DAMWATCH
ENGINEERING BEYOND THE SURFACE

Proposed Manapōuri Lake Control Improvement Project

Construction Planning – Proposed Methodology

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Prepared for
Meridian Energy Limited

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P +64 4 381 1300 F +64 4 381 1301
A Level 3, 88 The Terrace, PO Box 1549, Wellington 6140, New Zealand

DAMWATCH ENGINEERING
www.damwatch.co.nz

Damwatch Engineering Ltd
PO Box 1549
Wellington 6140
New Zealand
Telephone: +64 4 381 1300
https://damwatch.co.nz/
info@damwatch.co.nz

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Prepared by	Dougal Clunie		
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Executive Summary

The Waiau Arm channel conveys flow from the Lake Manapōuri to the Manapōuri Lake Control structure (MLC), where minimum flows, lake and flood flows, recreational flows and flushing flows are released to the Lower Waiau River downstream. The existing Waiau Arm channel does not have the flow conveyance capacity to reliably pass all flows over the full lake operating range. Using computational hydraulic modelling, Damwatch Engineering Limited (Damwatch) showed that deepening the Waiau Arm channel reach past the Mararoa Delta (immediately upstream of the MLC) will improve flow conveyance and reliability, particularly for flushing flows into the Lower Waiau River over a wider range of lake conditions.

Damwatch was accordingly commissioned by Meridian Energy to assist in planning of the Waiau Arm channel improvements, in preparation for a Resource Consent application.

This report presents the conceptual design and construction methodology proposed for the project. It addresses project constraints, alternative excavation methodologies considered, and the outcomes of in-stream trial excavations.

The methodology is not a finalised detailed design, and it is expected that modifications to this concept will be made by the construction contractor to best suit its available equipment and expertise, and the conditions encountered. The conceptual design is intended to convey an ‘envelope’ of expected work conditions, from which the range of potential construction effects can be assessed.

Potential methodologies were initially workshopped between Damwatch and Meridian. Alternative layouts for the excavation works were then developed to consider options which may help to reduce suspended sediment generation from the works and/or increase productivity rates and thereby limit the duration of other environmental effects.

To better understand the channel substrate across the proposed excavation area, and to quantify the concentrations of suspended sediment that may be generated from excavation within the open channel, a programme of instream trial excavations was planned and completed in February 2023. Visual observation and suspended sediment monitoring showed that bund construction and removal, and excavation of bed material, cause rapid increases in suspended sediment concentration and decreases in visual clarity.

The proposed channel improvement works developed include a parallel channel excavation arrangement, with the majority of excavation completed remote from the flowing river. The in-stream works component is restricted to the tie-ins to the Waiau Arm channel at the start and end of the parallel channel to minimise the potential for suspended sediment release into the Lower Waiau River.

Proposed 'parallel channel' excavation arrangement.

Key parameters of the concept arrangement are listed below:

- The primary means of sediment control is undertaking and completing a majority of excavation (87%) out of the river;
- Total excavation volume is approximately 225,000 m³;
- Estimated constructed programme is 4-5 months, including up to 5 weeks in-river;
- The flood risk is managed by undertaking a majority of work offline from the river.

It is emphasised that the arrangement described has been developed to a conceptual level, to provide an envelope for the assessment of effects for consent application. The construction methodology is expected to be refined to accommodate a contractor's innovations during detailed design and planning, match available plant and expertise, and be flexible enough to adapt to variations in site conditions.

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List of abbreviations

Abbreviation	Meaning
AEE	Assessments of Environmental Effects
AEP	Annual Exceedance Probability
LWR	Lower Waiau River
MLC	Manapōuri Lake Control
MSL	Mean Sea Level
NZTM	New Zealand Transverse Mercator 2000 projection grid
RL m	Reduced Level – elevation with Deep Cove 1960 mean sea level datum

1 Introduction

1.1 General

Meridian Energy Limited (Meridian) releases flows through the Manapōuri Lake Control Structure (MLC) to the Lower Waiau River (LWR) in accordance with existing resource consent conditions. The types of flow released include minimum flows, lake and flood flows, recreational flows and flushing flows. Each of these assists with managing nuisance periphyton growth and has benefits for river health. However, the current channel depth and alignment, and gravel accumulation in the Waiau Arm immediately upstream of the MLC, have been identified as the primary physical constraints affecting flow conveyance and reliability, particularly for flushing flows. The aim of this Project is to reduce these constraints by constructing a new and deeper channel adjacent and parallel to the Waiau Arm and by removing accumulated gravel, and to provide for any necessary maintenance of the Waiau Arm channels. Following construction of the new and deeper channel, more reliable conveyance of consented flows into the LWR is expected.

Using computational hydraulic modelling, Damwatch showed that improving the Waiau Arm channel reach past the Mararoa Delta (immediately upstream of MLC) will provide the ability to release flows over a wider range of lake conditions.

Damwatch was accordingly commissioned by Meridian Energy to assist in planning of Waiau Arm channel improvement works, in preparation for a Resource Consent application.

1.2 Objectives

The work presented in this report aims to:

- determine constraints on excavation profile, operational and environmental constraints, and sediment management options for alternative methodologies,
- consider and evaluate safe and practicable channel excavation methodologies,
- consider the lessons from trial excavations for a practicable and 'consentable' methodology,
- identify the most suitable channel excavation methodology, together with recommended channel excavation arrangement (width, depth and alignment), and
- develop a concept-level design for the proposed excavation methodology.

1.3 Scope and Content of Report

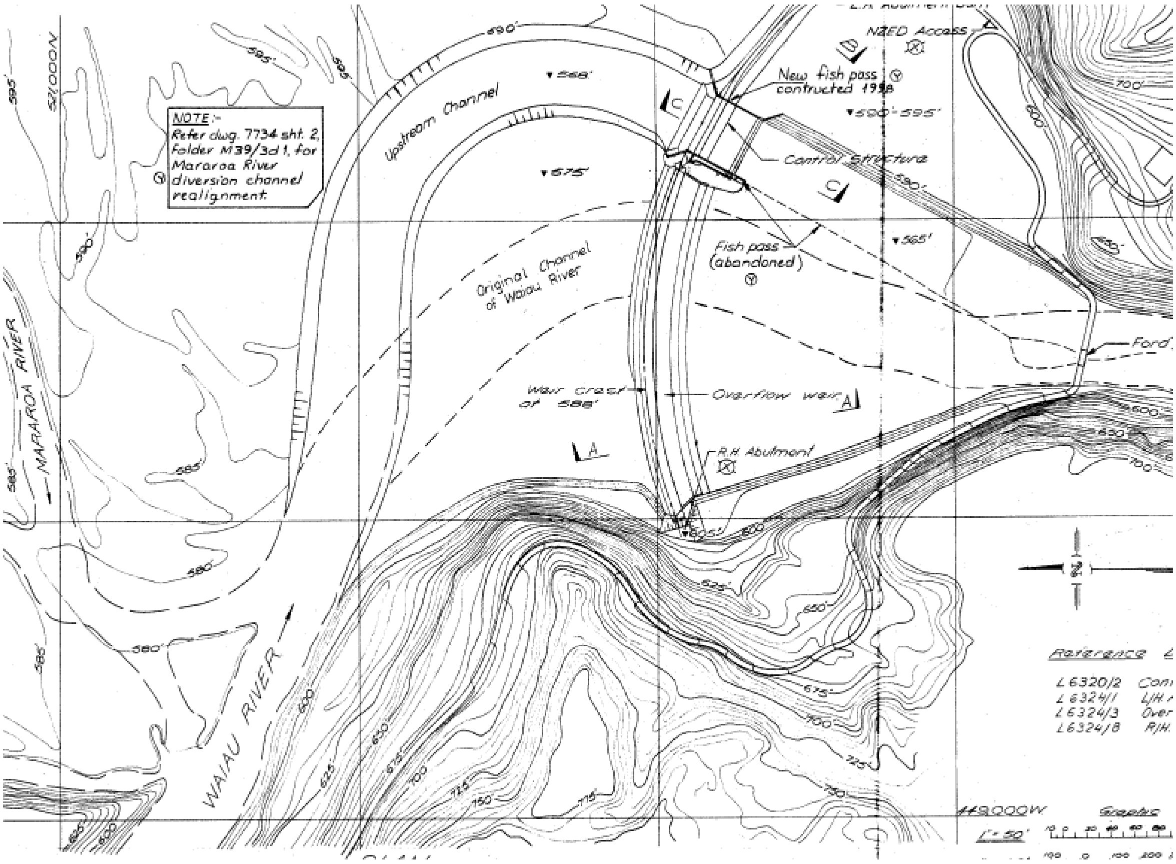
This report documents the background to the proposed excavation works (Section 2), site conditions and constraints (Section 3) and alternative excavation methodologies considered (Section 4). Following site investigations summarised in Section 5, the proposed arrangement and excavation methodology was developed, as described in Section 6.

The proposed arrangement and construction methodology was developed to a concept design level, suitable for assessment of potential environmental effects and preparation of Resource Consent applications. The final arrangement is subject to detailed design. Flexibility will be required under the resource consents to allow for the contractor's innovations and amendments to the methodology during implementation to best suit available equipment and expertise, and the site conditions encountered.

2 Background

The Manapōuri Lake Control Structure (MLC) was completed in 1976, about 600 m downstream of the confluence of the Waiau and Mararoa rivers. The gated structure controls discharge into the Lower Waiau River, providing storage in Lake Manapōuri by restricting outflow and allowing flow from the Mararoa River to be diverted to the lake. Water stored in the lake is used for hydropower generation in the Manapōuri Power Station.

Figure 2.1 shows the channel constructed upstream of MLC leading to the control gates, with a base elevation of RL 173.1 m (568’), with the original river channel and banks upstream of the overflow weir filled and excavated respectively to RL 175.3 m (575’).



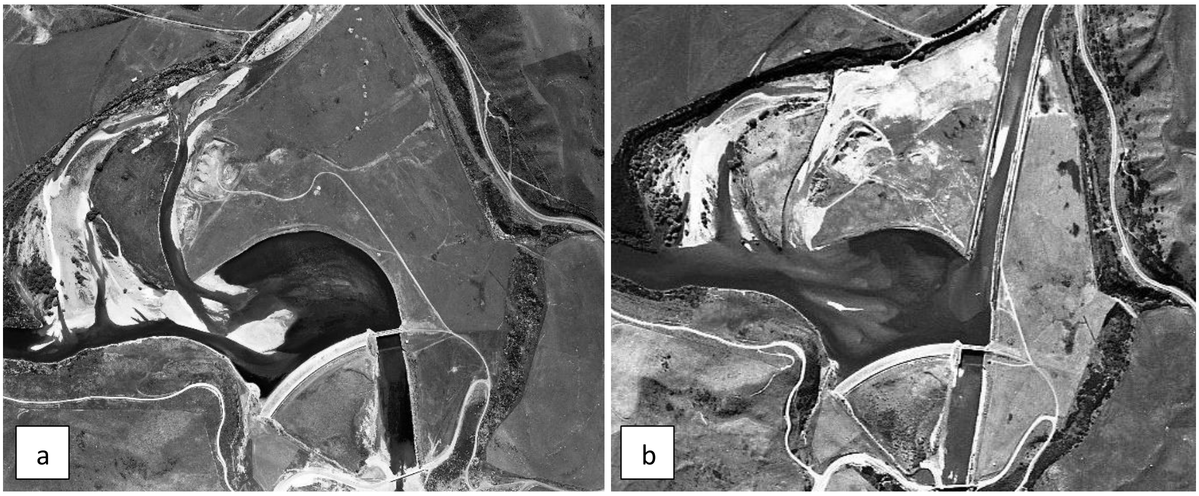
Source: As-built drawing L6320/1

Figure 2.1: MLC general layout plan showing upstream channel and Waiau-Mararoa confluence

In the early years of operation, diversion of turbid sediment-laden flood flows from the Mararoa to Lake Manapōuri caused problems. Aerial photographs from this period (Figure 2.2a) show a sediment delta built up within the Waiau Arm upstream of MLC where the Mararoa River joins.

In 1987 a new outlet for the Mararoa River was excavated to its present-day course, discharging the river directly through the MLC gates. Since this time, turbid flood water from the Mararoa is released directly downstream preventing it from entering Lake Manapōuri, while in non-flood conditions, clean water from the Mararoa is still diverted to the lake for hydropower storage and generation.

Minimum flow requirements from MLC to the Lower Waiau were introduced in December 1996. These are discussed in Section 3.1.



Source: Environment Southland Open GIS Data https://data-esgis.opendata.arcgis.com/

Figure 2.2: Historical aerial photographs (a): 1986, showing Waiau-Mararoa confluence upstream of MLC. (b): 1989, showing the realigned Mararoa outlet directly above the control gates.

2.1 Previous Excavation Work

In the summer of 1999, the lake reached a minimum level of RL 176.57 m. Below a lake level of about RL 176.80 m, flow from the lake was restricted by gravel deposits below the former Waiau-Mararoa confluence upstream of the MLC structure. In May 1999 a short 100 m long, 30 - 40 m wide channel was excavated through these deposits to a nominal invert level of RL 175.0 m, to ensure that minimum flows can be made up from Lake Manapōuri when there are low flows in the Mararoa River. A total of about 40,000 m³ of sand and gravel was excavated using excavators, dump trucks and a bulldozer. More excavation was intended but was prevented by the rising lake level (Worley, 1999).

Source: Worley (1999)

Figure 2.3: MLC looking south, January 1999. The Waiau Arm enters from the right, the Mararoa diversion cut flows from the lower left. The original confluence is on the right of the photo with the channel in the lower middle understood to be a diversion excavated during construction of MLC.

Further excavation of around 15,000 m³ of material, deepening the channel down to RL 174.5 – 174.0 m RL, was undertaken in 2007.

The nature of the river-system and physical changes to this environment results in ongoing gravel accumulation in front of MLC. Gravel accumulation within this site has implications on flows, efficiency of water movement and the integrity of the infrastructure. Meridian has previously undertaken gravel/sediment removal through various project of various scales, including the Waiau Arm excavation projects described above, in accordance with good engineering and hydrological practices to ensure that the channels are sufficient for their purposes.

2.2 Flushing Flows

Resource Consent conditions require Meridian to implement a voluntary protocol relating to flushing flows to assist in managing nuisance periphyton growth in the Lower Waiau River and promoting river health. The protocol was developed, approved and implemented in 2014.

The protocol requires regular surveys of periphyton cover in the Lower Waiau River over the summer period (November to April), and release of a flushing flow from MLC if surveyed conditions are "red", subject to lake levels, security of supply and other compliance obligations. The protocol provides for 4-5 flushing flows being provided each summer.

With the infestation of *Didymosphenia geminata* ('didymo') in the Lower Waiau, NIWA have defined an effective flushing flow as 160 m³/s peak with 24-hr average flow of 120 m³/s (previously ~50 m³/s flushes were released).

From 2015-2021, the Lower Waiau River was surveyed as being 'red' 24 times. Flushing flows were only provided on 8 of these occasions. The flow conveyance capacity of the existing Waiau Arm channel is a significant constraint to flushing flow volume releases at lower Lake Manapōuri levels.

Meridian accordingly intends to significantly improve flow conveyance and reliability out of MLC by means of this project.

2.3 Damwatch Studies

2.3.1 Computational Hydraulic Modelling

Damwatch investigated the flow conveyance capacity of the Waiau Arm Channel, and evaluated modified bed profiles for the lower end of the channel to improve flow conveyance and reliability of releases through the MLC structure to the LWR. The computational hydraulic modelling undertaken as part of this study showed that the Waiau Arm and MLC system does not have the conveyance capacity to pass the desired flushing flows at low Lake Manapōuri levels. A key reason for this is headloss in the shallower reach of the Waiau Arm through the historical Mararoa delta area (extending approximately 1 km upstream of MLC). A suitably sized channel excavated through this area (see Section 6.2) could improve flushing flow reliability to approximately 70%, from the current approximately 30%, based on the record of 'red status'[1] in the LWR from 2015 to 2021 and coincident lake levels. Modelling shows that the proposed excavation will allow

[1] Where instream surveys identify high periphyton biomass.

release of a 160 m³/s flushing flow at a minimum Lake Manapōuri level of RL 177.28 m, compared with the current operating experience that that the lake must be at or above RL 177.69 m to pass such a flow.

2.3.2 Geology Review

A desktop review of the Waiau Arm geology, aiming to help characterise the nature of the materials within the proposed excavation was completed by Damwatch (Damwatch, 2021). The review indicated that the channel bed between RL 170-175 m would likely consist of alluvial sediments over Damsite Formation members (varying from gravely sand with trace cobbles and boulders to silty clay). It was recommended that trial pits be excavated to confirm the geology and excavatability of the materials. Subsequent site investigations are described in Section 5.

3 Site Conditions and Constraints

The Waiau Arm channel is an arm of Lake Manapōuri, with water levels in the area of the proposed work reflecting the lake level with a small variation dependent on the flow rate in the channel. The flow rate is controlled by the MLC gates, just downstream of the Mararoa River confluence and some 10 km from Pearl Harbour on the shores of the lake proper (Figure 3.1).

The level of Lake Manapōuri is generally maintained within the main operating range of RL 176.80 to 178.60 m.

Source: Google Earth

Figure 3.1: Satellite image showing Waiau Arm in relation to Lake Manapōuri, Mararoa River and MLC

3.1 Manapōuri Lake Control Releases – Main Operating Range

When water levels in Lake Manapōuri are within its main operating range, flow releases from MLC are generally at Meridian's discretion, and optimised for energy production subject to:

- LWR minimum flow requirements, shown in Table 3.1,
- Higher 'recreational flows' of 35-45 m³/s are released monthly between October and April,
- When turbid flows (high suspended sediment concentration) are detected in the Mararoa River, all Mararoa flow (plus an additional 5 m³/s) should be released directly through MLC, and,
- Flushing flows should be released where possible when 'red' periphyton conditions are surveyed in the LWR.

Table 3.1: MLC minimum flow requirements (releases to Lower Waiau)

Period of year	Minimum flow release
1 April to 30 April	14 m^3/s
1 May to 30 September	12 m^3/s
1 October to 31 October	14 m^3/s
1 November to 31 March	16 m^3/s

In general, flow in the Waiau Arm may be from Lake Manapōuri to the Lower Waiau River, or from the Mararoa River to Lake Manapōuri, depending on Mararoa inflow rates and MLC release requirements.

3.2 Manapōuri Lake Control Releases – Flood Rules

There is a prescribed sequence of MLC gate openings to be followed when Lake Manapōuri rises above its maximum control level of RL 178.6 m [2] defined in the Flood Rules, which mimic a natural flood outflow.

At high lake levels rising above maximum control level, Waiau Arm discharge will be high and increasing, and conditions will likely be unsuitable for safe working in the channel.

It is understood that Meridian generally has a reliable 4-5 day forecast of inflows to the Te Anau – Manapōuri system for operational decision making.

Large flood flows are reasonably common (MLC releases exceeding 500 m^3/s have occurred in 7 of the last 10 years) and can be long-lasting with high flows persisting for 1-2 weeks or more.

The MLC weir itself will overtop when the local water level exceeds RL 179.22 m, as most recently occurred in December 2019 and April 2010 (Figure 3.2). The Probable Maximum Flood level at MLC is RL 183.53 m (see 2017 CDSR (Pickford et al. 2017)).

[2] Maximum control level is lower if full powerhouse discharge is not available, in which case flood releases from MLC are commenced earlier.

Source: 'Flood Impact Memo' B Sheehan to J Twiddle, 29 April 2010.

Figure 3.2: Floodwater spilling over MLC weir, 27 April 2010, approximate flow 800 m^3/s (following a flood peak of 1130 m^3/s on 26/4/10).

3.3 Historical Waiau Arm Levels and Flow Rates

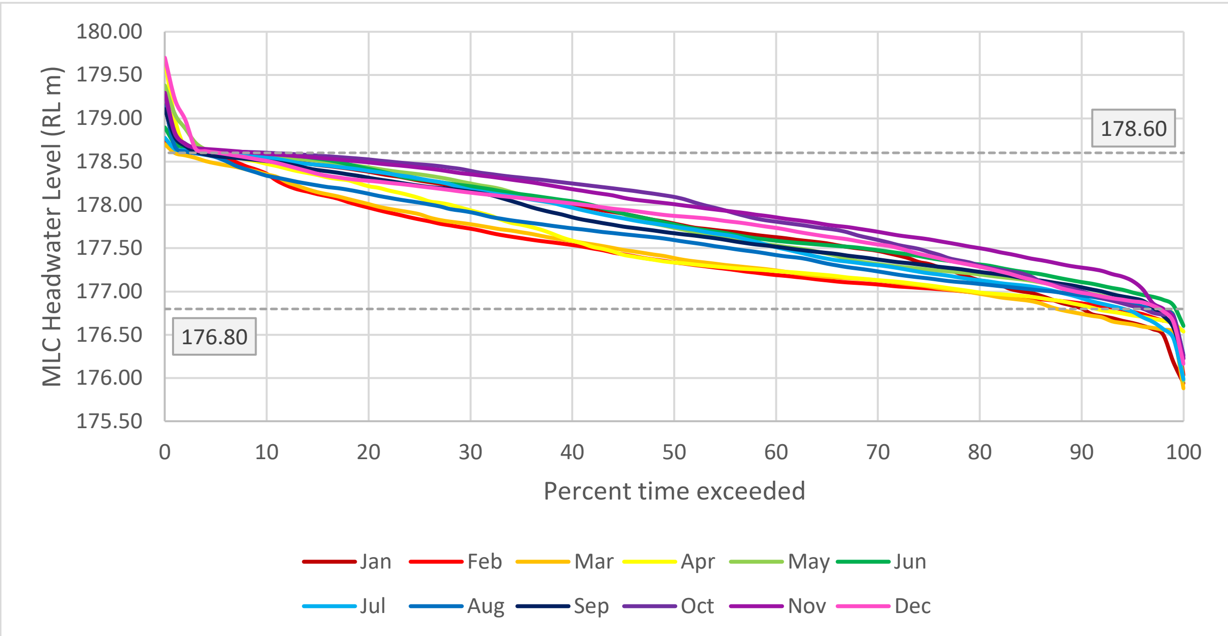
The level of Lake Manapōuri is regulated to provide up to around 150 GWh of energy storage. Given the value of this storage, it can be assumed that the lake level will not be controlled exclusively for the sake of facilitating construction of this project. Lake level management to facilitate safe and efficient completion of the works may be considered depending on the timing, duration and progress of the works, and prevailing hydrological conditions. For the current planning purposes, it is assumed that the historical water level and flow records will best define the possible conditions at the time of the works.

Historical water levels measured immediately upstream of MLC are typically lowest February-April and highest October-November, as shown in Figure 3.3.

Table 3.2: Historical MLC headwater level in RL m (1996-2022) duration statistics by month-of-year

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max	179.15	178.74	178.70	179.68	179.38	178.90	178.78	179.15	179.11	179.26	179.30	179.70
5%	178.60	178.57	178.48	178.59	178.62	178.63	178.61	178.55	178.56	178.63	178.64	178.61
25%	178.28	177.83	177.89	178.08	178.35	178.29	178.31	178.03	178.22	178.47	178.43	178.22
50%	177.78	177.34	177.39	177.33	177.74	177.78	177.75	177.59	177.67	178.09	178.01	177.87
75%	177.32	177.04	177.06	177.07	177.25	177.39	177.21	177.15	177.30	177.46	177.60	177.41
95%	176.64	176.77	176.62	176.72	176.84	176.99	176.77	176.86	176.92	176.83	177.12	176.89
Min	175.94	176.04	175.88	176.54	175.97	176.60	175.99	176.26	176.23	176.26	176.22	176.17

Data Source: Meridian Energy Ltd.



Data Source: Meridian Energy Ltd.

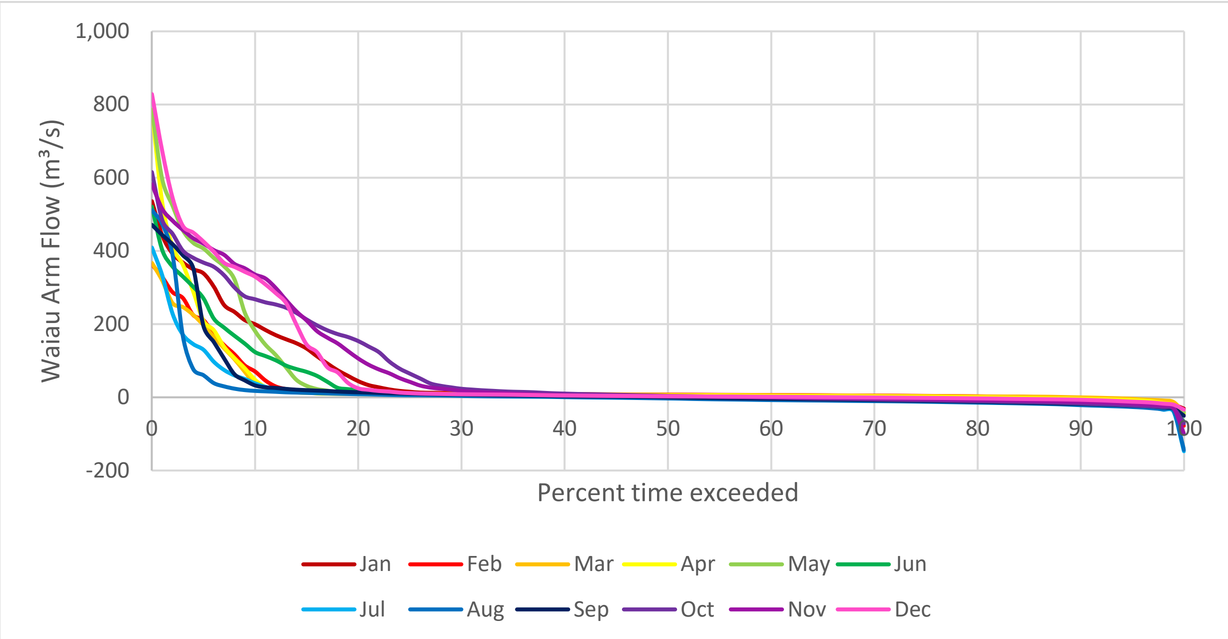
Figure 3.3: Historical MLC headwater level (1996-2022) duration curves by month-of-year

Historical Waiau Arm flow rates are presented in Table 3.3 and Figure 3.4. High flows can happen at any time of year, but are most likely in October to January. Negative Waiau Arm flow rates signify flow capture from the Mararoa River into Lake Manapōuri. It is assumed for planning of the channel excavation works that Mararoa flows will be released directly through MLC, so negative 'upstream' flow rates of any significance can be neglected.

Table 3.3: Historical Waiau Arm flowrates in m³/s (1996-2022) duration statistics by month-of-year. Positive from Lake Manapōuri to MLC, negative from MLC (Mararoa) to Lake Manapōuri

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max	536	363	367	785	785	520	409	511	471	615	582	828
5%	338	211	197	209	406	270	129	60	194	368	419	425
25%	15	10	10	8	7	11	7	6	9	65	42	11
50%	6	7	7	5	1	0	-1	-3	-1	4	2	2
75%	3	4	3	1	-7	-10	-11	-12	-10	-8	-6	-2
95%	-8	-6	-5	-8	-18	-20	-24	-27	-23	-22	-18	-13
Min	-32	-77	-43	-46	-40	-68	-148	-144	-51	-71	-101	-34

Data Source: Meridian Energy Ltd.



Data Source: Meridian Energy Ltd.

Figure 3.4: Historical Waiau Arm flowrates (1996-2022) duration curves by month-of-year. Positive from Lake Manapōuri to MLC, negative from MLC (Mararoa) to Lake Manapōuri.

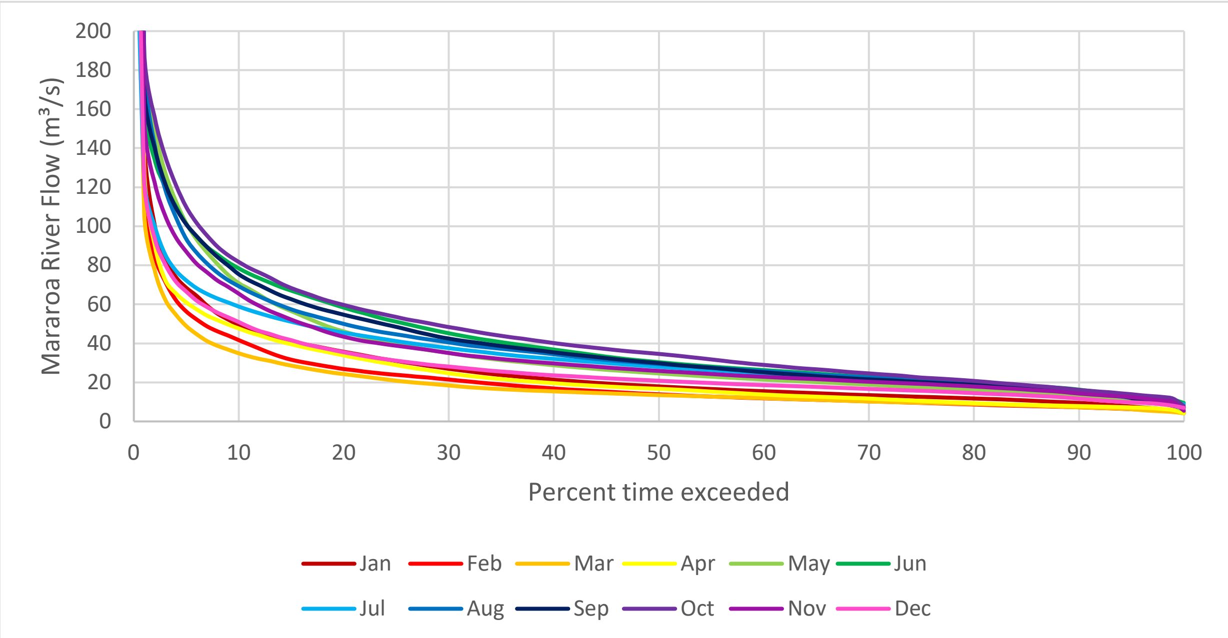
3.4 Mararoa River Flow Rates

Historical Mararoa River flows are presented in Table 3.4 and Figure 3.5. Flows are generally higher in May through to November, and lowest January to April. Very high inflows have occurred at all times of year.

Table 3.4: Historical Mararoa River flowrates in m³/s (1976-2022) duration statistics by month-of-year

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max	826	511	442	831	906	721	322	983	694	573	815	421
5%	68	56	49	61	102	101	72	94	101	110	87	67
25%	31	24	21	29	40	51	41	45	48	53	39	31
50%	18	14	14	17	25	30	28	29	30	35	26	21
75%	13	10	10	11	17	21	20	21	20	22	19	16
95%	8	6	6	7	11	14	12	13	12	14	12	10
Min	4	5	4	4	6	9	9	7	7	8	5	7

Data Source: Meridian Energy Ltd.



Data Source: Meridian Energy Ltd.

Figure 3.5: Historical Mararoa River flowrates (1976-2022) duration curves by month-of-year

In the high-flow months of June to October, the minimum flow release from MLC is usually (>95% of the time) met by flows from the Mararoa River. In the summer months, the lower flows in the Mararoa do not always meet the minimum release requirement (only 40% of the time in Feb-March), so additional flow is required from Lake Manapōuri down the Waiau Arm.

Table 3.5: Percentage of time where MLC minimum flow release is met by Mararoa inflows, by month-of-year

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min MLC Q (m^3/s)	16	16	16	14	12	12	12	12	12	14	16	16
% exceeded	58	43	38	60	92	98	96	97	95	95	86	74

3.5 Bathymetric and Topographic Survey

Meridian provided bathymetric data of the beds of the Waiau and Mararoa Rivers upstream of the MLC Structure, surveyed on the 5th November 2020. The data were provided as a 1 m gridded ascii file, with coordinates in NZTM and elevations relative to Mean Sea Level [MSL] Deep Cove 1960 datum. The data are shown in Figure 3.6, with the colour ramp indicating elevation, from red (RL 167 m) to blue (RL 179 m).

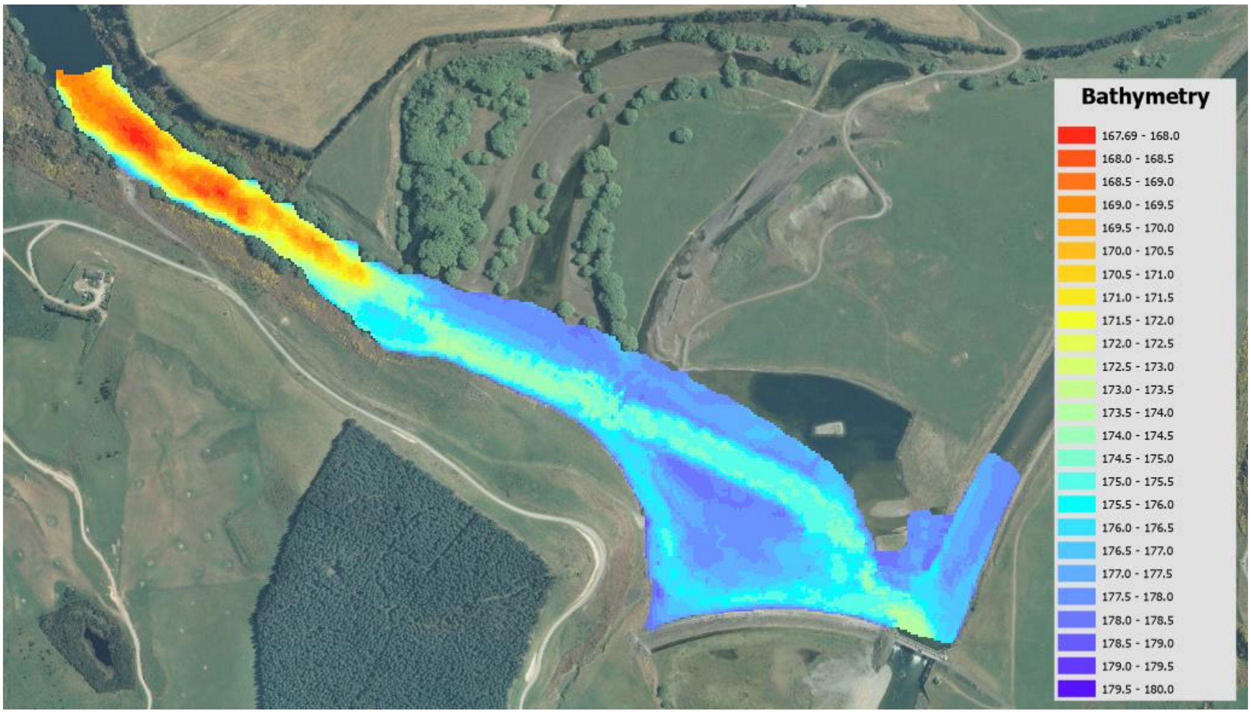


Figure 3.6: 2020 Bathymetric survey data of Waiau Arm channel through the Mararoa Delta area, with MLC Structure at bottom of image

Meridian provided a digital terrain model of site topography (and accompanying orthometric aerial imagery), captured by drone-based photogrammetry in August 2022. The DTM is shown in Figure 3.7.

