanket and rip-rap placement is designed to protect the upstream face and blanket. Therefore the lowered lake level and protection works lower the risk of the PFM occurring as the PFM becomes none credible as the lake level is below the sill level of 520.38 m RL.
	3	Post-extreme seismic	**Failure of the diversion culvert bulkhead –** initiated by insufficient strength to safely accommodate long-term loading conditions, resulting in structural failure, an uncontrolled release of the reservoir though the culvert, leakage through open joints along the culvert, erosion along the outside of the culvert, and a collapse of the overlying embankment.	Lowered lake levels (518.0 m RL and 513.0 m RL) will reduce hydraulic loading on the bulkhead. Construction of protection works on upstream face will not affect the bulkhead. Therefore the lowered lake level and protection works lower the risk of the PFM occurring.

Asset	PFM No.	Loading	PFM Description	Effects of lowered lake level and proposed dam protection works
	Category III – insufficient information			
	4	All	**Internal erosion into the diversion culvert –** initiated by internal erosion of core material into the diversion culvert through the culvert joints, resulting in the formation of a sinkhole, a linkage from the sinkhole to the reservoir and a breach of the embankment.	Lowered lake levels (518.0 m RL and 513.0 m RL) will reduce seepage pressures through the main dam and reduce the risk of internal erosion of core material into the diversion culvert. Construction of protection works on upstream face will not damage the upstream face impermeable blanket and rip-rap placement is designed to protect the upstream face and blanket. Therefore the lowered lake level and protection works lower the risk of the PFM occurring.
	5	All	**Internal erosion along the diversion culvert –** initiated by a concentrated leak adjacent to the culvert and a failure of the downstream filter to arrest the erosion, resulting in continued erosion, unravelling of the dam toe, and a breach of the embankment.	Lowered lake levels (518.0 m RL and 513.0 m RL) will reduce seepage pressures through the main dam and the reduce the risk of a concentrated leak adjacent to the culvert. Construction of protection works on upstream face will not damage the upstream face impermeable blanket and rip-rap placement is designed to protect the upstream face and blanket. Therefore the lowered lake level and protection works lower the risk of the PFM occurring.
	6	All	**Internal erosion into or through the foundation –** initiated by internal erosion of the upstream blanket through a poorly backfilled investigation shaft into or through the foundation material, resulting in the formation of a sinkhole, progressive erosion and a breach of the embankment.	Lowered lake levels (518.0 m RL and 513.0 m RL) will reduce seepage pressures through the foundation and the reduce the risk of internal erosion of the upstream blanket through a poorly backfilled investigation shaft into or through the foundation material. Construction of protection works on upstream face will not damage the upstream face impermeable blanket and rip-rap placement is designed to protect the upstream face and blanket. Therefore the lowered lake level and protection works lower the risk of the PFM occurring.

Asset	PFM No.	Loading	PFM Description	Effects of lowered lake level and proposed dam protection works
	7	All except for usual	**Structural failure of the diversion culvert –** initiated by insufficient strength to safely accommodate long-term loading conditions, resulting in structural failure, erosion and a breach of the embankment.	Lowered lake levels (518.0 m RL and 513.0 m RL) will reduce hydraulic loading on the diversion culvert. Construction of protection works on upstream face will not damage the upstream face impermeable blanket and rip-rap placement is designed to protect the upstream face and blanket. Therefore the lowered lake level and protection works lower the risk of the PFM occurring.
	8	Intermediate seismic, extreme seismic, and post-extreme seismic	**Stability failure of the diversion culvert's gate chamber** – initiated by an upstream slope failure of the embankment passing through the foundation beneath the gate chamber, resulting in open joints between culvert sections, erosion, and a breach of the embankment.	Lowered lake levels (518.0 m RL and 513.0 m RL) will reduce the risk of upstream slope failure of the embankment passing through the foundation beneath the gate chamber. Construction of protection works on upstream face will not damage the upstream face impermeable blanket and rip-rap placement is designed to protect the upstream face and blanket. Therefore the lowered lake level and protection works lower the risk of the PFM occurring.
	8*	Loading scenarios unconfirmed	**Liquefaction of the Fancy Sands in the main dam foundation –** refer notes accompanying this table regarding description.	This PFM is not in the PFM tables in the 2024 CDSR but is postulated in the text of the 2024 CDSR. Lowered lake levels (518.0 m RL and 513.0 m RL) will not increase the risk of liquefaction in the foundation. Construction of protection works on upstream face will not damage the upstream face impermeable blanket and rip-rap placement is designed to protect the upstream face and blanket. Therefore the lowered lake level and protection works do not increase the risk of the PFM occurring
Main Dam spillway	Category I – credible and requiring immediate attention			
	1	Usual, unusual flood, extreme flood, unusual seismic, extreme seismic, post-SEE	**Structural failure of spillway chute –** initiated by stagnation pressures at a vertical slab offset, resulting in the dislodgement of chute slabs, retrogressive erosion of the outwash gravel foundation, undermining of the spillway gate structure and a breach of the embankment.	Lowered lake levels (518.0 m RL and 513.0 m RL) will not cause the spillway to operate (spillway crest level RL 520.38 m RL). Construction of protection works on upstream face will not damage the upstream face impermeable blanket and rip-rap placement is designed to protect the upstream face and blanket. Therefore the lowered lake level and protection works lower the risk of the PFM occurring.

