Memo

To:	Kate Berkett & Brent Wilson (Meridian Energy)
From:	Dr Karina Dahl & Dr Grant Webby (Damwatch Engineering)
CC:	Stephen Christensen (Project Barrister)
Date:	28 April 2026
Subject:	**Pūkaki Fast-Track Application: Tekapo B Power Station Tailrace Weir & Chute Response to Questions from Review Panel**

1 Purpose of Memorandum

Meridian Energy (Meridian) has made an application under the Fast-track Approvals Act 2024 to obtain eased access to hydro storage in Lake Pūkaki below RL 518 m in the event of low inflows over the next three years (2026-2028). The probability of the low inflows occurring has been assessed by Meridian to be low. However, if low inflows did occur and Lake Pūkaki was drawn down below RL 518 m, this would require the Tekapo B Power Station tailrace weir and rock chute (hereafter referred to as the weir and chute structure) to be reactivated after being submerged by Lake Pūkaki for the last 47 years.

The purpose of this memorandum is to provide responses to questions about aspects of the weir and chute structure foundations posed by Dr Kaley Crawford-Flett, one of the Expert Review Panel Members, at the Project Overview Conference between Meridian and the Panel in Twizel on 1 April 2026.

2 Questions Posed by Review Panel

Our interpretation of the questions posed by Dr Crawford-Flett is as follows:

- What is the potential for "global instability" of the foundation materials under the weir and chute structure due to Lake Pūkaki being drawn down below RL 518 m to a minimum level of RL 513 m in the future?
- What is the potential for the function of the sand and gravel filter layers underneath the weir and chute structure to have been degraded by long-term submergence under Lake Pūkaki?
- What is the potential for deterioration of the sand and gravel filter layers underneath the weir and chute structure from future drawdown of Lake Pūkaki below RL 518 m to a minimum level of RL 513 m?

Our responses have been developed from a high-level assessment only of the weir and chute structure based predominantly on engineering judgement and knowledge of the foundation materials at the time of construction.

3 Description of Tailrace Weir and Chute Structure

3.1 Intent of Structure

The Tekapo B Power Station tailrace weir and rock chute was designed and constructed as a low-cost structure so that Tekapo B Power Station could generate power with the level of Lake Pūkaki up to 15 m below the designed minimum operating level of RL 518 m (MWD, undated-c). The design intent of the weir and chute structure was:

- to maintain tailwater levels in the upstream tailrace channel at a minimum tailwater level of RL 518 m or above so that power generation at Tekapo B Power Station was possible; and
- to ensure that the rock chute component safely dissipated the potential energy of the power Geometry and Construction of Structure

3.2 Geometry and Construction of Structure

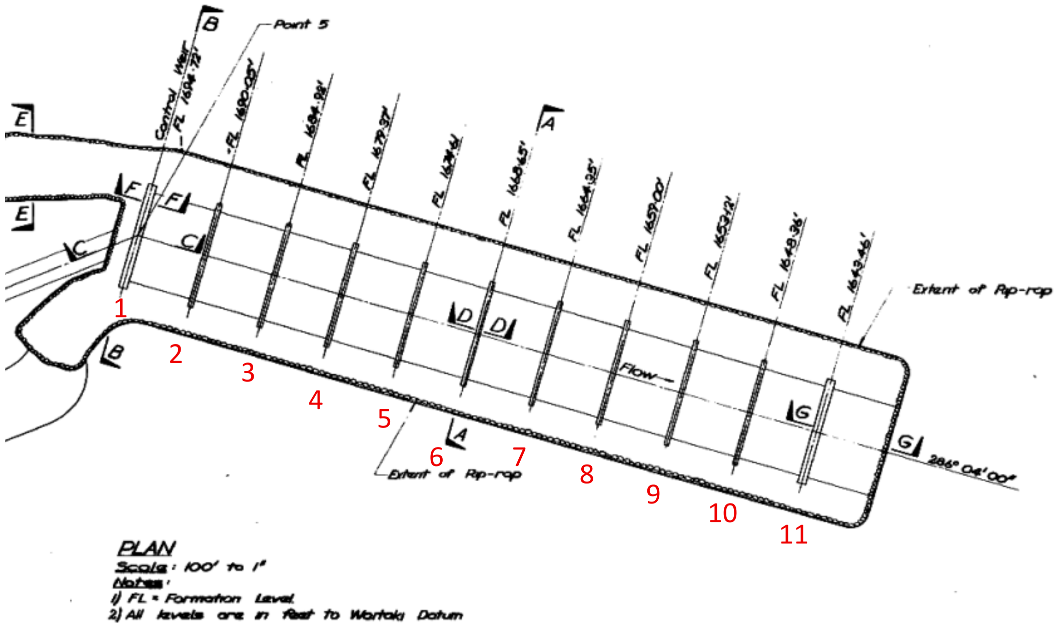
The weir and chute structure is comprised of a control weir at the upstream end and a long chute on a nominal 1V in 20H slope, except for a short steeper 1V in 8H sloping section at the lower end (see Figure 3.1b). The structure is approximately 375 m long and 50 m wide (see Figure 3.1a and b).

The control weir (referred to as Sill 1) has a trapezoidal long-section (see Figure 3.1c). The weir crest is formed by a concrete Sill 3.05 m wide by 3.26 m deep. The upstream sloping nose of the control weir and the compartment downstream of the weir are both rock-lined with riprap. The weir controls water levels in the upstream trapezoidal-shaped earth-lined tailrace channel.