Elevations in this DTM are to New Zealand Vertical Datum 2016 (NZVD2016). A 0.14 m offset was applied to convert NZVD2016 elevations to MSL Deep Cove, i.e.:

$$Elevation\ (MSL\ Deep\ Cove) = Elevation(NZVD16) + 0.14 \quad \textbf{Equation 3.1}$$

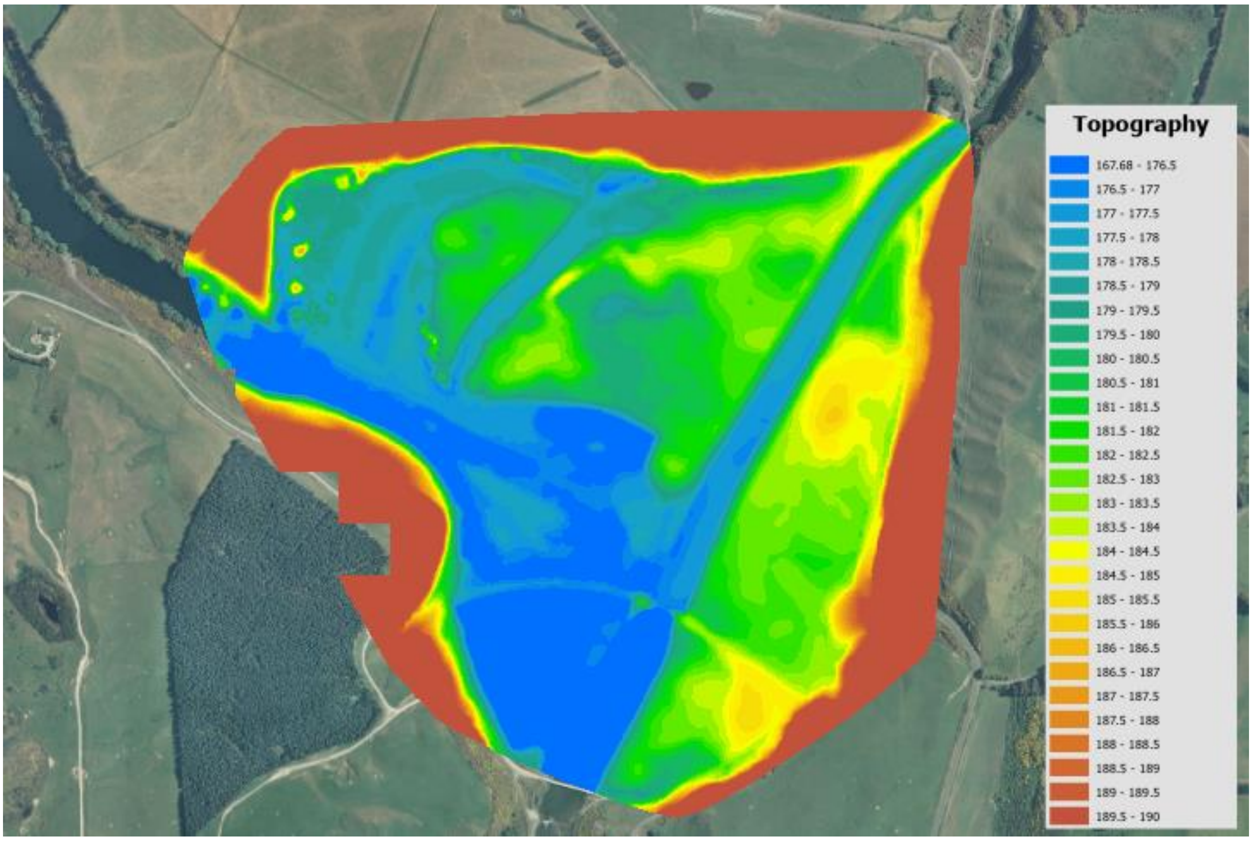


Figure 3.7: Digital terrain model, from drone-based photogrammetry

3.6 Environmental Constraints

3.6.1 Suspended Sediment

Generation of suspended sediment during the works is seen to be a key potential environmental effect to be managed.

The in-channel trial excavations described in Section 5.2 were carried out under the MLC maintenance resource consents, which include conditions limiting the reduction of visual clarity from upstream to downstream of the works. The visual clarity change limit was found to be very restrictive, due to the high clarity of the upstream 'lake' water. These maintenance consent conditions were intended to deal with quite a different set of works and circumstances than proposed in the current project, and are not appropriate for the full-scale excavation works.

The full-scale works will need appropriate measures to manage suspended sediment generation, and compliance thresholds in place that can practicably be adhered to.

During the last significant excavation exercise in March 2007, a bund was constructed across the downstream end of the Waiau Arm to provide 'dead water' conditions around the excavation to minimise the discharge of suspended sediment to the Lower Waiau.

3.6.2 Protected Species

The endemic black-billed gull (tarāpuka) is known to nest on islands and gravel bars or spits near MLC. The nesting season is around September to January. Works should be planned to happen outside of this period, should tarāpuka be roosting and nesting in the area.

3.6.3 Wetlands

Recent legislation[3] has increased restrictions on activities in and near natural wetlands. Areas that potentially meet the legislative definition of wetlands had been provisionally identified in the area close to the proposed works.

Meridian engaged Boffa Miskell to undertake a wetland survey around areas potentially impacted by the February 2023 trial investigations. Within the trial works area and environs, twelve wetland areas were identified, as reported by Boffa Miskell (2023).

3.6.4 Fish Passage

Fish are known to migrate through the area using the fish pass at MLC. Trout spawning season begins in April, meaning the fish pass will need to be open during any works at this time of year, but it is understood that keeping this open should not affect the works.

January to early May is the peak period for adult eel migration. Elver migration season is December to March. Adult lamprey migrate from April to November. The project is only likely to interfere with the elver trap and transfer.

3.6.5 Other Environmental Considerations

Other environmental considerations common to civil works projects will need to be considered, including dust management, noise management, contaminant and spill management, lighting, construction traffic and access, and temporary facilities for construction purposes and staff.

3.7 Construction Window

The environmental effects of various alterative excavation options were considered and discussed in a workshop setting (see Section 4.1 and Appendix A).

The best period for the works to be undertaken is considered to be January to September, based on:

- Avoiding tarāpuka roosting and nesting season.
- Avoiding elver migration season.
- Minimising hydrological risk. October-December is historically the ‘wettest’ period, with the highest median lake levels, and greatest probabilities of high Waiau Arm flow rates.

[3] National Policy Statement for Freshwater Management 2020 and National Environmental Standards for Freshwater 2020

4 Alternative Excavation Methodologies

4.1 Potential Excavation Methodology Workshop

Potential excavation methodologies were discussed in an online workshop between Damwatch and Meridian in April 2022. The attendees included:

Dougal Clunie, Daniel Bardsley, Grant Webby, David Cameron-Ellis, Steve McInerny (Damwatch); Joe Edwards (Independent Consultant); Nick Horswell, Chris Thomson, Neil Sutherland, Derek Pritchard (Meridian); Daniel Murray, Nicolle Vincent (T&T).

While various potential excavation methodologies were considered, the most viable identified were:

- Cutter suction dredging;
- Drag line excavation;
- Excavator from bunds;
- Excavator from barge.

These methods and their applicability for the proposed Waiau Arm excavation are described in Appendix A. In the workshop it was concluded that excavators working from the channel banks and constructed bunds was the most likely technology to be utilised, considering the project size, location and constraints.

4.2 In-channel Excavation from Bunds

Preliminary alternative arrangements for in-channel excavation (i.e. widening/deepening of the existing Waiau Arm channel), using excavators working from the channel banks and constructed bunds, were developed by Damwatch. The alternative options are described in Appendix A.

A high-level multi criteria comparison of the alternative options was undertaken in an online workshop setting in May 2022. It was concluded that there was not sufficient information to confirm the feasibility of all options and select a preferred option, given uncertainties around the nature of the bed material and the quantity of suspended sediment that would be generated by excavation.

Site investigations were carried out to address these uncertainties, as described in Section 5.

Outcomes of the site investigations were considered, and the final excavation arrangement was developed as described in Section 6. This selected arrangement comprises the excavation of a parallel channel, with the in-stream works minimised, to minimise the potential for suspended sediment release to the Lower Waiau River.

5 Site Investigations

5.1 Trial Pit Investigations

Damwatch undertook trial pit investigations along the Waiau Arm river banks adjacent to the proposed excavation area in February 2022, to provide further information on the expected material within the channel excavation area.

With a 13t excavator, nine trial pits (six on the true left bank, three on the true right) were excavated and logged, with samples taken and tested in a laboratory. In addition, geologic observation and mapping was undertaken on the true right bank.

The test pits on the left bank reached bottom elevations of around RL 176.5 m, all encountering alluvial material (gravels, and further from the river sandy silt layered with gravels). Test pits on the right bank were at higher elevations (down to RL 186 m) and encountered clayey silt, suspected to be Dam Formation Members D to F as described in MLC construction reports (GeoSolve, 2016). A glacial till material, interpreted to be Ramparts Till was observed along the true right riverbank.

The investigation confirmed the site geology generally consists of older glacial materials and younger alluvial sediments.

Figure 5.1: Alluvial gravels from left bank test pits (top); Clayey-silt in right bank test pits (bottom left); glacial till observed on right bank, including large-sized boulders (bottom right).

5.2 Trial Bund Construction and In-Channel Trial Holes

5.2.1 Purpose and Planning

To provide further information on the viability of considered excavation methodologies, an instream trial excavation programme was carried out.

The purpose of the trials was to:

a) assess the ability to excavate the riverbed material from a bund platform to a target depth of RL 172 m, including confirmation that a long-reach excavator has sufficient breakout force to excavate the *in situ* material efficiently,
b) quantify the levels of suspended sediment and increase in turbidity resulting from the excavation work, and
c) better understand the nature and characterisation of channel substrate material within the proposed excavation footprint.

The planned works included bund construction from the riverbank and excavation from the bund at three pilot sites (Locations A, B and C). The trial holes in the riverbed were excavated to RL 172 m - the same depth as the proposed final excavation works.

During the week of 13-17th February 2023 these three trial holes were excavated and two additional trial holes were excavated directly from the riverbank (Locations D and E). A 40 t long-reach excavator was used for all five trial holes. The locations from which the holes were excavated (i.e. positions of the long-reach excavator) are shown in Figure 5.2.

Figure 5.2: Locations of completed in-stream trial excavations.

5.2.2 Summary of Site Activity and Findings

In summary, the findings from the trial bund construction and in-channel trial holes include:

- Bunds constructed from locally sourced sandy gravels were a suitable working platform for a 40 t excavator.
- The long-reach excavator had no difficulty excavating riverbed material down to a depth of RL 172.0 m, including an 800 mm diameter boulder at Location B, and solid clay throughout the hole depth at Location C and below RL 172 m at Location A.
- The long-reach excavator was unable to excavate the near-side of the hole at Location E, assumed to be a very large boulder or the remnants of a riprap or boulder embankment formed during MLC construction.
- Samples of riverbed material were collected from Locations A to C at 0.5 m depth intervals. Riverbed materials encountered were:
  - Location A –sandy gravels with some cobbles, becoming finer gravelly sand with depth. d_{50} of samples ranging from 13.4 mm at bed surface to 1.9 mm at around RL 172.
  - Location B – cobbly, sandy gravels to gravels with some sand, d_{50} of samples 21 mm to 12 mm.
  - Location C – silt/clay with thin veneer of gravels on riverbed surface.
  - Location D – sandy gravel.
  - Location E – variable mixture of gravels and cohesive silts/clays. Suspected infill.

NIWA were engaged by Meridian to quantify the suspended sediment generated from the trial works. Data were generally recorded by NIWA at Duncraigen Bridge approximately 375 m downstream of the MLC gates, including:

- periodic visual clarity measurements (primarily to check compliance with the resource consent conditions under which the trials were undertaken),
- continuous records of turbidity from an optical turbidity sensor and an acoustic backscatter sensor,
- periodic suspended sediment gauging using a depth-integrated suspended sediment sampler (D-49), and
- measurements of deposited fine sediment at five transects upstream and downstream of Duncraigen Bridge.

Monitoring showed that bund construction and removal, and excavation of bed material, causes rapid increases in suspended sediment concentration and decreases in visual clarity. The maximum total cross section-averaged suspended sediment concentration during the trial was 25.7 g/m^3 and the minimum visual clarity was 0.5 m (with the baseline visual clarity being ~6 m).

Figure 5.3: 40t long-reach excavator, excavating trial hole at Location A from constructed gravel bund.

Figure 5.4: 40t long-reach excavator, excavating trial hole at Location D from riverbank, with pile of excavated gravels adjacent.

5.2.3 Channel Substrate Material

The channel substrate material encountered in the trial investigations was compared with historical aerial images and construction drawings, from which the following is surmised for the anticipated in-stream excavation (with reference to Figure 5.5):

- The upstream 500 m of excavation is expected to encounter alluvial gravels, similar to the material excavated from holes A, B and D. This is presumed to be material historically deposited by the Mararoa River at its historical confluence with the Waiau Arm (pre 1980s).
- The downstream 220 m of excavation is likely to be historical riverbank material untouched by MLC construction (construction drawings show the area levelled to RL 175.26 m (575')). The substrate material is expected to be similar to the silty-clayey material excavated from hole C, likely similar to the 'Dam Members' identified during MLC excavation (GeoSolve, 2016).
- The central 180 m reach is through the historical Waiau channel which was infilled during MLC construction. Material is expected to be a mixture of alluvial gravel and sand deposits, and variable fill, as encountered in hole E.
- In this central reach, remnants from the construction period (diversion bunds, riverbank protection) may be encountered. Trial hole E encountered a hard edge that could not be easily excavated, while excavation through this reach in 2007 noted "*The diggers are working on the channel just upstream of the gravel island and are extracting some significant sized boulders*." [4] Large boulders on the riverbed in this area are visible in drone footage from the trial excavations.

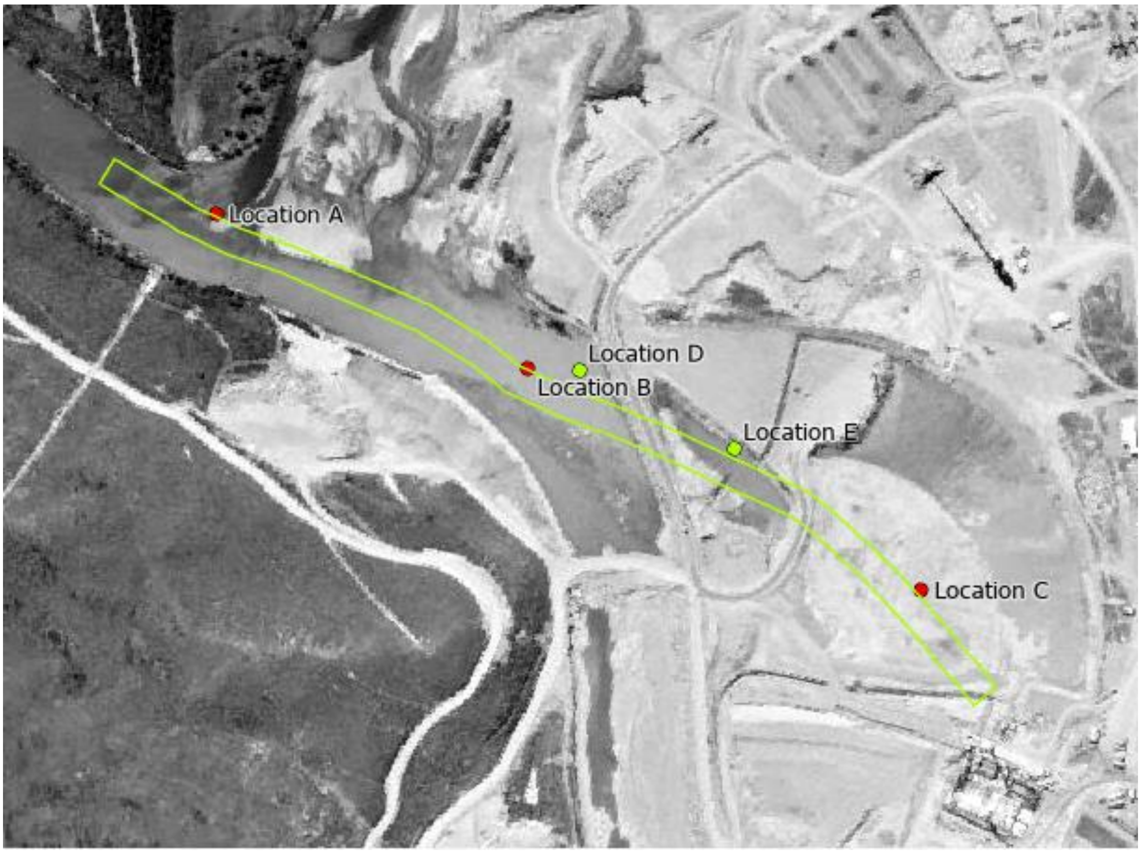


Figure 5.5: Trial hole locations and anticipated in-stream channel excavation footprint, overlaid on aerial image from MLC construction, March 1974

[4] Email J. Holloway to B. Paul and B Sheehan. *rip rap*. 22 March 2007

5.2.4 Bund Material Sources

One of the key outcomes of the trials was that bund construction and removal generated significant sediment plumes, from visual observation and confirmed by sediment monitoring results. The careful selection of suitable 'clean' material to construct bunds can be expected to be an important mitigation for suspended sediment generation.

Potential local sources of gravels that have been investigated are shown in Figure 5.6.

Figure 5.6: Potential gravel sources which have been investigated.

These are:

- TP04, sampled in February 2022, comprising GRAVEL with some cobbles, some sand and trace of silt;
- TP05, sampled in February 2022, comprising sandy GRAVEL with trace of silt, similar to the material used to construct Bund C during trial investigations;
- B1, sampled February 2023, comprising sandy cobbly GRAVEL with trace of silt, the material used to construct Bund B and the majority of Bund A during trial investigations;
- TP1ds, TP2ds, TP3ds, sampled April 2023, deposits on the true-right bank downstream of MLC gates, comprising cobbly GRAVEL with some sand.

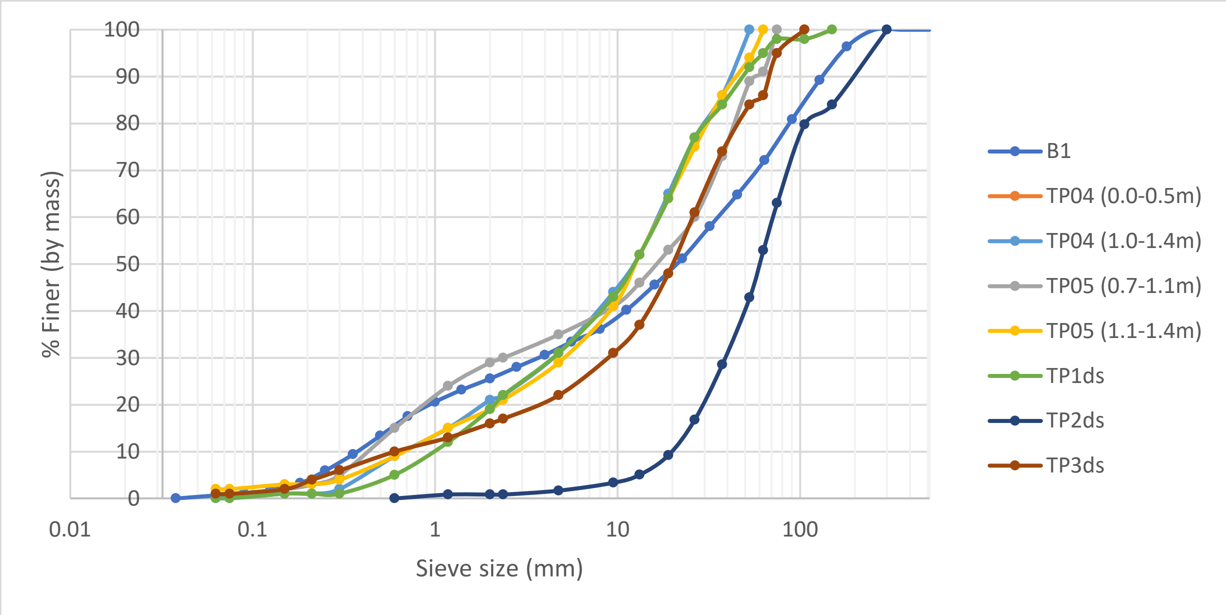


Figure 5.7: Particle size distributions of sampled gravels

During the February 2023 site investigations, the material used for Bund C, likely similar to the TP05 sample, appeared to create less of a suspended sediment plume than Bund B (sample B1). Comparison of these samples shows B1 had a higher percentage of fines, with 9% finer than 0.355 mm compared with 4-5% finer than 0.3 mm in sample TP05. Of the gravels sampled from upstream of MLC, TP04 below 1 m depth was the 'cleanest' material, with only 2% of material finer than 0.3 mm.

Gravel deposits from downstream of the MLC gates were sampled in April 2023. These samples generally included a lower proportion of fine silts and sands than samples from upstream of MLC, consistent with deposition in more turbulent flow conditions downstream of the gates. These materials were investigated for use with an alternative excavation arrangement (see Appendix A), and it will not be practicable to use these gravels for bund construction from the northern bank of the Waiau Arm from a logistical (haul distance) perspective.

6 Proposed Channel Improvement Methodology

6.1 Development of Conceptual Arrangement

The February 2023 trial excavations confirmed the variable channel substrate material, including cobbles and boulders, for which hydraulic excavators are expected to be the most appropriate equipment to construct an improved channel arrangement. The viability of using long-reach excavators to achieve the target excavation depth of RL 172.0 m was confirmed, although the long-reach excavator's breakout force was insufficient to excavate a particular area at 'Location E', assumed to be a very large boulder or the remnants of a riprap or boulder embankment formed during MLC construction.

The generation of suspended sediment during the trial excavation bund construction and removal and channel bed excavation was visually very obvious. It was the project team's opinion that the release of suspended sediment from in-channel excavation is a critical environmental effect requiring further mitigation to develop a suitable design. As such, further sediment management measures have been considered, and the arrangement of the works reconsidered to minimise in-stream works.

A parallel channel excavation arrangement was considered and developed, with the majority of excavation completed remote from the flowing river and in-stream works minimised, to minimise the potential for suspended sediment release into the Lower Waiau.

Figure 6.1: Proposed 'parallel channel' excavation arrangement - trapezoidal channel with base at RL 172.0 m, excavation extent in dark blue shading.

The arrangement includes approximately 225,000 m³ of excavation, to form a channel with a base width of 16 m at RL 172.0 m and 1V:3H side slopes.

The new channel alignment passes through a 'lagoon' area, where the original MLC gate approach channel was excavated in the 1970s (see Figure 2.1) and was subsequently isolated from the main channel by sediment deposition from the Mararoa River on its old alignment. The historical approach channel was excavated to a base of RL 173.13 m. If the base of the lagoon remains at or near this elevation on the channel alignment (around the north-eastern side of the constructed island), further excavation in this reach is unnecessary.

The proposed channel alignment avoids undercutting the foundations of the rock groyne constructed on the true right bank of the Mararoa cut, and of the submerged gabion baskets in front of the MLC forebay, to maintain stability of these structures.

The 1V:3H side slopes of the excavated channel are expected to remain stable across all anticipated flow conditions. Some winnowing of fine materials by high flows will occur on the channel side slopes, with a self-armouring gravel layer expected to develop. Sharp changes in channel profile, where the potential for erosion may be concentrated, are to be avoided.

6.2 Hydraulic Performance

The purpose of the channel excavation is to reduce velocities and thus hydraulic head losses through the Mararoa delta area when large flow rates are released from the MLC gates, allowing greater reliability in flow releases including flushing flows of 160 m³/s able to be released at lower lake levels than is currently possible.

Previous one-dimensional computational hydraulic modelling estimated that the existing main channel excavated to a base width of 25 m at RL 172 m would allow 160 m³/s to be released[5] at a Lake Manapōuri level of RL 177.28 m.

The hydraulic performance of the proposed excavation arrangements was modelled in a two-dimensional computational model using HEC-RAS software. The model showed that with a minimum water level upstream of the delta area of RL 177.26 m for the parallel channel excavation when releasing 160 m³/s at the MLC gates. This is comparable and consistent with the earlier 1D model predictions, given there is negligible water level difference between Lake Manapōuri and the deep Waiau Arm reach just upstream of the delta area.

The model setup is described in a memo (Damwatch, 2023) which also shows the resultant velocity magnitudes and patterns at low MLC discharge.

The modelled velocities through the delta area when releasing 160 m³/s from MLC gates is shown in Figure 6.2 for the proposed parallel channel excavation arrangement. The existing main channel remains available to convey flow, with some 65-70% passing through the new channel and 30-35% passing through the existing channels for this flow condition.

[5] With a minimal Mararoa River flow of 2 m³/s, so 158 m³/s down the Waiau Arm from Lake Manapōuri.

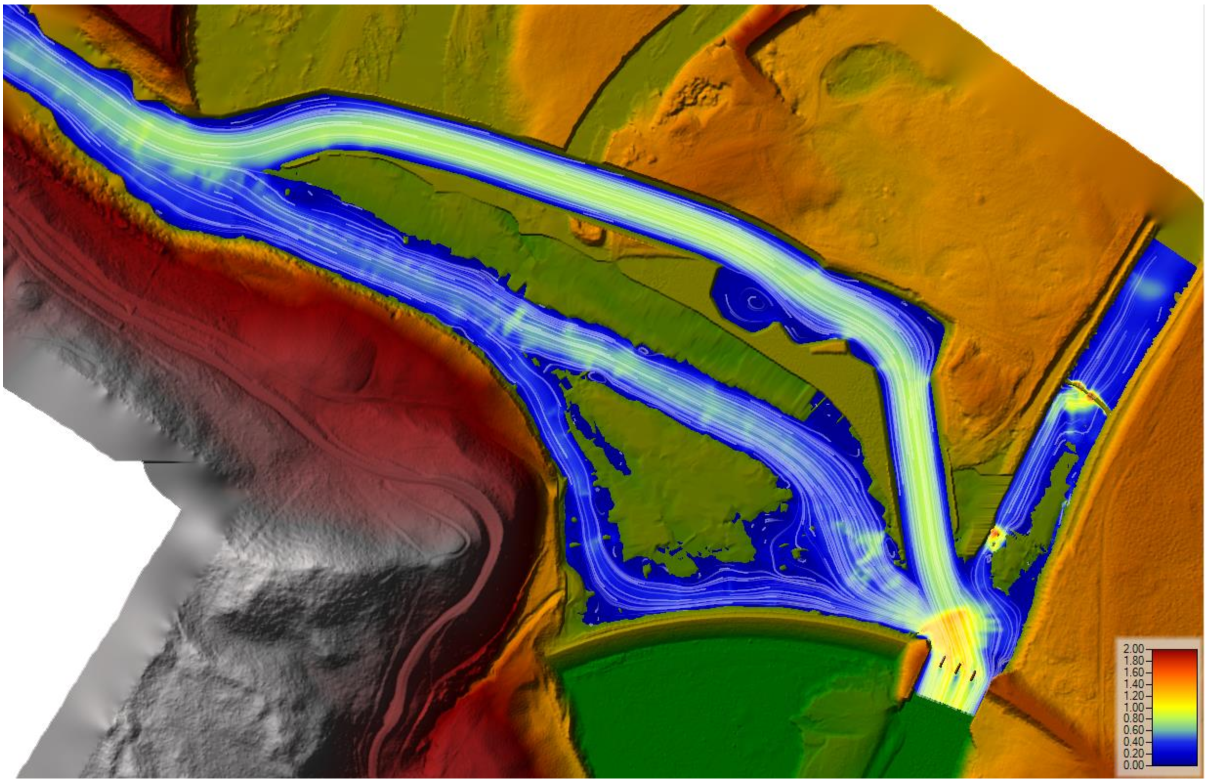


Figure 6.2: Velocity patterns with 160 m³/s MLC release, parallel channel excavation arrangement.

The arrangement will result in lower flow rates through the existing channels during normal operation. Computational hydraulic modelling was undertaken to quantify expected flow rates and velocities in the existing and new channels (Damwatch, 2023).

6.3 Conceptual Construction Methodology

This section of the report describes the anticipated methodology for excavation of the channel. The layouts, sequencing, programming, equipment etc. presented at this stage of the project are considered at a concept level of design only. Further detailed design and planning is required to take the concepts into implementation and this should take into account variations in site conditions including variable river levels that are likely to be experienced thought the construction period.

The proposed excavation arrangement and anticipated methodology aims to complete as much as possible of the excavation remote from the flowing river, to minimise the potential for suspended sediment release into the Lower Waiau River.

6.3.1 Works Arrangement and Sequencing

The overall works arrangement is shown conceptually in Figure 6.3. Some 85% of the excavation (by volume) will be completed remote from the Waiau Arm, behind flood-protection bunds built up on the left riverbank. This channel will then be connected to the Waiau Arm by removing the bunds and completing excavation of the new channel’s inlet and outlet.

Figure 6.3: Proposed excavation arrangement, with excavated channel footprint shown blue with channel base in green outline, haul roads in black outline, bunds to isolate the works from the Waiau Arm in orange.

The general site layout is indicated in Figure 6.4 below, and drawing E2243-101 (Appendix C). The different site areas, and activities comprising the conceptual methodology are described below.

6.3.1.1 Site Establishment

An area of approximately 20,000 m² is identified, close to the excavation footprint and incorporating the main access track into the site, for the Contractor's Establishment Area. This area will contain all of the contractor's temporary facilities including offices, lunchrooms, portable ablutions, storage for fuel, oil and other substances. In addition, the area will include space for parking and refuelling of plant.

The area is relatively flat, with existing ground varying from around RL 179 to 183 m. It includes the flat area that was historically used for gravel stockpiling. Setup activities will include the clearing of any vegetation or debris, and identifying and/or constructing flat areas above potential flood levels to locate facilities. It is noted that areas below RL 180.5 m elevation may constitute 'lake bed' for land use planning purposes, although there is no evidence of flooding up to this level. Any storage areas and temporary buildings will be sited on ground above this elevation.

Stormwater from buildings and any hardstand areas will be discharged to land. Fuel, lubricants, oils and any other hazardous substances will be stored with suitable secondary containment systems in compliance with hazardous substances regulations.

The Contractor will be responsible for defining and providing temporary site security and safety measures, in compliance with the Health and Safety at Work Regulations and other relevant regulations.

There will likely be a need to upgrade gravel access roads within the Meridian property, to facilitate the transport of large plant or temporary facility buildings to site. This is expected to include increasing the radius of bends on the track and clearing material from the track verges. These access track upgrades will benefit the long-term use of the site.

Site establishment will include setting up a source of water for site dust control. It is proposed that up to 60,000 litres of water per day will be extracted directly from the Waiau or Mararoa River at a suitable location. With appropriate intake screening to exclude aquatic organisms, water will likely be pumped directly to the tank of a water cart. Water will be extracted and used on an as-needed basis, during prolonged dry or hot/windy atmospheric conditions. Pumping will be intermittent, with the cart typically filled in the morning and refilled during the day if required, considering an expected cart capacity of 20, 000 to 30,000 litres. During dry conditions, the water cart will spray up to 5 mm of water per day on dust-prone areas, particularly the haul roads.

6.3.1.2 Spoil Area

The spoil area will be prepared as an initial stage. An area of grassland, previously planted in eucalypt and pine, was identified as a suitable spoil area totalling 120,000 m². The substrate is free-draining gravelly material. Existing topographic depressions have been identified as wetlands by an ecological survey (Boffa Miskell, 2023), and the identified spoil area avoids these with a minimum set back of 10 m.

To prepare the spoil area vegetation (including planted pine/eucalypts) and topsoil will be stripped, with topsoil stockpiled as perimeter silt control bunds, for later reinstatement over the area. Site observations suggest that there may be very little ‘soil’ as such, and the bunds will likely contain a mixture of what topsoil is present, and silty gravels. The bunds will be approximately 3.0m in height above the existing ground, with relatively gentle side slopes of 1V:3H. The bunds will retain run off from the spoil when placed, which will soak into the permeable gravel subgrade.

With a total area of approximately 120,000 m² and a total channel excavation volume of approximately 225,000 m³, the spoil areas will be filled an average of 1.9 m. The area will be filled in layers of approximately 0.3 m, spread and compacted by bulldozer and grader. Where the excavated material is clay, there may be a need for drying and potentially blending with dry gravels to keep the fill stable.

It is estimated that around 150,000 m³ of the excavated material may be alluvial sands and gravels, which may have value for reuse as a construction material. A portion of the spoil area has been set aside as a stockpile cell, where gravels will be selectively placed, for potential future reuse. The stockpile cell has a capacity for some 100,000 m³ of compacted spoil.

The spoil area will be contoured with minimum surface gradients of 2% draining toward the perimeter, to encourage surficial runoff of rainfall. At completion, the perimeter bunds will be trimmed to a gradient of 10% (1V:10H), with recovered topsoil material spread for surface rehabilitation and sown with exotic pasture species. The gravel cell portion of the area will not be finished with topsoil, but rehabilitated at the conclusion of gravel removal.

Gravel removal from the stockpile cell may continue over a number of years, and so to allow progressive rehabilitation, removal will continue to the final finished level in ‘bands’ working south to north. On completion of gravel removal from the cell, the resultant surface should be scarified and sown in pasture to match the surroundings.

6.3.1.3 Excavation Stage 1

The proposed stages of excavation are shown in Drawings E2243-102 and E2243-103 (Appendix C).

In the initial excavation stage, the highest areas on the new channel alignment will be excavated, with suitable excavated material used to construct dual-lane haul roads along the length of the new channel alignment on the true-left and bunding on the riverbanks on the new channel's true right.

Haul Roads and River-side Bunding

Haul roads and bunding will be built up above expected river levels (to an approximate 1/5 AEP or 800 m^3/s discharge level of RL 179.3 m), to prevent the direct flow of water into the new channel excavation area. For the majority of their length, the haul roads will be on existing ground. Where it crosses the historical Mararoa channels, the haul road will be built up approximately 1 -2 m above the current ground level, with culverts included in the road embankment construction. The exception is the road crossing of the western-most of the historical Mararoa channels, which doubles as a river-side flood protection bund. On this channel no culvert will be included, to maintain the exclusion of high river levels from the works, but this portion of haul road will be removed as part of Stage 3 excavation.

The anticipated culvert locations are shown indicatively in Figure 6.4 and Drawing 102 (Appendix C). Whilst the area to the north is only ephemerally flooded, and so is likely to contain low habitat value for aquatic organisms, the culverts will be appropriately sized, arranged and detailed during detailed design to provide continuity of habitat for aquatic organisms. This will include sizing the culverts to avoid excessive velocities, embedding the culvert invert within well-graded substrate and maintaining natural invert gradients.

The river-side flood bunding will prevent the direct flow of river surface water into these culverts and channels whilst in place through Excavation Stages 1 and 2. Bunding will be removed during Excavation Stage 3, described below.

Appropriate fish monitoring and salvage plans will be in place where bunding or roads are constructed across wetted areas.

Other Initial Works

Initial works will include clearance of vegetation including crack willows and other plants from the excavation and road footprint. Vegetation could be chipped for use in ground surface remediation at the conclusion of the works, though this may not be appropriate for invasive willows that can regrow from small fragments, for which a specific removal/eradication plan may be required.

Excavation Stage 1 will excavate high-points on the channel footprint down to RL 179.3 m, removing approximately 32,500 m^3 of material. Topsoil will be stockpiled in spoil area perimeter bunds. Some 15,000 m^3 of material may be reused to construct the roads and bunds, with the remaining material carted to the spoil area for disposal. Alternatively, riverbank gravels may be used to construct the bunds if the prevailing river level allows (the river banks are submerged at medium to high river levels). The use of local riverbank gravels may allow very rapid bund construction using a bulldozer.

The spoil areas and features of Excavation Stage 1 are shown in Figure 6.4. It is noted that a very small wetland of low ecological value (Wetland #1, Boffa Miskell 2023) is within the excavation area, and will be removed by the construction.

After site establishment and initial establishment of working spoil areas (estimated two weeks duration), it is estimated that excavation Stage 1 will take some two weeks to complete.