Asset	PFM No.	Loading	PFM Description	Effects of lowered lake level and proposed dam protection works
	7	Unusual flood, extreme flood, post-SEE	**Instability of lower spillway chute slabs –** initiated by high dynamic pressures within the toe region of the hydraulic jump, resulting in the dislodgement of lower chute slabs, retrogressive erosion of the outwash gravel foundation, undermining of the spillway gate structure and a breach of the embankment.	Lowered lake levels (518.0 m RL and 513.0 m RL) will not cause the spillway to operate (spillway crest level RL 520.38 m RL). Construction of protection works on upstream face will not damage the upstream face impermeable blanket and rip-rap placement is designed to protect the upstream face and blanket. Therefore the lowered lake level and protection works lower the risk of the PFM occurring.
	Category II – credible but not requiring immediate attention			
	2	Usual, unusual flood, extreme flood, unusual seismic (OBE), unusual seismic (MSE), extreme seismic	**Inability to operate spillway gates –** initiated by a rise of the reservoir level above the top of the core, resulting in seepage and erosion which overwhelms the chimney drain, unravelling of the dam toe, and a breach of the embankment.	Lowered lake levels (518.0 m RL and 513.0 m RL) will not cause the spillway to operate (spillway crest level RL 520.38 m RL). Construction of protection works on upstream face will not damage the upstream face impermeable blanket and rip-rap placement is designed to protect the upstream face and blanket. Therefore the lowered lake level and protection works lower the risk of the PFM occurring.
	3	Usual, unusual flood, extreme flood, unusual seismic (OBE), unusual seismic (MSE), extreme seismic	**Inability to operate spillway gates (partial breach) –** initiated by a rise of the reservoir level above the top of the closed gates, resulting in an uncontrolled discharge down the spillway chute.	Lowered lake levels (518.0 m RL and 513.0 m RL) will not cause the spillway to operate (spillway crest level RL 520.38 m RL). Construction of protection works on upstream face will not damage the upstream face impermeable blanket and rip-rap placement is designed to protect the upstream face and blanket. Therefore the lowered lake level and protection works lower the risk of the PFM occurring.
	4	Unusual flood, extreme flood	**Shockwave overtopping of upper chute walls –** initiated by overtopping of the chute side walls during floods larger than the 1 in 1,000 AEP flood, resulting in erosion of backfill materials and foundations, undermining of the walls, wall tilting or collapse, retrogressive erosion of the outwash gravel foundation, undermining of the spillway gate structure and a breach of the embankment.	Lowered lake levels (518.0 m RL and 513.0 m RL) will not cause the spillway to operate (spillway crest level RL 520.38 m RL). Construction of protection works on upstream face will not damage the upstream face impermeable blanket and rip-rap placement is designed to protect the upstream face and blanket. Therefore the lowered lake level and protection works lower the risk of the PFM occurring.