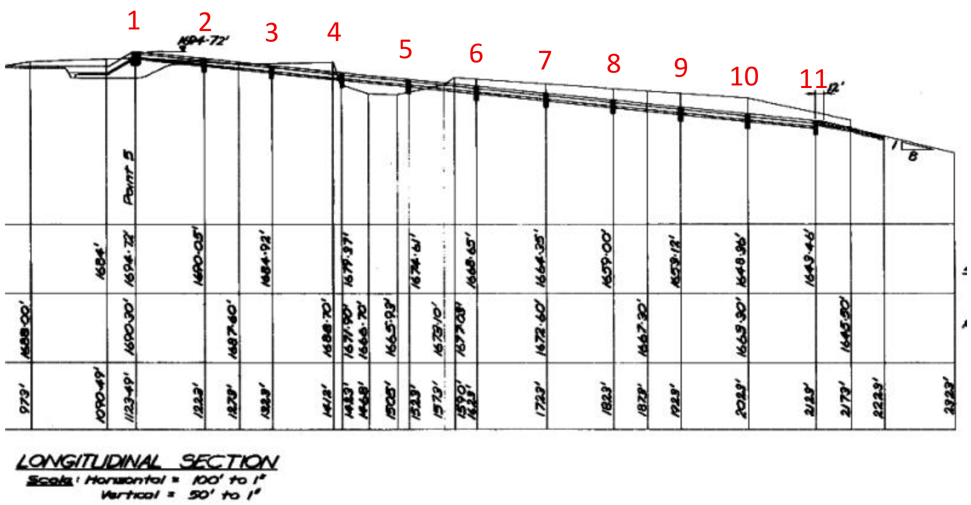
The chute downstream of the control weir has a uniform trapezoidal cross-section, approximately 40 m wide at the base with 2H:1V side slopes. It is lined with rock boulders of varying sizes overlying gravel and sand filter layers. The rock riprap material is held in place by ten concrete Sills (ribs) spaced every 30.5 m, each measuring about 1.2 m wide by 3 m deep. The cross-section profile of these Sills replicates the trapezoidal shape of the chute cross-section.

The Sills on the structure are numbered from 1 (the control weir) to 11 (at the downstream end). The control weir (Sill 1) is at approximately RL 518 m. Lake lowering is to approximately Sill 4 at RL 513 m. Table 3.1 lists the Sill numbers and associated levels.

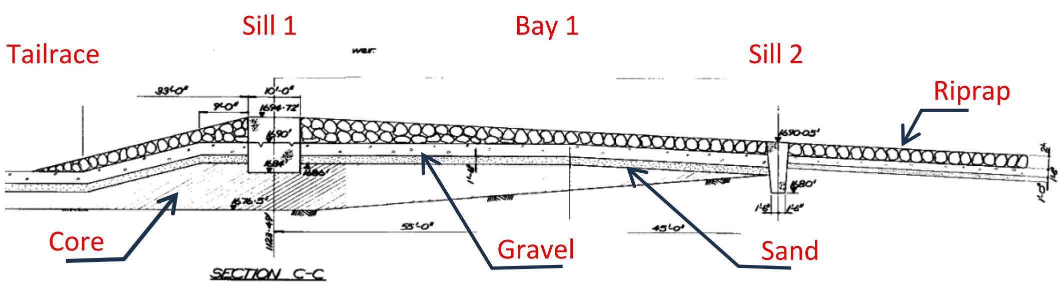
Further details on the construction of the weir and chute structure are provided in MWD (undated [- c) and Malan and Hancock (1979).



(a) Plan view of whole structure (Sill numbers marked in red)



(b) Long-section of whole structure (Sill numbers marked in red)



(c) Long-section of control weir (Sill 1), bay 1 of structure and Sill 2

Ministry of Works As-Built Drawing sheets T38/01/6-8

Figure 3.1: Tekapo B Power Station tailrace weir and chute: (a) plan view of whole structure; (b) long-section of whole structure; (c) long-section of control weir and bay 1 of structure

Table 3.1: Summary of sill levels

Sill No.	Sill Ref. No. in 1978 Construction Report	As-built Crest Level (RL m Lyttelton VD 1937)
1 (control weir)	1695 ft	517.85
2	1690 ft	516.43
3	1685 ft	514.87
4	1680 ft	513.14
5	1675 ft	511.72
6	1670 ft	509.91
7	1665 ft	508.60
8	1660 ft	506.96
9	1655 ft	505.17
10	1650 ft	503.90
11	1645 ft	502.23

Source: As-built drawing T38/01/6
Note: Conversion from ft to m is m = 0.2048(ft+4.27ft) (Damwatch, 2011)*

3.3 Hydraulic Performance of Structure

Ther original hydraulic performance of the structure is described in Thompson and Campbell (1979) and further discussed in Damwatch (2025a), Damwatch (2025b) and Damwatch (2026) with respect to Meridian's application. The hydraulic performance is also discussed in the statement of evidence prepared by Grant Webby (Webby, 2026) in response to a Section 53 submission to the Expert Review Panel by Genesis Energy.

3.4 Characterisation of Placed and Foundation Materials

The tailrace channel comprises placed materials and natural foundation soils.

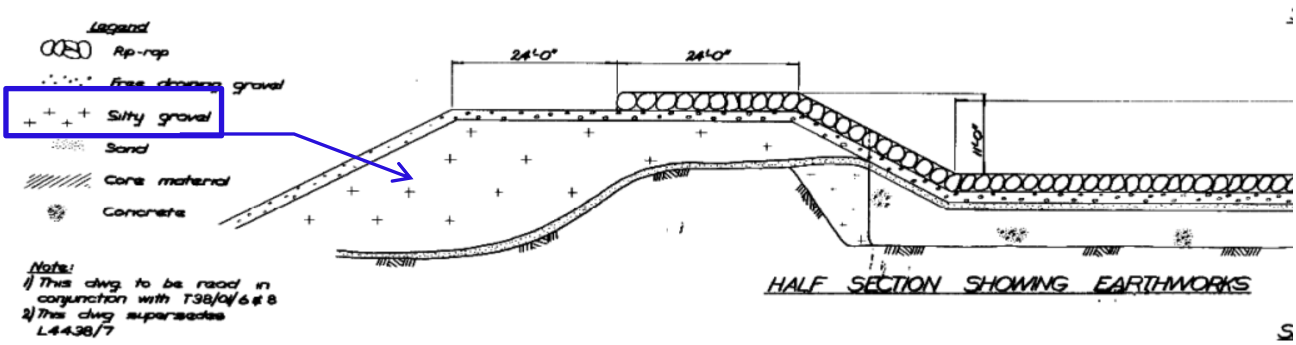
Placed Materials

Placed materials generally include the following layers (nominal thicknesses):

- Sand - 0.305 m thick (1 ft)
- Gravel – 0.61 m thick (2ft)
- Riprap – 0.91 m (2.5 ft)

Figure 3.1c shows general arrangement of these materials. The sand acts as a filter to the underlying soils. Figure 3.3 shows the corresponding specified grading curves (MWD, undated-a).