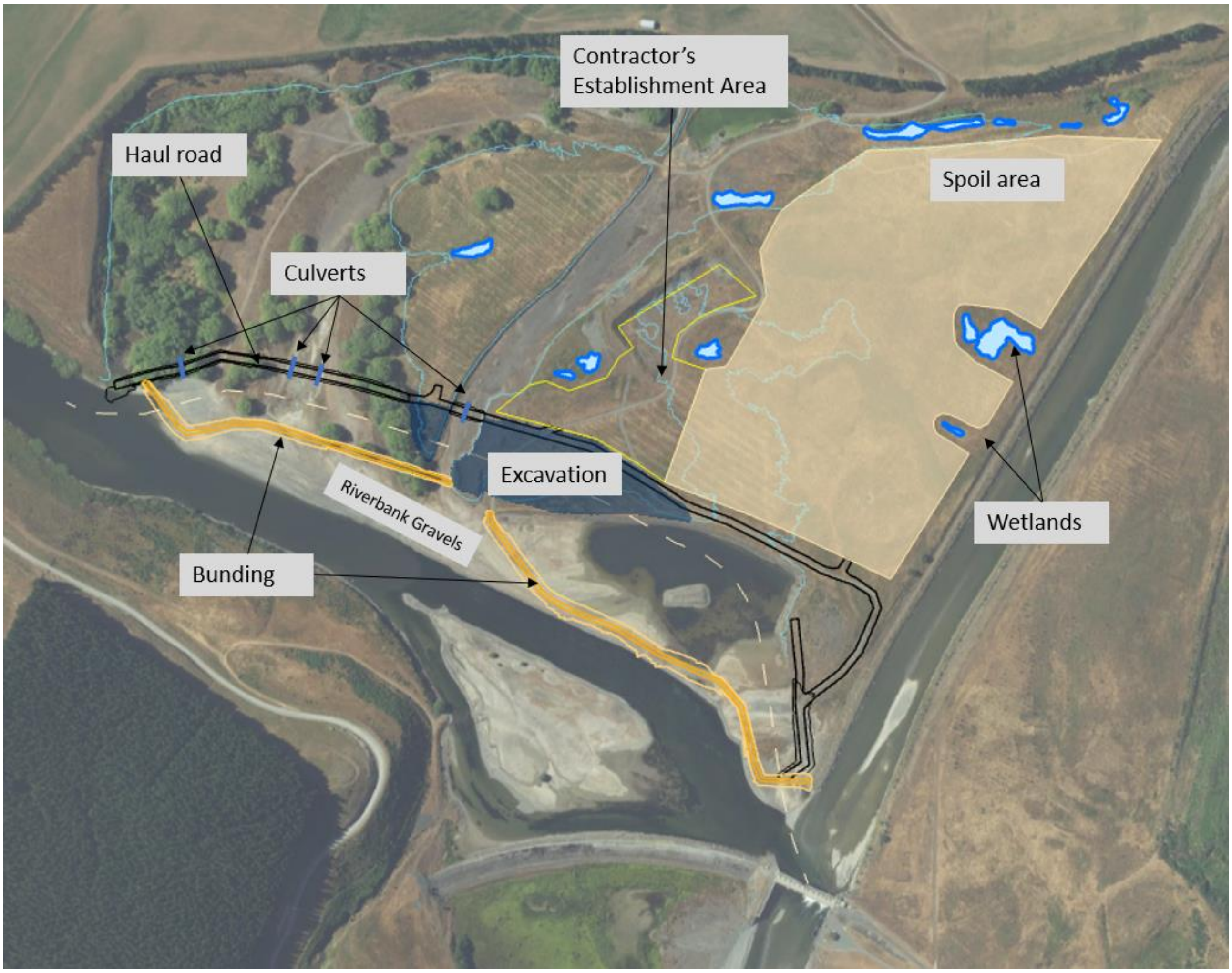


Figure 6.4: Excavation Stage 1, with areas of channel excavation to RL 179.3 m shown in dark blue. Wetland areas (in light blue) and the RL 180.5 m contour are also shown.

6.3.1.4 Excavation Stage 2

With the bunding in place, the bulk of the channel excavation, below potential river levels, can be undertaken. It is anticipated that excavation will progress at 2-3 work fronts simultaneously.

There will inevitably be water within the excavation, from existing groundwater (associated with the prevailing river level) as well as river water seeping through the riverbanks and bunds. The water level within the excavation will depend on current rainfall and river levels as well as the groundwater level driven by the river levels over recent days or weeks. Excavators will work from elevations above the prevailing water level within the excavation area (say 600 mm above water level), with long-reach diggers likely required to reach the ultimate depth of RL 172.0.

A total excavation volume of approximately 163,000 m^3 is anticipated to be removed during the Stage 2 excavations. It is estimated that 75% of this can be undertaken by standard-arm excavators and 25% by long-reach excavators, given typical river (and assumed groundwater levels).

The excavated material will be placed next to the working excavation face, to allow water to drain from the material, then carted by articulated dump trucks (ADTs) to the spoil area for disposal. The material may be left next to the working face for a few hours to allow the separation of activities of long-reach excavation and dump truck movements, and thus more efficient utilisation of the plant which may be working at different rates. These temporary stockpiles would be in the order of a few hundred cubic metres of material (or a few tens of truckloads).

It is estimated that excavation Stage 2 can be completed within 8 weeks, with 3 excavation fronts operating simultaneously (2x north-western area, 1x south-eastern area).

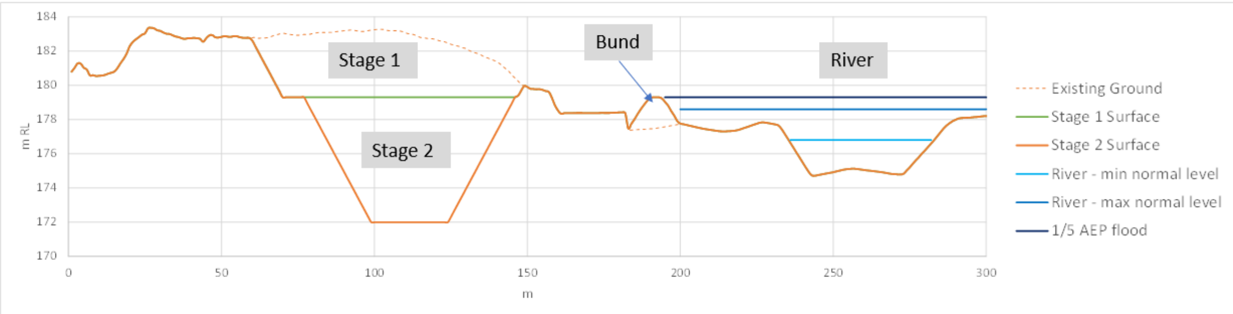


Figure 6.5: Cross-section through excavation, showing existing ground surface, Stage 1 excavation, Stage 2 excavation, bunding, and main river channel.

High prevailing river levels could mean higher water levels within the excavation than assumed, a higher working platform for the excavators, and a greater proportion of excavation having to be performed by long-reach excavators, with associated cost, and programme implications. Measures to mitigate this include:

- Managing lake levels and/or managing excavation progress such that excavation of deepest levels of the channel do not coincide with high lake levels.
- Allowing additional contingency in pricing and programming of works for a greater proportion of long-reach excavation.
- Partial dewatering of the excavation during initial Stage 2 excavations, if practicable.

Provisions for Groundwater Management

Potential provisions for partial dewatering of the excavation are described below and illustrated in drawing E2243-107 (Appendix C). Provisions have been considered to allow reduction of the surface water level within the excavation area by up to 2 m, however there is insufficient hydrogeological data to confirm the efficacy of these arrangements over all conditions, and the arrangement should be considered conceptual/indicative only.

The efficacy of dewatering methods will depend upon the proximity of the excavation to the river or lagoon area, the prevailing groundwater and river levels, and the permeability of the ground. It is considered unlikely that dewatering will be effective for the excavation area to the south-east of the lagoon area.

Potential dewatering provisions include:

- Submersible pumps in large excavated sumps adjacent to excavation, drawing down the local groundwater level by pumping to remote seepage ponds (Illustrated in Drawing 2243-107). A more formal well-point system (with multiple smaller pumps in smaller temporary wells in the same vicinity) may be preferred if the contractor has the equipment available, and
- Impermeable geomembrane lining placed on the riverside bund slope to reduce seepage from the river.

Groundwater will be pumped to a seepage pond or ponds, up to approximately 2,500 m² in area, constructed within the spoil area approximately 400 m north-east of the channel excavation adjacent to the Mararoa River. From the seepage pond, water will infiltrate into the underlying ground, where the water table will be influenced by the prevailing Mararoa River level.

The dewatering rate will be managed by a pump control system to maintain a maximum water level (nominally RL 182 m) in the seepage pond. Pumping rates, duration, frequency, volumes and times will thus depend upon the prevailing river levels and local groundwater levels, and the permeability of the ground beneath the seepage pond(s). The efficacy of pumping in effecting drawdown within the excavation will depend on such pumping rates and volumes, on the permeability of the riverbanks and ground near the excavation, and on prevailing river and local groundwater levels.

Pumping rates of up to 200 l/s may be required to effect a drawdown of the water surface within the open excavation of 2 m depth, based on permeability estimated from sampled ground particle size distributions. This remains uncertain however until the specific ground conditions (permeability and associated seepage rates) are proven. Higher pumping rates than this are unlikely to be feasible as the capacity of seepage pond will become a limiting factor (especially if affected by clogging from silty inflows) unless multiple or very large seepage areas are utilised, which would be impracticable. If seepage rates become a limiting factor, the drawdown depth would be reduced.

Maintenance of the seepage pond may be required to maintain its performance. This will include removing any fine sediments that have settled on the base of the pond to spoil and mixing the gravels that form the pond base to restore their permeability.

Especially as the excavation extent increases and gets closer to the river, pumping to make an appreciable difference to water level and construction efficiency within the excavation may not be practicable, fighting against excessive seepage into the excavation. It is anticipated that pumping to lower water levels within the excavation could only be potentially practicable for the first half of the Stage 2 duration, or approximately 4 weeks.

Once excavation dewatering becomes impracticable, the seepage pond will be repurposed for spoil disposal.

Lagoon Area

There is uncertainty around the current bed level of the lagoon, with recent bathymetric data not collected in this area. This area was part of the approach channel to the MLC gates excavated during the original MLC construction (see Figure 2.1 and Figure 5.5). Where the bed of the lagoon remains at or close to its constructed level of RL 173.13 m, it will provide sufficient hydraulic conveyance and there is no excavation required. It has been assumed that a portion of the south-eastern side of the lagoon will need to be excavated, as shown in Figure 6.6. Bathymetric data should be collected from the lagoon area to confirm current bed levels and the extent of excavation that will be required. Where excavation is required with the lagoon, it will likely be carried out by a long-reach excavator working from finger bunds.

In this method, a gravel bund is constructed in the lagoon as a 'finger' extending from the riverbank, to form a platform on which an excavator can work, excavating material from the riverbed in front of and adjacent to the bund. Excavation progresses with the finger itself and the riverbed underlying it excavated and works back toward the riverbank.

Bunds will be constructed from selectively stockpiled gravels from earlier channel excavation, and/or riverbank gravels to a nominal 'freeboard' level above the prevailing river level.

Figure 6.6: Excavation Stage 2, with channel base at RL 172 shown in green outline, and excavation area shown in blue. Dashed 'finger-bund' shown to allow excavation within lagoon area.

A modified channel profile is included at a location in the mid-reach of the new channel (600m upstream of MLC), providing a suitable slope for a temporary vessel haul-out slipway. The works include a 1V:6H ramp 'notched' into the true-left channel bank, as shown in Figure 6.7. The sides of the ramp will be excavated to a stable 1V:3H batter. This mitigates the loss of a similar existing facility on the channel excavation alignment used by Real NZ.

The location is indicative. An alternative location for the ramp inside the lagoon area may be considered if more suitable due to hydraulic conditions and manoeuvrability.

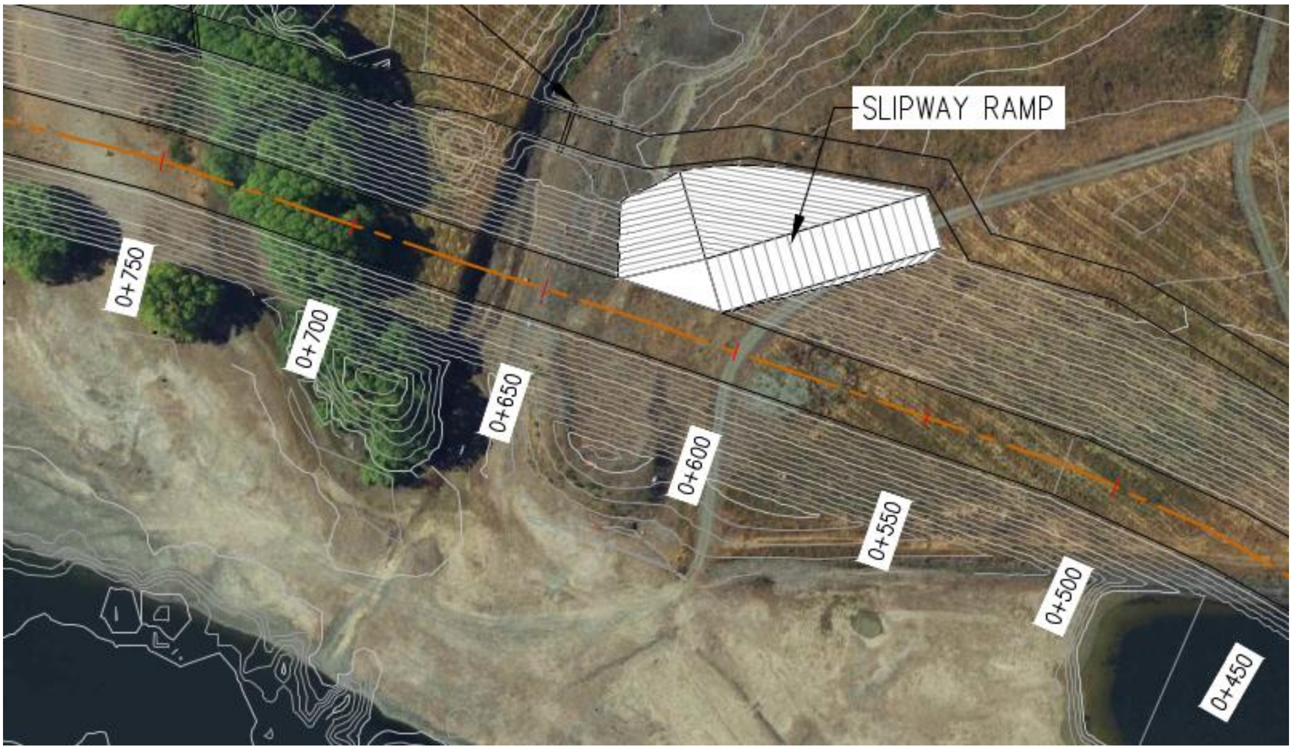


Figure 6.7: Excavated ramp to provide for temporary haul-out slipway (indicative location)

6.3.1.5 Excavation Stage 3

The final stage of the excavation involves in-river works to deepen the approach, inlet and outlet of the new channel and ‘cutting in’ to the existing main channel. Conceptual layouts for this stage are shown on drawings E2243-104 and E2243-105.

Activities include:

- In-stream excavation within the Waiau Arm at the new channel approach and inlet, by long-reach excavators working from finger bunds pushed out from the haul road on the northern (true left) bank.
- Rehabilitation of the bunding previously placed on the riverbanks in the preceding stage, entailing reshaping to a natural-looking topography. It is envisaged that this material will be spread out on the riverbanks rather than trucked back to the spoil areas.
- Removal of the riverbank ‘plug’ separating the upstream end of the excavated channel from the Waiau Arm, using a long-reach excavator.
- Removal of elevated haul road across the western-most historical Mararoa channel, to restore direct hydraulic connectivity to the old channel area to the north. As described above culverts will be placed below the haul road construction at the other historical Mararoa channel crossings, allowing road access to remain along the remainder of the new channel bank whilst providing hydraulic connectivity.
- In-stream excavation within the Waiau Arm at the new channel outlet, by a long-reach excavator working from a finger bund pushed out from the riverbank ‘plug’ behind the Mararoa groyne.
- Removal of the riverbank ‘plug’ separating the downstream end of the excavated channel from the Waiau Arm, using a long-reach excavator.

All of these activities are carried out 'in river' and will generate some degree of suspended sediment. It is anticipated that the largest concentration of sediment will be released at the final step when the downstream 'cut in' is completed, exposing the excavated channel to flow for the first time and flushing out suspended sediments contained within.

Management of this expected sediment release could include:

- Concurrent elevated flow release from MLC gates to dilute and help disperse suspended or settled sediment. Discrete releases of heightened flow and sediment would mimic natural flood pulses from the Mararoa and may be acceptable from an environmental effects mitigation perspective.
- Delaying the time of the final downstream cut-in to coincide with a natural fresh with elevated flow and suspended sediment levels in the Lower Waiau.

To reduce suspended sediment generation, the cleanest available gravel material should be utilised for finger bund construction. This may include selectively stockpiled gravels from earlier channel excavation, and/or riverbank gravels.

To minimise the duration of sediment release, the upstream end and downstream end should be excavated simultaneously. It is estimated that excavation Stage 3, including the removal of bunds from the riverbanks, in-stream excavation and cut-in of the final riverbank sections can be completed within approximately 5 weeks.

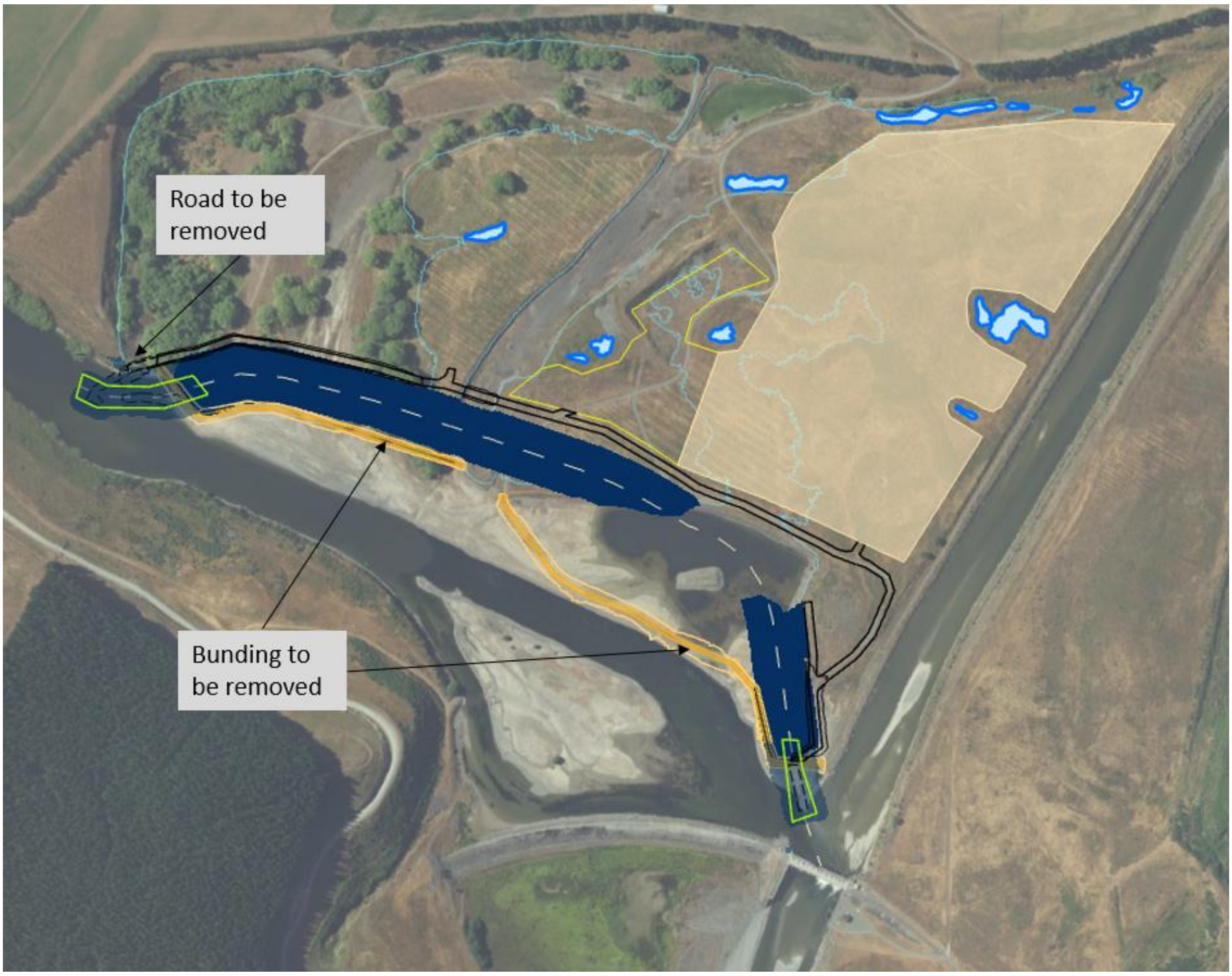


Figure 6.8: Stage 2 excavation shown in solid blue, Stage 3 excavation in transparent blue with channel base at RL 172 m outlined in green.

6.3.2 Flow and Lake Level Management

It is intended that the MLC gates will be operated to minimise flow in the Waiau Arm during the works, and avoid flows toward Lake Manapōuri. Gates will be opened to discharge the Mararoa River inflow plus a margin, ensuring that any suspended sediment generated by the works will not travel up the Waiau Arm toward Lake Manapōuri. If the level of Lake Manapōuri exceeds its maximum control level, discharge down the Waiau Arm will be required to adhere to statutory flood rules.

There may be the potential to manage Lake Manapōuri levels to de-risk the works at key moments. Having the lake level low will reduce the required volume of finger bunds to be constructed to allow in-channel excavation and subsequently removed.

Flooding of the work area caused by high inflows to Lake Manapōuri is a risk to the project, though is mitigated for smaller floods by the flood protection bunds to approximately a 1/5 AEP river stage (approximately 800 m^3/s MLC discharge) constructed around the majority of the work area. Lakes Manapōuri and Te Anau provide attenuation of high inflows, meaning flood rise is relatively slow (generally days rather than hours) but flood outflows may persist for days or even weeks. In addition, Meridian Energy have a system providing reliable forecast of catchment inflows 4-5 days in advance.

Inflow and lake level forecasts should be conveyed daily to the site foreman during the works. Procedures should be in place to withdrawal works from the river at defined trigger levels or forecasts. All plant should be moved to the establishment area ('go line') which should be situated on high ground well above potential flood levels.

6.3.3 Construction Equipment

It is anticipated that where practicable, the excavation work will be completed using standard-arm excavators, with the advantage of greater production rates than long-reach excavators. Long-reach excavators will be required for the deeper sections of Stage 2 excavation, and for Stage 3 excavation.

The following is a list of the anticipated main plant on site to execute the works with the methodology described, noting that not all of this equipment will be in use across all stages of the excavation works:

- 4 x 35t long reach excavators
- 4 x 33t standard excavators
- 6 x 35t articulated dump trucks (ADTs)
- 2 x Cat D8 or D6 bulldozer (possibly swamp-tracked for management of the spoil area)
- 2 x Cat 16 grader
- 5 x 4x4 utes
- 1 x 30t articulated water cart
- 1 x diesel-engine pump to fill water cart
- 2 x diesel-engine dewatering pumps
- 2 x gensets for night lighting

The actual size and quantity of machinery used will be subject to the contractor's available equipment and approach.

6.3.4 Construction Programme

The concept methodology considers the sequential completion of excavation in stages, with multiple work fronts progressing in parallel during each stage.

The overall construction period is envisaged to be approximately 4-5 months, with the duration of each stage of the excavation works outlined the sections above, and summarised in Table 6.1.

The construction work is proposed to be undertaken on a 7 days per week and up to 24 hours per day basis, which will require artificial floodlighting to be used outside of daylight hours.

Table 6.1: Estimated construction programme

Activity	Duration (approx.)
Planning (off-site)	**5 weeks**
Site Establishment, including initial setup of spoil areas	2 weeks
Stage 1 excavation, including haul road and bund construction	2 weeks
Stage 2 excavation	8 weeks
Stage 3 excavation	5 weeks
Site rehabilitation and demobilisation	2 weeks
Total on-site duration	**19 weeks**

6.3.5 Key Risks

Table 6.2: Environmental and personal safety risks identified in conceptual methodology

Identified Risk	Proposed Design Mitigation
The safety of workers on or near the water, particularly in times of high lake level and high flood discharge, as well as the security of construction plant, fuel, etc. against flood damage or loss.	Parallel channel arrangement, with the majority of the works being away from flowing water. Flood protection bunding to exclude flood flows from the majority of the work site. Inflow flood forecasting and river withdrawal procedures to be put in place.
The impact of floods on the works, including material being washed into work areas requiring rework and reconstruction of temporary works, or delays to in-river works when the river is in flood.	Parallel channel arrangement, with the majority of the works being away from flowing water. Flood protection bunding to exclude flood flows from the majority of the work site. Inflow flood forecasting and river withdrawal procedures to be put in place. Where possible, lake level management may be an option to minimise risk for in-stream portion of works (Stage 3 excavation).
Runoff of silt from excavated material entering waterways.	Excavation area expected to include silty standing water, but offline from flowing water until final excavation stage. Management of the expected sediment release at final excavation stage could include: • Concurrent elevated flow release from MLC gates to dilute and help disperse suspended or settled sediment. • Delaying the time of the final downstream cut-in to coincide with a natural fresh with elevated flow and suspended sediment levels in the Lower Waiau. Spoil area to include perimeter bunds to avoid surface runoff into waterways.
Generation of airborne dust or particulates from bare land and construction traffic, with negative impacts on workers and the environment.	Dust suppression using truck-mounted water spray.
Locating sufficient topsoil to rehabilitate the spoil areas, with insufficient rehabilitation leaving residual land stability and visual effects.	Acknowledgement that existing topsoil is sparse and the land 'bony'. Slopes in excavated areas and spoil area designed with gentle slopes. Suitable colonising species to be used for revegetation of disturbed areas.
The stability of flood protection bunds on the riverbanks during prolonged high water and/or high flow conditions.	Bunds designed with relatively low height above existing riverbank terrace, with stable profile. Requirements for protection of bund corners exposed to river currents to be evaluated during detailed design. Exposed corners potentially armoured with larger gravels.

Identified Risk	Proposed Design Mitigation
The stability of temporary finger bunds to support excavation machinery over water.	The process has been tested and viability confirmed during trial excavations, but warrants defensive construction measures e.g. preferential selection of angular gravels for construction, and ongoing monitoring and repair/enhancement work as required during use.

6.4 Site Rehabilitation

Following completion of the channel excavation, the site will be rehabilitated to leave a natural-looking topography. Rehabilitation activities will include:

- Removal of temporary bunding by spreading on riverbank flats.
- Contouring of spoil areas to allow runoff to be appropriately directed.
- Replacement of topsoil cover on spoil areas.
- Re-grassing or planting of spoil areas.
- As note above, the gravel stockpile cell of the spoil area will not be finished with topsoil at the completion of the project excavation works, but will be progressively rehabilitated as gravel is removed from the gravel stockpile area.
- Removal of all temporary structures from the Contractor's Establishment Area.

The concept design allows for the retention of some of the haul roads to allow for future maintenance, with culverts beneath the road surface providing hydraulic connection between the new channel and the historical Mararoa areas to the north.

6.5 Excavated Channel Maintenance

There is expected to be minimal maintenance required for most of the new excavated channel.

Gravel deposition has historically occurred in the area from material transported by the Mararoa River. With the 1980s realignment of the Mararoa River to join directly upstream of the MLC gates, and operational changes to ensure all turbid flows are released directly through the gates, there is little chance of coarse sediments being transported through the excavated channel reach and depositing.

Flows from Lake Manapōuri carry negligible sediment load, due to the trapping effect of the lake and more locally the deep upstream Waiau Arm channel. Sediment is reportedly introduced to the Waiau Arm from high inflows at Home Creek, although only very fine fractions will be transported to the Mararoa delta area.

Gravels transported by the Mararoa River do deposit immediately upstream of the gates and require periodic[6] removal. It is expected that there will be a need for ongoing channel maintenance with some transported gravel material depositing 'around the corner' in the downstream-most reach of the excavated Waiau Arm channel and the existing channels. The method used to remove deposited gravels and restore the channel depth, and the frequency of such works, can be expected to be similar to what is done

[6] Approximately 5 yearly, from discussion with Meridian Environmental Manager

currently, with an excavator working from a low-level temporary gravel bund. The alignment of the parallel channel directing large flow releases more directly toward the gates can be expected to have a positive influence in re-entraining and 'flushing' deposited material.

7 Summary and Conclusions

This report documents the proposed arrangement and construction methodology for Waiau Arm channel improvements, to provide greater reliability in flow releases from MLC.

Based on the objectives and site constraints, alternative methodologies for channel excavation were considered and debated in workshop settings. To provide further information on the viability of considered excavation methodologies, an instream trial excavation programme was carried out. The trial excavations confirmed a variable channel substrate, and the generation of significant amounts of suspended sediment from in-channel bund construction and excavation. These outcomes led to the preference of a parallel channel excavation arrangement, with the bulk of excavation completed remote from the flowing river and in-stream works minimised, to minimise the potential for suspended sediment release into the Lower Waiau.

The proposed excavation arrangement and methodology described in Section 6 of this report and the associated drawings (Appendix C) are to be used for assessments of environmental effects in preparation of an application for Resource Consent for the works.

It is emphasised that the arrangement described has been developed to a conceptual level, to provide an envelope for the assessment of effects for consent application. The construction methodology is expected to be refined to accommodate a contractor's innovations during planning, match available plant and expertise, and be flexible enough to adapt to variations in site conditions.

8 References

Boffa Miskell. (2023). *Memo: Manapōuri Lake Control Structure – Spoil Disposal Area Wetland Assessments*. Project № BM220277A. 11 January 2023.

Damwatch Engineering Ltd. (2021). *Waiau Arm Channel Geology Memo*. 1 December 2022. E2105.

Damwatch Engineering Ltd. (2023). *MLC Waiau Arm Excavation – Hydraulic Modelling of Alternative Channel (Issue 3).* Memo, 31 May 2023. E2243.

GeoSolve Ltd. (2016). *Geological Assessment, Manapouri Lake Control Structure*. Ref: 160557. October 2016.

Pickford, T., Grilli, J. and Pott, J. (2017). *Te Anau and Lake Manapouri Lake Control Structures Comprehensive Dam Safety Review*. April 2017.

Worley. (1999) *Manapouri Lake Control Structure Stage 2 – Gravel Management Study*, November 1999

Appendix A Alternative Excavation Methodologies

Potential Excavation Methodology Workshop

Potential excavation methodologies were workshopped between Damwatch and Meridian via Teams on 7 April 2022. The attendees included:

Dougal Clunie, Daniel Bardsley, Grant Webby, David Cameron-Ellis, Steve McInerny (Damwatch); Joe Edwards (Independent Consultant); Nick Horswell, Chris Thomson, Neil Sutherland, Derek Pritchard (Meridian); Daniel Murray, Nicolle Vincent (T&T).

While various potential excavation methodologies were considered, the most viable were identified as follows:

- Cutter suction dredging;
- Drag line excavation;
- Excavator from bunds;
- Excavator from barge.

These methods and their applicability for the proposed Waiau Arm excavation are described below.

Cutter Suction Dredging

Cutter suction dredging involves a suction pipe with a cutting head at its inlet, with material loosened by the cutting head and sucked up by a pump. The dredge slurry can be pumped directly to dewatering ponds on land.

This method is effective for consolidated fine sediments, but becomes inefficient when dealing with particle sizes over 30 mm. With the prevalence of gravels in the channel bed substrate of upstream reach of the proposed works area, including cobbles and boulders, cutter suction dredging is not considered a viable method to complete the full works.

Excavation at the eastern end of the proposed works area is likely to be in predominantly silty or clayey material, under a surface veneer of gravels. For this portion of works, a hybrid methodology using mechanical excavators to remove the current riverbed surface, with cutter suction dredging below, may be viable. This has not been further developed as a preferred methodology, as the mobilisation of additional plant and additional facilities to support multiple excavation methods is considered more costly and complex.

Source: Berky GmbH, Creative Commons

Figure A.1: Cutter suction dredge

Drag Line Excavation

A dragline excavator consists of a large bucket suspended from a boom, commonly a crane with a winch drum added on the front. The bucket is suspended on a hoist rope, with dragropes used to manoeuvre the bucket horizontally.

A small dragline setup was used in the 2007 excavation works, as shown in Figure A.2.

Figure A.2: Small dragline setup used in 2007 Waiau Arm excavation

This method was considered and discussed with crane suppliers. A large crane (100-150 t) and large bucket (8-10 m³) would be required to provide a decent reach and productivity rate. There are few available equipment and limited operators, and such a method is not considered to be economical for this project.

Excavators Working From Bunds

The excavation could be performed by conventional excavators ('diggers') working from temporary gravel bund platforms constructed in the channel, as was done in the 2007 excavation works (Figure A.3).

Figure A.3: Excavator working from bund in 2007 Waiau Arm excavation

Provided that bunds could support their weight, large excavators (~75t) could achieve production rates of up to 4000 m^3/day.

Depending on prevailing water levels (bund elevation), bund side slopes and spacing between bunds, some of the deeper excavation will likely require the use of long reach excavator arms. Long reach arms typically use a smaller bucket and can affect a lower breakout force than a conventional arm, meaning lower production rates.

It was anticipated that the using excavators working from bunds and at least two work 'faces' along the channel, the excavation could be completed in a period in the order of 3-4 months.

Excavators Working From Barges

Excavators working from floating barges (or other on-river platforms) was an option considered, with the advantages that they could dig almost directly down without the constraint of bund side slopes, and that material is not double handled to construct and then remove bunds.

Excavators working from barges are relatively common worldwide for dredging of rivers and canals, and harbour or port construction. This can involve specifically designed plant, or conventional excavators well secured to stable barge platforms.

Source: www.amphibiousexcavator.com

Figure A.4: Excavator working from floating platform with hopper barge

This option was considered to require excavation onto separate hopper barges, of which there would need to be multiple to keep up with production. In the relatively confined work area, this was seen as prohibitively restrictive.

An alternative would be to excavate from barge/platform onto a conveyor system, though such a system would be relatively complex to set up and could not easily be dismantled if flooding were forecast, and so is not a preferred solution.

Potential Methodologies Workshop Conclusions

In the workshop it was concluded that excavators working from the channel banks and constructed bunds was the most likely technology to be utilised, considering the project size, location and constraints. Alternatives options for the excavation method using excavators working from the banks and constructed bunds are explored below.

Alternative In-Channel Excavation Arrangements

Alternative methods and layouts for the excavation works were discussed in the April 2022 teleconferenced workshop, to consider options which may help mitigate the suspended sediment generation and/or increase productivity rates. Alternative options aimed to reduce flows and/or water levels in the work area.

The initial excavated arrangement considered is shown as the black outline (proposed 25 m width channel base at nominal RL 172 m) in Figure A.5, with the available bathymetric survey shown in the colourmap overlaying a satellite image of the area. This preliminary excavation outline was based on minimising excavation volume to achieve the desired channel level and dimensions.