Asset	PFM No.	Loading	PFM Description	Effects of lowered lake level and proposed dam protection works
	5	Extreme flood	**Spilling over chute sidewalls at junction with spillway gate structure** – initiated by overtopping of the chute side walls immediately downstream of the gate structure during an extreme flood, resulting in erosion of backfill materials and foundations, undermining of the walls, wall tilting or collapse, retrogressive erosion of the outwash gravel foundation, undermining of the spillway gate structure and a breach of the embankment.	Lowered lake levels (518.0 m RL and 513.0 m RL) will not cause the spillway to operate (spillway crest level RL 520.38 m RL). Construction of protection works on upstream face will not damage the upstream face impermeable blanket and rip-rap placement is designed to protect the upstream face and blanket. Therefore the lowered lake level and protection works lower the risk of the PFM occurring.
	6	Post-MSE, post- SEE	**Progressive failure of spillway chute side walls** – initiated by post-earthquake spillway discharges following earthquake damage to the side walls, resulting in progressive failure of the side walls, undermining of the gate structure and a breach of the embankment.	Lowered lake levels (518.0 m RL and 513.0 m RL) will not cause the spillway to operate (spillway crest level RL 520.38 m RL). Construction of protection works on upstream face will not damage the upstream face impermeable blanket and rip-rap placement is designed to protect the upstream face and blanket. Therefore the lowered lake level and protection works lower the risk of the PFM occurring.
	8a	Extreme flood, post-SEE	**Instability of gate structure** – initiated by high uplift pressures beneath the gate structure, resulting in destabilisation and displacement of the gate structure, and a breach of the embankment.	Lowered lake levels (518.0 m RL and 513.0 m RL) will not cause the spillway to operate (spillway crest level RL 520.38 m RL). Construction of protection works on upstream face will not damage the upstream face impermeable blanket and rip-rap placement is designed to protect the upstream face and blanket. Therefore the lowered lake level and protection works lower the risk of the PFM occurring.
	8b	Extreme seismic	**Instability of gate structure** – initiated by leakage along the interface of the embankment and gate structure, resulting in the erosion of embankment and foundation materials, destabilisation and displacement of the gate structure, and a breach of the embankment.	Lowered lake levels (518.0 m RL and 513.0 m RL) will not cause leakage along the interface of the embankment and gate structure (spillway crest level RL 520.38 m RL). Construction of protection works on upstream face will not damage the upstream face impermeable blanket and rip-rap placement is designed to protect the upstream face and blanket. Therefore the lowered lake level and protection works lower the risk of the PFM occurring.
Intake Dam	Category I – credible, highlighted			

Asset	PFM No.	Loading	PFM Description	Effects of lowered lake level and proposed dam protection works
	1	All	**Erosion due to structural failure of transition basin slab –** initiated by high uplift pressures beneath the transition slab, resulting in slab uplift, erosion of the slab's foundation, undercutting of the canal inlet structure, erosion of embankment materials and a breach of the embankment.	Lowered lake levels (518.0 m RL and 513.0 m RL) will only just allow the canal inlet to operate (inlet invert level RL 512.7 m RL) and will lower uplift pressures beneath the transition slab. Therefore the lowered lake level lower the risk of the PFM occurring.
	Category II – credible, not highlighted			
	2	Intermediate seismic, extreme seismic & post-extreme seismic	**Internal erosion along embankment/inlet structure interface –** initiated by a concentrated leak adjacent to the canal inlet structure and a failure of the downstream filter to arrest the erosion, resulting in continued erosion, unravelling of the dam toe and a breach of the embankment.	Lowered lake levels (518.0 m RL and 513.0 m RL) will only just allow the canal inlet to operate (inlet invert level RL 512.7 m RL) and will lower the risk of leaks and leak pressures adjacent to the canal inlet structure. Therefore the lowered lake level lower the risk of the PFM occurring.
	Category III – insufficient information			
	3	Extreme flood, intermediate seismic, extreme seismic and post-extreme seismic	**Structural failure of canal inlet structure –** initiated by structural failure of the gate structure walls, resulting in the erosion of embankment materials into the gate structure and a breach of the embankment.	Lowered lake levels (518.0 m RL and 513.0 m RL) will only just allow the canal inlet to operate (inlet invert level RL 512.7 m RL) and will not increase the risk of structural failure of the gate structure walls. Therefore the lowered lake level will not increase the risk of the PFM occurring.

12.3 Conclusion

It is concluded that dam safety is not impacted by construction of the dam protection works and operating the lake at lower levels. Twenty-one PFMs were identified in the 2024 CDSR. The risk of nineteen of the PFMs occurring is lowered by construction of the dam protection works and operating the lake at lower levels and the risk of the other two PFMs occurring is not increased. In many scenarios the risk is reduced when operating the lake at lower levels.