At the control weir, core material was placed below the sand filter to extend the seepage path from the upstream tailrace channel (refer to Figure 3.1c). The remaining sills and bays were founded in native soils except for construction of the side berms. Figure 3.2 shows that silty gravel was used to build the side berms and was placed above the sand filter.

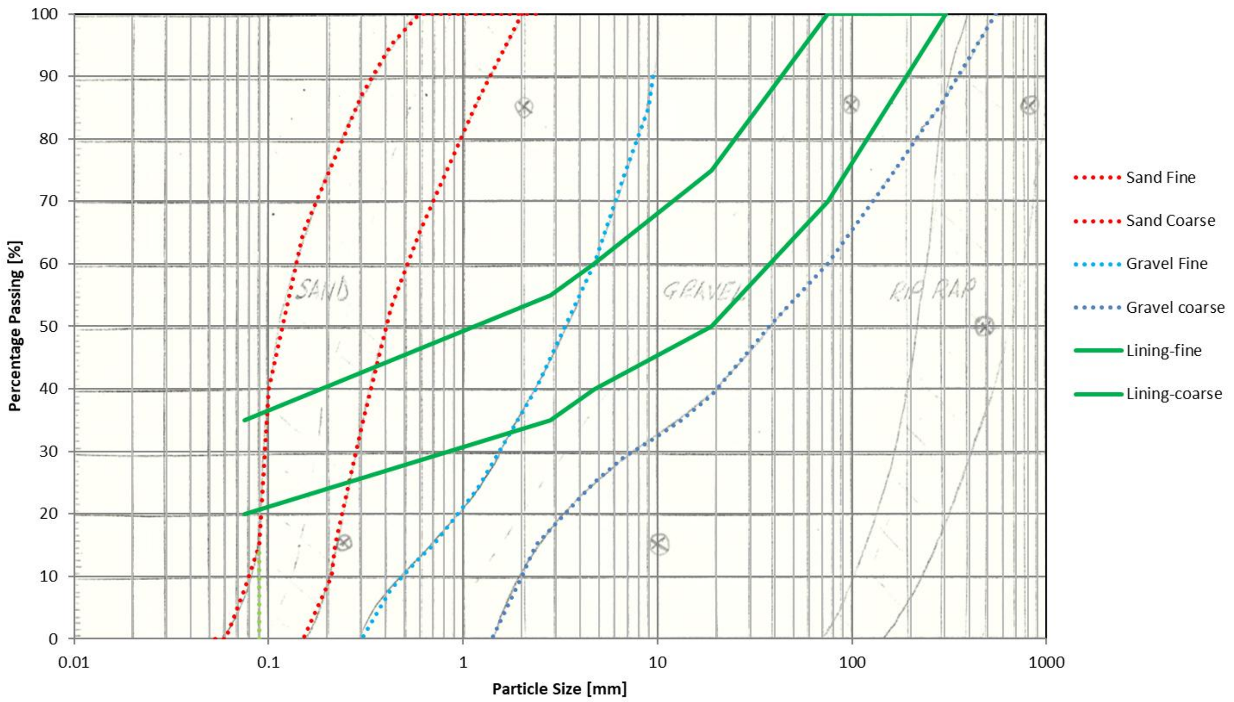


Source: Ministry of Works As-Built Drawing sheets T38/01/7

Figure 3.2: Cross section of berm constructed from silty gravel.

No information is available on the core and silty gravel materials other than a specified permeability (k) requirement of less than 1x10^{-5}cm/sec for the core (MWD, undated-a). The core permeability requirement is the same as that for the Tekapo Canal lining per Specification HD924 (MWD, 1973). The specified grading of the lining material is also shown on Figure 3.3. The lining material is much coarser than expected for a typical clay core but is considered reasonable for the glacial depositional environment. It was considered as a possible representative material for the core material.

Upstream of Sill 5 the size of the riprap was larger as discussed in the tailrace weir and chute condition assessment and review of bathymetric survey data (Damwatch, 2026). The sand and gravel layers serve as a bedding and filter transition between the underlying ground and the Riprap, which in turn protects both the underlying ground and filters.



Source: HD1147 and HD924

Figure 3.3: Specified grading envelops for filter layers, riprap and canal lining.

Natural Foundation Soils

There is limited documentation on the foundation geological units and their properties (URS, 2005). Geotechnical parameters utilised in this assessment were accordingly inferred from visual descriptions of the various materials, including those from nearby sites such as Pūkaki Dam. There is no detailed geological map relevant to the tailrace channel.

Native foundation soils at the tailrace channel primarily comprise alluvial fan deposits, which overlie Tekapo Till (TT). No grading information is available on the alluvial fan soils, which typically, comprise a mixture of silts, sands and gravels. Geologic mapping for Pūkaki Reservoir describes the post-glacial alluvial gravels as fine to coarse gravel with some sand, cobbles and very rare silt. It is noted that Tekapo outwash gravels contains higher silt/clay content.