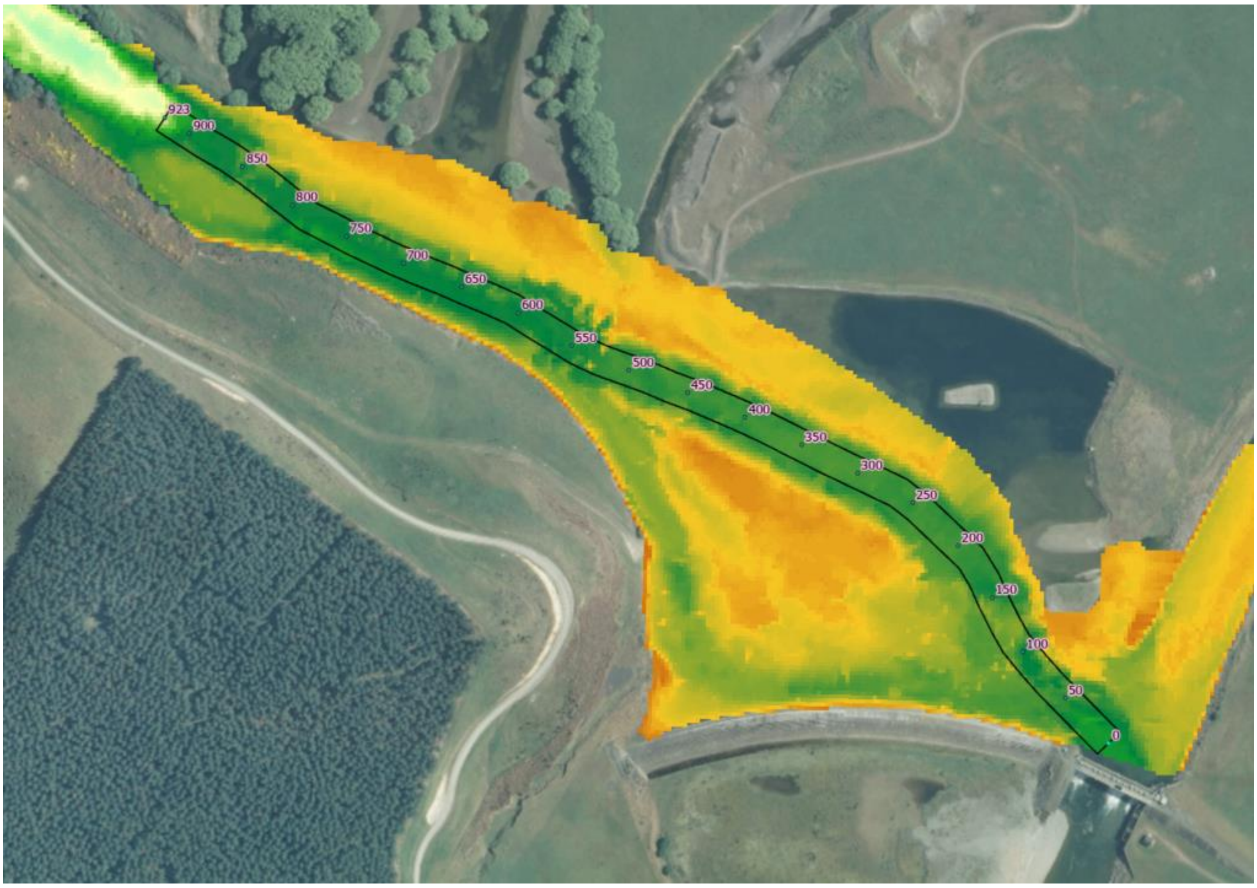


Figure A.5: Preliminary proposed excavation area (25 m width channel base) with chainages in metres displayed. Colourmap represents bathymetric survey data from red-orange (shallow) to green-blue (deep).

If a finished channel level of RL 172.0 m is not easily achievable with a given excavation methodology, preliminary hydraulic modelling showed that a shallower but wider channel could give an equivalent outcome in terms of flow conveyance. A wider channel would involve significantly more excavation of the channel bank, as shown in Figure A.5, and so alternatives concentrated on deepening the channel to RL 172.0 m.

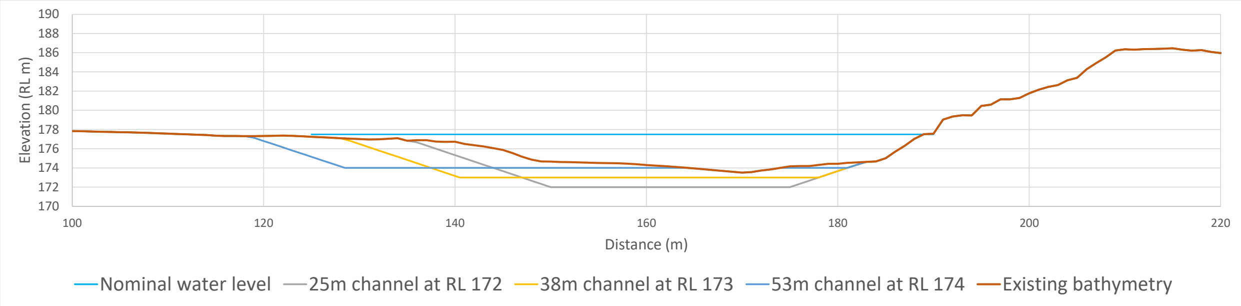


Figure A.5: Cross section at narrow upper reach (approximate chainage 800), showing 25m base-width channel at RL 172 m, and alternative finished cross sections with equivalent flow conveyance.

In the workshop and from post-workshop discussions, three alternative excavation options were identified and developed further:

1) Excavation from bunds pushed out from true left bank.
2) Excavation from bunds pushed out from true left bank, with isolation of downstream channel reach around gravel island.
3) Excavation within fully isolated Waiau Arm.

Alternative 1 - Excavation From Bunds

Alternative 1 involves all excavation being carried out by excavators on bunds, with flow in the Waiau Arm continuing past the works. This is shown conceptually in Figure A.6, where the colourmap represents the ground surface elevation (light green the finished excavation profile at RL 172 m, dark orange bund elevation nominally at RL 179 m).

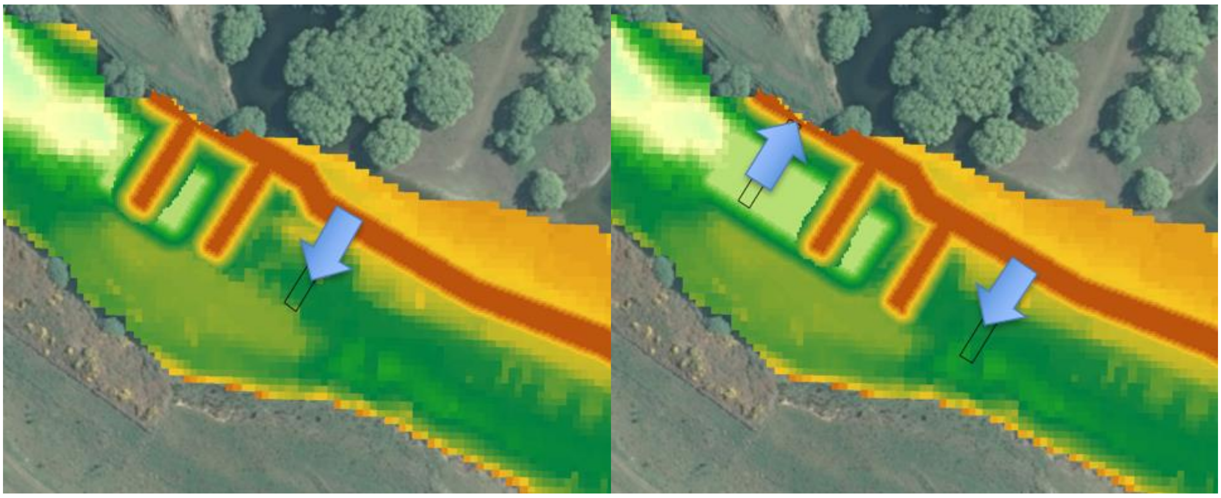


Figure A.6: Alternative 1 showing conceptual excavation method from finger bunds, with fingers being constructed in the channel, excavation undertaken around a finger before the finger is removed and the works progress up- or downstream with construction of the next finger.

It is anticipated that 2-3 bund 'fingers' would be in place at a time, creating platforms to work from and pushing any current to the far (true-right) side of the channel. Excavation at a given 'work front' would continue progressively with the channel excavated to full depth around a finger which is then removed (excavating to full depth while removing) while the next finger is constructed. This work may progress up- or downstream. It is expected that at least two work fronts would be active, to maintain a reasonable total duration of the works.

Relatively wide fingers are anticipated, such that excavated material can be placed directly on the fingers before being uplifted and carted to the spoil disposal area, making these two operations independent. Nominal 9 m wide fingers are considered. The spacing between fingers will depend on the reach of the plant used, with a nominal 30 m spacing considered. Depending on the prevailing water level and bathymetry of the channel section being worked on, each finger would have a volume of around 2,000-3,000 m³.

Bunds would be constructed to a nominal 'freeboard' level above the prevailing river level, to provide a safe working platform with an allowance for lake level rise.

Advantages of this method include:

- Low flows in the Waiau Arm are not restricted. Minimum flow release requirements from MLC can be maintained at all times.
- Finger bunds create semi-tranquil zones, diverting the river current to the far side of the channel, somewhat reducing the potential for suspended sediment generation from excavation activity.

Disadvantages of this method include:

- Construction, and then removal of fingers, necessitates significant double-handling of excavated material.
- The volumes or concentrations of suspended sediment that will be generated during the works cannot be quantified. Mitigation options for suspended sediment generation include minimising discharge through the Waiau Arm channel, and the use of silt curtains around the works, though this will add complexity and cost.
- High flood flows and associated high water levels may require work to be temporarily suspended and may require rework if fingers are washed out into already excavated areas. If a flood is forecast with sufficient notice, fingers can be pre-emptively pulled back and further bund construction suspended. Protocols will be required for flood warning, finger removal and plant withdrawal.

This alternative is estimated to require 5 months of works within the river channel, assuming that 24-hour, 6 day a week work is allowable.

Alternative 2 - Excavation From Bunds, With Isolation of Downstream Channel Reach

Alternative 2 takes advantage of the central gravel island immediately upstream of the MLC overflow weir, isolating the excavation area to the north of the island and allowing flow to continue around the southern side of the island. In the upstream half of the works Alternative 2 will be identical to Alternative 1, with excavation being carried out by excavators on finger bunds, and flow continuing past those works.

The conceptual arrangement for Alternative 2 is shown in Figure A.7, with the same colourmap from previous figures representing ground surface elevation, and the hatched area showing the 'online' river channel which is available to pass flows. The initial bunds will be pushed across to gain access to the gravel island, and spoil from ongoing excavation in the upper reach will be used to construct an elevated embankment around the island to isolate the main channel through this lower reach.

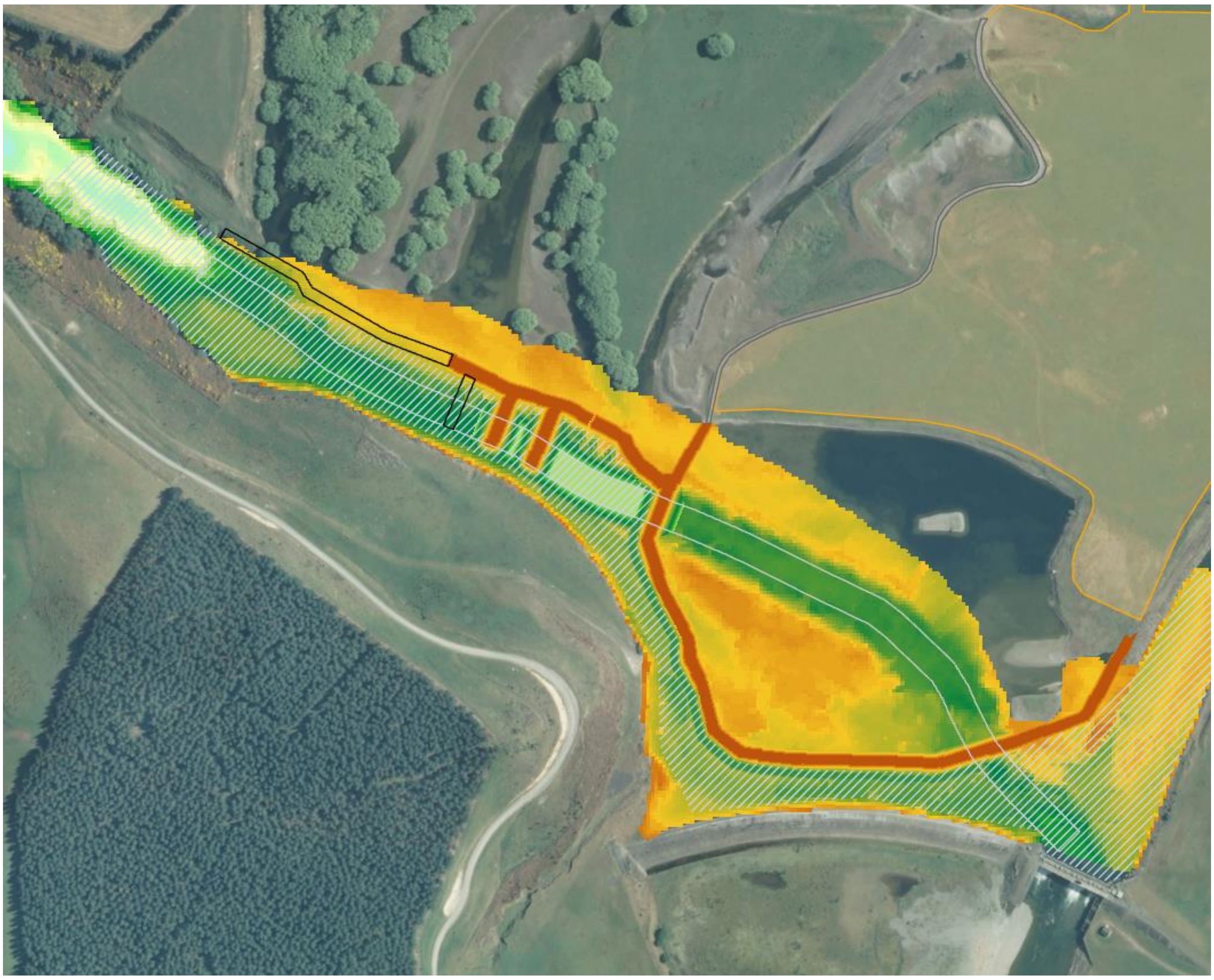


Figure A.7: Alternative 2 showing excavation from bunds in the upper reach, while the lower half of the excavation is isolated from river flows.

To ensure that the remaining channel has sufficient conveyance capacity to pass minimum flows at all lake levels, a small amount of excavation (>1.5 m, approximately 5 m in width) will be required to the channel on the southern side of the island.

Within the isolated area, excavation will progress from finger bund platforms as before, but the water will be still, and the risk of silt being transferred to the Lower Waiau River will be significantly reduced. Pumping may be used to reduce the water levels in this area allowing lower finger bunds and more efficient work, but there will likely be continuous seepage into the area through the isolation bunds and gravel island, so the efficacy of such dewatering is likely to be limited.

Advantages of this method include:

- Low flows in the Waiau Arm are not restricted. Excavation work to create a deeper channel around the southern side of the island may be required to ensure minimum flows can be passed if the prevailing water levels are near the low end of the Lake Manapōuri operating range.
- Approximately 40% of the excavation can be done isolated from river flows, which should significantly reduce suspended sediment generation.
- The more confined channel around the southern side of the island could be suitable for the installation of a silt curtain or similar suspended sediment mitigation, though an arrangement would need to be

devised that would allow small flow rates past (to ensure minimum MLC releases are met) and be removeable if large flood discharges are required.

Disadvantages of this method include:

- If Lake Manapōuri reaches flood levels and significant discharge down the Waiau Arm is required, the isolation bunds may need to be breached to restore the channel's flood conveyance capacity. Protocols will be required for flood warning, bund removal and plant withdrawal.
- In a significant flood, the embankment around the island may be submerged and significant rework may be required to reinstate the isolation arrangement.

This alternative is estimated to require 5 months of works within the river channel, assuming that 24-hour, 6 day a week work is allowable.

Alternative 3 - Excavation Within Fully Isolated Waiau Arm

Alternative 3 involves the complete isolation of the Waiau Arm with cofferdams cutting off the river upstream and downstream of the channel excavation area. Dewatering of the channel between the coffer dams will allow the excavation work to be performed in semi-dry conditions.

The conceptual arrangement is shown in Figure A.8, with the same colourmap from previous figures representing ground surface elevation. The Lake Manapōuri outlet will be isolated, meaning that MLC releases will be dependent on Mararoa River inflows only, and the cofferdams will have to be breached if flood releases from Lake Manapōuri are required.

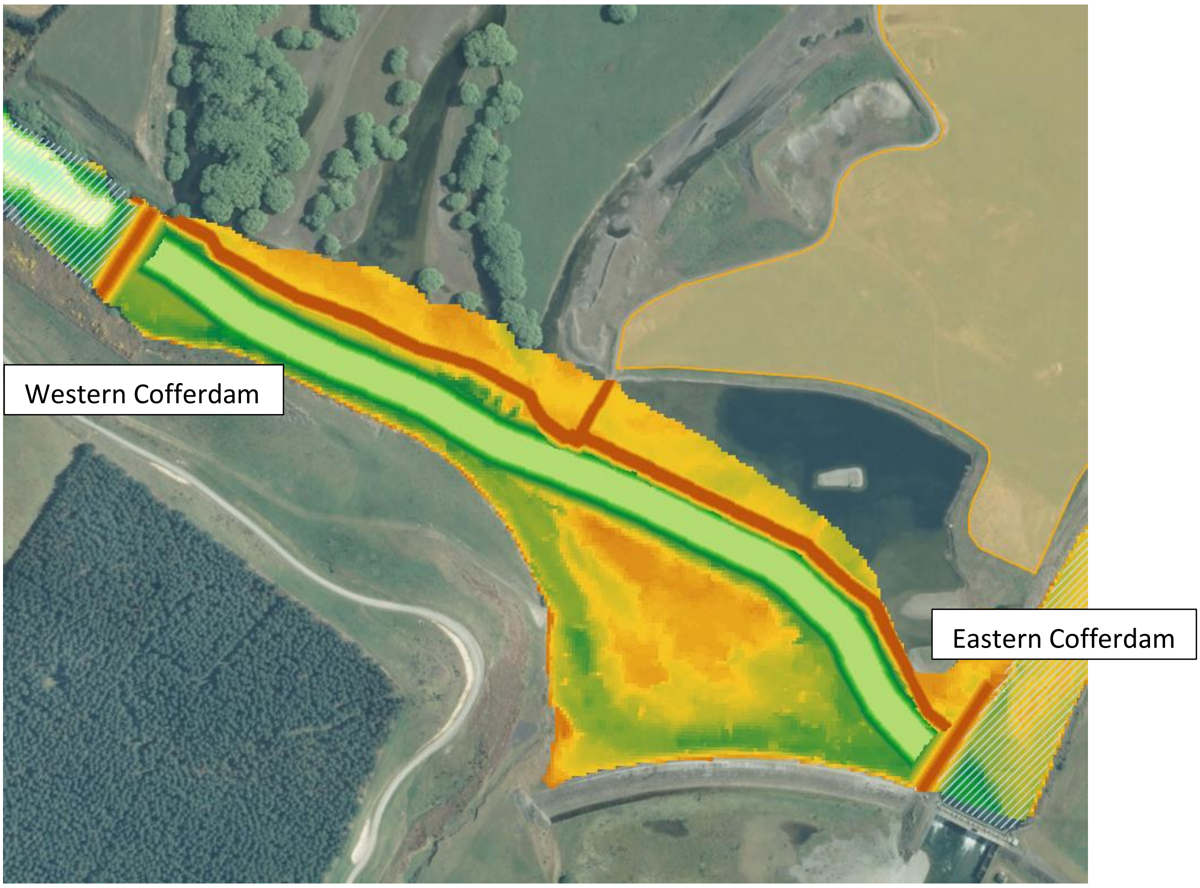


Figure A.8: Alternative 3 showing a western cofferdam isolating the works from Lake Manapōuri and an eastern cofferdam isolating the works from the Mararoa River.

The initial activity will be to construct access to the upstream (western) cofferdam site, then to dump material in still water (controlled by MLC gates) to form the cofferdam. The gates will then be used to progressively dewater the Waiau Arm downstream of the cofferdam, while adding fine material on the lake side of the coffer structure to reduce seepage through the dam and strengthen the cofferdam structure.

The conceptual design of the upstream cofferdam includes a 1V:1.5H upstream face, a flat downstream slope at 1V:3H and an 8 m wide crest. Additional layers of fine 'blinding' material will be placed on the upstream slope to reduce seepage sufficiently to allow the downstream area to be dewatered. Coffer dams of this nature are typically never watertight and seepage through and under the structure is nevertheless still anticipated. Allowance for sumps and pumping of seepage water near the toe of the coffer dams is accordingly necessary. A cofferdam of these dimensions will have a volume of some 8,800 m³, and it is assumed that 65% of the material will need to be imported angular rockfill.

With the western cofferdam in place and the channel downstream largely dewatered, the eastern cofferdam can be constructed in low water conditions, allowing for greater control over placement and compaction of the cofferdam material. A cofferdam with 1V:1.75H side slopes and a 6 m wide crest has been considered at this conceptual design phase. Sumps and pumping facilities, similar to the upstream coffer dam are also envisaged here. The downstream cofferdam would have a volume of some 5,900 m³ plus 700 m³ of riprap protection on the Mararoa River face. It is assumed that 65% of the rockfill material and 100% of the riprap will need to be imported.

With the cofferdams and pumping in place, excavation can be performed in the semi-dry, without the need for significant finger bund construction, allowing for a much quicker programme.

Ongoing groundwater seepage or piping into the excavation area is expected, and ongoing pumping out of the isolated area is likely to be necessary.

This alternative involves people working behind the protection of a cofferdam (i.e. failure of the cofferdam would expose them to the risk of inundation by water) and so dam safety is of critical importance. As such, the cofferdams will require detailed plans for construction and removal, suitably conservative design assumptions, construction monitoring and ongoing monitoring for the duration of their service. Appropriate dam safety plans, including consideration of potential failure modes, potential impacts of failure and emergency preparedness plans will be required.

Due to their temporary nature (intended design life of 5 weeks), it is unclear whether the cofferdams would strictly require a Building Consent, and some aspects of the Building (Dam Safety) Regulations 2022 are clearly not relevant (e.g. preparation of annual dam compliance certificates, 5-yearly reviews of the dams' potential impact classification). In saying this, the proposed cofferdams would appear be classifiable dams under the Building Act[7].

Following the New Zealand Dam Safety Guidelines (NZSOLD 2015) and considering safety obligations under Health and Safety at Work Act, the dams must be designed, constructed and maintained to a safety standard commensurate with the downstream population at risk, i.e. all workers relying on the cofferdams for protection.

[7] A *dam* is an artificial barrier that is constructed to hold back water and is used for the storage, control or diversion of water. A *classifiable dam* means a dam that has a height of 4 or more metres and stores 20,000 m³ or more of water (or height of 1 or more metres storing 40,000 m³ or more).

Advantages of this method include:

- This alternative will significantly reduce the discharge of suspended sediment to the Lower Waiau, with the only potential for suspended sediment generation being the cofferdam construction and removal. All sediment disturbed by the excavation will remain inside the isolated area, to be managed through discharge of pumped water into settling areas.
- Without the need to construct and deconstruct the high finger bund platforms, excavation work can progress much faster than the other alternatives, and so the duration of all associated environmental effects will be shorter.

Disadvantages of this method include:

- Initial construction activities including access/haul roads and cofferdam construction will require significant volumes of material before any significant channel excavation has begun. It is assumed that material can be won from excavation of the spoil disposal area, and that quarried rockfill will be imported and stockpiled for use in the cofferdam bodies.
- The cofferdams will have to be carefully designed, constructed and monitored to ensure their ongoing safety for the duration of the works, adding cost. The design process for this alternative will be significantly more involved than required for Alterative 1 of 2 and suitable design timeframes will need to be built into the planning of this option.
- The need for building consent is uncertain, but potentially likely considering the operations that will take place behind the coffer dams. The consenting process may defer the start of the construction to late, or possibly beyond, the anticipated construction window.
- The permeability of the coffer dam foundation is uncertain and continuous pumping is highly likely to be required, and management of these pumped flows together with entrained sediment will add cost.
- Discharge through the Waiau Arm is necessary to reduce Lake Manapōuri levels if these rise above the normal operating range. There will need to be protocols in place for flood forecasting and plans for abandonment of the site and controlled breaching of the cofferdams if high Lake Manapōuri levels arise.
- With the Waiau Arm isolated, minimum flow releases from MLC cannot be guaranteed, and releases to the Lower Waiau will be dependent entirely on Mararoa River inflows for the duration of the construction.
- Where Mararoa River inflows are higher than minimum release requirements, the additional water cannot be held for generation storage, but will be released to the Lower Waiau.

It is estimated that 2 months should be allowed for a contractor's planning, mobilisation and other preliminary and general (P&G) tasks, followed by 1 month for site setup, preparing the spoil disposal area, stockpiles, access and haul roads.

It is estimated that the critical in-channel works could then be completed within 5 weeks, including construction of the cofferdams, completion of the channel excavation, and reinstatement of flow past the cofferdams. This assumes that 24-hour working is allowable.

Comparison of Alternatives

A high-level multi-criteria comparison of the alternative options was undertaken in a teleconferenced workshop setting. A tabulated output from the workshop was produced, and is reproduced in Appendix B. This includes for each alternative descriptions of environmental effects and scoring (low-medium-high) of associated impacts and risks, indicative cost estimates and programme duration estimates, and quantitative descriptions of opportunities, constructability risks, health and safety risks, regulatory risks and operational risks.

It was concluded that there was not sufficient information to confirm the feasibility of all options and select a preferred option, given the uncertainty around:

a) the suitability of site material for cofferdam or berms construction,
a) the nature of the channel bed material across the excavation plan extent and through the full excavation depth,
b) the depths that can efficiently be excavated and the associated excavation processes and rates, and
c) the quantity of suspended sediment (and associated change in turbidity) that will be generated by excavation in the open channel.

In-channel trial excavations were carried out to address these uncertainties.

Developed In-Channel Excavation Methodology

The trial excavations confirmed the variable channel substrate material, including cobbles and boulders, for which hydraulic excavators are expected to be the most appropriate equipment to construct an improved channel arrangement. The viability of using long-reach excavators to achieve the target excavation depth of RL 172.0 m was confirmed, although the long-reach excavator's breakout force was insufficient to excavate a particular area at 'Location E', assumed to be a very large boulder or the remnants of a riprap or boulder embankment formed during MLC construction.

The generation of suspended sediment during bund construction or removal and channel bed excavation was visually very obvious, and it was the project control group's opinion that the release of suspended sediment from in-channel excavation is a critical environmental effect requiring further mitigation to develop a suitable design. As such, further sediment management measures have been considered, and the arrangement of the works reconsidered to minimise in-stream works.

An in-channel excavation arrangement, based on Alternative 2 described above, was developed with further consideration given to suspended sediment management.

Figure A.9: In-channel excavation arrangement developed - trapezoidal channel with base at RL 172.0 m (main channel) and RL 175.25 m (southern channel), excavation extent in dark blue shading.

This arrangement includes some 108,000 m³ of excavation within the existing main channel, to form a channel with a base width of 25 m at RL 172.0 m extending approximately 1000 m upstream from the MLC gates.

Hydraulic Performance

Previous one-dimensional computational hydraulic modelling estimated that the existing main channel excavated to a base width of 25 m at RL 172 m would allow 160 m³/s to be released[8] at a Lake Manapōuri level of RL 177.28 m.

The hydraulic performance of the excavation arrangement was modelled in a two-dimensional computational model using HEC-RAS software. The model showed that with a minimum water level upstream of the delta area of RL 177.25 m for the in-channel excavation arrangement when releasing 160 m³/s at the MLC gates. This is comparable and consistent with the earlier 1D model predictions, given there is negligible water level difference between Lake Manapōuri and the deep Waiau Arm reach just upstream of the delta area.

The model setup is described in a memo (Damwatch, 2023) which also shows the resultant velocity magnitudes and patterns at low MLC discharge. The modelled velocities through the delta area when

[8] With a minimal Mararoa River flow of 2 m³/s, so 158 m³/s down the Waiau Arm from Lake Manapōuri.

releasing 160 m³/s from MLC gates is shown in Figure A.10 for the parallel channel excavation arrangement.

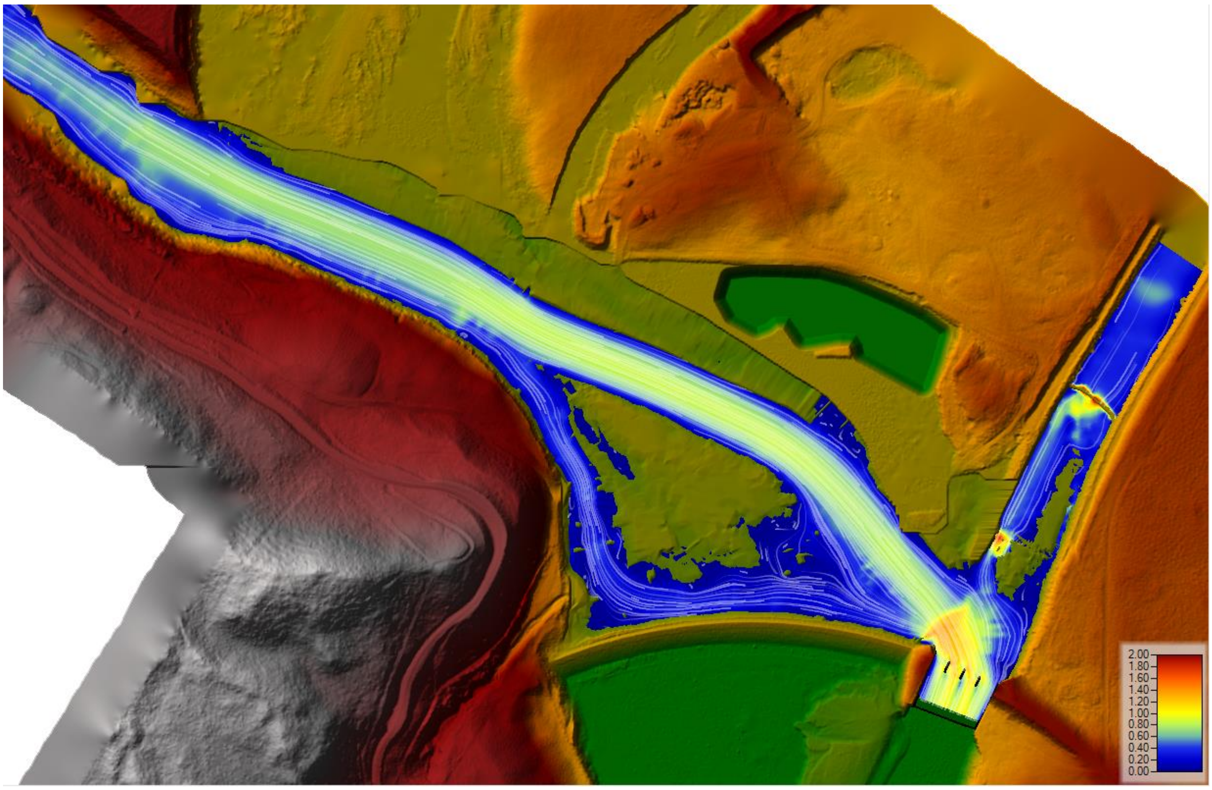


Figure A.10: Velocity patterns with 160 m³/s MLC release, in-stream excavation arrangement.

Conceptual Construction Methodology

This section of the report describes the conceptual arrangement for the in-stream excavation option. The layouts, sequencing, programming, equipment etc. presented at this stage of the project are considered at a concept level of design only. Further detailed design and planning is required to take the concepts into implementation and this should take into account variations in site conditions as well as water levels in the rivers that are likely to be experienced thought the construction period.

The proposed methodology to carry out this excavation is based on Alternative 2 described above, with the downstream half of the excavation works carried out 'offline' with Waiau Arm flow diverted around the gravel island.

Suspended sediment mitigation measures include:

- The 'southern channel' around the gravel island is initially deepened, allowing the Waiau Arm flow to be diverted and the downstream reach of the main channel excavation to be completed in still water. This approach will reduce the potential for suspended sediment discharges given the silty-clay substrate expected over much of this reach.
- Excavation of the upstream reach will be completed within 'cells' of approximately 100 m length, bounded by temporary groynes built out perpendicular to the channel bank from the left-bank haul road, and a silt curtain anchored between groynes parallel to the flow.
- Geofabric will be placed on groynes and isolation bunds to minimise scour and leaching of fines into the river.

- The upstream excavation footprint is realigned closer to the left bank, reducing velocities in the main channel past the tips of groynes and sweeping along the silt curtain.
- Utilising the cleanest practicable source of gravel material to construct groynes and isolation bunds, and consideration of washing and screening gravels before use, or importing cleaner material if necessary.
- Consideration of operational controls such as suspending flow releases and/or increasing flow releases to best programme and/or disperse sediment releases.

Consideration was given to installation of a silt curtain across the Waiau Arm exit, to form a restricted outlet and encourage suspended sediment to settle within the Arm. Following discussions with silt curtain suppliers, this arrangement was not considered feasible.

Complete blocking of the Waiau Arm exit to contain suspended sediment generated by the works creates problems for maintaining minimum flow releases from MLC, as well as release of flood flows, and the potential water quality effects of stagnated water. It was reportedly done for excavation works during 2006, when a relatively short duration of works, combined with low lake levels and relatively high Mararoa inflows, avoided the need for any flow releases. For the present excavation works, expected to extend over several months, there is a high probability that flow will need to be released from the Waiau Arm during the course of the works. For this reason, it has not been considered as part of the methodology.

The overall excavation works arrangement is shown conceptually in Figure A.11. It is assumed that excavation of the Upstream Reach and Downstream Reach will be done concurrently. The timing of particular sediment-generating activities, such as the construction of the downstream isolation bunds and the upstream groynes, could be staged separately or completed concurrently, depending on what is considered better from an effects perspective.

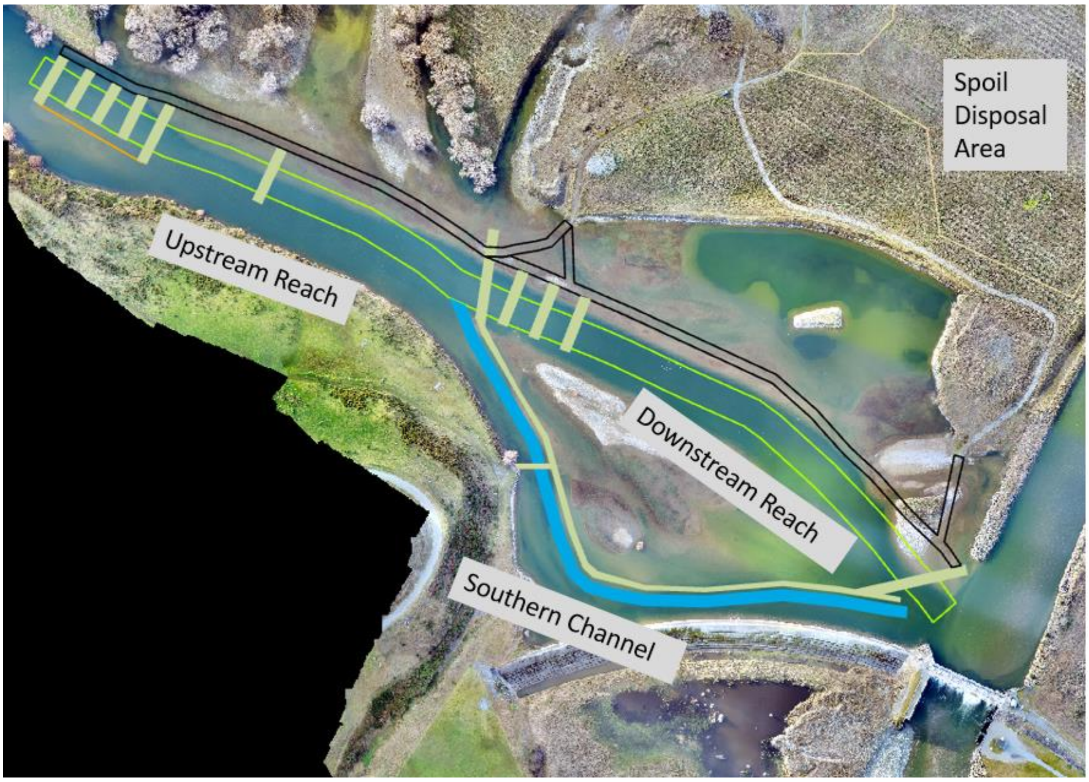


Figure A.11: Overall excavation works arrangement, with excavated channel footprint shown in green outline, haul roads in black outline, deepened southern diversion channel in blue.