12.3.1 Dam safety controls

Additional controls for operating the lake at lower levels are not required as the existing controls allow for the lake to be operated between RL 513.0 m RL and 518.0 m RL when a SSA or OCC is initiated by the SO.
As the lake hasn't been operated within this range since it was filled, the following additional dam safety surveillance measures are recommended to be added:

1. Visual inspection of rip-rap on Main dam during periods when lake level is between RL 513.0 m and 518.0 m RL (the frequency of inspections to be determined by Meridian staff and as part of Annual Dam Safety Review).
2. Review of rip-rap profile by survey (the frequency of survey, and triggers (e.g. storm/wave event) to be determined by Meridian staff and as part of Annual Dam Safety Review). An as-built survey should be undertaken on completion of rip-rap placement.
3. Carryout monthly route marches and monitoring prior to, during and after the works (the frequency of to be determined by Meridian staff).
4. Review, during dam safety reviews, rip-rap performance and any interaction with lake levels.

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13. Natural Hazards

13.1 Lake Level Changes

The potential lake shore stability and geomorphological effects associated with the operation of the lake at levels below 518.0 mRL are addressed in the GHD report *Lake Pūkaki Reservoir Hydro Storage and Dam Resilience Works – Lake Processes and Geomorphology (GHD 2025B).* In terms of shoreline stability and erosion, GHD 2025B concluded that:

- The lake shore morphology is continuing to adapt to the construction of the Waitaki Power Scheme and raising of the lake. Broad scale response is slow with a lag of decades or a century. Therefore, short periods of lake levels below 518.0 mRL are not expected to trigger large-scale morphology adaption.
- Short-term, localised event-driven morphological change is feasible during storm events. Although the external lake processes will not change, impacts could affect the shoreline at elevations below 518.0 m RL. However, storm events typically occur in summer and winter, whereas low lake levels are modelled to occur during the spring. Therefore, the likelihood of adverse impact is anticipated to be low. Should minor morphological change occur, it would be anticipated that storm events during subsequent months would result in a reversion to pre-change conditions.

13.2 Pūkaki High Dam

Section 12 of this report provides a dam safety assessment associated with the proposed works and activities based on recently completed dam safety assessments by others. The completed dam safety assessments have considered a comprehensive range of risks associated with the dam including natural hazard risks such as earthquakes and associated ground liquefaction. As discussed in Section 12, the proposed works and activities will either lower the identified risks or have no impact.

14. References

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National Institute of Water & Atmospheric Research Limited. (2013). *Lake Pukaki Extreme Wave Analysis.*
New Zealand Society on Large Dams. (2024). *New Zealand Dam Safety Guidelies 2024. Module 3 - Investigation Design and Analysis.*
Pickford, T., Grilli, J., & Pott, J. (2024). *Pukaki Reservoir Comprehensive Dam Safety Review.*
U.S. Army Corps of Engineers. (2003). *Coastal Engineering Manual Part II.*

Appendix A

Curriculum Vitae

A GHD Principal

Geoffrey Farquhar CPEng, IntPE(NZ), RecEng(PIC, DSAP) CEng(UK)

Geotechnical and Dams Engineer

Wāhi noho / Location

Tāmaki Makaurau, Aotearoa

Wheako / Experience

47 years

Ngā Tohu Mātauranga / Qualifications/Accreditations

- Diploma of Imperial College (Soil Mechanics and Engineering Seismology),1986
- Master of Science (Soil Mechanics and Engineering Seismology), 1986
- Bachelor of Engineering (Civil), 1977
- Chartered Professional Engineer (NZ)
- Recognised Engineer (Potential Impact Classification, Dam Safety Assurance Programme)
- International Professional Engineer (NZ)
- Chartered Engineer (UK)

Whakaurutanga / Memberships

- Fellow of Engineering New Zealand
- Fellow of Institution of Civil Engineers (UK)
- Member of technical societies - NZ Geotechnical Society (life member), NZ Society on Large Dams, NZ Society of Earthquake Engineering, NZ Tunnelling Society, NZ Hydropower Group

Pūkenga Matua / Management skills

- Leadership of geotechnical teams and projects
- Provision of technical advice
- Registration, assessment and regulation of engineers and engineering geologists
- Member of Chartered Professional Engineers Board (Engineering New Zealand)
- Project governance
- Knowledge of all relevant codes and standards

Pūkenga Matua / Technical skills

- Dam safety
- Geotechnical risk assessment and mitigation for dams and hydraulic structures
- Leadership of geotechnical teams and projects
- Geotechnical investigations, design and construction of infrastructure and buildings
- Seismic design and slope stability
- Pavement engineering, dams, retaining walls, deep foundations, tunnels and bridges
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Arotau ki te Tūranga / Suitability for the Role

Geoff has learned that the best results for projects are gained when one does not get buried in the detail but has a good technical understanding of the geology, ground and groundwater conditions, geotechnical and seismic risk, and the constraints that these pose to the project. During his career, Geoff has amassed a significant catalogue of effective risk mitigation strategies to suit a range of situations. This is why he is relied upon by many clients and is sought after for his peer review abilities.