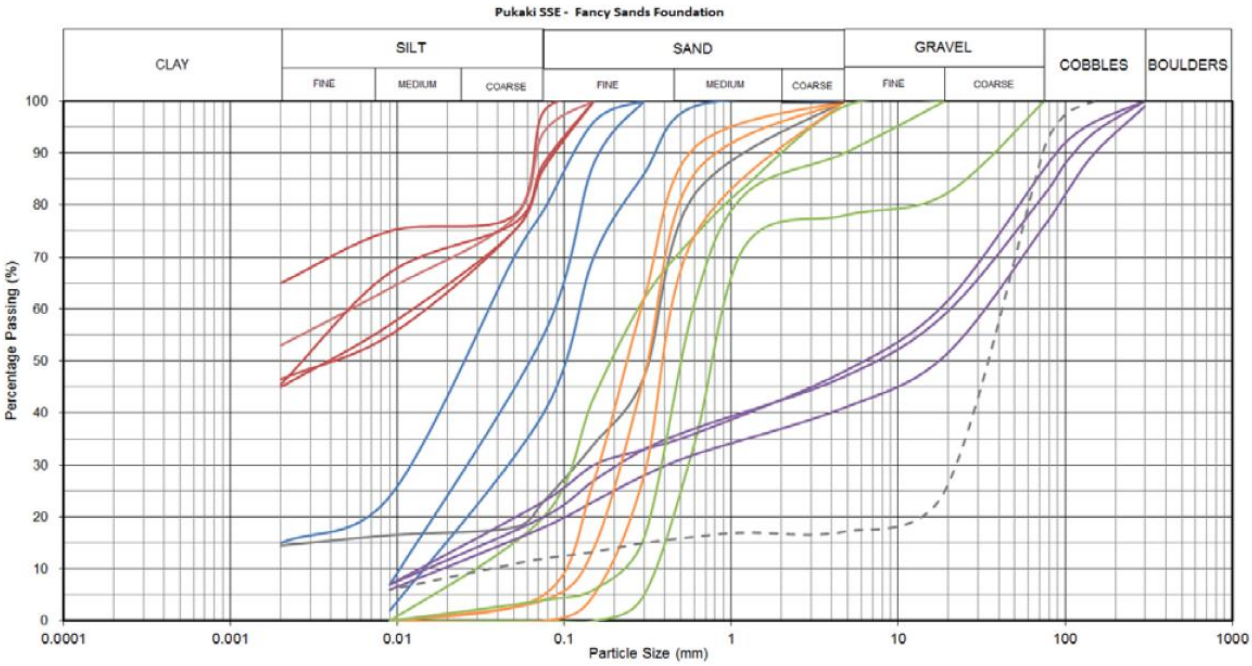
Locally, poor foundation conditions were encountered in the lower section of tailrace channel. A band of blue-grey silt ('pug') was encountered between Sill 10 to Sill 11. Within this area and in addition to the 'pug' were fine sand beds, which graded to coarser soils towards the upstream end. These soils are a lacustrine deposit, which lies below the alluvial fan deposit.

The adjacent powerhouse excavation, up to 38 m in depth (~RL 506 m), encountered highly variable glacial (TT), fluvioglacial and lacustrine deposits (URS, 2005). The upper 13 m comprised alluvial gravels of silts to bouldery gravels. Underlying soils (below RL 493 m) were a mixture of lacustrine deposits comprising silts, sand, sandy and silty gravel with clean sandy beds. These lacustrine deposits are consistent with the poor foundation conditions experienced at the tailrace channel Sill 10 and 11, RL 504 to 502 m.

Pug soils were also encountered at the Pūkaki Dam site (NZGS, 1976). The 'pug' at Pūkaki Dam is a component of the Fancy Sand geologic unit, which was deposited on retreat of the last glacial advance, Tekapo, some 14,000 years ago. It is described as a blue, soft, highly plastic silty clay with beds of gravel and sand throughout. The 'pug' has a geologic age of 11,950 ± 200years.

The Pūkaki 'pug' has similar characteristic to the soils encountered at the tailrace channel. Figure 3.4 shows the available Fancy Sands grading curves where we consider the finer gradings (red and blue curves) to be the 'pug' soils. Atterberg limits tests performed on the 'pug' material indicate a plasticity index (PI) of 8-18, classifying the soil as low plastic clay (CL) and a PI of 22-30 classifying it as high plastic silt (MH). The corresponding liquid limit (LL) is 26-48 and 77-84, respectively. These gradings and plasticity are considered in this assessment given the similarity in description, consistency and composition to that encountered at the tailrace channel.

The coarser Fancy Sands gradings (blue, yellow and green curves) provide an indication of foundation alluvial soils that may exist at the tailrace channel. Composition of alluvial soils may vary significantly spatially due to their depositional environment.



Source: modified from Pūkaki Da Engineering Geological Completion Report (NZGS, 1976)

Figure 3.4: Fancy sand grading curves.

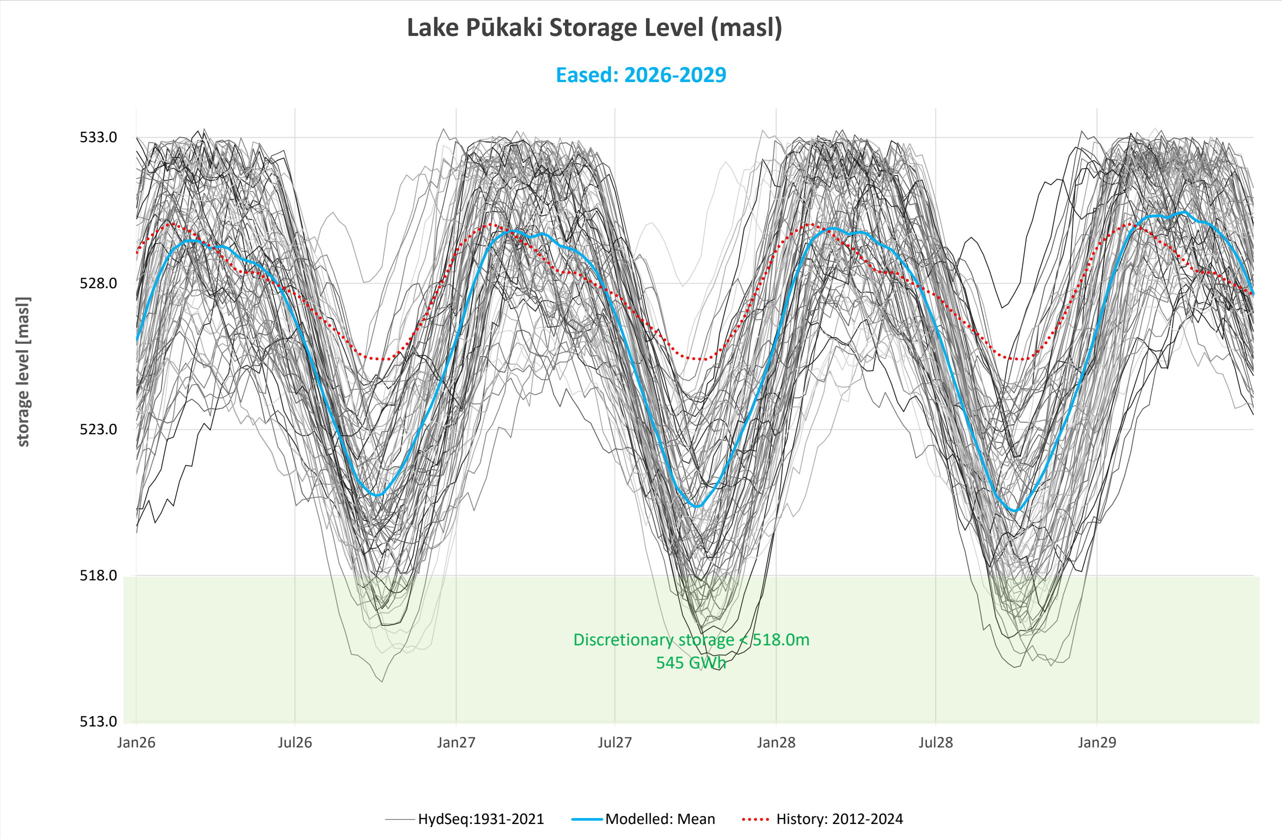
4 Characterisation of Future Lake Levels with Eased Operation