Downstream Reach

The initial step in isolating the main channel in the downstream reach is to gain excavator access to the gravel island (see Figure A.12), and deepen the secondary channel on the southern side of the island as necessary to ensure sufficient flow can be passed through this 'southern channel' to meet MLC discharge requirements.

A relatively small volume of gravels (200-300 m³) would be required to build a causeway to access the island from the southern bank (Figure A.12). The selected location for the causeway coincides with the position of a former river crossing used during the construction of the MLC. (Refer Figure 5.5). Aerial imagery of the area under low flow conditions indicates that remnants of the former access remain present, providing what is expected to be a shallower foundation for the causeway. The causeway would be placed in relatively still water, with the main current in the channel to the north of the island.

Figure A.12: Causeway to gravel island

Access to this area can be gained from Duncraigen Road south of the MLC. The material to construct this causeway would likely be obtained from gravel deposits on the true right riverbank below MLC gates, with a haul distance of approximately 1600 m indicated on Figure A.12.

With excavator access to the island, the 'southern channel' would be deepened to provide a channel 10 m wide at an elevation of RL 175.25 m. This is the same elevation that the area upstream of MLC weir was finished to during construction in the mid 1970s, so the 3,500 m³ of material to be excavated is expected to consist of alluvial gravel and sands subsequently deposited.

With the main channel north of the gravel island isolated, this excavated southern channel has been modelled with the HEC-RAS 2D model to be capable of passing a flow of 12 m³/s[9] at minimum lake control level (RL 176.80 m), and 31 m³/s[10] at a lake level of approximately RL 177.32 m or higher. The modelling shows that a flushing flow of 160 m³/s can only be passed down this southern channel at high lake levels (above RL 178.5 m).

As the southern channel is excavated, material removed will be progressively placed as a working track around the southern perimeter of the gravel island to provide excavator access to the southern channel. This work is envisaged to be completed by a long-reach excavator, supported with a second excavator to trim excavated material.

This road will be built up to form a low-level embankment, to a suitable flood protection level (provisionally the 1/5 AEP at RL 179.3 m) to prevent water flowing into the northern channel once this is isolated. To build the embankment up to an elevation of RL 179.3 m, some 11,000 m³ of material will be required, while only 3,500 m³ is required to be excavated from the southern channel. It is assumed that material from the island itself can be recontoured to form the embankment to this level of flood protection. Following the main channel excavation works, it is assumed that the embankment material will be recontoured on the gravel island leaving a natural-looking topography and will not need to be carted off the island.

[9] Which combined with the minimum recorded Mararoa River discharge of 4 m³/s will be sufficient to provide minimum MLC releases of up to 16 m³/s across all normal conditions.
[10] Combined with at least 4 m³/s from Mararoa to provide a recreational flow release of 35 m³/s.

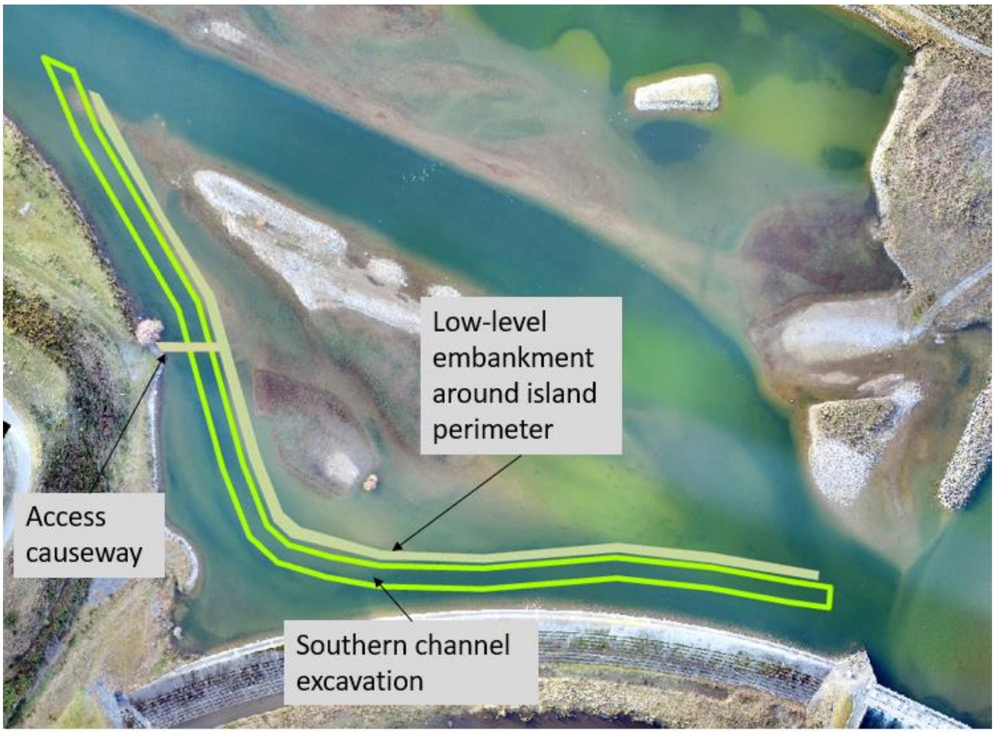


Figure A.13: Deepened southern channel to ensure minimum flow release capacity, with working track around the island perimeter built up to a low level embankment.

With the southern channel excavated, bunds will be pushed out to isolate the northern channel and the causeway removed to open up the southern diversion (Figure A.14). Clean fill material should be used for these bunds. It is anticipated that this will be won from the areas described in Section 5.2.4 on the true left (northern) bank, with the isolation bunds pushed out from this left bank of the main channel.

The isolation bunds will be constructed to provide a level of flood protection (provisionally the 1/5 AEP at RL 179.3 m) to the works within the isolated area. Flood withdrawal procedures should be developed for the works. If a large flood is forecast, it may be preferable to remove or partially remove the isolation bunds in advance, to re-establish full channel capacity to release flood flows at the MLC gates.

With the isolation bunds in place and flow diverted to the southern channel, excavation of the main northern channel can take place in still water. This will be undertaken using finger bunds as access, with most of the excavated material (largely silt/clay) taken straight to the spoil disposal area. This may require the disposal area to have containment bunds installed and additional excavator work to spread and dry the clays and silts. Alluvial materials excavated from the upper end of this reach will be recycled for finger bund construction.

Excavation at the Mararoa confluence will be done from fingers pushed out from the eastern isolation bund. Work in this relatively small area will have no protection from sediment release, but is similar to maintenance that is routinely done upstream of the gates. Being a relatively small area, the timing of this work could be opportunistically programmed to suit site conditions, e.g. coincident with naturally elevated turbidity levels in the Mararoa. This footprint may be enlarged to include 'maintenance' removal of gravels from around the gate approach.

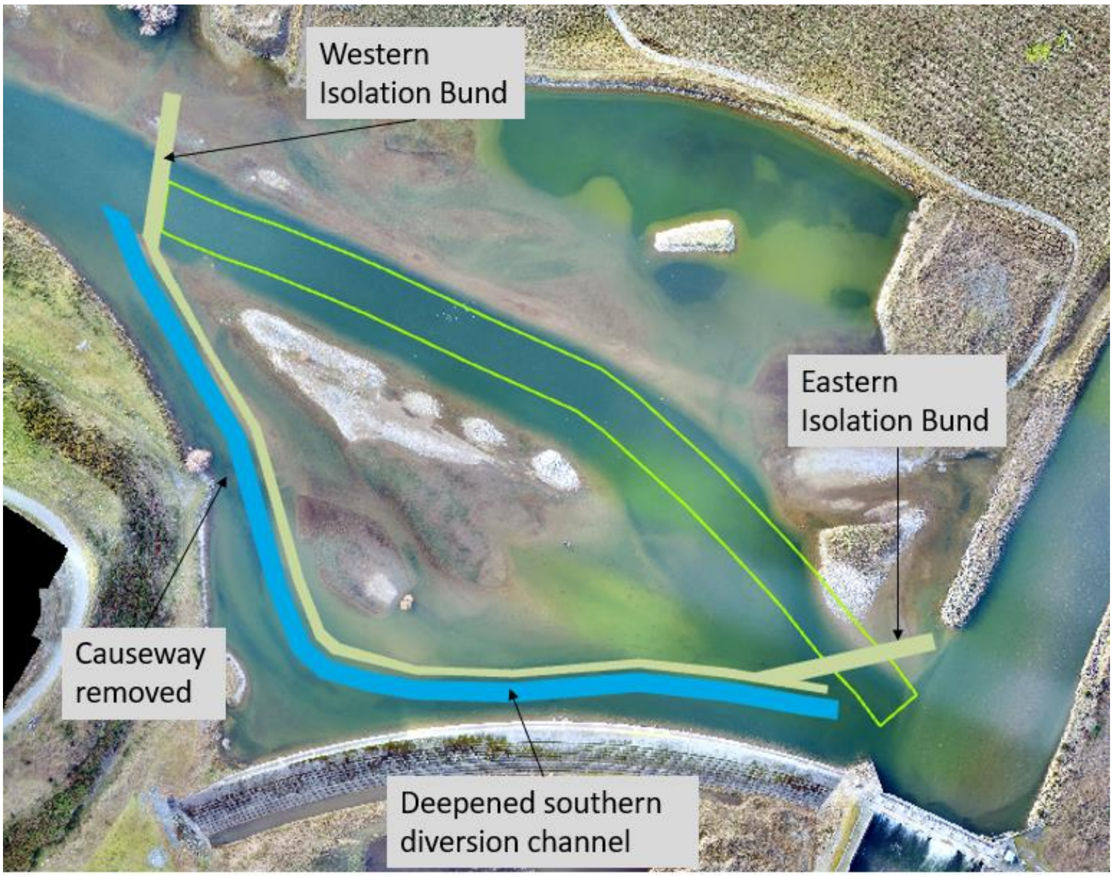


Figure A.14: Isolation bunds in place with flow diverted to southern channel, main excavation footprint shown in green outline.

With the excavation complete, the western isolation bund would be removed first, followed by removal of the eastern isolation bund. It can be expected that a pulse of sediment will be released when the main channel area is reopened to flow, so the timing of this should consider prevailing environmental conditions and the potential for a flushing release to disperse the sediment downstream.

Upstream Reach

The upstream reach will be excavated within distinct 'cells' bounded by temporary bunds herein termed 'groynes', with a silt curtain anchored between them. It is envisaged that the work will continue sequentially, with four of these cells constructed, approximately 100 m each in length.

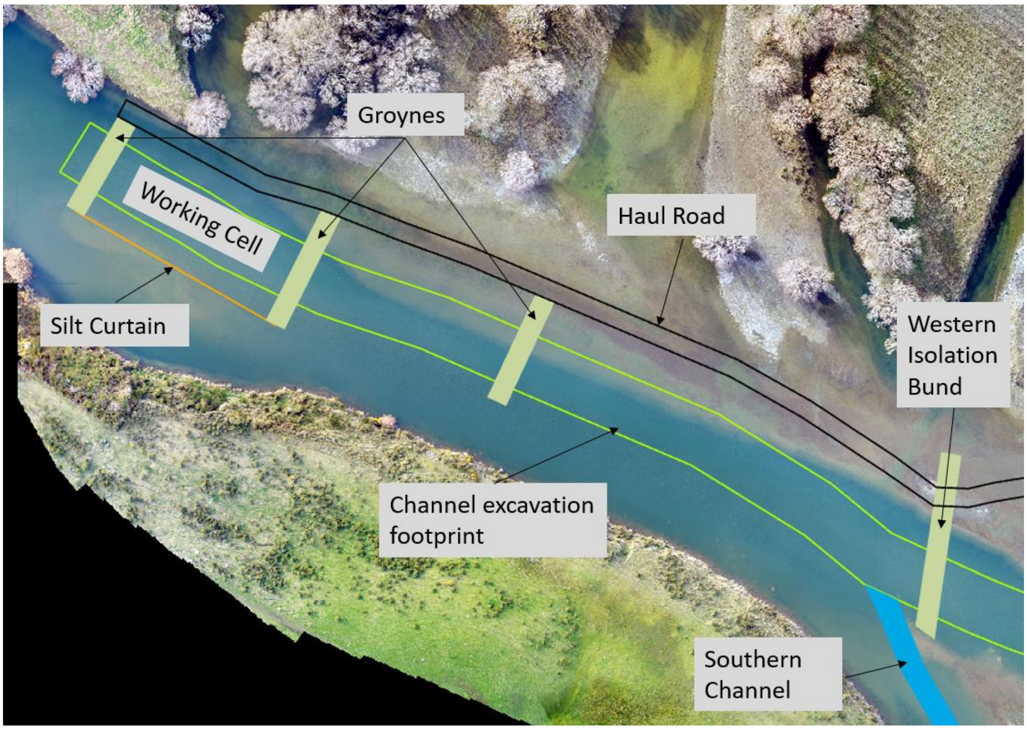


Figure A.15: Arrangement of excavation works in upstream reach.

Within each cell, excavation will be completed by long-reach excavators working from finger bunds. Fingers between the groynes are expected to be 9 m wide at 25 to 33 m centres to suit the reach of the long reach excavators (Figure A.16). When the material either side of the finger is excavated the finger is retreated back to the haul road.

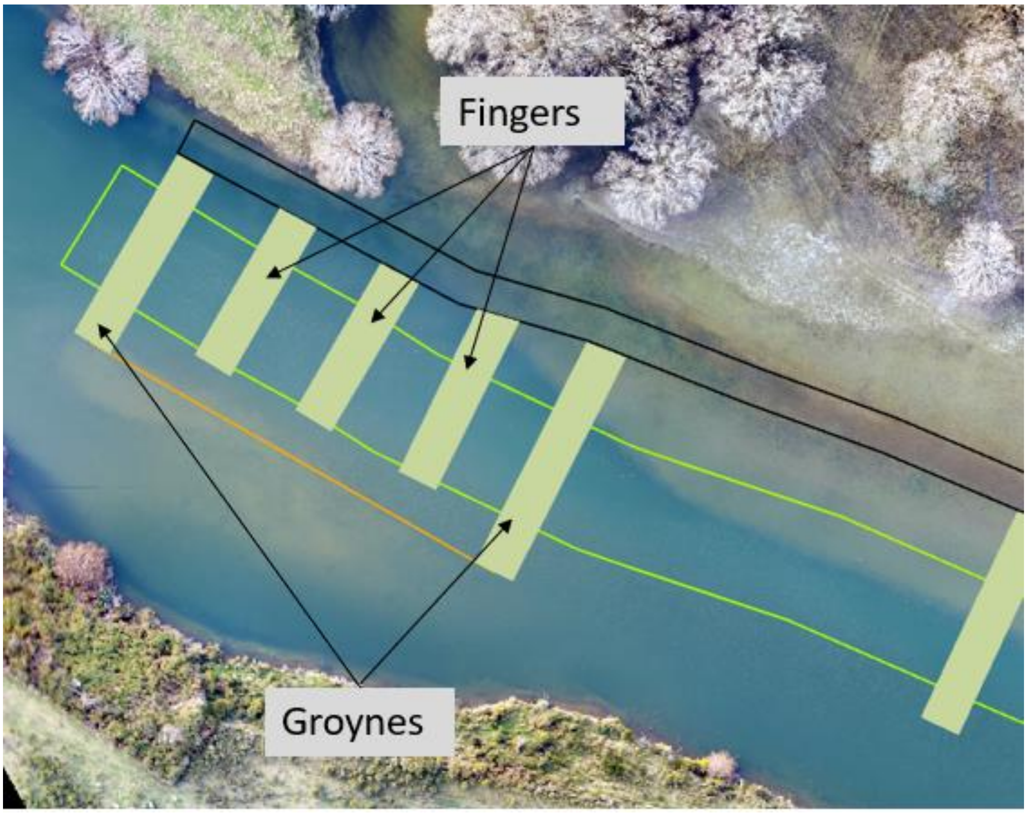


Figure A.16: Finger bunds constructed within working cell to provide access for long-reach excavators.

It is envisaged that the excavation will start from the upstream end of the reach, to avoid material being washed into already-completed areas in the event of large flood discharge.

The silt curtain bounding each cell allows excavation to be undertaken in near-still water. The silt curtain will be 100 m long and anchored at each groyne with a 'dead man' anchor, potentially precast concrete blocks chained together. The curtain would have a top wire anchored into the dead man anchors and used to support curtain floats. Allowance has been made to have the curtain 3 m deep. There are envisaged to be four 'cells' within the upstream reach, hence four deployments of the silt curtain. There are likely to be two silt curtains, each deployed twice, allowing flexibility in the timing of curtain removal (and resultant potential sediment release) while having the subsequent cell in place and work underway minimising channel excavation down time.

The channel excavation footprint in the upper reach has been realigned closer to the left bank compared to earlier arrangements considered. This provides more river cross sectional area to the south of the construction groynes and a reduction in water velocity past the groyne ends and silt curtain. This increases the total bulk excavation volume from some 95,000 m³ to 108,000 m³.

Groyne Construction

The groynes are anticipated to each contain 3,000 to 6000 m³ of material, depending on local bathymetry and take between 5 and 9 shifts to construct. As an added protection a Bidim A44 or similar geofabric will be placed on the upstream and southern (end) face of each groyne to minimise scour and leaching of fines into the river. This sediment mitigation will not be able to be undertaken until the groyne is constructed.

The protection would consist of a weighted geofabric cloth lowered into the water on the upstream face of the groyne using two to three excavators, depending on the length. Field trials would be required to determine the length of the cloth protection but is expected to be in the order of 60 m to cover 20 m of the upstream face and the southern face. These are anticipated to be one use only, as damage can be expected when removing them.

When excavation within a 100 m section is completed, and the next section of work will be ready for excavation (groynes in place, silt curtain installed) the upstream groyne can be removed. This will take the same amount of time as it took to construct. Following the removal of the upstream groyne the haul road will be removed and reshaped to final contours.

Spoil Disposal Area

An initial step in the works will be to prepare a spoil disposal area to place the material excavated from the channel. An area of grassland, previously planted in eucalypt and pine, has been identified as a suitable spoil area totalling 15 hectares (150,000 m²). The ground in this area is free draining, likely to comprise alluvial materials.

Approximately 110,000 m³ of material is to be excavated from the channel. If placed to 2 m height, this would require some 5.5 hectares, which can be accommodated within the identified area, along with contractor's establishment and laydown areas.

Excavated material will be stockpiled on the northern parts of the identified spoil area, suitably shaped and graded to allow natural drainage. To prepare the area, topsoil will be stripped and stockpiled for later reinstatement, with some potentially used for silt control bunds along the boundaries of the stockpile.

The spoil disposal area will be set back from the wetland areas identified in ecological surveys by a minimum of 10 m.

Haul Roads

The excavation methodology has focussed on working from the true left (northern) bank of the river, given the proximity to suitable gravel sources, spoil disposal area and favourable topography. The true right (southern) bank is generally steep, with limited access to the river, and would involve a 5 km trip to reach the proposed spoil disposal area.

Construction of a haul road along the northern bank is a key initial activity, providing access to the upstream groyne location to prepare for excavation work in the upper reach, and the isolation bund locations to prepare for work in the lower reach.

The haul road will span the length of the work along the channel edge, allowing material to be carted from finger bunds to the spoil disposal area. The anticipated extent of the haul roads is shown in Figure A.17. Haulage from the riverbanks to stockpile area is anticipated to utilise the existing access roads, widened to accommodate two-way traffic.

The haul roads would be constructed to allow two lanes of traffic, considered to be 40t ADTs. The roads are essentially raised sections of riverbank, ensuring that works can continue with water levels in the river varying over the full main operating range of Lake Manapōuri.

The total volume of the haul roads with a layout as shown in Figure A.17, at 8 m width to a finished level of RL 178.80 m is 13,500 m^3. Where possible, clean fill material should be used to minimise silt leeching into the Waiau Arm. The roads are aligned immediately adjacent to the river channel, and at medium to high lake levels water will be lapping against the edges of the roads. The roads need to be constructed from sound material, which is anticipated to be available from riverbank gravels adjacent to the road.

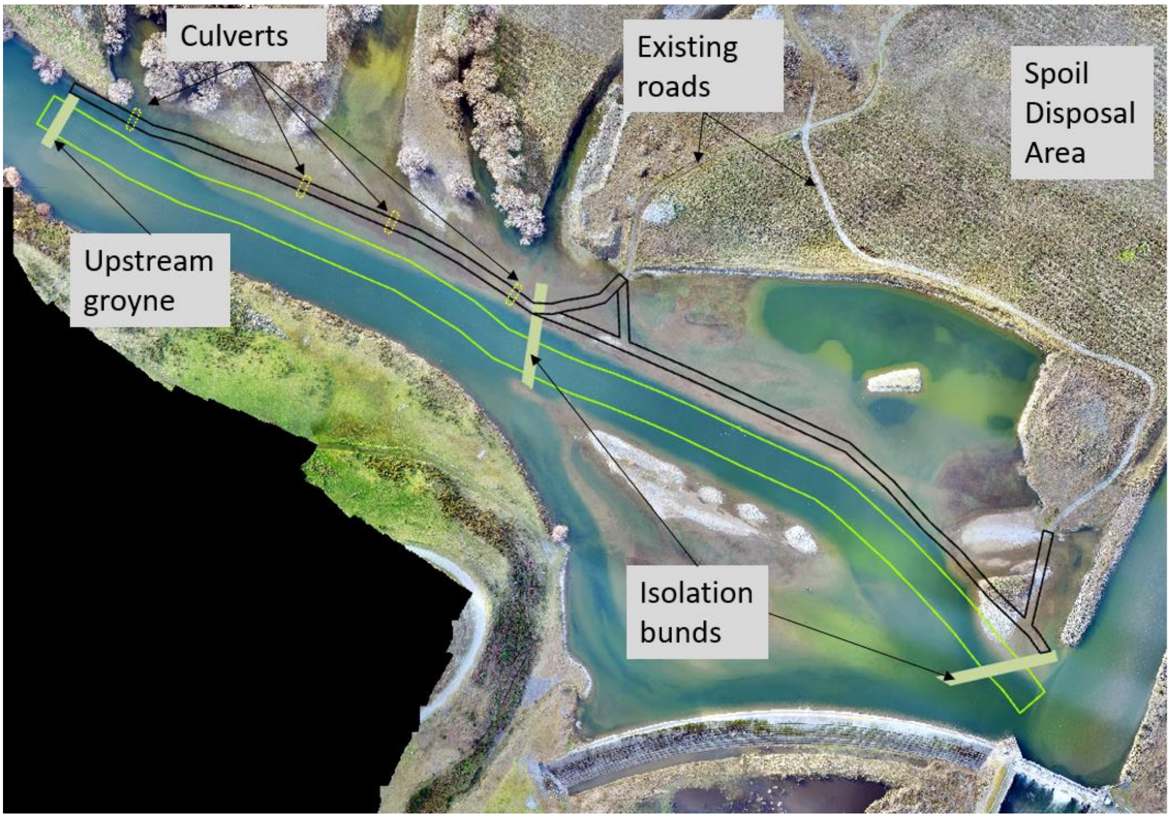


Figure A.17: Anticipated extent of haul roads in black outline on true-left channel bank connecting the channel edge to existing access roads and spoil disposal area.

Haul roads crossing the historical Mararoa outlet may affect the hydraulic connection with the river. To allow water to flow into and out of these areas, culverts should be placed beneath the haul road.

When sections of the haul road are no longer required (i.e. excavation in a given reach is completed), the road should be scraped back to an elevation similar to the existing banks, and the culverts removed. A finished permanent level of RL 177.5 m, an elevation exceeded by the Waiau Arm water level around 50% of the time, is proposed.

Equipment

The following is a list of the anticipated main plant on site to execute the works with the methodology described:

- 4 x 35t long reach excavators
- 4 x 33t standard excavators
- 6 x 35t articulated dump trucks (ADTs)
- 1 x Cat D8 bulldozer
- 1 x Cat 16 grader
- 5 x 4x4 utes
- 1 x 30t articulated water cart
- 1 x diesel-engine pump to fill water cart

The actual size and quantity of machinery used will be subject to the contractor's available equipment and approach.

When not in use, equipment should be parked at the establishment area situated well above potential flood levels. The establishment area will include fuel storage and other consumables, and other contractor's facilities (site office, smoko room, ablutions, temporary workshop, etc.).

Programme

The overall construction period is envisaged to be 6 to 6.5 months.

Compared to earlier programme estimates, the increase in time allows for installation and removal of silt curtains and extra double handling plus the increased bulk excavation volume.

Sequencing of parallel work will be important, as will programming of potential silt generating activities or releases. The current review allows for parallel activities. There may be better programme rationalisation that the chosen contractor can add later.

The construction period estimate is based on a consent allowing 24 hour working days, seven days a week, including public holidays. To take advantage of multiple working shifts, artificial floodlighting will need to be used outside of daylight hours.

Key Risks

The following risks have been identified for the above methodology:

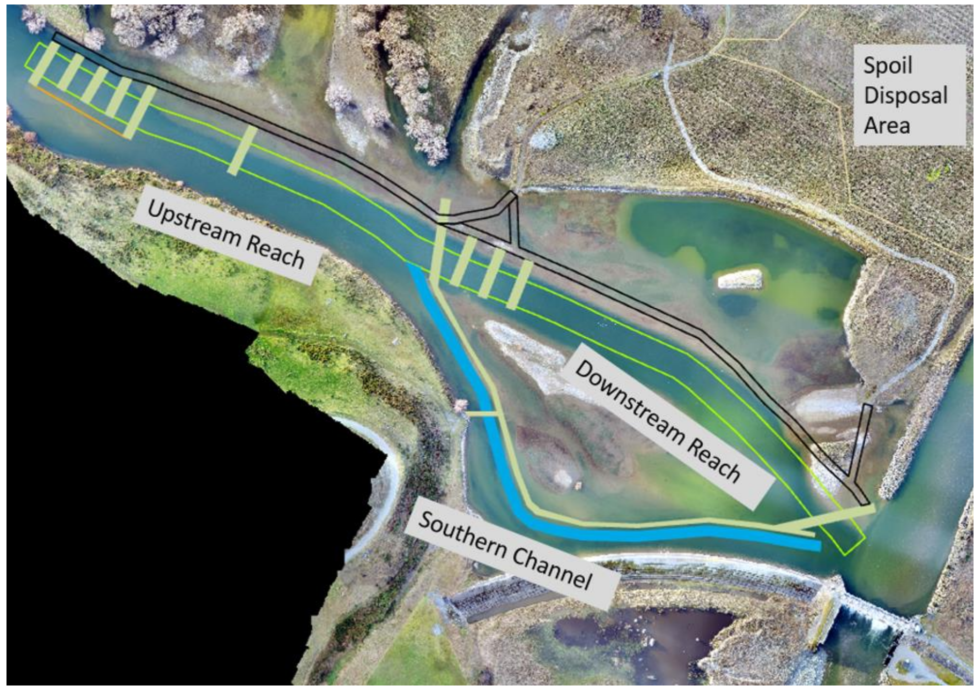
- The safety of workers on or near the water, particularly in times of high lake level and high flood discharge, as well as the security of construction plant, fuel, etc. against flood damage or loss. Inflow/flood forecasting and river withdrawal procedures are a key mitigation.
- The impact of floods on the works, including material being washed into work areas requiring rework, any reconstruction of temporary works, fingers and silt control systems, as well as down time when the river is in flood. Construction programming and sequencing, including adaptability to prevailing and forecast lake levels, will be important in minimising impacts, as well as appropriate procedures for withdrawal of works from the river in advance of a forecast flood.
- The management of pockets of very soft material that preclude the construction of access roads, fingers and haul roads. These areas if found would require over excavation and backfilling with rock, with cost and time impact.
- Potential downtime to manage the timing of sediment releases when e.g. groynes and bunds are installed and removed.
- The efficacy of geofabric in minimising leaching of fine material from the groynes.
- The anchoring arrangements and efficacy of silt curtains.
- Consent conditions not allowing night work or work on weekends or public holidays. This would increase the duration of the project work on site.
- The management of suspended sediment generation in the unprotected excavation area at the Mararoa confluence.
- The management of underwater obstructions, large boulders, etc, when encountered by long reach excavators.
- If screened and washed material is used to construct bunds and groynes, delays to the screening that impacts the main earthworks.

Appendix B Excavation Project Methodology Final Shaping and Design Workshop

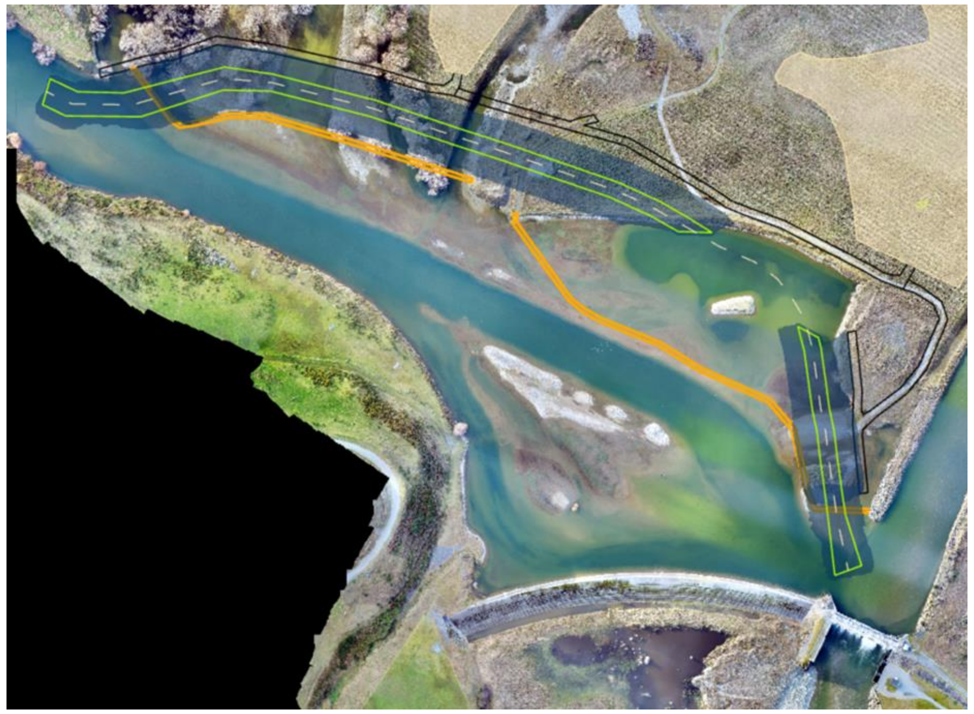
Excavation Project Methodology Final Shaping & Design Workshop

High Level Environmental Impact Assessment & Technical Specialist Allocation

Alternative Methodology 2 (Modified from First Assessment)



Alternative Methodology 4 Parallel Cut (New)



Item	Alternative 2 Instream (Modified From First Assessment) – Isolate Northern Channel				Alternative 4 – Parallel Cut – New Methodology				Responsibility
Effects -Assessment	Description/ Impact H = 3 /M= 2/L=1	Score Env Impact	Score Project Risk	Risks to gaining consent – further work -– notes on assessment	Description/ Impact H = 3 /M= 2/L=1	Score Env Impact	Score Project Risk	Risks to gaining consent -further work- – notes on assessment	Consultant
Hydrology high flows that could disrupt works	Damwatch High inflows from Te Anau / Manapouri catchments lead to high lake level, and Flood Rules being triggered. High water levels could overtop groynes in Upstream Reach or isolation bunds in Downstream Reach. Potential impacts include - safety risk for personnel and plant/equipment - release of high SSC from contained work areas. - erosion of groynes/bunds/fingers releasing sediment and requiring rework (extending duration of all other effects) High flows (when Flood Rules triggered) mean high velocities around groynes, potential for erosion and threat to silt curtain anchoring. NIWA Key environmental consideration is that this could cause a pulse of suspended sediment released downstream. Effect similar from all options Tonkin Taylor	1	3	Mitigations - forecasting - develop protocols on when to withdrawal from river Proposed that Downstream Reach isolation bunds built to 1/5 AEP of 179.30, noting that the MLC weir overtops at 179.22	Damwatch High inflows from Te Anau / Manapouri catchments lead to high lake level, and Flood Rules being triggered. If this occurs during inlet/outlet excavation, could overtop fingers - safety risk for personnel and plant/equipment - erosion of fingers suspending sediment and requiring rework (extending duration of all other effects) NIWA Key environmental consideration is that this could cause a pulse of suspended sediment released downstream. Effect similar from all options Tonkin Taylor Loss of structures and related suspended sediment release – likely inconsequential during the high flow event itself, but additional effects during the rebuild.	1	2	Mitigations - forecasting - develop protocols on when to withdrawal from river - relatively short period of in-river work, and relatively minor in-channel structures (could 'pull finger' with a few days' notice?) Proposed that bunds/roads to isolate majority of work are built to 1/5AEP of 179.30, noting that the MLC weir overtops at 179.22	Damwatch/NIWA

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	Effect of high flows and dam failure from an environmental effects perspective								
Hydrology minimum flow	Damwatch Southern Channel excavated initially, to ensure min flow can be passed at min lake control level when main channel isolated. NIWA Assume all flows from Mararoa would be sent down the LWR under this option to avoid sending suspended sediment up the Arm. Tonkin Taylor There is potential for a small period of time where flows may be reduced. Following excavation of the southern channel, less risk.	1	1		Damwatch No effect. NIWA Assume flows from Mararoa would be able to be diverted up the Arm under this option whilst the 'dry' excavation is occurring, i.e., less impact on normal operations Tonkin Taylor No issues.	1	1		Damwatch/NIWA
Hydrologically connected water Effects	Damwatch Potential to reduce water level in isolated Downstream Reach to facilitate excavation. This reach likely to be hydraulically connected to the 'bird island lagoon', but filtered through gravel riverbank. Pumping clean water out of lagoon may lower water levels for excavation. Need to understand if hydraulicly connected. Potentially temporary increase in groundwater levels from saturated material placed in disposal area. Tonkin Taylor Dewatering effect (if any) and related impacts on any wells and hydraulically connected wetlands	1	1		Damwatch Expect 'dry' excavation to have significant groundwater level, with the majority underwater if no controls. Potential to reduce water level in excavation and so facilitate quicker excavation by pumping - Clean water out of bird island lagoon in advance of excavation works. - Clean water out of wells outside of excavation footprint to lower groundwater table. - Silty water out of excavation into settling ponds. Elevated haul road along northern side of excavation will prevent water into/out of historical Mararoa channels. Expect rainfall to infiltrate ground rather than pond. Potentially temporary increase in groundwater levels from saturated material placed in disposal area. Tonkin Taylor Rates & volumes of dewatering, location and sizing of wells and/or settling ponds, and any discharge	1	2		Damwatch/NIWA