The confidence that GHD places in Geoff's leadership and technical skills is demonstrated in his role as a Principal of the business. In this role, Geoff helps to keep GHD at the forefront of technical excellence in project delivery. His ability to bring international leading experience is based his geotechnical and dam engineering experience in the UK, US, SE Asia and the Pacific.

Geoff brings skills in technical leadership, managing and leading teams and has a long history of successfully working in multi-disciplinary teams to develop often complex and pragmatic geotechnical designs for infrastructure projects. His wealth of experience means he knows what works and what doesn't, and is able to advise and challenge the team to develop robust and pragmatic geotechnical solutions.

Wheako Whakahaere Kaupapa / Project Experience

Stockton Coal Mine Dam PIC Assessments

BT Mining Ltd | 2024
Recognised Engineer

Geoff was NZ reviewer for PIC assessments for five stormwater detention dams (Low PIC).

Waitahinga Dam PIC Assessment

Whanganui District Council | 2023 - 2024
Recognised Engineer

Geoff was NZ reviewer for PIC assessment (Medium PIC) for 16m high concrete gravity dam.

Waimea Community Dam Diversion Design

Fulton Hogan & Taylors Contracting JV | Tasman | 2019 - 2024
Project Director and Geotechnical Engineer

Project Director and geotechnical engineer for design and construction supervision of diversion works for construction of Waimea Dam.

Waimea Community Dam

Waimea Water Ltd | Tasman | 2020 - 2025
Project Director and Geotechnical Engineer

Project Director and geotechnical engineer for independent peer review of design changes to the dam during construction.

Wakamoekau Community Dam

Wairarapa Water Ltd | Masterton | 2020 to 2021
Geotechnical Reviewer

Review feasibility study for 40m high rockfill dam and irrigation scheme.

Dam Wave Crest Barrier

Opuha Water Ltd | Fairlie | 2017-2019
Project Director

Design of a precast concrete wave wall on the crest of the dam.

Ruataniwha Water Storage Project

OHL Hawkins Joint Venture | Hawkes Bay | 2016
Geotechnical Lead

Geotechnical Lead for investigations and ground model for detailed design 80m high Central Core Rockfill Dam and irrigation network.

Upper Mangatawhiri Dam

Watercare Services Ltd | Hunua | 2006-2007
Geotechnical Engineer

The protection works were difficult to investigate and design because the spillway operated infrequently but the previous erosion and the potential for future erosion was significant. Because the ground model was uncertain, I developed a solution which catered for changes in ground conditions thus leasing Watercare's contractual risks.

I was the lead geotechnical engineer for the investigation and design of scour protection works for plunge pool at the end of the spillway.

NZ Sugar Water Supply Dams - Safety Review

NZ Sugar Co | Auckland | 2004
Dam Safety Engineer

Dam Safety Engineer for initial dam safety assurance examination of four 100yr old 4-5m high earthfill (puddle cay core) embankment dams with brick weirs.

Wilsons Dam Feasibility Study

Whangarei District Council | Ruakaka | 1998-1999
Geotechnical Engineer

Geotechnical Engineer for investigations and feasibility design for 18m high earthfill dam on a weak alluvial foundation. In particular assessment of stability and seepage beneath dam.

Lake Onslow Pumped Storage Scheme – Feasibility Study (Confidential Project)

MBIE | Roxburgh, Otago | 2021 - 2023 |
Geotechnical Lead for surface structures

I worked closely with Mott MacDonald to evaluate options for development of the project.

My role has been to provide geotechnical engineering assessment for feasibility design of the main dam foundation, Lake Onslow intake structures, Clutha River off take structures, and reservoirs and tunnel inlet structures.

Lake Onslow is a large pumped storage scheme. I am part of a project team investigating the feasibility of the project. Studies have included engineering feasibility design and environmental assessments.

Arnold Dam Stability upgrade

Manawa Energy (formerly Trustpower Ltd) | 2016 - 2025
Project Director and Reviewer

I am NZ reviewer for the investigation, detailed design of stability upgrade works of the gravity spillway block and construction observations. The original assessment included stressed ground anchors for which a trial anchor was installed and tested. The anchors were not needed after the PIC was re-assessed by Riley to be medium rather than high. The works to the spillway block include a downstream apron and piled scour cutoff wall. Riley is responsible for the earth dam which abuts the spillway block.