4.1 Future Lake Level Predictions

Lake Pūkaki levels typically exhibit an annual cycle with levels peaking in late summer (after the lake fills up during late spring and early summer) and then falling to a low point in early spring (reflecting low autumn, winter and early spring inflows relative to the draw-off from the lake for hydro generation purposes).

Meridian has carried out power system modelling using historical inflow sequences from 1931 to 2021 to forecast the range of possible lake level outcomes for the next three years under conditions of eased operation for Lake Pūkaki. The results of this modelling are summarised in Figure 4.1. The graph in Figure 4.1 shows forecast weekly levels as a function of time from January 2026 to January 2029. The green shaded band on the graph indicates discretionary storage in Lake Pūkaki below RL 518 m.

It can be seen from Figure 4.1 that incursions into the discretionary storage range only occur with some of the assumed hydrological inflow sequences (i.e. those sequences with lower average autumn, winter and early spring inflows).



Source: Grant Telfar (Meridian Energy)

Figure 4.1: Predicted Lake Pūkaki storage levels for the period 2026-2028 under conditions of eased operation

4.2 Analysis of Rates of Fall and Rise for Hydrological Sequences Resulting in Incursions into Discretionary Storage Range

A range of forecast lake level sequences which dropped into the discretionary storage range over the 2026-2028 period was analysed to assess the average daily rates of fall and rise during these incursions. The results are summarised in Figures 4.2, 4.3 and 4.4.

Note that the daily rates of rise and fall plotted on the graphs in Figures 4.2, 4.3 and 4.4 are averaged over seven days so the actual daily rates could be slightly higher or lower within each week (expected to be no more than about 10% due to the large area of the lake, the limited outflow capacity of the Pūkaki Canal Inlet Structure through which lake outflows are drawn off and the very small negative rate of change of inflows during low inflow periods).

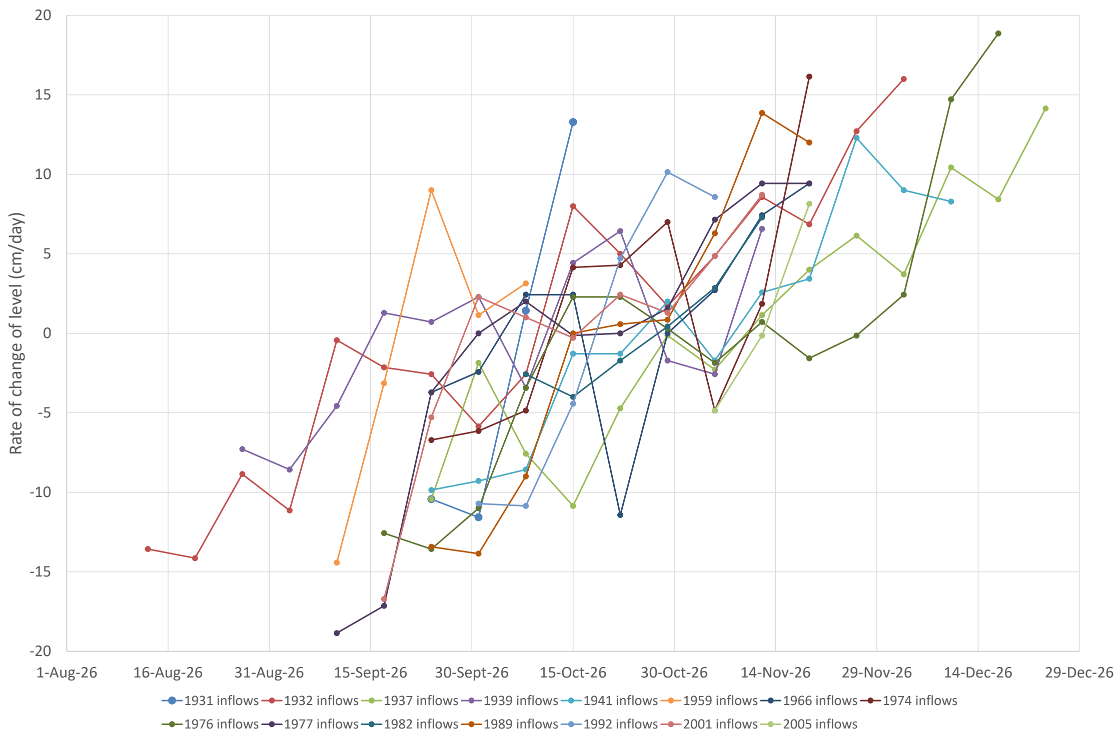


Figure 4.2: Average daily rates of change in level (cm/day) for periods of incursion into the discretionary storage range for Lake Pūkaki from forecast levels for 2026 and selected hydrological inflow sequences