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					points (if required) currently unknown – will be needed for consent application. Risks and effects (both construction and environmental effects) from inadequate dewatering and/or treatment.				
Sediment control, methodology and management	Damwatch Excavation in Downstream Reach isolated from river. Upstream reach excavated in 'cells' behind silt curtain. Geofabric placed over isolation bunds and groynes creating cells to minimise silt leeching. Placement and removal of isolation bunds and groynes is expected to generate significant volumes of suspended sediment. NIWA The instream excavation without sediment control is relatively low with this option – southern channel (3500 m3) and Mararoa confluence (1400 m3). However, this option involves adding 46400 m3 of 'clean' material to form the causeway, low level embankment, groynes and isolation bunds (prior to adding geotextile), haul roads and finger bunds around the Mararoa confluence. This material will then be removed again. Even with use of 'clean' material the adding and removing process will generate suspended sediment and some of this will become deposited on the bed. Overall, the total material to be excavated, reworked, added and removed again is 51,300 m3, slightly more than with the parallel channel option. Tonkin Taylor At the upstream end, finger bunds will be created to enable excavation in between, in 'tranquil' areas to reduce potential sediment discharge. At the downstream end, isolation of northern channel will allow for excavation of the island and northern area in very low water / the dry, which reduces sediment generation relative to Alternative 1.	2.5	3	Potential further mitigations include - Timing of bund/groyne removal in opportune times to reduce impact of sediment e.g. during fresh - Flow release management with bund/groyne removal e.g. release a flush afterward to dilute and disperse sediment More involved flow release management could involve partitioning gates to allow Waiau Arm flow to be halted while releasing Mararoa flows.	Damwatch Majority of excavation isolated from river. Excavation of inlet and outlet, including placement and removal of finger bunds is expected to generate significant volumes of suspended sediment. NIWA The parallel channel is mostly excavated in the dry, however, it involves excavation of 29,500 m3 without sediment control. It also involves adding 20,000 m3 of (assumed) 'clean' material to form the roads, isolation bunds and finger bunds for the cut in areas. This material will then be removed again. Even with use of 'clean' material the adding and removing process will generate suspended sediment and some of this will become deposited on the bed. Overall, the total material to be excavated, reworked, added and removed again is 49,500 m3, slightly less than with the insstream excavation option. Tonkin Taylor Best option on the table for minimising suspended sediment effects. However, those works which interface with the river are likely to still generate suspended sediment which may not meet regional plan WQ standards after reasonable mixing. Non-complying activity status still likely to apply. The AEE will need to demonstrate that durations of suspended sediment release are kept to the minimum practicable and effects are appropriate.	1.5	1.5	Potential further mitigation could include - Flow release management with bund/groyne removal e.g. release a flush afterward to dilute and disperse sediment More involved flow release management could involve partitioning gates to allow Waiau Arm flow to be halted while releasing Mararoa flows.	Damwatch And NIWA expertise as required
Plant communities (macrophytes, periphyton, phytoplankton)	NIWA Direct effects of excavation activities - This option will destroy benthos in excavated area, this option is probably worst as the area to be excavated is greatest. We expect that the communities will gradually re-establish as the new channels age. Macrophyte and periphyton communities upstream will provide propagules for recolonisation. Longer term effects of reduced water velocities following excavation - The lower water velocities may	1.5 1.0	1.5 1.0		NIWA Direct effects of excavation activities - This option will destroy benthos in excavated area, this option has less impact as the wetted area to be excavated is smaller. We expect that the communities will gradually re-establish as the new channels age. Macrophyte and periphyton communities upstream will provide propagules for recolonisation. Longer term effects of reduced water velocities following excavation - substantial increased risk of	1.0 1.0	1.0 1.0		

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	result in a more favourable environment for macrophyte establishment than at present. However, the effects of high velocities in individual high flow events from the Mararoa River may have an over-riding effect on long term variability in macrophyte abundance and depth extent. Increased risk of phytoplankton blooms in the newly excavated channels due to reduced water velocities (3 to 5 times the number of days under high risk). In the Lower Waiau River, elevated loads of suspended sediment are expected the affect the periphyton community primarily through growth reduction (because of reduced light from reduced water clarity and direct smothering by deposited fine sediment), followed by increased potential for sloughing of existing periphyton mats. This option is expected to be slightly worse due to slightly higher potential for sediment generation and longer duration of potentially elevated SSC. Tonkin Taylor Partial loss from instream works and during isolation period..	2	1.5		phytoplankton blooms over the risk in the existing channels in both excavation options (i.e., 3 to 5 times the number of days under high risk). The increased risk is greater under the parallel channel option than under the instream excavation option (e.g., 17 additional days of predicted high risk in the main channel). In the Lower Waiau River, elevated loads of suspended sediment are expected the affect the periphyton community primarily through growth reduction (because of reduced light from reduced water clarity and direct smothering by deposited fine sediment), followed by increased potential for sloughing of existing periphyton mats. This option is expected to be slightly better due to slightly lower potential for sediment generation and shorter duration of potentially elevated SSC. Tonkin Taylor Reduced level of effect relative to Alternative 2.	1.5	1.0		
Macroinvertebrates	NIWA Existing benthic macroinvertebrate communities in the Waiau Arm will be physically disturbed, destroyed and removed due to activities (e.g., digging, pumping) in the excavation area. The nature of these effects will be greater under this option due to the larger area of disturbance. We expect that macroinvertebrates will recolonise from upstream areas and tributary sources and re-establish in the new channel overtime. On top of already moderate to poor status of macroinvertebrate communities in the Lower Waiau River, increasing fine sediment (both suspended and deposited) is expected to lead to a temporary further decline in status. High levels of turbidity and increased sediment deposition may also result in increased drift of macroinvertebrates, with some taxa moving downstream. The effects of additional suspended and deposited fine sediment from the excavation on macroinvertebrate habitat will be temporary. We expect that macroinvertebrates will recolonise from upstream and tributary sources following the excavation.	1.5 2.0	1.0 1.5		NIWA Existing benthic macroinvertebrate communities in the Waiau Arm will be physically disturbed, destroyed and removed due to activities (e.g., digging, pumping) in the excavation area. The nature of these effects will be less under this option due to the smaller area of disturbance. We expect that macroinvertebrates will recolonise from upstream areas and tributary sources and re-establish in the new channel overtime. On top of already moderate to poor status of macroinvertebrate communities in the Lower Waiau River, increasing fine sediment (both suspended and deposited) is expected to lead to a temporary further decline in status. High levels of turbidity and increased sediment deposition may also result in increased drift of macroinvertebrates, with some taxa moving downstream. The shorter duration of increased sediment inputs under the parallel channel option will reduce the severity of effects. The effects of additional suspended and deposited fine sediment from the excavation on macroinvertebrate habitat will be temporary. We expect that macroinvertebrates will recolonise from upstream and tributary sources following the excavation.	1.0 1.5	1.0 1.0		NIWA

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Fish - effects of elevated sediment	Direct effects - Most direct physical effects of elevated suspended sediments are attributed to the clogging, thickening and damaging of the fishes' gills. Expected SSC no greater than Mararoa floods therefore duration of elevated SSC the greater concern. In terms of digging instream , the largest catch-per-unit effort of longfin eels in the Waiau catchment in 2021 surveys was in the Waiau Arm. Effects on longfin eels are possible due to increased deposited and suspended fine sediment in the Waiau Arm upstream of the MLC. Indirectly downstream, suspended sediments affect fish through decreases in VC (i.e., increased cloudiness/turbidity), which can alter feeding success and consequently habitat quantity and quality. Movement or migration patterns can also be impacted either due to the changing distribution of suitable habitat or through suspended sediments altering behaviour or blocking migratory cues. Considering known freshwater fish species distributions in the Waiau catchment, as well as expected sensitivities to elevated suspended and deposited fine sediment, we expect the greatest risk of activities in the Waiau Arm to be to salmonids (brown trout and rainbow trout) and longfin eel. Species that might be at risk to elevated sediment in the Lower Waiau River include Southern flathead galaxias and Gollum galaxias. In relation to salmonids, we expect any additive effects of deposited fine sediment to spawning grounds to be negligible as most spawning will occur in the headwaters of any tributaries. However, pre-spawning trout may show behaviour changes as a result of elevated suspended sediment. There is a risk that in low flow conditions, trout aggregating at the confluence of the Mararoa and Waiau Arm will be exposed to elevated suspended sediment, especially from the instream excavation option, which may impede migration given the 6 to 6.5 month timeframe of the operation. However, any effect on trout movement is likely to be very localised, hence minor in the context of the catchment's population as whole. Non-migratory galaxias species such as the Southern flathead galaxias and the Gollum galaxias are regarded as highly sensitive to increased fine sediment levels. Both are found in the Lower Waiau	2.0 2.0	1.5 1.5		As with instream excavation but reduced effect mostly due to shorter duration.	1.5 1.5	1.0 1.0		

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	River below the MLC. Potential impacts are more likely at low flows and are most likely to be associated with the instream excavation option because of its longer duration.								
Fish passage (and fish migration/fish communities)	NIWA There is a risk that in low flow conditions, trout aggregating at the confluence of the Mararoa and Waiau Arm will be exposed to elevated suspended sediment, especially from the instream excavation option, which may impede migration given the 6 to 6.5 month timeframe of the operation. Jan-May is the peak period for adult eel migration. Waiau arm is the main migration corridor for d/s migration of Longfin eels, therefore timing of works is very important. We expect downstream migrant eels to migrate via the southern channel. Migration in March-May will be impacted by this option. Upstream migration of adult lamprey adult has been documented over April-Nov, so they could be impacted by works in winter. However, it's hard to assess impact on lamprey as we don't know what flows they can navigate the structures or quite how they're getting through them. Tonkin Taylor Effect of construction methodology on fish passage	1.5	1.5		NIWA Less interruption due to shorter timeframe, could avoid instream works in March-May. Tonkin Taylor Fish passage unaffected. Ecology effects report will need to address timing and duration of suspended sediment release on key species.	1.0	1.0		NIWA
Trap and transfer programme Consent Condition	NIWA Adult T&T (Jan-May) could carry on as normal regardless of option. Migrant eels captured for the trap and transfer program could be released further downstream (i.e., not directly below MLC) to avoid any potential impacts of increased suspended sediment. Key elver recruitment time Dec-March, so works should avoid this time regardless of option.	1.5	1.0		NIWA Adult T&T (Jan-May) could carry on as normal regardless of option. Migrant eels captured for the trap and transfer program could be released further downstream (i.e., not directly below MLC) to avoid any potential impacts of increased suspended sediment. Key elver recruitment time Dec-March, so works should avoid this time regardless of option.	1.0	1.0		NIWA
Fish Pass Management Consent Condition Salmonids	Damwatch Mitigation option of partitioning gate approaches would mean MLC fish pass only leads to Mararoa.	1.0	1.0	Trout/Salmonoids will have access to arm and M/R	Damwatch Mitigation option of partitioning gate approaches would mean MLC fish pass only leads to Mararoa.	1.0	1.0		NIWA
Wetlands (onsite)	Boffas • No wetlands directly affected or removed. • Sedimentation effects and / or hydrological changes to wetlands adjacent to spoil disposal area (all are of low or low-moderate ecological value).	1.0	1.0	• Spoil disposal area designed to avoid wetlands with a minimum set back of 10 m. • Sedimentation managed via bunds, other erosion and sediment control methods, re-vegetating spoil.	Boffas • Wetland #1 (very small wetland of low ecological value) either affected or removed. • Greater volume of spoil (110,000 m^2 vs 225,000m^2). Sedimentation effects and / or hydrological changes to wetlands adjacent to spoil disposal area (all are of low or low-	1.5	1.0	• NES-F consent likely required if Wetland #1 affected or removed. • Spoil disposal area designed to avoid wetlands with a minimum set back of 10 m.	Boffa Miskell

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	Tonkin Taylor Effects of construction on the wetland areas to the north of the river channel, may be some dewatering effect. Also wetlands in/adjacent to stockpile area.			• Hydrological effects 'Above Mararoa Weir Wetland' Wetland ('lake-bed') mitigated by placing culverts beneath the haul road.	moderate ecological value) but spoil disposal area designed to avoid wetlands with a minimum set back of 10 m and managed via bunds, other erosion and sediment control methods, re-vegetating spoil. • Pumping from wells excavated on the landward side of the channel could result in drawdown to nearby wetlands, but this is considered unlikely. • Construction of haul road and bunding as shown will temporarily remove surface water connection between 'Above Mararoa Weir Wetland ('lake-bed') and Waiau Arm (for up to 4 months). Tonkin Taylor Loss of wetland #1. Larger area and volume of spoil disposal, but can still be managed via buffers and appropriate sediment control (bunds etc). Potential dewatering effects (depending on the methodology) on wetlands may need to be addressed.			• Sedimentation managed via bunds, other erosion and sediment control methods, re-vegetating spoil.	
Wetlands (off site)	Boffas • MLC minimum flows able to be provided across all normal conditions at minimum lake control level. • Potential for sediment deposition in downstream riparian wetlands during higher flows from excavation of upstream reach and deepening of low-flow southern channel (but isolating northern channel reduces potential for sediment discharge compared to Alt. 1). This option is expected to be slightly worse than Alt 4 due to slightly higher potential for sediment generation and longer duration of potentially elevated suspended sediment. Tonkin Taylor Same as Alternative 1	1.5	1.0	• Refer to mitigation options included for 'Sediment control, methodology and management' item.	Boffas • MLC minimum flows able to be provided across all normal conditions at minimum lake control level. • Sediment deposition in downstream riparian wetlands slightly reduced compared with Alt 2 as most excavation completed remote from the Waiau Arm. • Potential for sediment deposition in downstream riparian wetlands during higher flows primarily during Stage 3 activities (during instream excavation) and particularly when the downstream 'cut in' is completed (up to 7 weeks) This option is expected to be slightly better due to slightly lower potential for sediment generation and shorter duration of potentially elevated suspended sediment. Tonkin Taylor As per Boffa's comments.	1.0	1.0	• Refer to mitigation options included for 'Sediment control, methodology and management' item.	Boffa Miskell
Avian impact gulls nesting	NIWA Birds are most likely to be disturbed by the movement of heavy machinery associated with excavation works. Because freshwater birds are reasonably mobile, it is likely that individuals would move away from the area for the duration of the proposed excavation works (both methodologies) if the effects are too great. This would be problematic if works were to occur during the breeding season (September to January) when individuals are sitting	1.5	1.0		NIWA As with instream excavation option, but slightly less risk as September can be avoided. Tonkin Taylor Of all options involves the least disturbance within the river bed, but may still impact on nesting birds.	1.0	1.0	Timing of work impt in score assessment avoid August to December. Works should be started to before nesting period	NIWA

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	on nests or chicks are present. However, it is less likely to be an issue at other times of the year. Tonkin Taylor Impacts on nesting birds during construction programme								
Landscape – visual assessment e.g stockpiling area and remediation Plan	Tonkin Taylor Same as Alternative 1 Boffas During construction, works would remain associated with bunding and fingers which are progressively shifted along a modified river margin and facilitate excavation which is predominantly submerged below the existing water level. Isolating the Gravel Island with bunding and access will expand the construction footprint and apparent modification within the existing river channel. The removal of temporary bunding and haul roads during Site Rehabilitation would ensure the resulting disturbance will remain largely concealed beneath the surface of the water. Rehabilitation along the margins of the river should avoid straight edges and be recontoured to resemble the existing sinuous form. The footprint and height of spoil would remain subject to effective rehabilitation, encompassing recontouring to remain sympathetic to the surrounding stepped river terrace form and subsequent re-establishment in pasture.	1.5	1.0		Tonkin Taylor Increased footprint and height from larger volume, but effects likely to be manageable subject to appropriate contouring and rehabilitation. Boffas During construction, increased disturbance and expansion of the river corridor will be apparent beyond the existing river margins. Bunding and access will delineate an expanded construction footprint within which the extent of excavation will remain evident. Temporary bunding and haul roads which are removed may remain above the water level in some areas. Site Rehabilitation will require recontouring the margins and islands of the river to avoid straight edges and reflect a broader semi-braided sinuous river form. The resultant footprint and height of extracted material will increase in the context of the adjoining modified terrace and would remain subject to effective rehabilitation, encompassing recontouring to remain sympathetic to the surrounding stepped river terrace form and subsequent re-establishment in pasture.	2.0	1.5		Boffa Miskell
Dust management	Damwatch Water cart to reduce dust from haul roads (included in cost estimate). Disposal area – assume material would come in wet, could be covered with topsoil as you go. Could include hydroseeding to rehabilitate disposal area and reduce dust potential. Tonkin Taylor Same as Alternative 1	1.0	1.0		Damwatch Water cart to reduce dust from haul roads (included in cost estimate). Disposal area – assume material would come in wet, could be covered with topsoil as you go. Could include hydroseeding to rehabilitate disposal area and reduce dust potential. Tonkin Taylor Slightly increased dust risk from dry cut methodology and increased stockpile size, but still manageable with appropriate controls (e.g. water cart). Might require some form of staged rehabilitation to reduce effects? (i.e. not having the entirety of the site 'open' at one time)	1.5	1.5		?
Contaminant spills and management	Damwatch Majority of excavation isolated (Downstream Reach) or within contained cells (Upstream Reach).	1.5	1.0		Damwatch Majority of excavation isolated from river.	1.0	1.0		?

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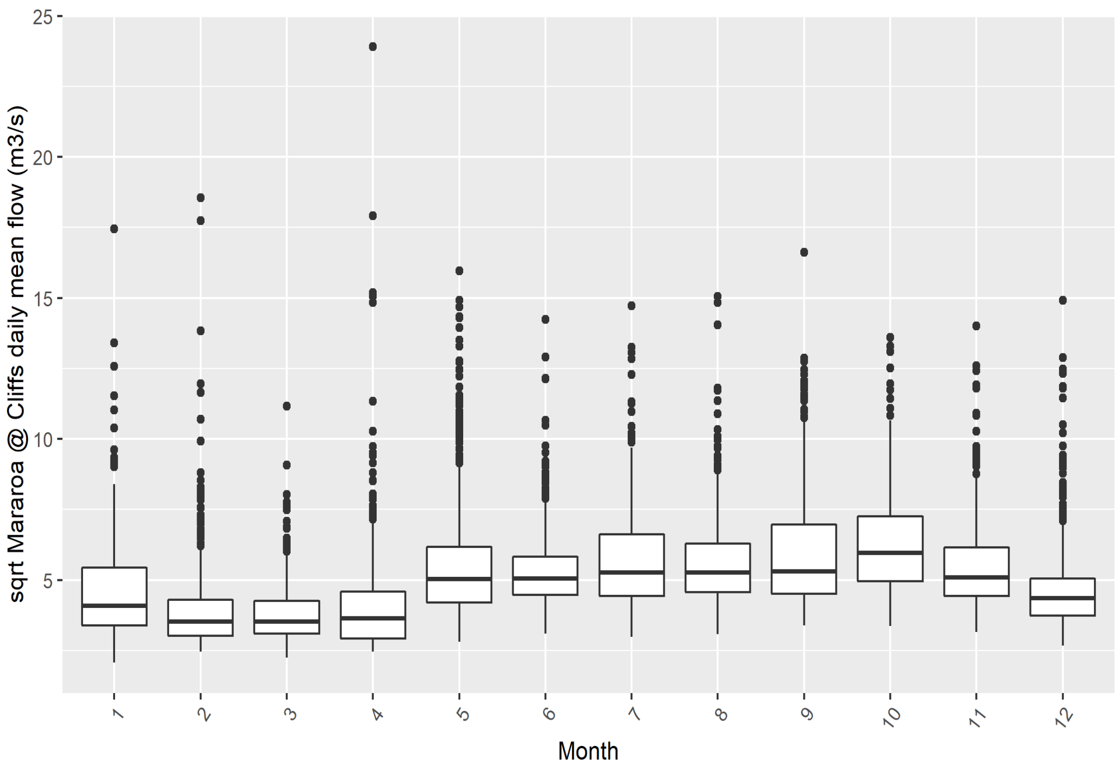
	Tonkin Taylor Same as Alternative 1 but works in/near water decreased slightly.				Tonkin Taylor Least risk option but AEE will still need to demonstrate how spills will be avoided/minimised and managed if they occur.				
Noise management	Damwatch Considering 24hr working to minimise programme duration. Tonkin Taylor Likely that construction will be undertaken 24 hrs, 6 days a week. Pumps will likely be required to maintain a low water level, or to dry out the northern channel. Potential for noise effects within a rural area.	1.5	1.5		Damwatch Considering 24hr working to minimise programme duration. Tonkin Taylor Similar to other options, although slightly greater buffer to the nearest residence.	1.5	1.5		?
Periphyton and recreational flow management Consent Condition	Damwatch Flow diverted around Southern Channel has lower conveyance - recreational release (35m³/s) and flushing release (160m³/s) only possible at lake levels of 177.x and 178.x respectively **update** NIWA Periphyton management occurs from Nov-April. Requirements for flushing flows during this period.	1.5	1.5		NIWA Periphyton management occurs from Nov-April. Requirements for flushing flows during this period	1.5	1.5		NIWA
Waiua Arm WQ Compliance Reporting	NIWA Water quality compliance report occurs over Jan-April.	1.0	1.0			1.0	1.0		NIWA
Light Spill	Tonkin Taylor Likely to be manageable subject to standard controls (direction of lighting, shielding, etc).	1.5	1.0		Tonkin Taylor Likely to be manageable subject to standard controls (direction of lighting, shielding, etc).	1.0	1.0		
Cultural values statutory acknowledgement	Tonkin Taylor Sediment/WQ impacts over a prolonged period, but slightly reduced relative to Alternative 1	2.0	2.0		Tonkin Taylor Best from a WQ perspective, but may be some concerns with temporary loss of water connection and ecological values? Risk of iwi not supporting the proposal and not providing cultural values statement / written approvals. Council declining application due to Iwi concerns.	1.5	1.0		Tonkin Taylor
Overall Impact		37					30		
Overall Risk			34					29.5	

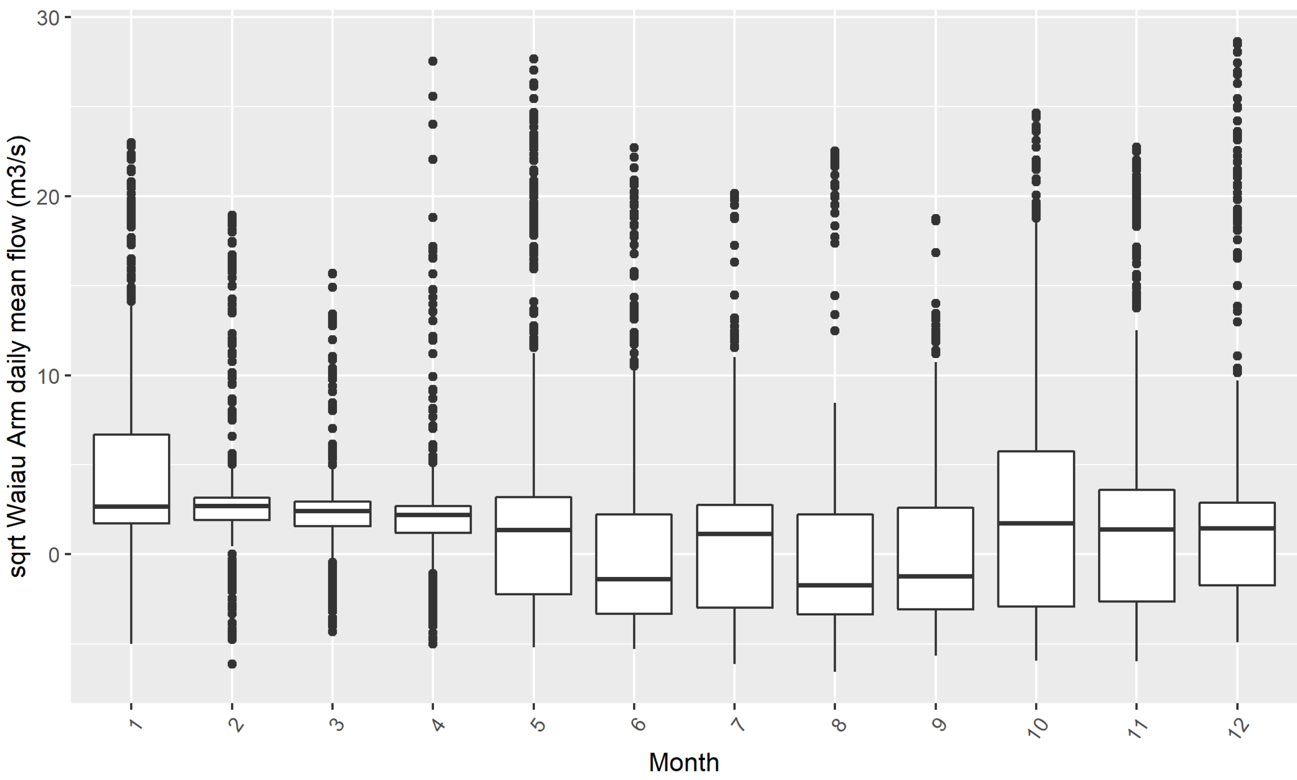
Item	**Alternative 2 Instream (Modified From First Assessment) – Isolate Northern Channel**	Alternative 4 –Dry Cut Methodology	Responsibility
Cost range	$4.3M +$1.1M risk contingency (excl.GST)	$5.2M +$0.8M risk contingency (excl.GST)	Damwatch
Timeframe/ schedule	2 months planning and mobilisation Set up disposal area 1 week, then ongoing as spoil is deposited. Allow 6 – 6.5 months in the river including haul roads March-September 2024 suggested as construction window.	2 months planning and mobilisation 4-5 weeks 'Stage 1' - set up disposal area, excavation above river levels, construct roads and bunding. 5 weeks 'Stage 2' - excavation off-line from river 4-7 weeks 'Stage 3' - excavation of inlet and outlet in-river Allow 4 month overall on-site construction programme. March-July 2024 suggested as construction window.	Damwatch
Opportunities	Fingers only need to be built to prevailing lake level, plus freeboard. Isolated northern channel - if water level is low and/or can be lowered, opportunity for less double handling and faster progress.	If water level within excavation is low and/or can be lowered by pumping, opportunity for faster progress.	Damwatch
Constructability & risks	To meet timeframe, will likely require double-shift work (i.e. through the night, using floodlights) Risk – variation in fuel costs. Flood risk – down time when river is in flood, reconstruction of temporary works, rework. Bunds (and whole island) isolating northern channel at risk of inundation and washout in flood conditions - ensure bunds are high enough and robust enough. Soft ground risk – for access and haul roads, fingers, soft material may need to be over-excavated and replaced. Risk - Suitability of excavated material to construct isolation bunds and groynes without processing. Finding enough suitable material for initial roads, isolation bunds and groynes before excavation of channel begins. Risk – may need to remove silt curtain and pull back groynes if high flows forecast.	To meet timeframe, will likely require double-shift work (i.e. through the night, using floodlights) Risk – variation in fuel costs. Flood risk – down time when river is in flood, reconstruction of temporary works, rework. The majority of the work being offline from the river, with bunding constructed to provide flood protection, reduces this risk. - inflow/flood forecasting and river withdrawal procedures are a key mitigation.	Damwatch
Risks H&S	Working around flowing water. Working at night. Working behind isolation bunds Flood warning system, and protocols for withdrawal of plant	Working around flowing water. Working at night. Working behind isolation bunds Flood warning system, and protocols for withdrawal of plant	Damwatch
Other Regulatory Risk Building Act/Dam Safety	Some ambiguity as to whether the isolation bunds for the Downstream Reach would be defined as a dam under the Building Act – probably not, as analogous to stopbanks (which are specifically excluded from the Building (Dam Safety) Regulations 2022), but if the water level inside the excavation area is lower than the river, then potentially the bunds are a 'dam': A dam, as defined by section 7 of the Building Act 2004: (a) means an **artificial barrier**, and its **appurtenant structures**, that – (i) is constructed to **hold back water** or other **fluid** under **constant pressure** so as to form a reservoir; and (ii) is used for the storage, control, or diversion of water or other fluid; and If so it would be a 'classifiable dam' ("has a height of 1 or more metres and holds 40,000 or more cubic metres volume of water") If so, the regulations would require the owner to classify the dam according to the potential impact of failure, and prepare a dam safety assurance programme. Regulations come into effect May 2024.	Bunds to isolate work area from the river would not be considered a 'dam' under the Building Act – clearly analogous to river stopbanks. Flooding safety obligations under Health and Safety at Work Act.	

Item	**Alternative 2 Instream (Modified From First Assessment) – Isolate Northern Channel**	Alternative 4 –Dry Cut Methodology	Responsibility
	In addition: - Meridian will have its own policies around dam safety. - Safety obligations under Health and Safety at Work Act (probably the relevant context under which safety is managed)		
Operational Risk Generation/Asset Management	Likely need to 'pull in' groynes if high discharge required (flushing flows or flood releases), disrupting excavation work. Restricted capacity of Waiau Arm when Southern Reach is isolated - likely can't pass flushing flows if required. Flushing flow release probably unlikely given time-of-year. Ideally not have any generating unit outages, as this will force more strict Flood Rules, meaning high flow releases (and disruption to work) at lower lake levels.	When completing in-river inlet and outlet excavation, likely need to 'pull in' fingers if high discharge required (e.g. flood releases), disrupting excavation work. Ideally not have any generating unit outages, as this will force more strict Flood Rules, meaning high flow releases (and disruption to work) at lower lake levels.	

NIWA

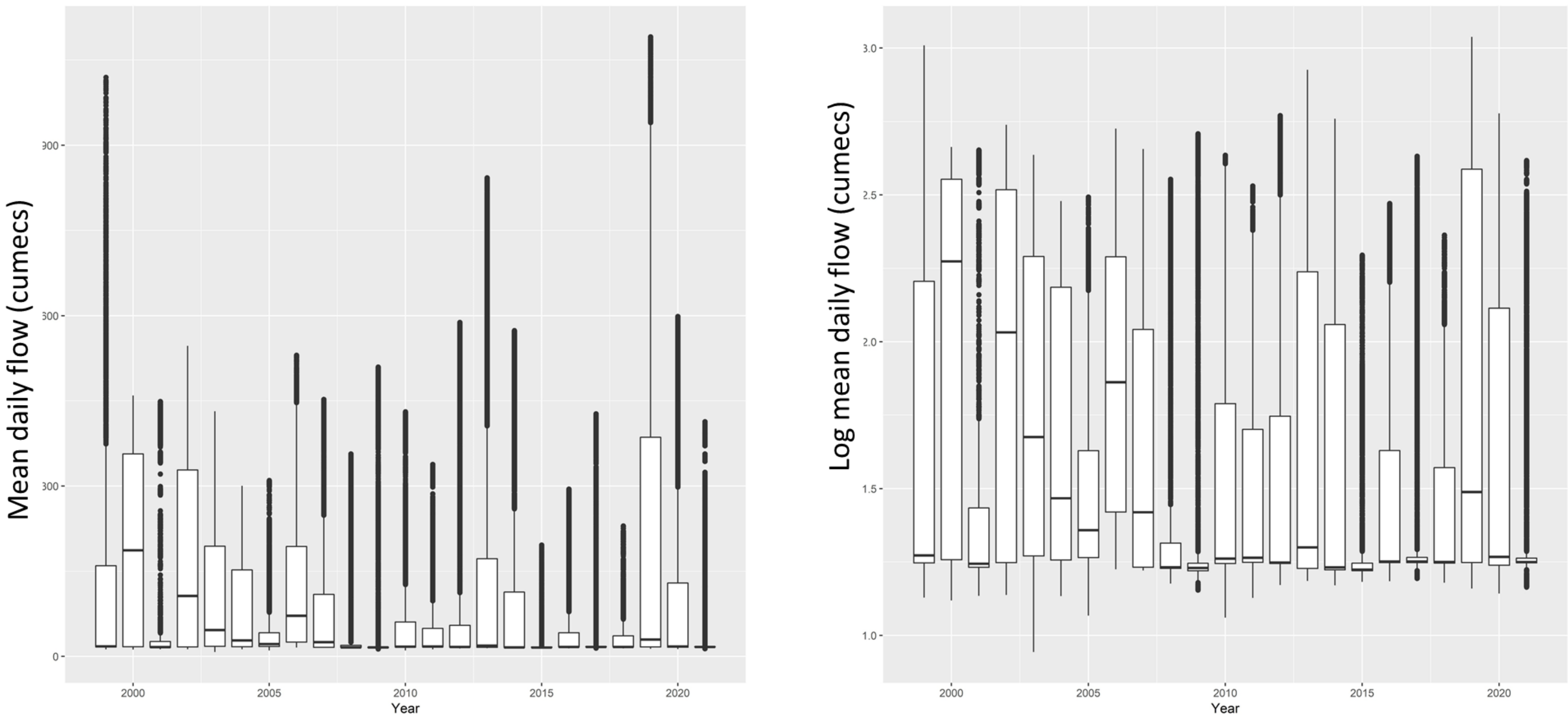
Supplementary flow data





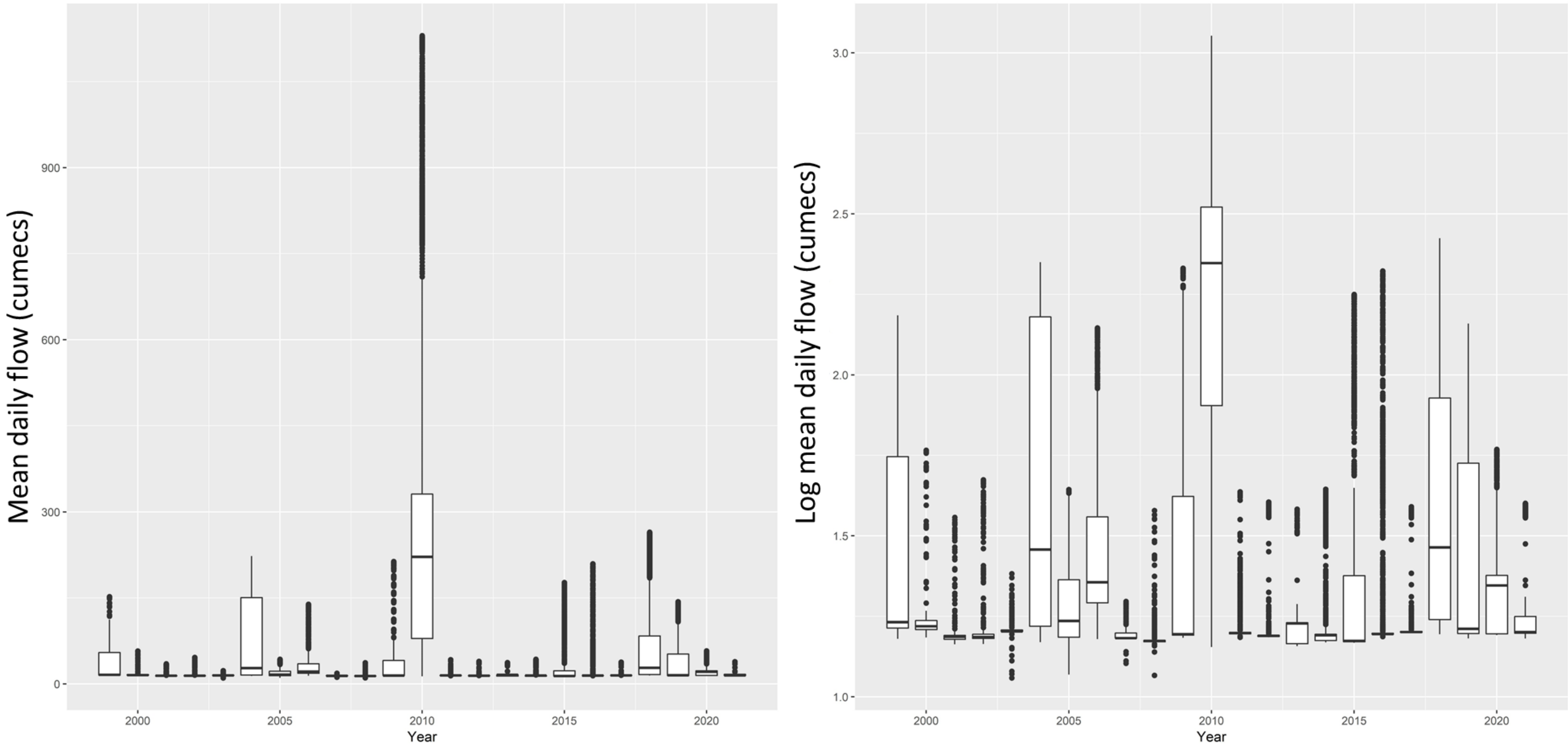
Expected range of monthly flows based on data from 2004 to 2021. Data are square-root transformed as it's hard to see the patterns using untransformed data.