GHD's input to the project comes mainly from Australia through Jon Williams and Amanda Ament but since it is a NZ GHD project I am responsible for technical review and as Project Director need to authorise the release of deliverables. Geotechnical engineering and civil and structural construction observation of GHD designed elements is being provided by NZ which I am responsible for. I am also the NZ signatory where producer statements other building consent documentation is required.

Pukaki Dam spillway gates lifting gear

Damwatch Engineering for Meridian Energy | 2020 - 2021
Project Director and Reviewer

I was the NZ reviewer for the seismic structural safety assessment of the gate lifting gear.

Moawhango Dam Comprehensive Dam Safety Review

Genesis Energy Ltd | Waiouru | 2013
Geotechnical Inspector/Project Director/Dam Safety Reviewer

I was the geotechnical inspector and lead dam safety reviewer. A challenge was conflicting monitoring and observational data pertaining to dam stability which I was able to resolve.

The concrete arch and gravity dam with high Potential Impact Classification required a Comprehensive Safety Review by a team of specialists.

Purari Hydropower Project

PNG EDL Ltd | Papua New Guinea | 2012
Geotechnical Reviewer

Geotechnical Reviewer for Geotechnical Interpretive Report for a 2,500MW dam-based hydropower development. Scheme comprises 160m high dam (RCC or earth embankment), 14m diameter diversion tunnels, surface penstocks and powerstation and reservoir containment (saddle dams) set in weak sedimentary geology (sandstone, siltstone, mudstone).

Comprehensive Safety Reviews: Poutu Intake, Canal and Dam; Rangipo Dam; Otamangakau Dam; Te Whaiau Dam

Genesis Energy Ltd | Tongariro | 2012
Dam Safety Engineer and Reviewer

I was Dam Safety Engineer and reviewer for Comprehensive Safety Review reports. Another engineer carried out the inspections.

North Bank Hydro Power Project

Meridian Energy Ltd | Waitaki River | 2009-2011
Geotechnical Engineer

One particular challenge for me was addressing preventing water leaking out of and into the canal. A key personal highlight for was developing the concept of the groundwater cut-off wall to enable construction of the canal and overcome loss of both groundwater into the canal and canal water into the ground. He devised a 7km long groundwater cut-off wall connected to the greywacke rock foothills that the canal skirted along, effectively forming a 'bath tub'.

I led the geotechnical engineering for a feasibility level study of a 250MW tunnel-based development on the lower reaches of the Waitaki River utilising a gross head of 123m. He also reviewed the Construction Description and Engineering Description Reports for complete project. He was responsible for geotechnical investigations, design of a canal (13km, 8m water depth, 260m3/s), groundwater studies, materials for canal construction particularly canal lining, preliminary seismic hazard assessment for scheme.

Stockton Mine water control dams, Comprehensive Dam Safety Reviews

BT Mining Ltd | Westport | 2019 - 2022
Lead Dams Reviewer

I was the technical and dam safety reviewer for CDSR's performed for 6 low PIC dams at Stockton Mine by a team of NZ and Australian inspectors. I did not take part in the onsite inspection.

Tauwhatanui detention dam

Gisborne District Council | Gisborne | 2019-2021
Geotechnical Reviewer

The challenges included scoping appropriate investigations, understanding local geotechnical risks and using judgement to assess the results to develop pragmatic solutions. Spoil disposal was an issue and I needed to understand the requirements of the landowner farmer for use of his land and the timeframes for carrying out the works to suit farming operations.

I reviewed the investigations and design for desilting the reservoir behind a rural stormwater detention dam and providing erosion protection for the spillway.

Mahi o-mua / Employment history

2015 - present	GHD, Auckland, Technical Director – Dams & Geotechnical, GHD Principal
2014 - 2015	URS (now AECOM), Auckland, Principal Geotechnical Engineer
2001 - 2014	AECOM, Auckland, Technical Director - Ground Engineering and Tunnelling (& Geotechnical Engineering Manager)
2000	Schnabel Engineering Inc, Washington DC, Geotechnical Engineer
1989 - 1999	Worley Consultants (now AECOM), Auckland, Geotechnical Engineering Manager
1986 - 1989	Geotechnical Consulting Group, London, Senior Geotechnical Engineer
1985 - 1986	Imperial College, London, MSc
1985	Meredith and Associates, Western Samoa, Civil Engineer
1977 - 1985	Various geotechnical, civil and structural roles

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