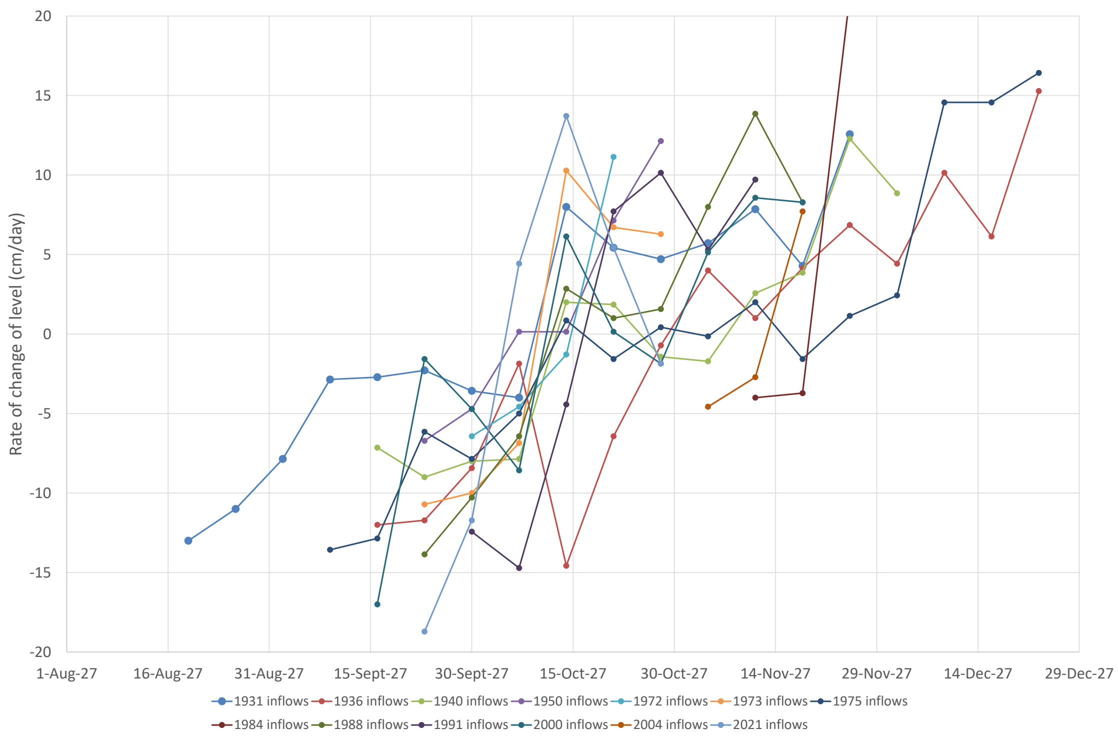


Figure 4.3: Average daily rates of change in level (cm/day) for periods of incursion into the discretionary storage range for Lake Pūkaki from forecast levels for 2027 and selected hydrological inflow sequences

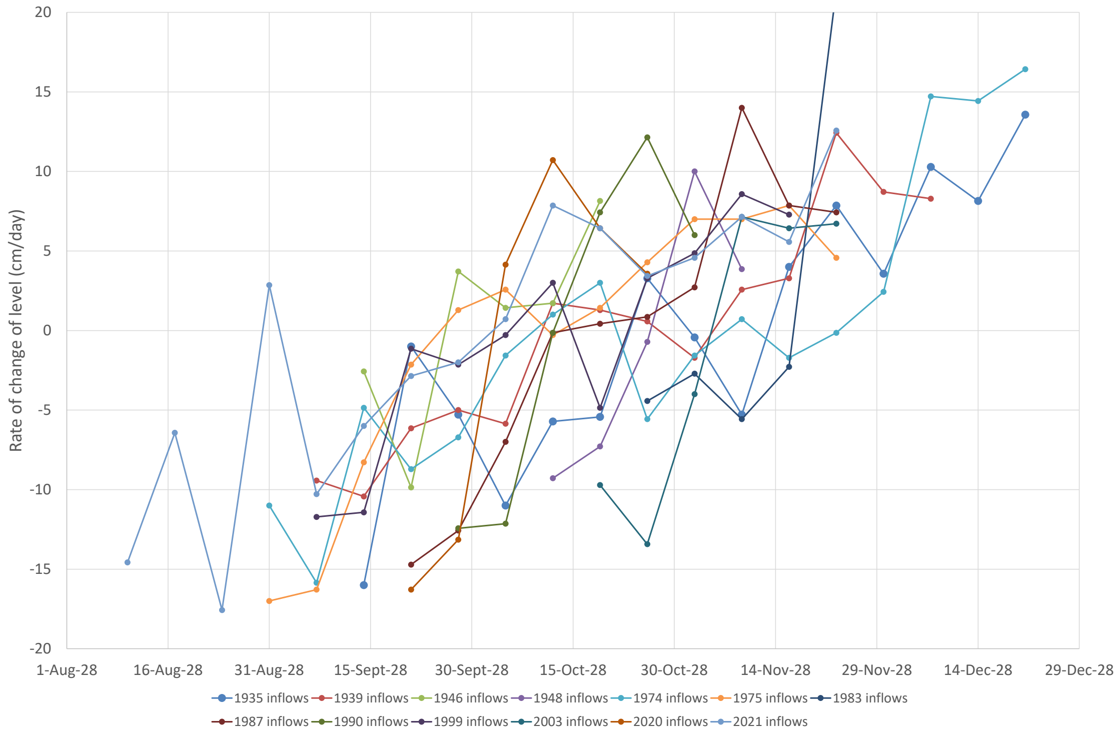


Figure 4.4: Average daily rates of change in level (cm/day) for periods of incursion into the discretionary storage range for Lake Pūkaki from forecast levels for 2028 and selected hydrological inflow sequences

Note that negative rates of change (cm/day) in Figures 4.2, 4.3 and 4.4 correspond to falling lake levels while positive rates of change correspond to rising lake levels after the lake level sequence has bottomed out.

With respect to the first and third questions posed by Dr Crawford-Flett, the negative rates of change of level are those of primary interest.