Summer



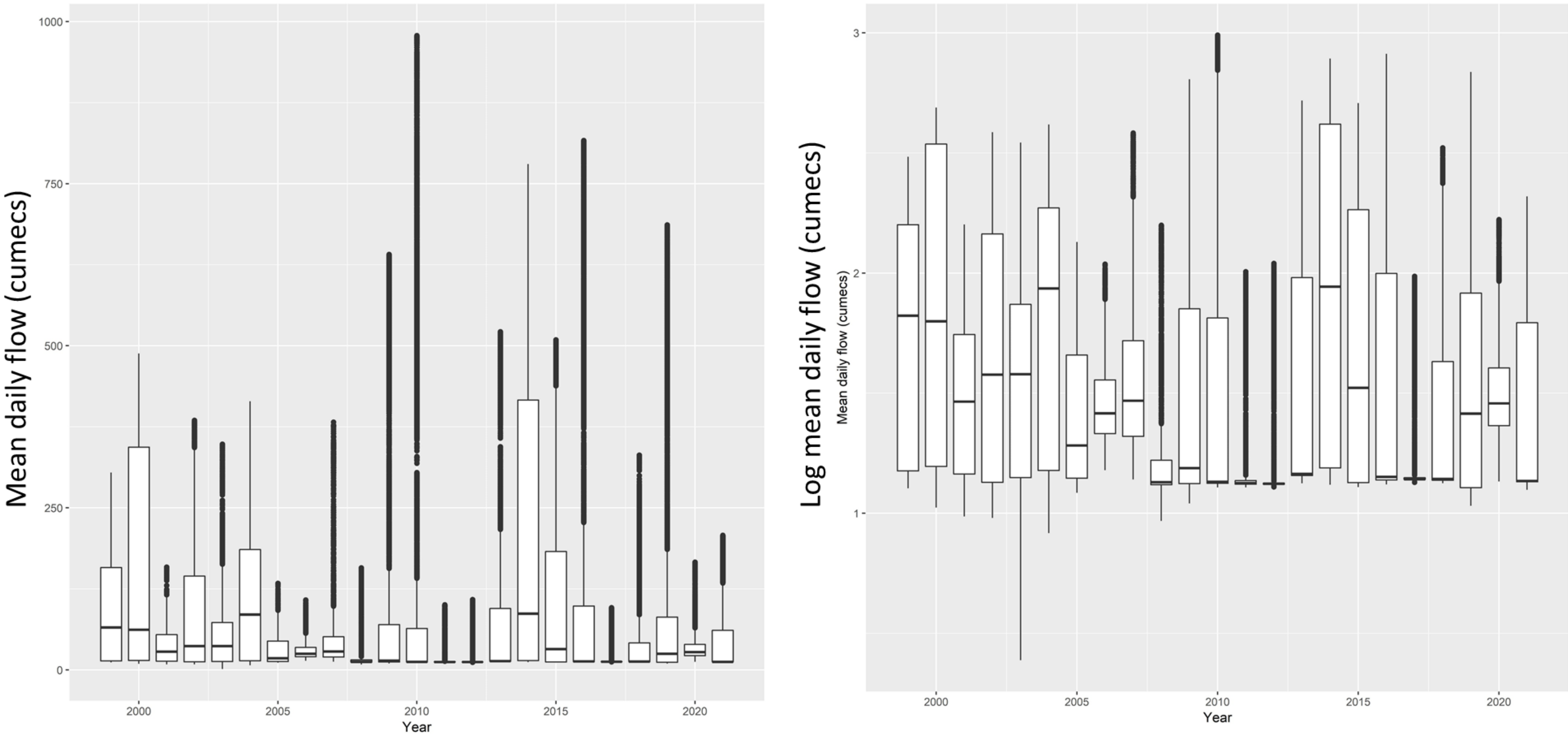
Variability in Summer flows at the MLC over time

Autumn



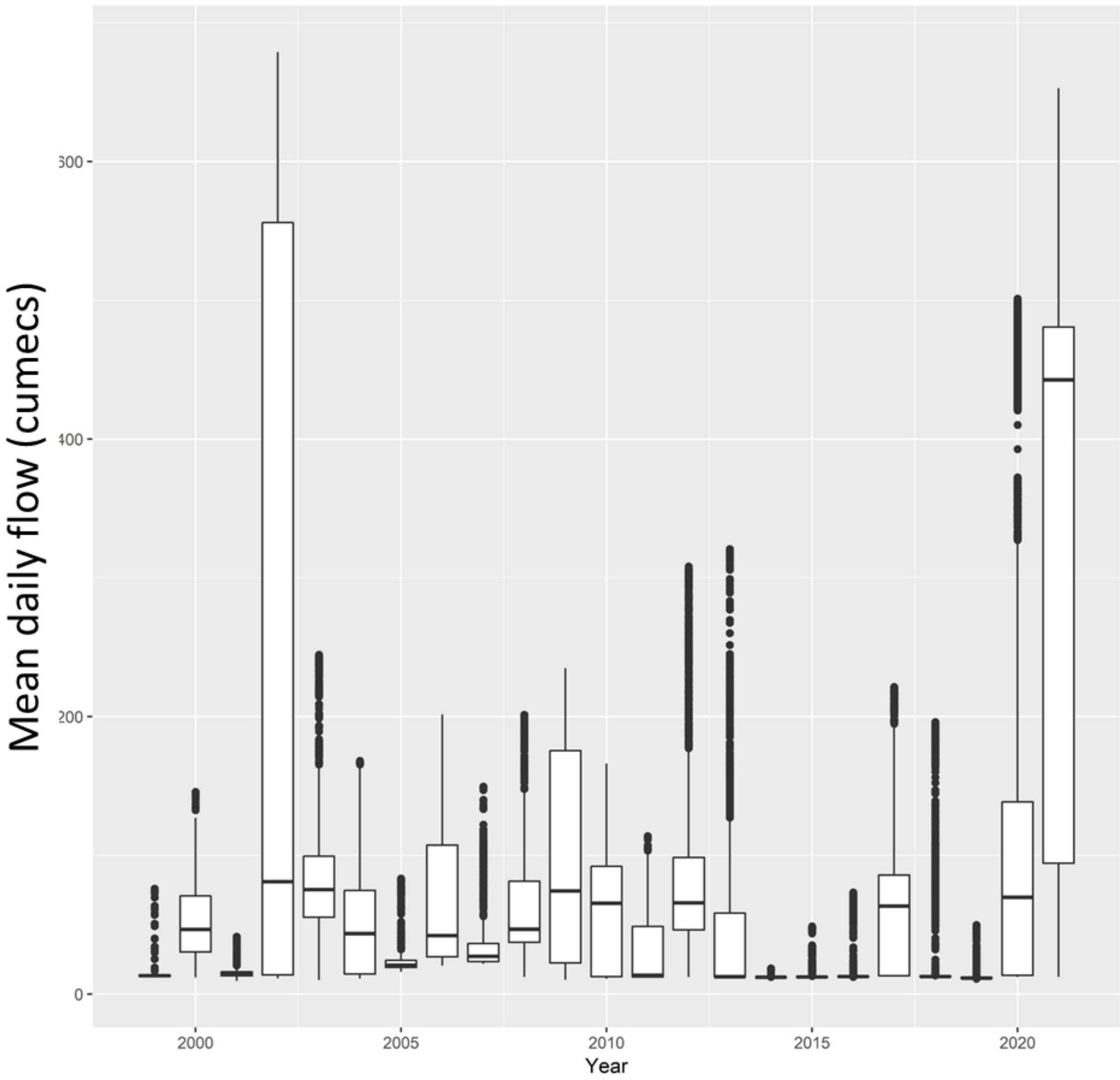
Variability in Autumn flows at the MLC over time

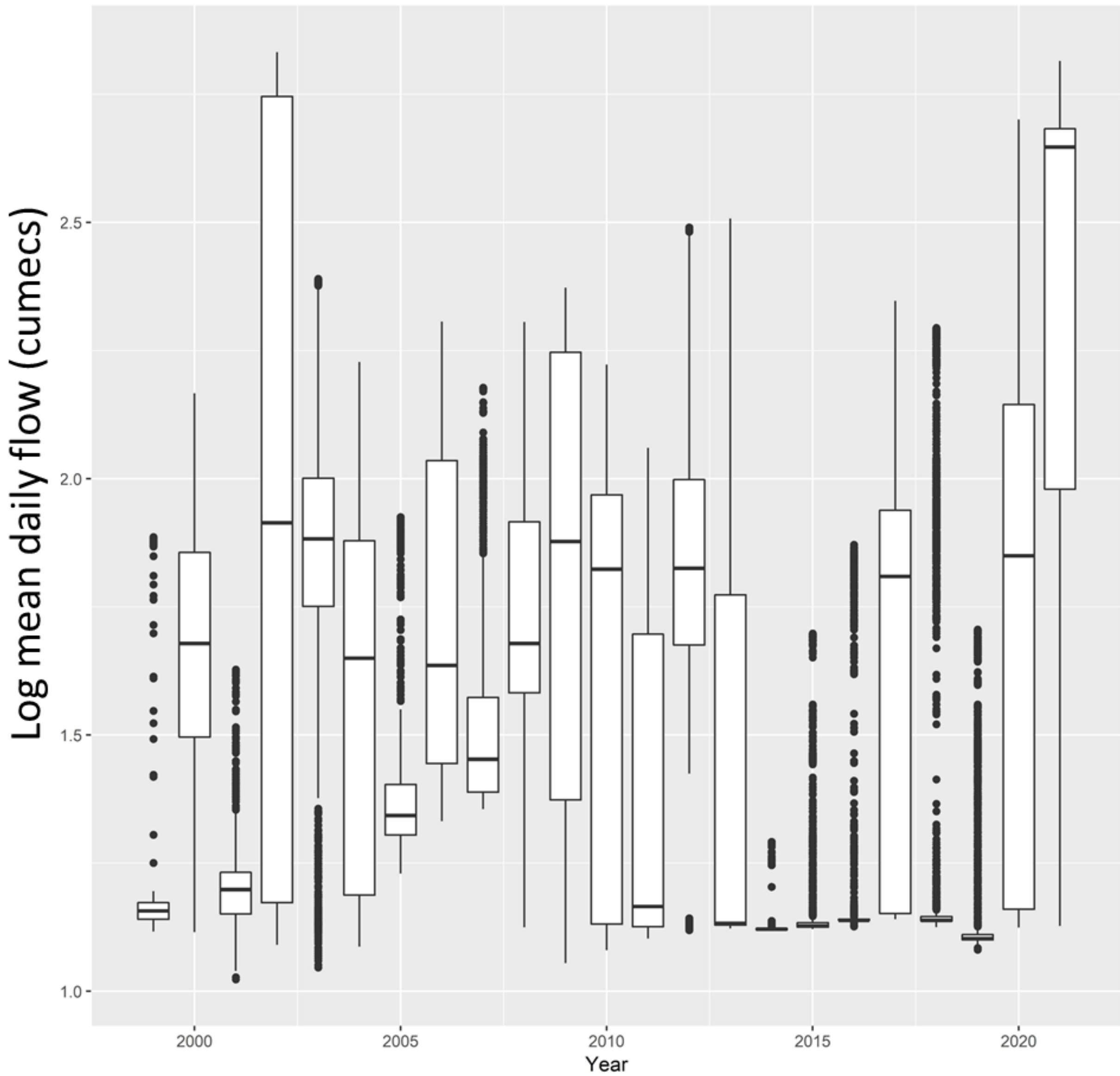
Winter



Variability in Winter flows at the MLC over time

Spring





Variability in Spring flows at the MLC over time

Fish Passage Table:

Table Error! Use the Home tab to apply Heading 1 to the text that you want to appear here.: Key migration periods for native freshwater fish present in the Waiau River catchment. ↑ = upstream movement, ↓ = downstream movement. An asterisk (*) denotes species/life stages where more research is needed to confirm the migration period[1]. Note, black flounder and yellow-eye mullet are not included as there is very little known about their migration times. Species highlighted in purple require passage above the Manapōuri and Te Anau Lake Control Structures although some species can readily form non-migratory (landlocked) populations (discussed in section **Error! Reference source not found.**).

	Freshwater fish			Summer			Autumn			Winter			Spring		
Group	**Common name**	**Species**	**Life stage**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
Eels/tuna	Longfin eel	*Anguilla dieffenbachii*	Juvenile	↑	↑	↑	↑								↑
			Adult		↓	↓	↓	↓	↓				↓	↓	
	Shortfin eel	*Anguilla australis*	Juvenile	↑	↑	↑	↑								↑
			Adult		↓	↓	↓	↓							
Lamprey	Lamprey	*Geotria australis*	Juvenile					↓	↓	↓	↓	↓			
			Adult					↑	↑	↑	↑	↑	↑	↑	↑
Galaxiids	Giant kōkopu	*Galaxias argenteus*	Juvenile	↑								↑	↑	↑	↑
			Adult					↓	↓	↓	↓	↓			
	Īnanga	*Galaxias maculatus*	Juvenile	↑	↑	↓	↓	↓				↑	↑	↑	↑
			Adult	↑	↑	↓	↓	↓	↓↑	↑	↑	↑	↑	↑	↑
	Kōaro	*Galaxias brevipinnis*	Juvenile					↓	↓	↓		↑	↑	↑	↑
			Adult*					↓↑	↓↑	↓↑	↓↑				
Bullies	Bluegill bully	*Gobiomorphus hubbsi*	Juvenile	↑	↑	↑	↑								↑
			Adult	↓	↓	↓	↓						↓	↓	↓
	Common bully	*Gobiomorphus cotidanus*	*Juvenile*	↑	↑	↑	↓							↓↑	↓↑
			Adult					↓	↓	↓		↓	↓		
	Redfin bully	*Gobiomorphus huttoni*	Juvenile	↑	↑	↑	↑								↑
			Adult	↓	↓	↓	↓						↓	↓	↓
	Common Smelt	*Retropinna retropinna*	Juvenile	↑	↑	↑	↓	↓	↓	↓				↓↑	↓↑
			Adult	↑	↑	↑	↓	↓	↓						↑
	Torrentfish	*Cheimarrichthys fosteri*	Juvenile	↓	↓	↓	↓	↓	↓	↓					
			Adult*					↑	↑	↑	↑	↑	↑	↑	↑

[1] https://www.mpi.govt.nz/dmsdocument/7992/direct

Assumptions

Lake levels (thresholds) of interest are:

- 178.6 m – design lake level (bunds and cofferdams built to withstand up to this water level)
- 179.1 m – level of bund crest in Alternative 1
- 179.6 m – level of bund crest in Alternative 2
- 180.1 m – level of upstream cofferdam crest in Alternative 3

In all three alternatives, Mararoa flows will have to be passed through the MLC rather than upstream into the Arm and lake because of turbidity risk.

Calculations

The tables below show percentages of time when the lake level exceeded each threshold, by month (left hand table), and the percentage of years in which the thresholds were exceeded (right hand table)./.

Numbers in the top two tables were calculated from all available data (44 years from 1978 to 2021 – complete years of data only).

Numbers in the lower two tables calculated from recent data only (24 years from 1998 to 2021, since minimum flows established in the Lower Waiau)

Data used were mean daily lake levels from Lake Manapouri at Supply Bay

Results

In both periods , March and August (green-shaded) had low risk of exceedance of all thresholds.

In the 44-year period, the risk of exceedance of all thresholds was also low in July (green-shaded).

In the more recent 24 years, the risk of exceedances of the higher thresholds (179.1 m and greater) was also low February and July (grey-shaded).

1. Total percentage of time (days) when lake level exceeds threshold, by month

Lake level thresholds (m)

Data	**Month**	**178.6**	**179.1**	**179.6**	**180.1**
1978 to 2021	**1**	20.8	8.1	3.4	1.4
(44 years)	**2**	16.7	4.6	1.0	0.0
	3	8.0	0.9	0.4	0.0
	4	9.6	1.8	0.9	0.2

2. Percentage of years in which level exceeds threshold in each month

Month	**178.6**	**179.1**	**179.6**	**180.1**
1	45	27	11	5
2	34	18	7	0
3	23	7	2	0
4	25	5	5	2

5	12.9	4.3	1.8	0.4
6	15.3	2.7	0.3	0.0
7	7.9	0.5	0.0	0.0
8	4.2	1.5	0.6	0.0
9	10.9	6.1	1.6	0.0
10	27.9	9.8	2.7	1.1
11	20.9	9.2	3.9	1.4
12	19.8	8.7	2.8	1.0

5	39	16	9	2
6	39	14	5	0
7	20	5	0	0
8	18	5	2	0
9	27	14	9	0
10	50	30	14	2
11	45	30	18	5
12	43	25	16	5

Data

1998 to 2021

(24 years)

	178.6	**179.1**	**179.6**	**180.1**
1	17.9	4.0	0.8	0.0
2	10.8	0.3	0.0	0.0
3	8.2	0.3	0.0	0.0
4	9.5	3.3	1.7	0.3
5	15.0	7.7	3.2	0.7
6	18.5	2.8	0.6	0.0
7	10.9	0.9	0.0	0.0
8	4.6	2.3	1.1	0.0
9	8.6	3.9	1.3	0.0
10	27.7	5.7	1.9	0.0
11	22.8	8.6	2.5	0.0
12	14.3	6.1	3.0	1.8

	178.6	**179.1**	**179.6**	**180.1**
1	42	21	4	0
2	25	4	0	0
3	17	4	0	0
4	25	8	8	4
5	38	25	17	4
6	38	13	8	0
7	29	8	0	0
8	17	4	4	0
9	25	13	4	0
10	50	25	13	0
11	46	38	17	0
12	33	21	8	4

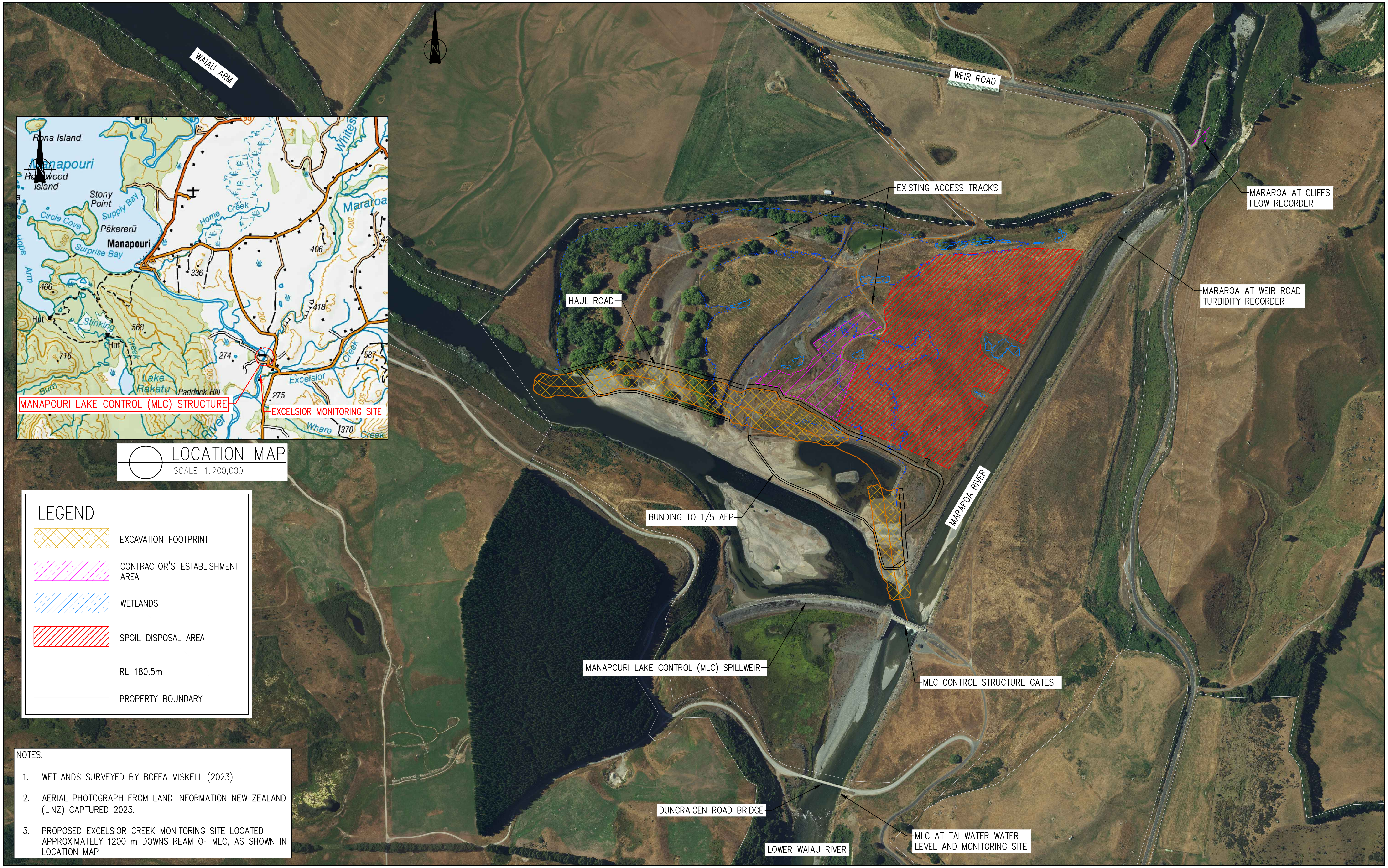
Table 5-1: Turbidity, sedimentation and afforestation effects ranking for key freshwater fish species. Ranking categories are low (1-3), medium (4-6) and high (7-9) with zero not applicable

Functional Group	Spawning Calendar	Turbidity		Sedimentation				Afforestation	Totals
	Species	Migration/Recruitment	Feeding	Reduced cover	Foraging and food	Spawning	Morphology	Reduced flows	
Non-migratory Galaxiids*	Alpine galaxias	3	5	9	9	9	9	8	52
	Bignose galaxias	3	5	9	9	9	9	8	52
	Canterbury galaxias	3	5	7	7	7	7	7	43
	Dusky galaxias	3	5	9	9	9	9	8	52
	Dwarf galaxias	3	5	9	9	9	9	8	52
	Eldons galaxias	3	5	7	7	7	7	7	43
	Taieri flathead galaxias	3	5	7	7	7	7	7	43
	Gollum galaxias	3	5	6	6	6	6	7	39
	Upland longjaw galaxias	3	5	9	9	9	9	8	52
	Lowland longjaw galaxias	3	5	9	9	9	9	8	52
	Roundhead galaxias	3	5	9	9	9	9	8	52
	Dwarf inanga	2	4	2	2	4	0	2	16
Salmonid Sportfish	Atlantic salmon	3	6	7	7	8	7	5	43
	Brook Char	3	6	7	7	8	7	5	43
	Brown trout	3	5	7	6	8	6	5	40
	Chinook salmon	3	6	7	7	8	7	5	43
	Mackinaw	2	4	2	2	4	0	2	16
	Rainbow trout	3	6	7	7	8	7	5	43
	Sockeye salmon	3	6	7	7	8	7	5	43
Koura	Northern	3	3	7	6	3	8	5	35
	Southern	3	3	7	6	3	8	5	35

Volumes of material to be excavated, reworked, added and removed using each excavation methodology.

Activity	Volume (m^3)	Notes
Instream excavation		
Causeway	300	Added then removed, plan to use clean material
Low level embankment	7,500	Added then removed, partly above water
Groynes and isolation bunds	24,000	Added then removed, plan to use clean material
Haul roads	13,500	Added then removed, some/most may be above water
Finger bunds around Mararoa confluence	1,100	Added then removed, plan to use clean material
Southern channel	3,500	Excavated without sediment control
Area at Mararoa confluence	1,400	Excavated without sediment control
total	***51,300***	
Parallel channel		
Isolation bunds and roads	15,000	Added then removed, plan to use clean material
Finger bunds at cut in areas	5,000	Added then removed, plan to use clean material
Cut in	29,500	Excavated without sediment control
total	***49,500***	

Appendix C Drawings



LOCATION MAP

SCALE 1:200,000

LEGEND

- EXCAVATION FOOTPRINT
- CONTRACTOR'S ESTABLISHMENT AREA
- WETLANDS
- SPOIL DISPOSAL AREA
- RL 180.5m
- PROPERTY BOUNDARY

NOTES:

1. WETLANDS SURVEYED BY BOFFA MISKELL (2023).
2. AERIAL PHOTOGRAPH FROM LAND INFORMATION NEW ZEALAND (LINZ) CAPTURED 2023.
3. PROPOSED EXCELSIOR CREEK MONITORING SITE LOCATED APPROXIMATELY 1200 m DOWNSTREAM OF MLC, AS SHOWN IN LOCATION MAP

A3 SCALE 1:7500

0 0.1 0.2 0.3 0.4 (km)

DRAWING STATUS: NOT FOR CONSTRUCTION

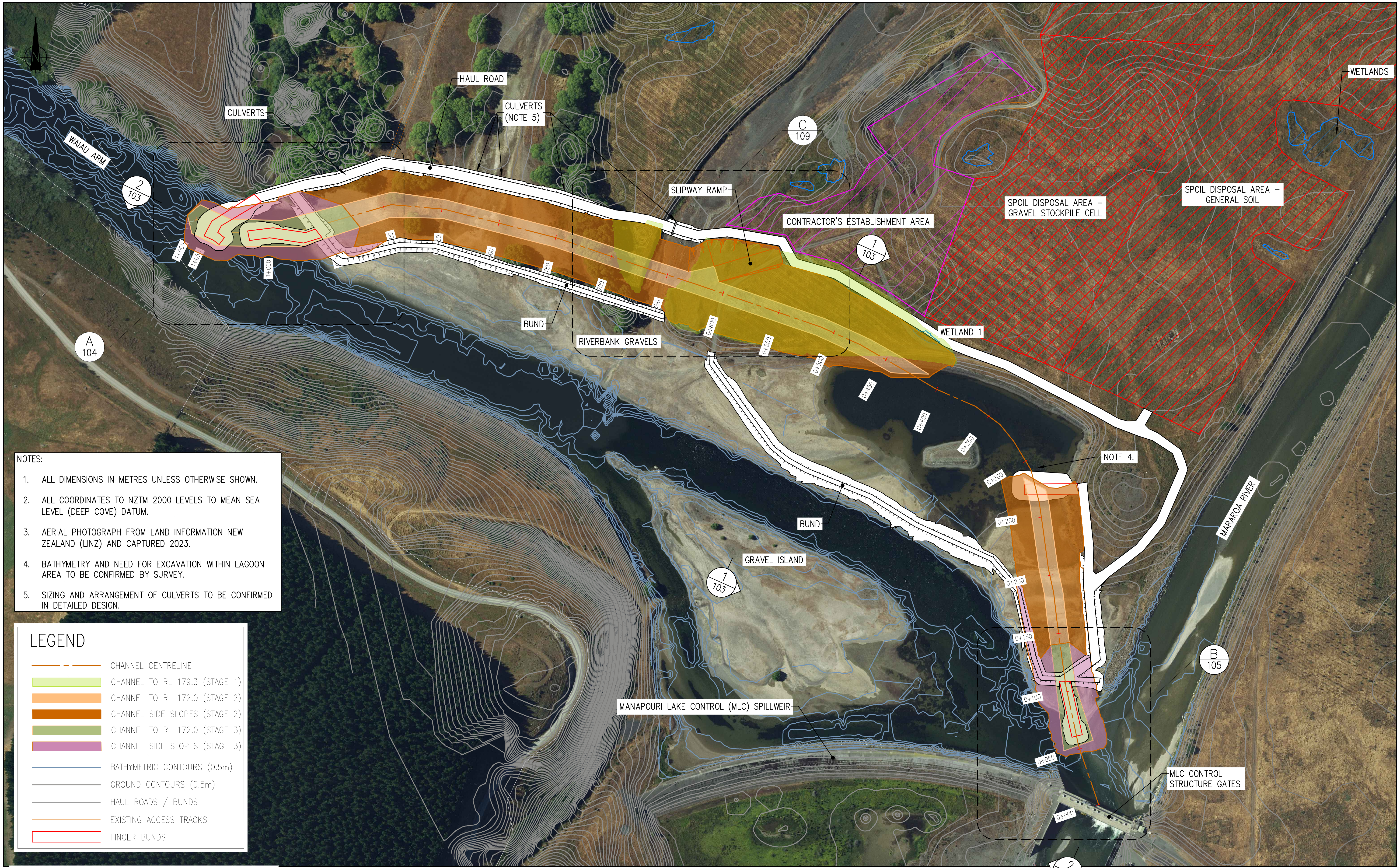
ISSUE	AMENDMENT	BY	CH'D	COMPANY	PROJECT	APP'D	DATE
A	ISSUED FOR INFORMATION	JA	DC	DAMWATCH	E2243	DCE	07/23
B	ISSUED FOR INFORMATION	JA	DC	DAMWATCH	E2243	DCE	10/23
C	ISSUED FOR INFORMATION	JA	DC	DAMWATCH	E2243	DCE	11/23

Meridian.

MANAPOURI LAKE CONTROL

WAIAU ARM CHANNEL EXCAVATION
CONCEPT DESIGN
LOCATION PLAN

FOLDER:
DISTRIBUTION: C
DRAWING:
COMPANY: DAMWATCH
NUMBER: E2243-101
ISSUE: C



NOTES:

1. ALL DIMENSIONS IN METRES UNLESS OTHERWISE SHOWN.
2. ALL COORDINATES TO NZTM 2000 LEVELS TO MEAN SEA LEVEL (DEEP COVE) DATUM.
3. AERIAL PHOTOGRAPH FROM LAND INFORMATION NEW ZEALAND (LINZ) AND CAPTURED 2023.
4. BATHYMETRY AND NEED FOR EXCAVATION WITHIN LAGOON AREA TO BE CONFIRMED BY SURVEY.
5. SIZING AND ARRANGEMENT OF CULVERTS TO BE CONFIRMED IN DETAILED DESIGN.

LEGEND

- CHANNEL CENTRELINE
- CHANNEL TO RL 179.3 (STAGE 1)
- CHANNEL TO RL 172.0 (STAGE 2)
- CHANNEL SIDE SLOPES (STAGE 2)
- CHANNEL TO RL 172.0 (STAGE 3)
- CHANNEL SIDE SLOPES (STAGE 3)
- BATHYMETRIC CONTOURS (0.5m)
- GROUND CONTOURS (0.5m)
- HAUL ROADS / BUNDS
- EXISTING ACCESS TRACKS
- FINGER BUNDS

A3 SCALE 1:3000
0 50 100 150 200 (m)

PLAN ON WAIAU ARM

DRAWING STATUS: **NOT FOR CONSTRUCTION**

ISSUE	AMENDMENT	BY	CH'D	COMPANY	PROJECT	APP'D	DATE
A	ISSUED FOR INFORMATION	JA	DC	DAMWATCH	E2243	DCE	07/23
B	ISSUED FOR INFORMATION	JA	DC	DAMWATCH	E2243	DCE	10/23
C	ISSUED FOR INFORMATION	JA	DC	DAMWATCH	E2243	DCE	11/23

Meridian.

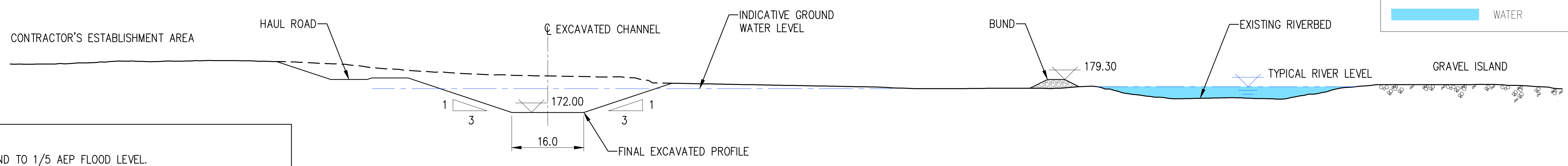
MANAPOURI LAKE CONTROL

WAIAU ARM CHANNEL EXCAVATION
CONCEPT DESIGN
EXCAVATION PLAN

FOLDER: DISTRIBUTION: C
DRAWING:
COMPANY: DAMWATCH
NUMBER: E2243–102 ISSUE: C

LEGEND

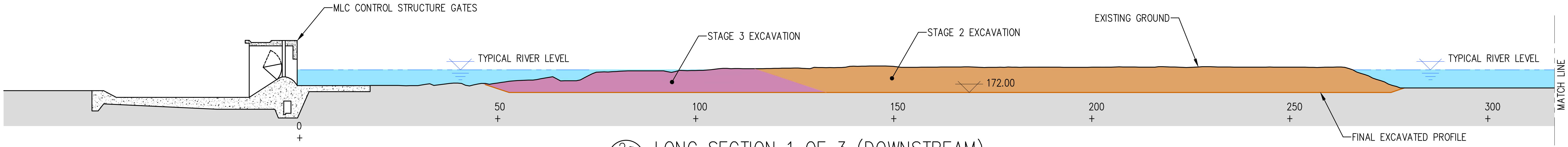
- CHANNEL TO RL 179.3 (STAGE 1)
- CHANNEL TO RL 172.0 (STAGE 2)
- CHANNEL TO RL 172.0 (STAGE 3)
- WATER



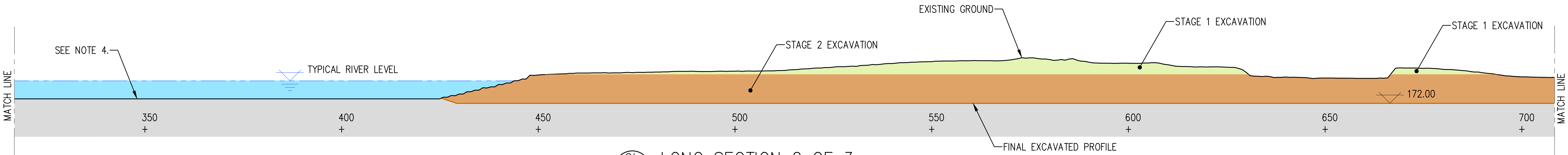
1/102 CROSS SECTION
SCALE1:1000

NOTES:

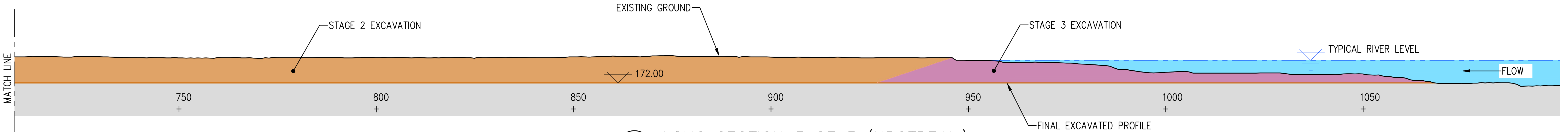
1. BUND TO 1/5 AEP FLOOD LEVEL.
2. ELEVATIONS ARE IN METRES TO MEAN SEA LEVEL (DEEP COVE) DATUM.
3. DIMENSIONS ARE IN METRES UNLESS OTHERWISE SHOWN.
4. LAGOON AREA BATHYMETRY INFERRED FROM CONSTRUCTION DRAWINGS, TO BE CONFIRMED BY SURVEY.



2a/102 LONG SECTION 1 OF 3 (DOWNSTREAM)
SCALE 1:1000



2b/102 LONG SECTION 2 OF 3
SCALE 1:1000



2c/102 LONG SECTION 3 OF 3 (UPSTREAM)
SCALE 1:1000

A3 SCALE 1:1000
0 5 10 15 20 30 40 50 (m)

DRAWING STATUS: NOT FOR CONSTRUCTION

ISSUE	AMENDMENT	BY	CH'D	COMPANY	PROJECT	APP'D	DATE
A	ISSUED FOR INFORMATION	JA	DC	DAMWATCH	E2243	DCE	07/23
B	ISSUED FOR INFORMATION	JA	DC	DAMWATCH	E2243	DCE	10/23
C	ISSUED FOR INFORMATION	JA	DC	DAMWATCH	E2243	DCE	11/23

Meridian.

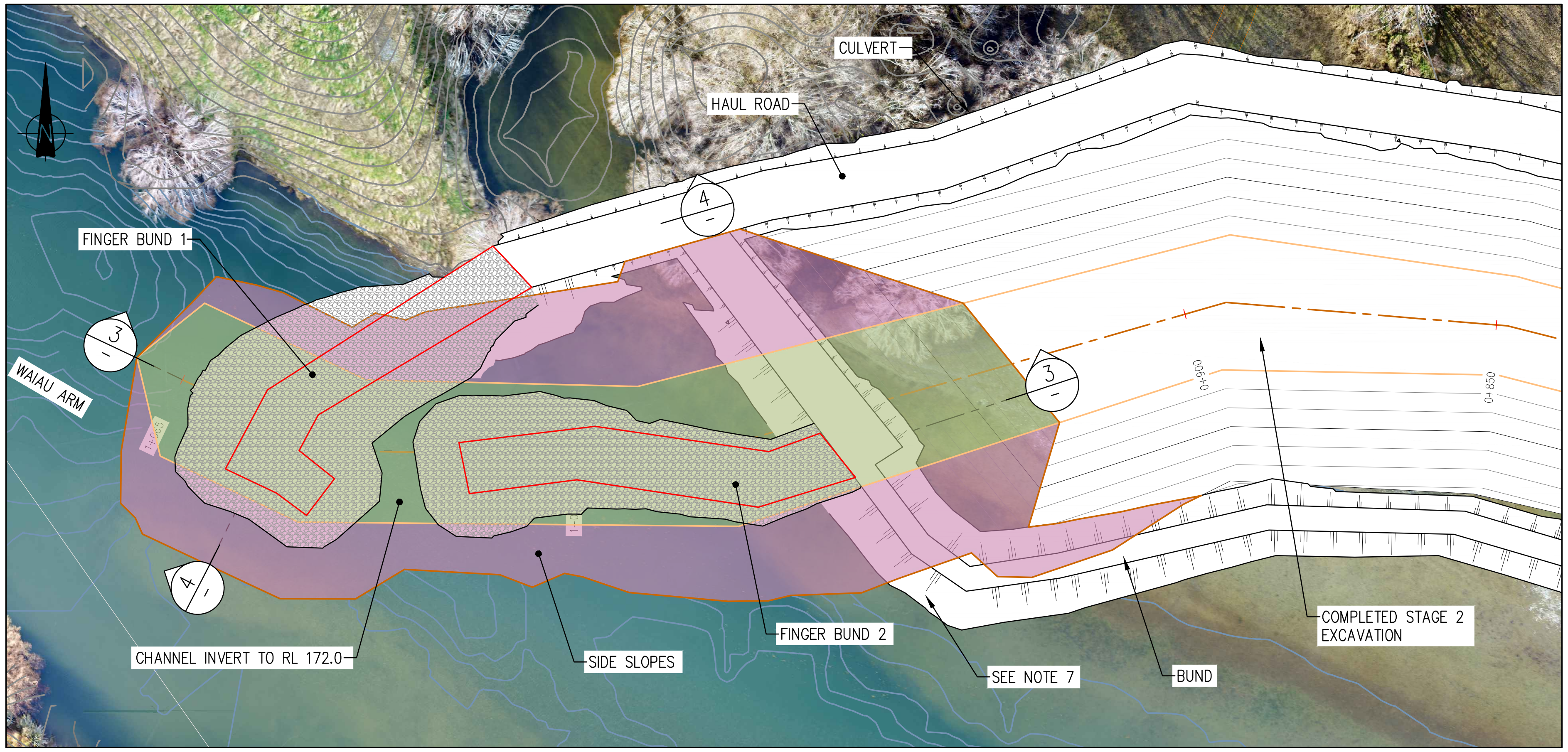
MANAPOURI LAKE CONTROL

WAIAU ARM CHANNEL EXCAVATION
CONCEPT DESIGN
EXCAVATION DETAILS

FOLDER:
DISTRIBUTION: C
DRAWING:
COMPANY: DAMWATCH
NUMBER: E2243-103
ISSUE: C

NOTES:

1. BATHYMETRIC CONTOURS FROM NOVEMBER 2020 SURVEY BY WSP.
2. AERIAL IMAGE FROM AUGUST 2022 UAV FLIGHT BY BOFFA MISKELL.
3. BUND TO 1/5 AEP FLOOD LEVEL.
4. FINGER BUNDS TO PREVAILING RIVER LEVEL PLUS APPROPRIATE FREEBOARD.
5. ELEVATIONS ARE IN METRES TO MEAN SEA LEVEL (DEEP COVE) DATUM.
6. LAYOUT AND SPACING OF FINGER BUNDS WILL DEPEND ON CONTRACTOR'S AVAILABLE EQUIPMENT AND DETAILED CONSTRUCTION PLANNING.
7. REQUIREMENTS FOR PROTECTION OF BUND CORNER EXPOSED TO CURRENT TO BE EVALUATED.

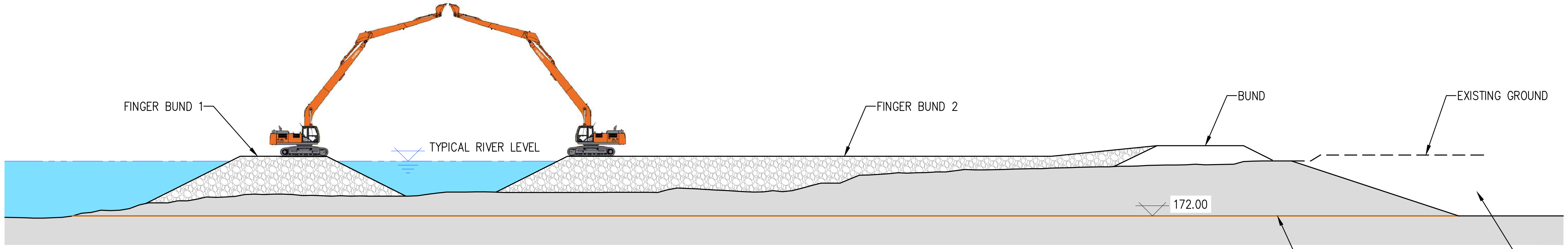


LEGEND

- WATER
- CHANNEL TO RL 172.0 (STAGE 3)
- CHANNEL SIDE SLOPES (STAGE 3)

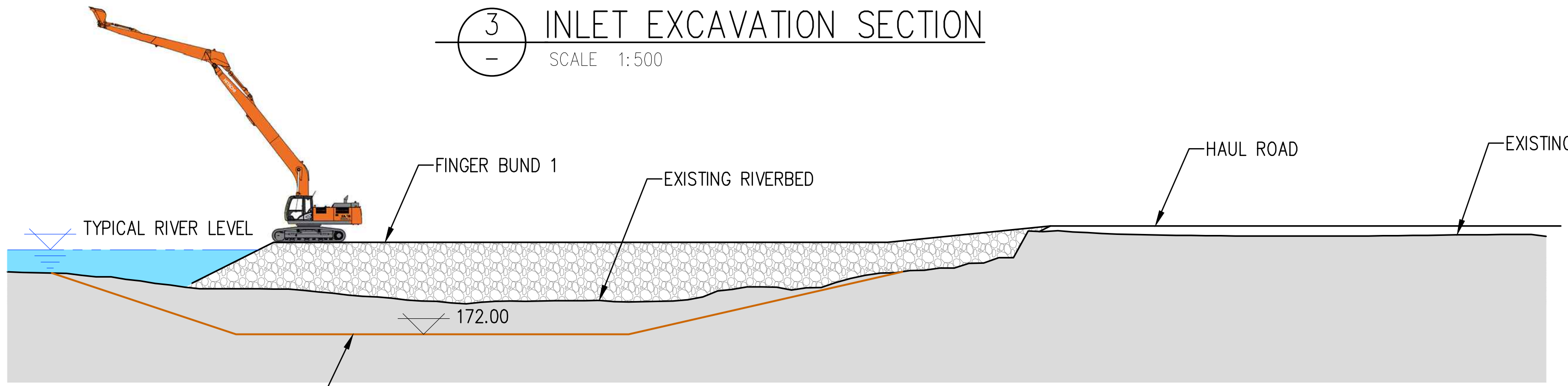
A/102 INLET EXCAVATION PLAN

SCALE 1:1000



3/– INLET EXCAVATION SECTION

SCALE 1:500



4/– INLET EXCAVATION SECTION

SCALE 1:500

A3 SCALE 1:1000 — 0 5 10 15 20 30 40 50 (m)

A3 SCALE 1:500 — 0 5 10 15 20 25 (m)

DRAWING STATUS: NOT FOR CONSTRUCTION

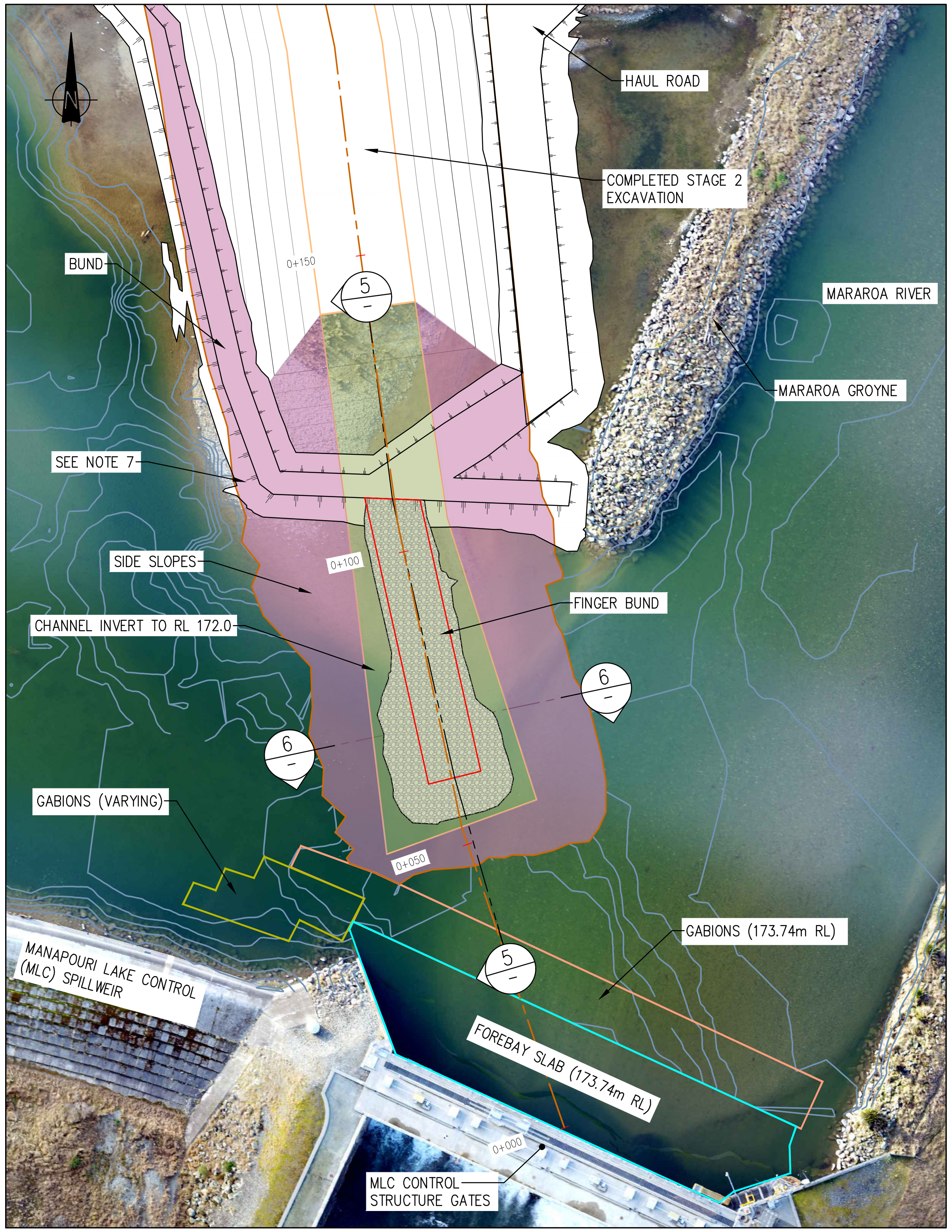
ISSUE	AMENDMENT	BY	CH'D	COMPANY	PROJECT	APP'D	DATE
A	ISSUED FOR INFORMATION	JA	DC	DAMWATCH	E2243	DCE	07/23
B	ISSUED FOR INFORMATION	JA	DC	DAMWATCH	E2243	DCE	10/23
C	ISSUED FOR INFORMATION	JA	DC	DAMWATCH	E2243	DCE	11/23

Meridian.

MANAPOURI LAKE CONTROL

WAIAU ARM CHANNEL EXCAVATION
STAGE 3 CONCEPT DESIGN
INLET EXCAVATION PLAN & SECTIONS

FOLDER:	DISTRIBUTION: C
DRAWING:	
COMPANY:	DAMWATCH
NUMBER: E2243–104	ISSUE: C



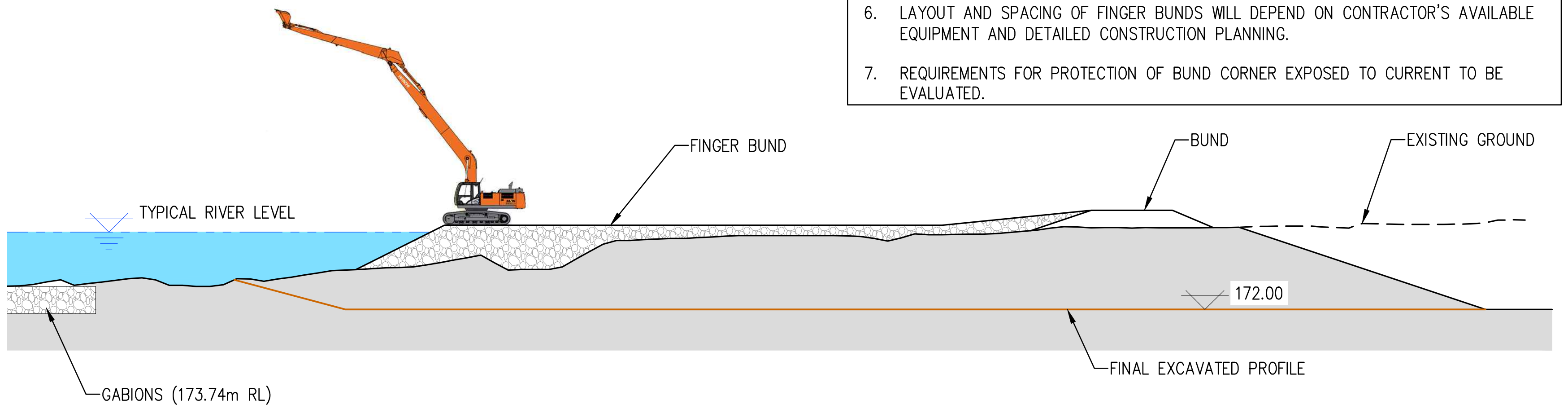
B / 102 OUTLET EXCAVATION PLAN
SCALE 1:1000

LEGEND

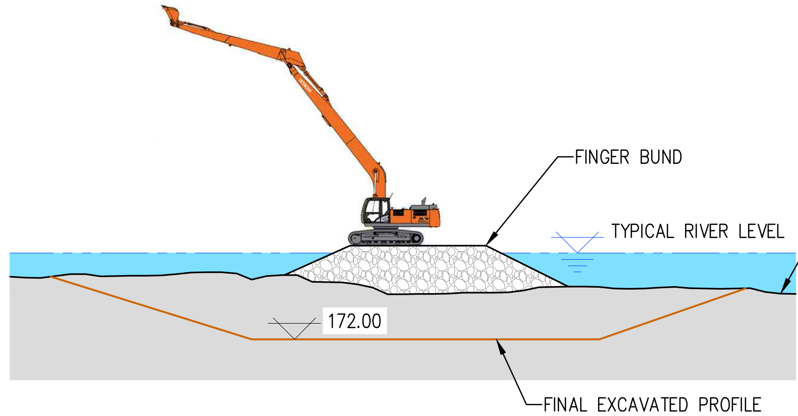
- WATER
- CHANNEL TO RL 172.0 (STAGE 3)
- CHANNEL SIDE SLOPES (STAGE 3)

NOTES:

1. BATHYMETRIC CONTOURS FROM NOVEMBER 2020 SURVEY BY WSP.
2. AERIAL IMAGE FROM AUGUST 2022 UAV FLIGHT BY BOFFA MISKELL.
3. BUND TO 1/5 AEP FLOOD LEVEL.
4. FINGER BUNDS TO PREVAILING RIVER LEVEL PLUS APPROPRIATE FREEBOARD.
5. ELEVATIONS ARE IN METRES TO MEAN SEA LEVEL (DEEP COVE) DATUM.
6. LAYOUT AND SPACING OF FINGER BUNDS WILL DEPEND ON CONTRACTOR'S AVAILABLE EQUIPMENT AND DETAILED CONSTRUCTION PLANNING.
7. REQUIREMENTS FOR PROTECTION OF BUND CORNER EXPOSED TO CURRENT TO BE EVALUATED.



5 / – OUTLET EXCAVATION SECTION
SCALE 1:500



6 / – OUTLET EXCAVATION SECTION
SCALE 1:500

A3 SCALE 1:1000 — 0 5 10 15 20 30 40 50 (m)
A3 SCALE 1:500 — 0 5 10 15 20 25 (m)

DRAWING STATUS: NOT FOR CONSTRUCTION

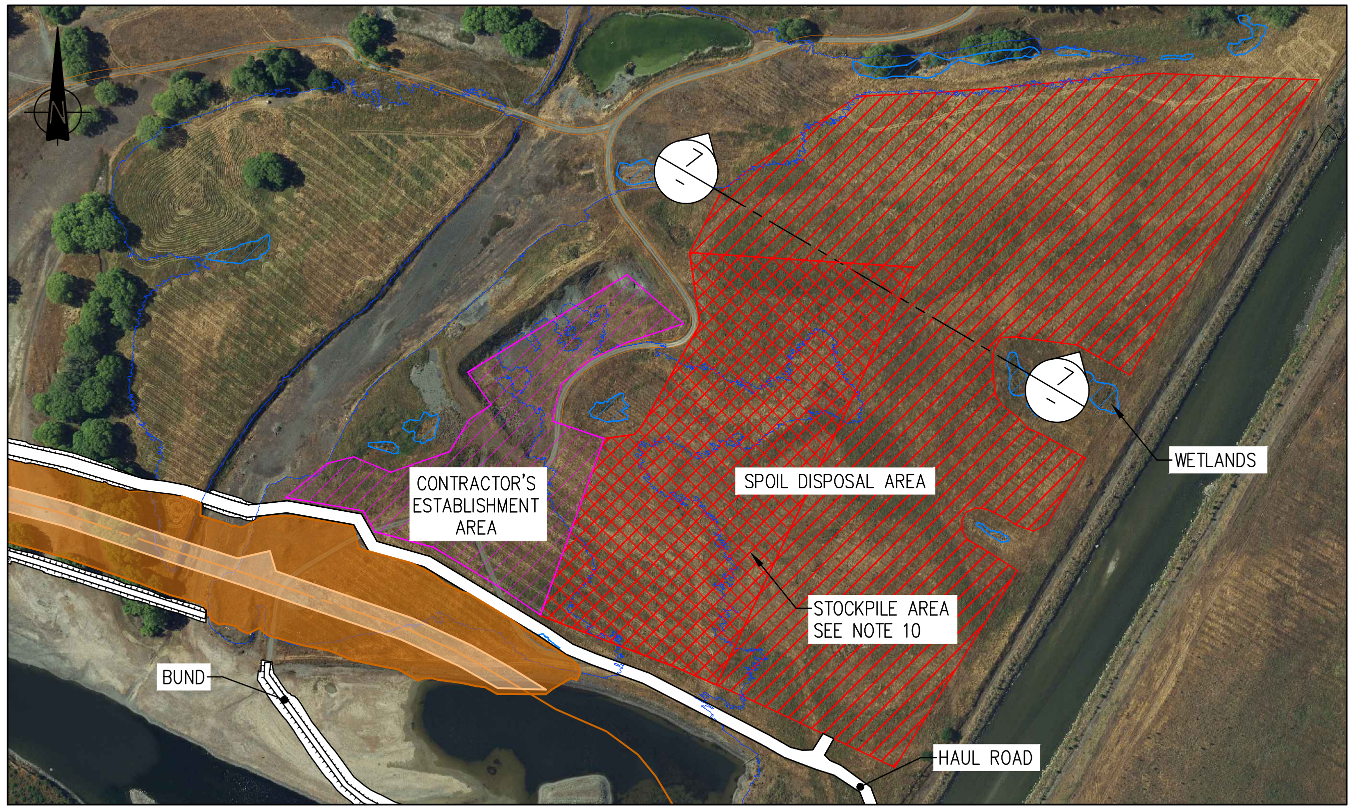
ISSUE	AMENDMENT	BY	CH'D	COMPANY	PROJECT	APP'D	DATE
A	ISSUED FOR INFORMATION	JA	DC	DAMWATCH	E2243	DCE	07/23
B	ISSUED FOR INFORMATION	JA	DC	DAMWATCH	E2243	DCE	10/23
C	ISSUED FOR INFORMATION	JA	DC	DAMWATCH	E2243	DCE	11/23

Meridian.

MANAPOURI LAKE CONTROL

WAIAU ARM CHANNEL EXCAVATION
STAGE 3 CONCEPT DESIGN
OUTLET EXCAVATION PLAN & SECTIONS

FOLDER:
DISTRIBUTION: C
DRAWING:
COMPANY: DAMWATCH
NUMBER: E2243-105
ISSUE: C



LEGEND

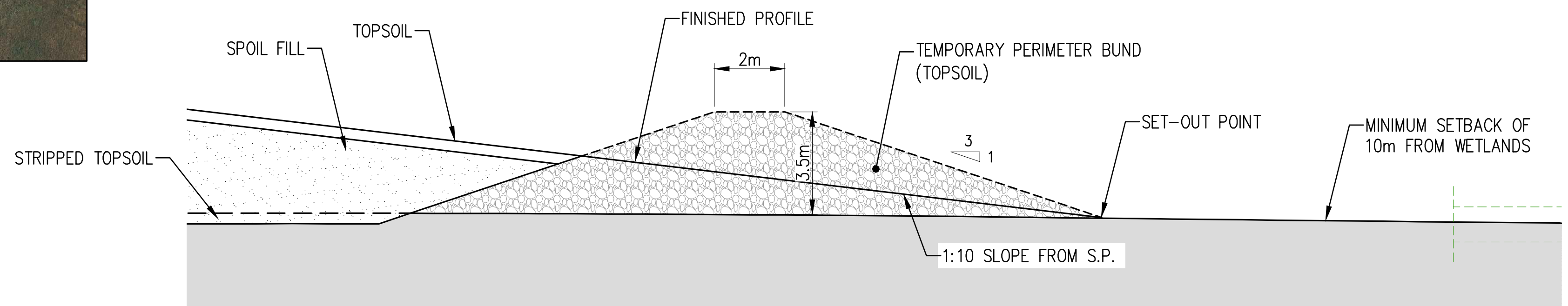
- CONTRACTOR'S ESTABLISHMENT AREA
- WETLANDS
- SPOIL DISPOSAL AREA
- GRAVEL STOCKPILE AREA
- CHANNEL TO RL 172.0 (STAGE 2)
- CHANNEL SIDE SLOPES (STAGE 2)
- RL 180.5m

NOTES:

1. ALL DIMENSIONS IN METRES UNLESS OTHERWISE SHOWN.
2. ALL COORDINATES TO NZTM 2000 LEVELS TO MEAN SEA LEVEL (DEEP COVE) DATUM.
3. AERIAL PHOTOGRAPH FROM LAND INFORMATION NEW ZEALAND (LINZ) AND CAPTURED 2023.
4. ANY DIESEL STORAGE SHOULD BE INSTALLED WITHIN AN IMPERVIOUS BUND, SPILL TRAY OR OTHER METHOD TO INTERCEPT ANY DRIPS OR SPILLAGES DURING REFUELLING OF EQUIPMENT, AND APPROPRIATE SPILL KITS SHALL BE AT HAND AT ALL TIMES.
5. OTHER MINOR QUANTITIES OF HAZARDOUS SUBSTANCES INCLUDING OILS AND LUBRICANTS SHALL BE KEPT IN PORTABLE STORAGE LOCKERS WHEN NOT IN IMMEDIATE USE.
6. ANY TEMPORARY BUILDINGS, STORAGE OF FUEL AND OTHER CHEMICALS, AND REFUELLING AREA TO BE ABOVE RL180M CONTOUR.
7. WITHIN UTILISED SPOIL DISPOSAL AREAS, TOPSOIL SHALL BE STRIPPED TO AT LEAST 150 MM AND STOCKPILED IN PERIMETER BUNDS.
8. UPON COMPLETION, PERIMETER SLOPES GRADED TO 1V:10H, WITH BUND MATERIAL REUSED TO REHABILITATE SURFACE.
9. IF CONTAMINATED LAND IS ENCOUNTERED IN WORKS AREAS, IT SHALL BE REMOVED TO BE DISPOSED OF AT A FACILITY AUTHORISED TO HANDLE SUCH WASTE.
10. CLEANER GRAVELS TO BE SELECTIVELY PLACED WITHIN IDENTIFIED STOCKPILE AREA FOR LATER RECOVERY AND REUSE.

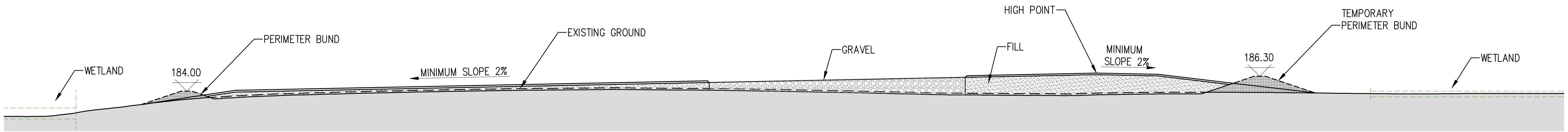
SPOIL DISPOSAL AND ESTABLISHMENT AREA – PLAN

SCALE 1:5000



TYPICAL SECTION – PERIMETER BUND

SCALE 1:200



7 CROSS-SECTION

SCALE 1:750

A3 SCALE 1:5000 — 0 50 100 150 200 250 (m)

A3 SCALE 1:750 — 0 5 10 15 20 25 30 35 40 (m)

A3 SCALE 1:200 — 0 2 4 6 8 10 (m)

DRAWING STATUS: **NOT FOR CONSTRUCTION**

ISSUE	AMENDMENT	BY	CH'D	COMPANY	PROJECT	APP'D	DATE
A	ISSUED FOR INFORMATION	JA	DC	DAMWATCH	E2243	DCE	07/23
B	ISSUED FOR INFORMATION	JA	DC	DAMWATCH	E2243	DCE	10/23
C	ISSUED FOR INFORMATION	JA	DC	DAMWATCH	E2243	DCE	11/23

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MANAPOURI LAKE CONTROL

WAIAU ARM CHANNEL EXCAVATION
CONCEPT DESIGN
SPOIL DISPOSAL AREAS, ESTABLISHMENT AREA, CROSS-SECTION & NOTES

FOLDER:
DISTRIBUTION: C
DRAWING:
COMPANY: DAMWATCH
NUMBER: E2243-106
ISSUE: C

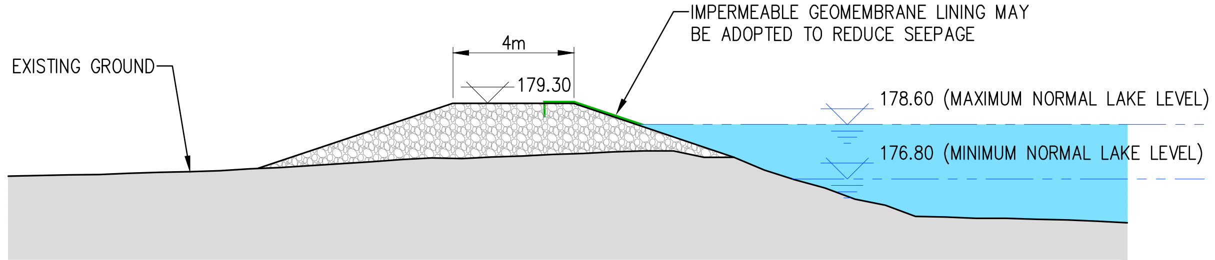
PLAN
SCALE 1:5000

LEGEND

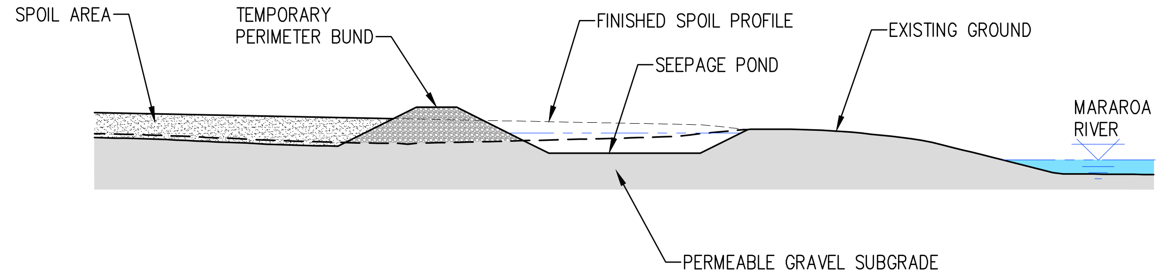
- CONTRACTOR'S ESTABLISHMENT AREA
- WETLANDS
- SPOIL DISPOSAL AREA
- GRAVEL STOCKPILE AREA
- CHANNEL TO RL 172.0 (STAGE 2)
- CHANNEL SIDE SLOPES (STAGE 2)

NOTES:

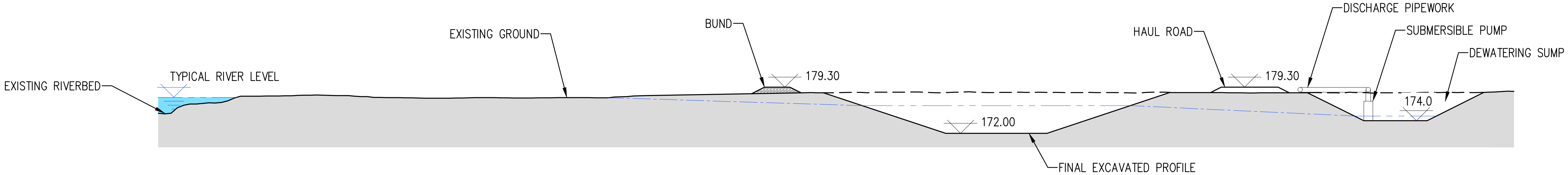
1. BUND TO 1/5 AEP FLOOD LEVEL.
2. ELEVATIONS ARE IN METRES TO MEAN SEA LEVEL (DEEP COVE) DATUM.
3. DIMENSIONS ARE IN METRES UNLESS OTHERWISE SHOWN.
4. SIZE OF SEEPAGE POND INDICATIVE ONLY, LARGER OR ADDITIONAL PONDS MAY BE REQUIRED DEPENDING ON DEWATERING RATE AND DURATION, AND SUBGRADE PERMEABILITY AND CLOGGAGE.



8 BUND TYPICAL SECTION
SCALE 1:250



9 SEEPAGE POND SECTION
SCALE 1:750



10 DEWATERING SUMP SECTION
SCALE 1:750

A3 SCALE 1:5000 — 0 50 100 150 200 250 (m)
A3 SCALE 1:750 — 0 5 10 15 20 25 30 35 40 (m)
A3 SCALE 1:250 — 0 5 10 15 (m)

DRAWING STATUS: **NOT FOR CONSTRUCTION**

ISSUE	AMENDMENT	BY	CH'D	COMPANY	PROJECT	APP'D	DATE
A	ISSUED FOR INFORMATION	JA	DC	DAMWATCH	E2243	DCE	07/23
B	ISSUED FOR INFORMATION	JA	DC	DAMWATCH	E2243	DCE	10/23
C	ISSUED FOR INFORMATION	JA	DC	DAMWATCH	E2243	DCE	11/23

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MANAPOURI LAKE CONTROL

WAIAU ARM CHANNEL EXCAVATION
CONCEPT DESIGN
POSSIBLE DEWATERING PROVISIONS

FOLDER:
DISTRIBUTION: C
DRAWING:
COMPANY: DAMWATCH
NUMBER: E2243-107
ISSUE: C

NOTES:

1. ALL DIMENSIONS IN METRES UNLESS OTHERWISE SHOWN.
2. ALL COORDINATES TO NZTM 2000 LEVELS TO MEAN SEA LEVEL (DEEP COVE) DATUM.
3. AERIAL PHOTOGRAPH FROM LAND INFORMATION NEW ZEALAND (LINZ) AND CAPTURED 2023.
4. BATHYMETRY AND NEED FOR EXCAVATION WITHIN LAGOON AREA TO BE CONFIRMED BY SURVEY.
5. SIZING AND ARRANGEMENT OF CULVERTS TO BE CONFIRMED IN DETAILED DESIGN.

LEGEND

- CHANNEL CENTRELINE
- CONTOURS (0.5m)
- ACCESS ROADS
- EXISTING ACCESS TRACKS
- PROPERTY BOUNDARY

A3 SCALE 1:3000
0 50 100 150 200 (m)

PLAN ON WAIAU ARM

DRAWING STATUS: **NOT FOR CONSTRUCTION**

ISSUE	AMENDMENT	BY	CH'D	COMPANY	PROJECT	APP'D	DATE
A	ISSUED FOR INFORMATION	JA	DC	DAMWATCH	E2243	DCE	10/23
B	ISSUED FOR INFORMATION	JA	DC	DAMWATCH	E2243	DCE	11/23

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MANAPOURI LAKE CONTROL

WAIAU ARM CHANNEL EXCAVATION
CONCEPT DESIGN
REHABILITATED SITE PLAN

FOLDER:
DISTRIBUTION: B
DRAWING:
COMPANY: DAMWATCH
NUMBER: E2243-108
ISSUE: B

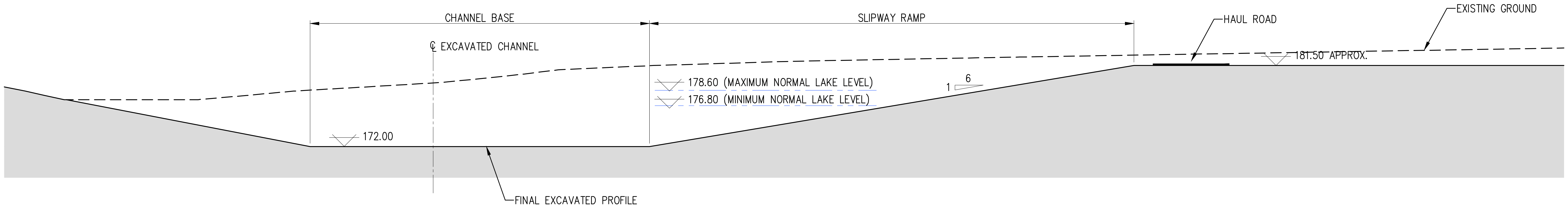
NOTES:

1. BUND TO 1/5 AEP FLOOD LEVEL.
2. ELEVATIONS ARE IN METRES TO MEAN SEA LEVEL (DEEP COVE) DATUM.

LEGEND

- WETLANDS
- CHANNEL TO RL 172.0 (STAGE 2)
- CHANNEL SIDE SLOPES (STAGE 2)

C / 102 SLIPWAY EXCAVATION PLAN
SCALE 1:1000



7 / – SLIPWAY EXCAVATION SECTION
SCALE 1:500

A3 SCALE 1:1000 — 0 5 10 15 20 30 40 50 (m)

A3 SCALE 1:500 — 0 5 10 15 20 25 (m)

DRAWING STATUS: NOT FOR CONSTRUCTION

ISSUE	AMENDMENT	BY	CH'D	COMPANY	PROJECT	APP'D	DATE
A	ISSUED FOR INFORMATION	JA	DC	DAMWATCH	E2243	DCE	11/23

Meridian.

MANAPOURI LAKE CONTROL

WAIAU ARM CHANNEL EXCAVATION
CONCEPT DESIGN
SLIPWAY PLAN & SECTION

FOLDER:
DISTRIBUTION: A
DRAWING:
COMPANY: DAMWATCH
NUMBER: E2243–109
ISSUE: A