4.3 Observations on Negative Rates of Change in Lake Level

From the analysis described in Section 4.2 of the rates of change in lake level during incursions into the discretionary storage range below RL 518 m, the following key observations were made:

- The largest negative rates of average daily change in lake level (-10 to -20 cm/day) occur when the lake level is just being drawn down into the discretionary storage zone.
- After the forecast weekly lake level drops into the discretionary storage zone below RL 518 m, the draw-off from the lake for hydro generation purposes is more conservative with rates of average daily change in lake level mostly less than -10 cm/day and often less than -5 cm/day.
- Large positive rates of average daily change in lake level (> -10 cm/day) reflect large inflow events into the lake in the historical inflow record.

5 Assessment of Potential for Global Instability of Foundation Soils

Damwatch assessed the potential for global instability of the foundation soils from lake lowering. As the lake is lowered, the stabilising force of lake water is removed from the tailrace channel slope and shear stresses increase. The stability of the slope may be governed by undrained or drained shear strengths depending on the permeability of the placed and underlying foundation soils. Although the 'pug' was not encountered within the range of lake lowering, Damwatch performed a sensitivity check to confirm the channel stability if it exists within this area.

The characteristics of the core material are unknown other the specified permeability of $1x10^{-5}$ cm/s, which is indicated by the specified lining material (refer to Figure 3.3). Sensitivity to variation of the core material's properties (i.e., permeability and shear strength) was also checked.

Lake Lowering Rate and Soils Behaviour

Undrained conditions will prevail when the rate of unloading (i.e., lake lowering) is faster than pore pressure can dissipate from within the placed core material or possible low permeable foundation soils. Damwatch used Terzaghi 1D consolidation theory to estimate the characteristic drainage time and compared it to the imposed lake lowering time.

The following outlines the evaluation steps and results obtained.

- Step 1: Estimate the characteristic drainage time of the core (silt) and 'pug' (t_d)
  - Coefficient of consolidation, c_v
    - Core with permeability of $1x10^{-5}$ cm/s and c_v of 10 for lean clay (CL)
    - 'pug' with c_v of 2 based on glacial lake clays (Look, 2014)
    - Alluvial soils and 'pug' mixtures with c_v of 20 to 120 based on liquid limit of 50 and 30, respectively (Look, 2014)
  - One directional seepage path, H_d
    - H_d= 0.9 m - sand, silty gravel (0.3 m) and gravel
    - H_d= 2.3 m - sand, silty gravel (1.4 m) and gravel
- Step 2: Estimate time of the imposed unloading (t_l) based on lake level change and drawdown rate
  - Water level change from RL 518 to RL 513 m; 5m
  - Drawdown rate of -20 cm/day (maximum) to as low as -5 cm/day (minimum)
- Step 3: Compare time of unloading to imposed loading, $R = t_l/t_d$
  - Where the core has a c_v of 10 or greater, R >1 infers primarily drained conditions
    - Partially drained conditions (0.1< R <1) may exist for the longer drainage path, H_d of 2.3 m
  - For the 'pug' case with c_v of 2, we expect:
    - Partially drained conditions for H_d of 0.9 m and
    - Undrained conditions (R>1) for H_d of 2.3 m

Given there is uncertainty in the soil parameters (c_v) and drainage path, undrained conditions and associated shear strengths were considered in estimating the channel global stability, as discussed below.

Stability Assessment

Stability of the tailrace channel from lowering of the lake from RL 518 m to RL 513 m was assessed using simplified Infinite Slope Method by Duncan (2014) under rapid drawdown conditions.

Factors critical to the stability of the channel include:

- Slope angle: Channel slope of 1V:20H, $\beta = 2.86°$

- Undrained shear strengths of core and foundation materials (‘pug’)
  - Undrained strengths – back calculated for minimum factor of safety (FoS)=1.5
- Change in water level (5 m) and
- Depth of slip surface from 2.3 m to 7 m

Of these factors, the slope angle controls the channel safety factors. The mild slope provides inherent stability to the tailrace channel even if ‘pug’ soils exist at depth. Undrained strengths of the core or possible ‘pug’ soils is a secondary factor for channel stability. Sensitivity to the undrained strength was checked. A minimum cohesion, c, of about 5-10 kPa was estimated within the core or ‘pug’ to achieve an acceptable factor of safety of 1.5. This factor of safety is consistent with best practice in accordance with the New Zealand Dam Safety Guidelines (NZSOLD, 2024) although the tailrace channel slope is not classified as a dam or appurtenant structure.

This high-level assessment indicates the tailrace channel has sufficient stability for the proposed lake lowering operations.

6 Assessment of Potential for Filter Layers to have Degraded Due To Long-term Submergence

The potential for filter layers degradation due to long-term submergence was assessed based on their filter compatibility and recorded performance.

The filter layers were designed using material compatibility standards at the time the chute structure was constructed. These standards have since been superseded. Damwatch checked the material compatibility of the core (‘pug’) to sand and sand to gravel layers using the no erosion boundary method for existing dams by Foster and Fell (Foster & Fell, 2001).

Without a grading curve, Damwatch estimated the minimum particle diameter of the core material, as the base material at 85 percent passing by weight (DB85) required for the ‘No Erosion” boundary. The minimum DB85 is 0.02 mm. Coarser core material will meet this criterion, such as DB85 of 0.075 mmm, which is consistent with the finer Fancy Sands gradings. We expect that the placed core material meets this requirement and that the natural foundation soils (i.e., alluvial and ‘plug’) will likewise comply.

The lining material is coarser than the sand filter and we accordingly also checked the compatibility of the fine sand to the coarse lining (reverse seepage direction).

Table 6.1 summarises this assessment. ‘No Erosion” is expected between both the core and sand filter and between the fine sand and fine gravel. The interface between the fine sand and the coarse gravel lies within the ‘Some Erosion’ boundary, where some erosion will occur before self-healing takes place.

Table 6.1: Summary for material compatibility assessment of the filter layers in terms of Foster and Fell criteria

Interface	Erosion Boundary	Comment
Fine sand to coarse core (lining)	No Erosion	• Scenario considers the sand erodes into lining material given its coarse grading • Foundation seals with practically no erosion
Finest core to coarse sand	No Erosion	• Requires the core to have a DB85 of 0.022 mm or larger

Interface	Erosion Boundary	Comment
Fine sand to fine gravel	No Erosion	• Foundation seals with practically no erosion
Fine sand to coarse gravel	Some Erosion	• Foundation seals after "some" erosion

Assessment of the current condition of the tailrace channel is provided in Damwatch memo 'Tekapo B Power Station, tailrace weir and chute structure (Damwatch, 2026). It was noted that the bathymetric survey showed some unknown 'smooth' patches in areas of the riprap lining of the tailrace channel between Sills 4 and 5. Of note per construction report (MWD, undated-c), Below Sill 5, the as-built survey found that the Sills were all about 457 mm (18 inches) low due to over-excavation in the poor foundation materials. This difference was distributed linearly over the top four Sills to ensure that the control weir was at RL 517.85 m (1695 ft). This may provide understanding of the 'smooth' areas although closer inspection of these 'smooth' areas on digital versions of the bathymetric imagery (rather than paper prints) indicate that boulders are present but possibly masked by deposited sediment (Paragraph 21 of Webby (2026)).

No other degradation or settlement of the tailrace channel was noted in the bathymetric survey review and dive inspection.

Based on the filter compatibility assessment and observed performance to date, we consider it unlikely that the filter layers have degraded under the long-term submergence since 1978.

7 Assessment of Potential for Further Deterioration in Filter Layers Due to Proposed Lake Level Drawdown Below RL 518 m

Our evaluation of the potential for further deterioration in the filter layers due to proposed level drawdown below RL 518 m relies on our assessment of the material compatibility of the filter layers, previous performance and expected site supervisor actions during the proposed operations.

Our review of the compatibility of the filter layers indicates that 'No Erosion' to 'Some Erosion' may occur but self-healing is expected. Thus, no deterioration in filter capability is expected within these layers, provided the riprap overlay is maintained.

The placed filter layers (sand and gravel) and protective riprap performed satisfactorily during the 1977-78 operations. While scour holes developed at Sill 5 (RL 511.72 m) and Sill 9 (RL 505.17 m) (Damwatch, 2026), these areas will not be impacted by proposed lake lowering operations. In any event, these scour hole areas were repaired and did not deteriorate with further operations of the tailrace channel (Damwatch, 2026) (Webby, 2026).

Based on these observations, no further deterioration is expected. However, it is prudent to follow the original operation guidance with regular visual observations during operations and maintaining riprap stockpile and plant available to make any repairs, if needed.

8 Summary and Conclusions

This memorandum provides high-level responses to the three questions posed by the Panel discussed in Section 2.

Future Lake Level Drawdown Rates under Eased Operation

During future incursions into the discretionary storage range for Lake Pūkaki under conditions of eased operation:

- The largest negative rates of average daily drawdown of -10 to -20 cm/day will occur when the lake level just drops into the discretionary storage zone.
- After the lake level drops into the discretionary storage zone below RL 518 m, the rates of average daily change in lake level will mostly be less than -10 cm/day and often less than -5 cm/day.

Potential for Global Instability of Foundation Materials

Our high-level assessment indicates the tailrace channel has acceptable global stability under the lake level lowering conditions. This is based on the Infinite Slope stability analysis of the channel slope. A minimum undrained shear strength of between 5-10 kPa is needed to achieve an acceptable factor of safety of 1.5. Such a factor of safety is consistent with best practice in accordance with the New Zealand Dam Safety Guidelines (NZSOLD, 2024) although the tailrace channel is not classified as a dam or appurtenant structure. We consider the underlying core materials, and if present the 'pug' soils, meet this minimum undrained shear strength requirement.

Potential for Filter Layer Degradation Due to Long-Term Submergence

The potential for filter layers degradation due to long-term submergence was assessed based on the filter compatibility between the various layers, as well as their current condition. The filter layers include underlying core material, the sand filter and overlying gravels. Grading curves for the sand and gravel used in this assessment are shown in Figure 3.3. No information is available on the core material which may be like the lining material used in the canal construction(refer to Figure 3.3), which has the same permeability characteristics. A finer grading like the Fancy Sands for the core was also considered in our evaluation.

Damwatch assessed the material compatibility of these filter interfaces using the no erosion boundary methods by Foster and Fell (2001). Table 6.1 provides a summary of this assessment. The filter interfaces lie within the "No Erosion" and "Some Erosion" boundaries for the fine sand to the coarse gravel where some erosion will occur before self-healing occurs.

The current condition of the filter layers is based on the bathymetric survey review and dive inspection. Review of this information identified no settlement or degradation of the filter layers (Damwatch, 2026).

Based on the filter compatibility assessment and observed performance to date, we consider that it is unlikely the filter layers have degraded under the long-term submergence since 1978.

Potential for Deterioration of Filter Layers Due to Future Lake Level Drawdown Below RL 518 m

The potential for deterioration of the filter layers due to future lake level drawdowns below RL 518 m to RL 513 m was qualitatively assessed based on the filter compatibility assessment, past operations and expected monitoring during proposed operations.

The design of the filter layers indicates no to some erosion may occur but will self-heal. We expect the filter layers will not deteriorate under the proposed lake lowering provided the riprap protection is maintained.

When the tailrace channel was operated in 1977-78, scour holes developed below Sills 5 and 9, which will remain submerged under the proposed lake lowering. These holes were repaired and no further degradation is evident based on the bathymetric survey and dive inspection. No deterioration was recorded in the area between Sill 1 (control weir) and Sill 5, noting that the lake will not be operated below Sill 4 with the proposed lake lowering.

Based on these observations, no further deterioration is expected. However, it is prudent to follow the original operating guidance of:

- Regular visual observations of the structure during operation to identify any abnormal flow behaviour, such as erosion, unusual turbulences, slope instability or breakout of flow.
- Maintaining a stockpile of riprap material nearby, together with the availability of suitable plant, would allow rapid response and repair should any erosion of the lining occur.

9 References

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